Wireless and Tiredness

Investigating Interrelated Influences of Electronic Media Use, Sleep, and Fatigue

A thesis presented in partial fulfilment of the requirements for the degree of

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Abstract

This thesis investigates the relationships between electronic media use, sleep, and fatigue. This thesis opens by introducing a conceptual framework for understanding electronic media use and evaluating terminology of sleep and fatigue concepts. The current research field of electronic media use–sleep health in adults is then mapped through an umbrella scoping review. This review revealed a predominance of correlational studies between subjective addiction symptoms and sleep satisfaction through which causal relationships were impossible to delineate. A theoretical perspective is developed on the causal interrelationships between electronic media use, sleep health difficulty, and fatigue through an investigation into experimental and theoretical studies. A novel intervention is then introduced to encourage self-directed use of electronic media in service of sleep health. The intervention is tested using a multiple-baseline single case experimental design study with sailors in active duty with Te Taua Moana O Aotearoa, The Royal New Zealand Navy. Through analysing changes in behavioural and self-report measures of electronic media use, sleep health, sleepiness, vigilance, and fatigue, no immediate effects of the intervention were observed. While longer-term improvements were observed in subjective fatigue at six-month follow-up, these could not be solely attributed to the intervention. Conceptual, theoretical, and practical complications of researching these topics are discussed throughout this thesis and summarised at the end.

Preface

Acknowledgements

I wish to open by extending gratitude to the mountain Ruapehu and Te Awa Tupua, the river that flows from there, for their recursive guardianship over the course of this project.

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The study described in Chapter 5 was reviewed and approved by the Massey University Human Ethics Committee: Southern A, Application 21/34; Organisational Research at Te Ope Kātua O Aotearoa - New Zealand Defence Force: reference 5000/PB/5/3; and Te Ope Kātua O Aotearoa - New Zealand Defence Force Research Ethics Committee 21 July 2021; My thanks to all the members of the respective committees for taking the time to review and support this research. My thanks also to Jo Hughes for support with digitising and administrating the intake surveys, and to Maritime Component Commander Mathew Williams; thank you for sponsoring and supporting this research.

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Ngā manga iti, ngā manga nui e honohono kau ana, ka tupu hei Awa Tupua.
The small, large, and deep streams flow into one another and grow to form one river.

Nō reira, tēnā koutou kātoa.
Greetings and thanks to you all.

Personal Reflection

I grew up in a period of transition from analogue to digital media. My family did not have a television until I was around 8 years old. Early memories of electronic media use (EMU) for me are using the Encarta software and playing the DOS games Hover and Mystic Towers on the family computer. Every Friday, we would ritualistically go to our local video rental, Alice in Videoland, to hire a movie to watch at home, initially encoded by VHS, then later DVD, over a habitual meal of fish n' chips. I got my first cell phone at 12 years old and watched the maturation of smartphones through my teenage years and early twenties. My sister and I used to tape our favourite TV shows on VHS to watch later and skip ad breaks. I have fond memories of us recording radio broadcasts of favourite songs, jokes, and skits onto cassette tape. I now have access to instant video entertainment on YouTube, audio streaming on Spotify, Soundcloud and Bandcamp and am constantly taking voice notes on my smartphone. Instead of browsing the aisles at the video rental, my choices in media consumption are now contained within the same EMU context as the consumption itself. Recommender algorithms suggest content that can keep me engaged on whatever platform I find myself using to unwind and detach or easily procrastinate work or sleep whenever I choose. I have often found myself passively consuming this content over actively seeking it.

Throughout my childhood, I struggled to sleep. I can remember an early insomnia intervention that was trialled with me: a boom box that my parents brought into my room to play a specific CD called Wondrous Waterfall, an ambient music soundscape by Hughes et al. (1997). This intervention has likely led to a bias around the relationship between EMU and sleep for me: One of my first encounters with

EMU was as a sleep aid. Given recall bias and lack of outcome measurement at the time, I am unable to report on its effectiveness. Listening to the same album now gives me a mix of emotions, on the one hand, a nostalgic sense of calm, on the other, a slight anxiety. I may have ended up with a conditioned response to the music associated with my own sleep anxiety at the time.

In 2012, following my leaving home after the 2011 Ōtautahi Earthquakes, I was introduced to the Multiplayer Online Battle Arena game League of Legends, at the time one of the most popular games worldwide (Gaudiosi, 2012). Between 2014 and 2017 I often stayed up until 0200h playing this game, then I would have to wake up for work at 0700h the next day. Although the game was incredibly enjoyable, and I was generally able to get through the working day safely in a customer-facing job in hospitality, if I was in a high-risk work environment, then my lack of sleep during this period may have been unsafe. I returned to university in 2017 to continue my studies in psychology, in part to break away from this gaming habit. Despite my gaming quantity decreasing significantly (I replaced the time-consuming League of Legends with the more thought-consuming online correspondence chess), EMU remained similarly pervasive in my life. I spent most of my days using electronic media in the form of study-related programs and activities, word processing, research, and data analysis.

During this time, I developed a more general interest in the effect of EMU on sleep, work productivity, and well-being. I was also interested in the responsibilities of working environments to foster well-being and the reciprocal importance of leisure time outside of the working day for effective recovery to support work performance (Employment New Zealand, 2024; Liu et al., 2020). For societal roles where performance carries high responsibility to others, errors may be insidious, and their consequences could have far-ranging community ramifications (Reason, 1991). Because of this, I was excited by the opportunity to support community safety by trialling an EMU intervention with Te Taua Moana O Aotearoa – Royal New Zealand Navy to see whether sleep health and fatigue outcomes could be improved for people in this high responsibility population. I was also interested in forming a better understanding of the psychology of the relationship between EMU and sleep, and its impacts on waking life.

While growing up, and the internet was burgeoning, my sister and I discovered Neopets and often went online after school to complete daily tasks using the family computer. Our parents introduced the idea of a time-use log, inspired by how they kept track of study time and finances: “We don’t prevent ourselves from doing what we want to do; it’s just a way of noting it for ourselves, and that seems to help” (Personal communication, B. Peters, 11 November 2024). On this log we simply wrote down how long we spent on the computer on an A4 sheet of paper, which sat on the computer desk. While many interventions from this time (e.g., see Young, 1998, Recovery strategy 13; p.155) are used for parental and external accountability, this log was not there to set time limits, rather to promote accurate awareness. On reflection on the conceptual mechanisms discussed in this thesis, this log facilitated self-reflection with the assumption that this supported flexible self-regulation. The intervention introduced in Chapter 4, and trialled in Chapter 5, draws its inspiration from that childhood time-use log.

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Key Acronyms

American Psychiatric Association	APA
Electronic media use	EMU
Electronic media use self-reflection intervention	EMU-SRI
Fatigue assessment scale	FAS
Multiple baseline single case experimental design	MBD
Percentage of nonoverlapping data	PND
Pittsburgh sleep quality index	PSQI
Psychomotor vigilance task	PVT
Reciprocal reaction time	RRT
Reliable change Index	RCI
Samn Perelli fatigue scale	SPFS
Sleep efficiency	SE
Sleep onset latency	SOL
Standard deviation	SD
Te Ope Kātua O Aotearoa - New Zealand Defence Force	NZDF
Te Taua Moana O Aotearoa - Royal New Zealand Navy	RNZN
Karolinska Sleepiness Scale	KSS
Media and Technology Usage and Attitudes Scale	MTUAS
Research Representative	RR
Suprachiasmatic nuclei of the hypothalamus	SCN
Time in bed	TIB
Total sleep time	TST
Wake after sleep onset	WASO

List of Appendices

Note to the reader.

This thesis has been designed to be printed double sided.

Eight leaves are designed to be printed on A3 paper and fold out.

Fold out pages are: 164, 250, 431, 445, 459, 473, 487, and 501.

Goods are imbued with significance through ritual

(Kien, 2009, p. 28)

Prologue: Wireless and Tiredness

Across academic and popular media, there is a general understanding that electronic media use (EMU) negatively impacts sleep (Exelmans, 2020; Pacheco & Truong, 2023). This thesis presupposes that EMU may be a contributing factor to sleep health difficulty (Liu et al., 2020; Snyder & Chang, 2019) and that the relationship between EMU, and sleep requires further understanding (Bauducco et al., 2024; Exelmans & Van den Bulck, 2019). In this thesis, I conceptualise EMU as an interactivity between a user, their context, and electronic media hardware, software, and content. I evaluate EMU and sleep relationships discussed in the reviews of the field and conceptualise a relationship between EMU and sleep interlinked with the motivational control and self-regulatory experience of fatigue. I introduce a self-reflection intervention to support EMU–sleep health and evaluate the intervention's efficacy for sailors in active duty with the Te Taua Moana O Aotearoa - Royal New Zealand Navy (RNZN).

Over the past few decades, EMU has become a staple activity, insidiously and increasingly spread throughout the daily lives of most (Anderson & Perrin, 2017; Boniel-Nissim et al., 2015; Roberts & Foehr, 2008; Twenge et al., 2019). The total number of internet users currently approximates 68% of the world's population (see S. Kemp, 2025a for a comprehensive overview of current worldwide EMU trends). Within Aotearoa New Zealand, the proportion of internet users is around 96% (S. Kemp, 2025b). By current estimates, around 98% of the population in Aotearoa New Zealand own a smartphone, 71% own a laptop or desktop computer, and 58% own a smart TV (S. Kemp, 2025b). Worldwide, the total proportion of the population that are active social media software users was estimated to be 64% (S. Kemp, 2025a) and an estimated 79% of the population in Aotearoa New Zealand are active social media users, with 89% of the adult population aged 18 and over actively using social media (S. Kemp, 2025b). In adults, 63% of the population in Aotearoa New Zealand access the internet between two to four hours per day outside of work, most of that time being spent using social media software (Matika, 2023). Additionally, 27% of the adult population in Aotearoa New Zealand access the internet outside of work time for five or more hours per day (Matika, 2023). For many currently, a significant proportion of the day involves EMU.

The amount of sleep that one needs to thrive varies from person to person (Kuna et al., 2012). For adults, the latest recommendation from the U.S. National Sleep Foundation is an average of 7–9 hours of sleep per night with a smaller proportion of individuals possibly needing as little as 6 hours or as much as 10 hours (Hirshkowitz et al., 2015). Sleep guidelines in Aotearoa New Zealand reflect this same recommendation (Manatū Hauora: Ministry of Health, 2024). Globally, subjective sleep durations have been shrinking for the past decades, though this is apparently rarely reflected in objective measures (Bin et al., 2012; Matricciani et al., 2017). Nevertheless, the latest statistics in Aotearoa New Zealand estimated that between 27–37% of adults do not meet recommended sleep duration metrics (Manatū Hauora: Ministry of health, 2024a). Sleep health difficulties also reflect general trends in health inequities associated with social determinants: disability status, housing, education, access to suitable healthcare, social economic status, and ethnicity; for example, within Aotearoa New Zealand, Māori populations, a population more likely to experience many social and health inequities by colonial metrics, also experience higher likelihood of sleep health difficulties ranging from sleep duration and efficiency to insomnia and obstructive sleep apnœa (e.g., Baddock et al., 2024; Manatū Hauora: Ministry of health, 2023, 2024b; Paine et al., 2005, 2004; Paine & Gander, 2016; Paine & Muller, 2023). Sleep is an important issue in Aotearoa New Zealand.

How do difficulties with sleep and EMU interact? To begin answering this question, a framework for generally understanding causality and interaction in psychology is required. Below, I briefly describe the social cognitive theory (Bandura, 1986) which is central to this thesis for framing understandings about interactions between people, their environment, and their behaviour. The language of this theory is applied through this thesis where appropriate to clarify causality in the complex interactions between EMU, sleep, and fatigue.

Bandura's Social Cognitive Theory

Bandura's (1986) social cognitive theory centres on a core causal heuristic of *triadic reciprocal causation* that holds that personal, environmental, and behavioural determinants each interact and reciprocally influence each other. Personal determinants include one's beliefs, their cognitions, emotions, and somatic reactions. Behavioural determinants include activities and interactions with the social environment and the self. Finally, environmental determinants include all contextual and social aspects of the universe outside of the self. When first introduced, Bandura (1986) described this model with reference to the following example of television viewing:

> Although the potential televised environment is identical for all viewers, their actual televised environment depends on what they choose to watch. Through

> their viewing behavior, they partly shape the nature of the future televised environment. … the options provided in the televised environment partly shape the viewers' preferences. Here, all three factors—viewer preferences, viewing behavior, and televised offerings—reciprocally affect each other. (Bandura, 1986, p. 24)

Bandura stressed the interactive nature of individuals, their environments, and their behaviour and the shaping forces that each has on the other. This concept of triadic reciprocal causation has permeated through Bandura's later work (Bandura, 1991, 1997, 2009) and has been described as providing "strong theoretical foundations for explaining, predicting, and changing human behavior." (Zhai et al., 2023, p. e71). As triadic reciprocal causation is a broad and heuristic theory and given its breadth, it may be misapplied (Zhai et al., 2023), a brief example is given for how its three frames are applied to this thesis: Personal determinants include such ideas as sleep health status, fatigue propensity, and state of fatigue. Environmental determinants include electronic media hardware, software, and content, and other contextual aspects. Behavioural determinants important to this thesis are EMU, and sleep. These concepts are unpacked further in Chapter 1. Chapter 3 explores how they may interact.

Structure of the Thesis

This thesis is arranged in five core chapters. Broadly, this thesis begins by evaluating concepts in Chapters 1 and 2, discusses theories and causal mechanisms in Chapters 3 and 4, and covers practical application in Chapter 5. Chapter 1 explores working definitions for EMU, sleep, and fatigue. Chapter 1 also outlines adjacent concepts and relevant interventions that have been identified in the literature for managing difficulties with each. Chapter 2 contains an umbrella scoping review of EMU and sleep health in adults. Slated for publication in a sleep-related journal, this umbrella scoping review focuses specifically on the EMU–sleep health relationship in adults and charts how this has been discussed by other reviewers of the field. Chapter 3 investigates the mechanisms through which EMU and sleep health may interact to speculate on a theoretical maintenance model of EMU and sleep health difficulty; positioning the experience of fatigue as described by Hockey (2013) as a central maintenance mechanism of a theoretical causal model. In Chapter 4, Bandura's (1991) social cognitive theory of self-regulation is applied to frame the development of a new EMU self-reflection intervention (EMU-SRI). EMU-SRI is designed to facilitate self-directed EMU with the hypothesis that this may lead to improved sleep health and subsequently decreased fatigue propensity. Finally, Chapter 5 documents a test of EMU-SRI with a multiple baseline single case experimental design study (MBD) with sailors in the RNZN. An epilogue concludes this thesis emphasising the importance of staying vigilant to conceptual accuracy in the study of these complex topics.

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Chapter 1

Defining Concepts: Electronic Media Use, Sleep, and Fatigue

Conceptualising how EMU interacts with sleep is an ongoing challenge in psychology and sleep science and requires an enhanced understanding of EMU (Exelmans & Van den Bulck, 2019). Defining the interaction between sleep and fatigue poses an adjacent conceptual challenge (Balkin et al., 2023). As this thesis aims to contribute towards the resolution of these difficulties, this chapter opens by providing a perspective, unfolding, and defining EMU, sleep, and fatigue constructs. If people are experiencing difficulties with EMU, sleep, or fatigue, these difficulties may be related to each another (Exelmans, 2019). To my current knowledge, these issues have yet to be explicitly conjointly addressed. However, they have each been addressed separately. Therefore, towards the conclusion of this chapter, interventions are described for managing difficulties with EMU, sleep, and fatigue.

A Perspective for Studying EMU

To open this thesis, a definition of EMU is proposed. EMU refers to an individual or group in a certain context, interacting with sensory experiences facilitated through devices that use the properties of electrons to run algorithms.

The task of settling on a construct definition for EMU was difficult. This difficulty stemmed from carefully balancing terminological sensitivity and specificity and embracing different viewpoints. At the inception of this project, *screen time*, the main EMU-based medical subject header (J. Duncan, personal communication, March 6, 2020; National Library of Medicine, 2019) was facing scrutiny for lack of focus on content, likened to discussing *food time* when speaking about nutrition (Przybylski, 2019). Other research focussing on more specific EMU concepts such as smartphones (e.g., Elhai et al., 2017; Mac Cárthaigh et al., 2020), internet use (e.g., Alimoradi et al., 2019), television watching (e.g., Dempsey et al., 2014), or patterns of internet gaming (e.g., Lam, 2014) showed blurred edges that are difficult to define (see Chapter 2). For example, smartphones may include internet use, internet gaming can happen on a television, and people may play games that resemble internet-based games while not connected to the internet. Difficulties with conceptualising electronic media were summarised by Medoff and Kaye (2017): "Digitization and convergence have blurred the lines that distinguish one medium from another, such that the traditional definitions of these media need to be reevaluated" (p. 31). In EMU, many types of media may mediate between the information and the perception of the user. For example, a word processor might be accessed through a downloaded application on someone's computer, or it might be accessed through a web-browser on that same device. The experience of these might be similar with different software and hardware acting between the information and the user, and they might be different.

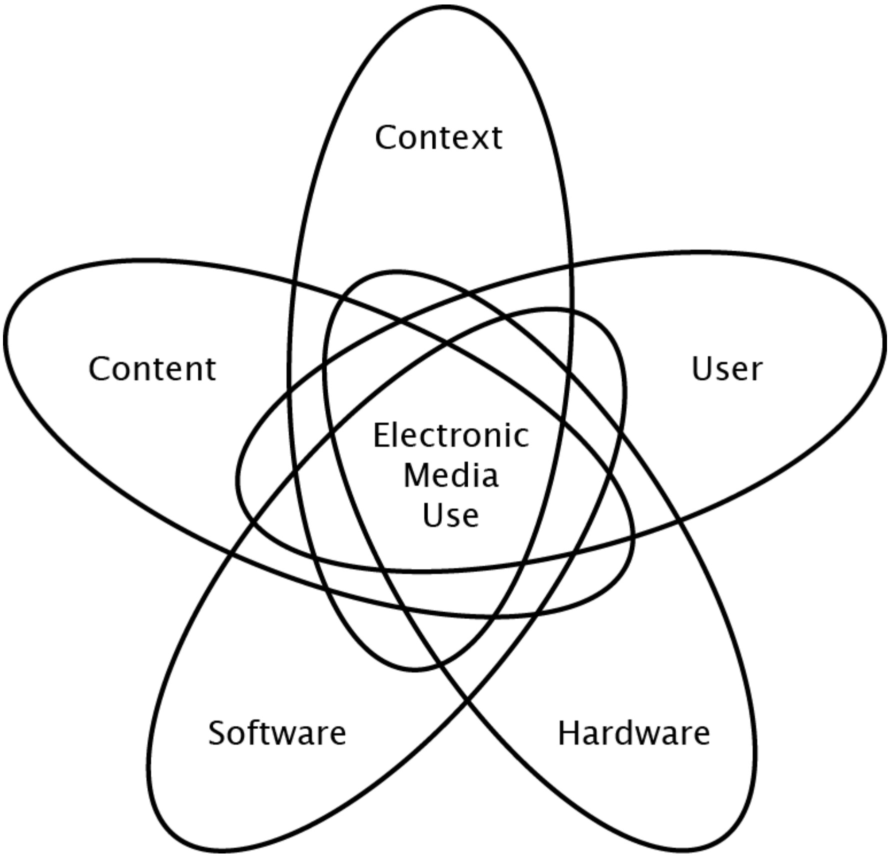
> With digital technology, various media are used at the same time over one device. In other words, when connected to the Internet via a broadband connection, listeners can access an online radio station, retrieve email, listen to iTunes music, download a book, or use instant messaging to have a real-time conversation (including both audio and video) with others. Smartphone users receive calls, send and receive text messages, digital pictures, and video, store and play MP3 music files, and surf the Web. Smartphones have the

> capability to remotely program household devices like a thermostat or light fixtures. (Medoff & Kaye, 2017, p. 31)

These difficulties have precluded a thorough understanding of the impacts of EMU on biology, psychology, and behaviour (Exelmans & Van den Bulck, 2019). A new framework is introduced below to help analyse some of the conceptual complexities of EMU. For developing this framework, Exelmans and Van den Bulck (2019) suggested paying attention to context, content, and device characteristics which are understudied in the field. Similarly, Bauducco et al. (2024) recently advocated for both device and content to be documented when discussing presleep technology use and sleep. The framework introduced below expands on each of these by also emphasising user and software attributes as fundamental to EMU. This novel framework separates EMU into component parts to support development of standardised terminology. The following *five-lens conceptual framework* describes how EMU can be understood through *user*, *context*, *hardware*, *software*, and *content* variables. Figure 1, opposite, illustrates this proposed framework to create a foundation for further discussions about EMU, and to assess and address gaps in our knowledge on the subject. Figure 1 graphically shows the interaction between environmental determinants of context, content, software, hardware; the personal determinant of user; and situates EMU as a behaviour that emerges through the interaction of each of these facets. This conceptual framework was developed over the course of this thesis and will be referred to as a frame for understanding EMU.

Figure 1

The Five-Lens Conceptual Framework for Studying EMU



Note. each lens may subsume constructs that only apply to itself or apply across lenses. For example, the *internet* may be seen as an emergent interaction between hardware, software, content, and context, whereas *internet gaming disorder* is contained in the user lens, as it summarises symptoms of a psychiatric diagnosis (American Psychiatric Association [APA], 2022). *Electronic media* refers to both hardware, software, and content. Electronic media exerts causal effect on personal determinants through its use, *EMU* that requires an interaction between electronic media, context, and user. The 24 intersects between each combination of lenses are left blank to acknowledge that this conceptual framework is in its infancy.

User

Core to the use aspect of EMU is the user. The user encompasses the attributes and personal determinants (Bandura, 1986) that influence EMU. For current purposes a human user is assumed with certain describable attributes. User is a lens through which to view EMU that incorporates any descriptors applying to the person in question using electronic media. Examples that may be relevant in EMU studies vary from basic measurements such as age and heartrate, to fuzzier constructs of gender, health status, symptoms, and diagnostic labels, including, for example, behavioural addiction symptoms, current state of fatigue, personal bio-psycho-social history, alertness, sleep health history, thoughts, emotions, personality patterns, trauma history, family history, and social connectedness. It is through this level that such diagnostic labels as *internet addiction* (Cash et al., 2012) or *internet gaming disorder* (APA, 2022) may be subsumed. A user attribute, therefore, could include, for example, a user's scores on an internet addiction questionnaire. As with the other lenses of this framework, the vast ways in which sub attributes can be categorised is only limited by the imagination of the investigating researcher, who may draw on intergenerational knowledge for capturing human traits into symbolic language for analysis.

Many current studies focus on aspects of EMU that researchers define through the problems that it causes in users' lives. Part of the increasing level of interest in pathology pertaining to media use was sparked by the inclusion of *internet gaming disorder* as a condition for further study in the APA's Diagnostic and Statistical Manual of Mental Disorders – Fifth Edition (DSM-5; APA, 2013; Kristensen et al., 2021). Many studies (see Chapter 2) link sleep with user constructs like *problematic* *internet use* (e.g., Breslau et al., 2015), *problematic smartphone use* (e.g., Elhai et al., 2017; Mac Cárthaigh et al., 2020), *smartphone addiction* (e.g., Panova & Carbonell, 2018), *internet addiction* (e.g., Alimoradi et al., 2019; Cash et al., 2012), *internet gaming disorder* (Han et al., 2020), or *pathological video gaming* (King, Haagsma, et al., 2013). These labels capture user attributes and clusters of symptoms typical of behavioural addictions: preoccupation, cravings, tolerance, loss of control, restlessness, deception, and problems in other areas of life (e.g., Cash et al., 2012).

Davis (2001) separated internet addiction into two broad categories: either specific, or generalised pathological internet use, depending on the extent of the repertoire of behaviours that one engages in online. The specific form, Davis conceptualised as often driven by a "pre-existing psychopathology, which becomes associated with online activity" (p. 192). Davis (2001) described the more generalised pathological internet use as often driven by social isolation, wherein the internet becomes ones "lifeline to the outer world" (Davis, 2001, p. 193). The ætiology of addictions, whether chemical or behavioural are often understood as stemming from problems in other aspects of an individual's life, rather than stemming necessarily from the object of addiction itself (Maté, 2018). Internet addiction from its earliest conception was seen as a manifestation of other mental distress: Young (1998) noted that many who experience addiction symptoms also experience other psychological difficulties that predispose internet addiction. By definition, solely investigating these symptoms, with a focus only on the *user* aspect, the personal determinant, neglects investigating actual behaviour and the complex interactivity of context, hardware, software, and content.

Context

As with all behaviour, EMU is taken to occur in a certain describable context. Investigating EMU through this lens involves describing the environmental determinants, situations, spatial and temporal, within which EMU occurs. Context attributes may include, though are not limited to time of day, season, physical space, temperature, presence of others and their interactivity, layout of hardware elements and their ergonomics, the distance from the user to the screen, and environmental lighting and noise. One could note the influence of social settings, community practices and norms and social values, or more broadly, socio-political landscapes that provide a setting for, and could influence EMU experiences (e.g., N. J. Burke et al., 2009).

A framework for analysis of *context* can be found in Bronfenbrenner's (1993/1994) ecological model, which delineates different levels of contexts that reciprocally influence individuals and groups. In this ecological model, five embedded context levels shape human development: the *microsystem* refers to one's immediate and direct social contexts; the *mesosystem* refers to the interactions between microsystem elements within which individuals also directly interact; the *exosystem* refers to the interactions between an individual's microsystem and other systems that they do not directly interact with; and the macrosystem refers to the broader cultural and societal contexts within which the other systems are embedded. Finally the *chronosystem*, refers to the systemic impact that time contexts exert on the structure of all the other systems including the individual (Bronfenbrenner, 1993/1994). EMU and the mass communication that it facilitates, uniquely gives users direct parasocial access to their mesosystem; they can view how mutual friends and organisations interact with each other without directly interacting themselves (cf. Forster, 2023). EMU has facilitated an expansion of exosystem access into what Bandura (2009) described as a “globally distributed consciousness” (p. 98). In the sections that follow, it is important to acknowledge that electronic media itself, including hardware, software and content are all environmental determinants of behaviour, and that EMU facilitates communication between contexts. For the parsimony of this framework, the context lens is taken to mean the local context of the user while engaging in EMU; Expanded contexts that are accessed *through* EMU can be analysed through the lenses of hardware, software, and content which embeds them.

Hardware

The hardware lens captures details about the physical electronic media devices that are the object of use. This lens incorporates descriptions of input and output mechanisms that form the potentiality of the EMU experience. For example, in the case of screen-based hardware, this lens includes information like screen size, potential brightness, refresh rate, number of displays and their details, and information about any attached peripheral devices, wired or wirelessly connected.

Hardware descriptions may occur at various degrees of granularity from instances of fine-grained componentry to broad categorisation. Broad hardware categorisations are often used informally when discussing the relationship of EMU to sleep, for example, “tempting as it might be to use your computer or phone before bed, studies have shown these devices can interfere with sleep by suppressing the production of melatonin” (Pacheco & Truong, 2023, para. 1). The five-lens framework aims for conceptual accuracy. I was unable to find any studies that a phone suppresses the production of melatonin. Though, light emissions that emerge as a result of hardware, software, and content have the potential to interact with the human circadian timekeeping system (see Chapter 3).

Hybrid devices that challenge the boundaries between colloquial hardware categories are common (McLellan, 2015). New categories of media, immature niches, and varying terminology are common and difficult to operationalise. For example, the differences between virtual reality, augmented reality and *spatial computing* platforms may be vague and indistinct, though increasing in popularity (Brownlee, 2024). Increasing developments in connectivity of many seemingly ordinary and extraordinary objects (Gomes & Baunach, 2021), strike at the importance of describing EMU through the hardware lens, where relevant, as accurately as possible, in order to ensure accurate interpretation for future insights.

Some examples of fine-grained attributes that may be useful to include when EMU is being studied includes the potential brightness and sizes of screens, or potential loudness and frequency response curves of speakers, connected peripherals, weight and portability, battery life expectancy, or processing speed. Instances of makes and model numbers when available are useful for capturing many device attributes for later reference as these tend to remain consistent. They are retrievable through databases such as GSMArena (https://www.gsmarena.com) for many portable hardware, and DisplaySpecifications (https://www.displayspecifications.com) for various computer monitors and television sets. The ways in which hardware is described should depend on the kinds of information that is sought about its use. As with each category, the most specific, and detailed attributes of hardware (e.g., the schematics of the central processing units) may be too burdensome for research parsimony to justify capturing. Nevertheless, a broad definition and delineation of hardware as separable from software and content is useful to bear in mind. Hardware represents the potentiality of the EMU experience which is actualised through channelling software and content in EMU.

Software

Software refers to the algorithms that run on the hardware to enable information transmission and interaction. The software lens of the EMU framework captures relevant attributes of these algorithms where useful and available, and relevant information on programs or applications that structure and shape content interaction. Broad categorisations could include, though are not limited to, describing operating systems, applications, file and web browsers, websites, content aggregators, and streaming services. General terms such as social media, media players, internet browsing, games, descriptions of specific user interface elements, interactivity, and potential connectivity metrics may also be incorporated by the software lens. If describing specific software, instances or version numbers should be specified when relevant as updates to software may change the user experience while the name remains the same.

To give an example of the importance of the change in software over time, Bauducco et el. (2024) suggested that post-bedtime notifications may be a significant factor in limiting and interrupting sleep from mobile devices. However, certain hardware running certain software might by default mitigate this. Since the Apple iPhone operating system iOS14 was released in 2020, Apple has improved aspects of their native *health* application to limit exposure to potentially sleep-disturbing notifications after user-set expected bedtimes (Apple inc., 2024). Software attributes may also include customisations and applications for accessibility, monitoring, or setting software-determined limits to the use of other software (Simon, 2018). Changes to default settings within software can be adjusted in many software instances and if utilised, should be documented, as they may lead to interesting findings (e.g., Duraccio et al., 2021). Software, within this framework, may also link neatly with discussing *platforms*, "we define platforms as (re-)programmable digital infrastructures that facilitate and shape personalised interactions among end-users and complementors, organised through the systematic collection, algorithmic processing, monetisation, and circulation of data" (Poell et al., 2019, p. 3). Poell et al. (2019) describe the powerful ways in which the flexibility of software and the power structures inherent in software design have led to significant shifts in the exosystem (cf. Bronfenbrenner, 1993/1994). Overall, software represents the algorithms that act as medium between content and hardware and frame the EMU experience.

Content

"Content is that which fills the container" (Jarvis, 2023, p. 3). The content lens describes the information being sought, consumed, or interacted with. Whereas software, hardware, and context interact to form the potentiality of sensory stimulation; content ultimately determines the actualised attributes of the electronic media environmental determinant, interacting with a user's sensory sensitivity in their context. Viewing EMU through the content lens implies understanding what is being experienced moment to moment by the user. Content may therefore include broad views of categories like *news*, *music, movie, TV show* or *research*. In addition, specific movies, games, or songs, or defined social or parasocial experiences may be understood through the content lens. Aspects of genre may also be captured and analysed through this lens as described by the Kantar New Zealand (2021) report on media audiences in New Zealand, "Content: Refers to genre on the whole, for example news, current affairs, documentaries, or comedy. Different sources use different definitions for genres, but wherever possible these are presented in a comparable way" (p. 8).

Use and Limitations of the Five-Lens EMU Framework

Taking each lens into consideration may help with forming a holistic picture of EMU. Investigating the full extent of each lens would be practically impossible. The framework aims to be useful for comparing studies on EMU and also for broadening the view on which variables may need to be controlled for in experiments. EMU studies that analyse EMU through the same lens may be comparable, whereas studies that view EMU through different lenses may be more difficult to compare. In Chapter 2, this framework is employed in an umbrella scoping review to map EMU and sleep health literature. The science and ergonomics of lighting environments (For reviews see Chambe et al., 2023; Xiao et al., 2021) may be compatible with the current framework of EMU, particularly as recent developments in lighting technology have led to lights' hardware running software, and potentially signalling information through automation (e.g., Philips hue, n.d.). However, for parsimony in the review in Chapter 2, environmental lighting studies are excluded. The distinction here is complicated (see Chapter 3) and its full explication, if necessary, will require further research.

This novel five-lens conceptual framework illustrates the perspective taken for analysing EMU in this project. Importantly, this framework does not aim to be *prescriptive* of how EMU should necessarily be studied; it aims to be *descriptive* of different lenses through which EMU can be understood. The five-lens framework was introduced as a Venn diagram to signify that different areas of study may apply to certain intersects between lenses of the framework. For example, the ecological study of platformisation (Poell et al., 2019) could be seen as analysing the interaction between software and context. Each of these five lenses, or frames of reference may be highly embedded as "the 'content' of any medium is always another medium" (McLuhan, 1964, p. 21). This project employs the framing of these five lenses where useful and relevant, though acknowledges that the contents of these lenses are ever developing. The granularity of captured attributes depends on the detail that the analysis requires. I anticipate that making use of this framework to delineate user, context, hardware, software, and content aspects will be helpful for clarifying EMU-related concepts in understanding the relationship between EMU and sleep.

Sleep

Sleep is often defined quite simply, for example, "a reversible behavioural state of perceptual disengagement from and unresponsiveness to the environment" (Carskadon & Dement, 2017, p. 15), or poetically, for example, "a radical withdrawal from the waking world" (Coveney et al., 2023, p. 118). Sleep is a multifaceted, and complex experience (Kleitman, 1963; Krueger et al., 2016), an *assemblage* of many ideas that revolve around a frequently occurring state of disengagement (Coveney et al., 2023). Sleep functions to regulate, consolidate, and restore immune, neural, and cognitive processes (Beijamini et al., 2014; Krueger et al., 2016). Sleep supports cardiovascular and metabolic health, safety and recovery, and general life expectancy (Borbély et al., 2016; Luyster et al., 2012). In sleep, blood pressure drops to support cardiovascular health, episodic memories are consolidated into general constructs, neurotransmitter levels and synaptic networks find balance and adaptation to relevant waking tasks; protein debris buildup from wake is cleared; growth hormones and prolactin are released to support organ maintenance (Vorster et al., 2024). Sleep functions to maintain physical and cognitive functioning. The functioning of sleep itself can be understood as regulated by two broad, interactive, and independent processes, the homeostatic sleep drive, and circadian timekeeping system (Achermann & Borbély, 2017; Borbély et al., 2016).

The Two-Process Model of Sleep

Sleep Homeostasis. The homeostatic sleep drive is a sensed or measured pressure to sleep that increases as one stays awake and decreases as one sleeps (Borbély et al., 2016). The mechanism of this homeostatic process is enigmatic, though recent research has associated the homeostatic system of sleep with the maintenance of *criticality*; an ideal information processing environment in the brain (Suppermpool et al., 2024; Xu et al., 2024). The homeostatic sleep drive controls and counters deviations from normal sleep requirements through interacting with the structure or architecture of sleep; for example, slow-wave sleep, the deepest sleep stage, typically increases in quantity and intensity during sleep if homeostatic sleep pressure is high (Achermann & Borbély, 2017; Xu et al., 2024). The homeostatic sleep drive functions to maintain an optimal physical and cognitive environment for effective functioning (see Achermann & Borbély, 2017 for an overview of different models of sleep).

Circadian Timekeeping System. The circadian timekeeping system regulates cycles of rest and activity, sleep and wake, evolved to approximate the 24-hour rhythm of day and night on Earth (Borbély et al., 2016). The circadian timekeeping system is endogenous, though it synchronises and adapts to the rhythms of the environment through timekeeping cues, known as *zeitgebers*, from German, meaning *time givers* (Bear et al., 2015). By maintaining an endogenous timekeeping system, synchronised with the rhythm of the environment, prediction of and regulation to a temporal niche is optimised (Roenneberg & Foster, 1997). In humans, light and darkness are the primary zeitgebers through which our endogenous central circadian timekeeping system is synchronised (Berson et al., 2002). This photic entrainment system involves specialised cells in the retina linking into the suprachiasmatic nuclei of the hypothalamus (SCN), which, in turn, through oscillating nerve signals and hormonal signals of histamine, orexin, and melatonin via the pineal gland conducts the numerous circadian rhythms throughout the body (Tubbs et al., 2019; Withrow et al., 2019). Short wavelength light corresponding to the blue–cyan–green range between 470–510 nm is where the synchronising system of photic entrainment is most sensitive (Rea et al., 2012).

While the circadian timekeeping system operates similarly for most, it does not lead to the same behaviours in everyone (Chellappa, 2021). People differ in the times that they prefer to go to bed and to sleep (Roenneberg et al., 2019). *Chronotypes* describe a normally distributed predisposition for wake and sleep timing; influenced by age, genetics, and the salience of the light–dark cycle in the local environment (Roenneberg et al., 2019). While primarily biologically driven, sleep timing can regulate with social and environmental influence (Roenneberg et al., 2003, 2019; Wittmann et al., 2006). A common example of this adaptation is in the case of shift work, where sleep is often expected outside of biologically adaptive timing. When people are awake during their biologically optimal time for sleep, and asleep during their biologically optimal time for wake, sleep health and wake functioning becomes compromised, impacting all the downstream outcomes that healthy sleep benefits (Matheson et al., 2014; Vlasak et al., 2022).

Sleep Health Dimensions

To refine a focus on important, measurable dimensions of sleep that support other domains of health, Buysse's (2014) taxonomy and conceptual framework for sleep health initially emphasised five key aspects: *timing*, the alignment of sleep with the day-night cycle; *efficiency*, how much sleep one gets over how much time one allocates for it; *duration*, the total temporal quantity of sleep gained in a 24-hour period; *alertness*, which refers to how alert or sleepy an individual feels while awake, and s*atisfaction*, a purely subjective sense of how good one believes their sleep to be. The sleep health framework has helped to maintain consistent terminology in the study of sleep (e.g., Frazier, 2023; Hale et al., 2020; Harvey & Buysse, 2017; Sarfan et al., 2023; Swope et al., 2023). When introduced, Buysse (2014), also suggested other potential dimensions of sleep variability, sleep depth, and sleep restorativeness, though noted only nascent research into those dimensions. A decade since it's definition, a reevaluation has formally included *breathing*, that is, snoring or oxygen saturation while asleep; *variability*, the consistency of sleep timing from sleep to sleep; and *sleep disorders*, referring to the presence of nuanced parasomnias or other specific difficulties with sleep that the other dimensions of timing, efficiency, duration, alertness, satisfaction, breathing, and variability might fail to capture (Vorster et al., 2024).

Delineating Wakefulness Constructs

An irony of the sleep health framework is that it captures wakefulness constructs within it. Sleep satisfaction requires a wakeful judgement, and alertness is an element of wakefulness. Buysse (2014) defined the *alertness/sleepiness* dimension of sleep health as "the ability to maintain attentive wakefulness" (p 11). The irony indicates the important intertwining influence of sleep and wakefulness: if people get good quality and quantity of sleep at the right times in their rhythms, they will more likely feel alert and awake, function better during their waking hours, and judge their sleep as having been of high quality (Buysse, 2014; Kleitman, 1963).

Wake functioning has crucial implications for safety (M. D. Weaver & Barger, 2019; Wray, 2019). In addition to sleepiness, at the antithesis of alertness, also lies *fatigue* (cf. Åkerstedt & Gillberg, 1990; Samn & Perelli, 1982). Of great importance to this thesis is the subject of fatigue. Fatigue is a crucial concept in this thesis for a few key reasons: fatigue interacts with sleep health; fatigue interacts with and is caused by time on task; and fatigue leads to safety concerns (Balkin & Wesensten, 2011; Belenky et al., 2014; Hockey, 2013). The covarying aspects of sleepiness and fatigue both contribute to task performance and show circadian rhythms that, for example, have been starkly reflected in motor vehicle accident statistics in Aotearoa New Zealand (Gander, 2023, Figure 2.3). In Chapter 3, fatigue is situated as a key emotional experience (Hockey, 2013) that may lead people into continuing or commencing EMU. Fatigue is a nuanced term that has historically admitted a variety of definitions across and within disciplines; the study of fatigue lacks an overarching definition that applies across its use cases (Balkin et al., 2023). The sections that follow attempt to contribute to the delineation of these wakefulness constructs for the purposes of conceptual clarity within this thesis.

Sleepiness and Vigilance. The experience of sleepiness involves a sense of fighting a need for sleep, associated with rapid sleep onset (Åkerstedt & Gillberg, 1990). For the purposes of this thesis, *sleepiness* and *vigilance* are taken as antonyms. While sleepiness is typically used to refer to falling asleep when one is usually awake; in the root of vigilance, *vigil* refers to an act of staying awake when one would typically be sleeping, indicating an ability to maintain attention tuned to detecting and responding to salient environmental determinants (Correia & Cohen, 2011). The task of being vigilant, between environmental changes, may resemble an act of unstructured waiting, or doing nothing at all (cf., Kubey, 1986). When one is sleepy, maintaining vigilance becomes more difficult: “sleepy people (or other animals, for that matter) do not stay awake doing nothing” (Balkin & Wesensten, 2011, p.55). The task of maintaining vigilance itself may also lead to fatigue (Hockey, 2013).

Fatigue and Flow. While sleepiness and vigilance typically apply to periods of waiting for stimuli to respond to, or changes in the environment, fatigue typically applies during the expression of some task or activity and represents an acute state of deteriorated functioning (e.g., Hockey, 2013; Balkin & Wesensten, 2011). The experience and function of fatigue was elaborated in Hockey's (2013) motivational control theory which conceptualised fatigue as a central self-regulation mechanism that occurs during ongoing tasks:

> Fatigue is a mechanism for maintaining motivational equilibrium. It responds to falling utility (benefits to costs ratio) of current behaviour by interrupting the flow of control, thus allowing a reassessment of the cost and benefits of alternative actions. ... Do you really want to continue with what you are doing? Would you rather do something else? (Hockey, 2013, p. 136-137).

This fatigue experience may be clarified when contrasted to the following definition of *flow*:

> A sense that one's skills are adequate to cope with the challenges at hand, in a goal-directed, rule-bound action system that provides clear clues as to how well one is performing. Concentration is so intense that there is no attention left over to think about anything irrelevant, or to worry about problems. Self-consciousness disappears, and the sense of time becomes distorted. (Csikszentmihalyi, 1990, p. 71)

In states of flow, one is focussed on the task at hand; attention to performance and effort maintenance is minimal. The opposite is true for a state of fatigue: one is interrupted from the task at hand, attention is drawn to performance and effort maintenance, and alternative actions are considered. Hockey (2013) frames fatigue as serving "an adaptive function of preventing motivational fixation on current activities and redirecting behaviour towards those that have a higher utility (greater rewards or lower costs)" (Hockey, 2013, p. 135).

Physical and cognitive fatigue show interactive physiology and effects (Gantois et al., 2021; Meeusen et al., 2021), and depending on the method of study, fatigue may be seen as a unitary construct (Michielsen et al., 2004). The differentiability of physical and cognitive fatigue may be particularly important when discussing the nuances involved in the relationship between activity and sleepiness, as Kleitman (1963) observed, "muscular activity was a decisive factor in enabling the person or animal to remain awake for a longer time than usual" (Kleitman, 1963, p. 5). For the purposes of this thesis, fatigue is discussed as a whole construct that assumes both performance and motivational elements, with the acknowledgement that physical and cognitive aspects of fatigue are possibly differentiable and closely interactive (Hockey, 2013).

Fatigue Propensity and Endurance. Belenky et al. (2014) summarised fatigue as "the final common pathway integrating the interacting effects of sleep/wake history (time awake, sleep loss), circadian rhythm (time of day), and workload (time on task, task intensity, and task complexity)" (p. 245). One of the difficulties in studying fatigue is that definitions of fatigue are often convoluted with a variety of antecedents or consequences that do not necessarily define its actual experience or measurement (Balkin et al., 2023). For clarifying *fatigue* further, a distinction is here drawn between *fatigue* and *fatigue propensity*. Fatigue propensity and its near antonym, *endurance*, for the purposes of this thesis, refers to an interactive physical and cognitive ability to maintain performance and resist fatigue. Low endurance, or high fatigue propensity only indicates a vulnerability to fatigue, and does not manifest as fatigue until some cognitive or physical task leads to an acutely fatigued state. Therefore, *fatigue propensity* as a construct subsumes from *fatigue* those personal determinants described by Belenky (2014) that may exacerbate or potentiate the fatigue experience.

Sleep Health Buffers the Effect of Time on Task on Fatigue.

When people are sleep deprived: “mental and muscular performance in various tests can be maintained at normal levels if the tests are of short duration, but sustained effort is impossible” (Kleitman, 1963, p.229). When tasks are more difficult, people may become more prone to becoming fatigued (Belenky et al., 2014). As mentioned earlier, the main function of sleep that this thesis is concerned with is its maintenance of an ideal environment within the body and brain that supports effective wake functioning. Recent conceptualisations of the function of sleep link sleep with the maintenance of *criticality*; a balance point between order and chaos that facilitates complexity and efficient information processing (O’Byrne & Jerbi, 2022). Sleep is positioned as a crucial homeostatic activity required for effectively maintaining criticality for efficiently responding to unfolding contexts (Suppermpool et al., 2024; Xu et al., 2024). These modern conceptualisations of sleep and criticality were interestingly threaded throughout early academic conceptualisations of sleep, for example, Kleitman (1963) described the impacts of sleep deprivation as “a fatigue of the higher levels of the cerebral cortex—the levels that are responsible for the critical analysis of incoming impulses and the elaboration of adequate responses in the light of one’s previous experience” (p. 229).

Much of the experimental evidence for the impact of sleep on waking performance comes from studies that manipulate sleep duration (e.g., Van Dongen et al., 2003). The psychomotor vigilance task (PVT: e.g., Dorrian et al., 2004) has gained predominance in assessing changes to waking performance influenced by sleep health. PVTs involve monitoring for, and rapidly responding to successive stimuli. They require vigilance in their performance and performance of this task may deteriorate over time, thus simultaneously assessing fatigue and sleepiness (Balkin & Wesensten, 2011; Dorrian et al., 2004). Vigilance is assessed by PVTs as they require waiting and monitoring for stimuli that require a response. Fatigue can also be simultaneously induced and measured by PVTs: The PVT is in itself a task that one may spend time on, with performance deteriorating over time if fatigue propensity is high (e.g., Balkin & Wesensten, 2011).

In an early PVT study, before the PVT name was standardised, Lisper and Kjellberg (1972) investigated the length that these kinds of tasks needed to be to reliably capture an impact of sleep deprivation. Lisper and Kjellberg found that performance deterioration in accuracy and reaction time only became significant for sleep deprived participants after the first five minutes of the test had elapsed. Lisper and Kjellberg also suggested that the *intensity* of the task was important; if the successive presentation of stimuli to be responded to occurred more rapidly, performance would decrease more quickly. Balkin and Wesensten (2011) framed the declining performance over the course of a 10-minute PVT as crucial for understanding fatigue and differentiating fatigue from sleepiness: Previous sleep duration and circadian phase showed a small effect on mean response speed at the beginning of the PVT, a larger effect of mean response speed being observed towards the end: A slope of decreasing mean response speed for each minute of the PVT can be observed that indicates fatigue accrual (Balkin & Wesensten, 2011). In this way, Balkin and Wesensten showed that with a 10-minute PVT, sleepiness and vigilance can be inferred from the overall score, whereas towards the end of the task, performance was impacted by fatigue. Unchanged performance over the 10-minute PVT would imply low fatigue propensity; progressively worse performance over the course of the PVT would indicate that fatigue propensity would have been high at the beginning. While sleep deprivation may influence fatigue propensity, time on some task needs to occur for fatigue to manifest. Therefore, it appears that sleep health may exert a buffering influence on the effect of time on task on fatigue.

When assessing the impact of sleep deprivation on wake functioning, both subjective and objective assessment are important to measure. Van Dongen et al. (2003) studied 48 adults to investigate the relationships between total sleep deprivation and more long-term partial sleep restriction on performance and subjective sleepiness. After two weeks of sleep restriction to four hours a night, participants had similar accuracy on PVTs as participants who had three days of total sleep deprivation, while the increase in subjective sleepiness had plateaued for the partially sleep deprived. Participants with sleep opportunity restricted to six hours a night for the same timeframe showed less-extreme lapses on the PVTs—equivalent to around 1.5 days total sleep deprivation—but their subjective sleepiness plateaued to the same level as the four-hour sleep duration group (see Van Dongen et al., 2003, fig 1 A&B). The subjective experience of recovery from sleep deprivation may also improve quickly while behavioural metrics remain impaired. In a study on recovery from sleep restriction, Axelsson et al. (2008) restricted nine male participants to a four hour sleep opportunity window, 0300h–0700h, for five days, followed by three recovery days with eight-hour sleep windows, 2300h–0700h. Subjective sleepiness and PVT assessment was conducted throughout the experience. Whereas subjective sleepiness returned to baseline after three recovery days, vigilance as measured by the PVT remained worse than baseline. Following periods of restricted sleep, people might believe themselves to be recovered, while their performance may still be impaired (Axelsson et al., 2008). A subjective evaluation of sleepiness appears to adapt to chronically restricted sleep (Axelsson et al., 2008; Van Dongen et al., 2003). As a consequence, in the case of chronic partial sleep restriction, people may have impaired performance without necessarily realising how impaired they might be. When they recover, it may take some time before objective performance catches up to subjective evaluation. Therefore, both subjective and objective measures are important to capture when evaluating how changes to sleep may influence wake functioning

Mitigating Fatigue and Supporting Sleep Health

Mitigating Fatigue. If the tasks that one must do hold high levels of risk, impairments in performance associated with fatigue can cause significant safety issues (Belenky et al., 2014; Gander et al., 2014; Luyster et al., 2012; Reason, 1991; M. D. Weaver & Barger, 2019; Williamson & Friswell, 2013). Issues with fatigue tend to happen in a daily rhythm, ensuring work and rest schedules are appropriate to time of day, supposing synchronicity with endogenous circadian rhythms, will mitigate fatigue related risks (Balkin & Wesensten, 2011; Belenky et al., 2014; Gander, 2023). To mitigate fatigue related risks, basic strategies appear to follow two streams. The first stream is an application of general recommendations for mitigating fatigue related risk, for example specifying "(1) maximum hours of work in any work period, (2) maximum cumulative hours of work across a week or month, (3) minimum rest requirements between work periods, (4) maximum number of consecutive work periods prior to a day or days free of work, and (5) limitations relating to night work" (Sprajcer et al., 2023, p. 260). Outside of the workplace, general recommendations for avoiding fatigue include managing and pacing daily activity to avoid fatigue, resting as needed, and ensuring adequate diet and hydration (National Institute for Health and Care Excellence, 2021). Dynamic fatigue risk mitigation strategies emphasise the importance of adapting to idiosyncratic circumstances and change over time, ensuring work is tuned to appropriate times in the day and ongoing evaluation and troubleshooting (Gander, 2005; Sprajcer et al., 2023). These fatigue mitigation strategies apply within the workplace as well as outside of the workplace, where similar principles of pacing work to avoid fatigue, and adaptation to idiosyncratic and dynamic changes over time are present within fatigue management in chronic fatigue syndrome (Casson et al., 2023). Throughout fatigue mitigation strategies, supporting sleep health is crucial; if people have difficulty with their sleep health, then other fatigue mitigation strategies will fail to compensate (Dawson & McCulloch, 2005).

Supporting Sleep Health. Sleep health is crucial for supporting wake functioning (Dawson & McCulloch, 2005; Espie, 2022). To support sleep health, many recommendations, and interventions have been developed. These are described briefly below and range from specific recommendations and interventions to general principles. People may experience many combinations of sleep health difficulties that apply across various dimensions (Buysse, 2014). The sleep health framework mentioned above can be used in understanding which specific prevention and intervention strategies may be useful to support sleep health (Harvey & Buysse, 2017; Vorster et al., 2024).

General Principles. Espie (2022) recently codified general cross applicable sleep health promotion principles. These five cross-applicable recommendations were promoted to frame reflection and self-directed sleep health support. Espie urged people to recognise the value of their sleep, prioritise their sleep over other activities, personalise and experiment with their sleep, trust that sleep will come when it needs to, and protect their sleep from external influences. These principles were positioned by Espie as a contrast to the more specific sleep hygiene recommendations that are often drawn on when people experience sleep health difficulty.

Sleep Hygiene. Sleep hygiene interventions take various forms that can range from general education modules to specific education on specific difficulties. General education components typically involve teaching about sleep systems and recommendations about substance use, the importance of exercise, bedroom layouts, avoiding naps, and the importance of regularity and managing stress (K.-F. Chung et al., 2018). These kinds of education modules and healthy sleep behaviours are often a first line support for people who struggle with their sleep (Hauri, 1991; Kaplan & Harvey, 2014). While sleep hygiene recommendations may be seen as easily generalisable, they can take the form of standard rules that must be followed, though which may not be completely applicable to their target audience. For example, Shriane et al. (2023) noted that sleep hygiene practices typically recommend consistent sleep scheduling and recommend against napping, which may be inappropriate for shift workers, for whom consistent sleep schedules may be impossible, and for whom naps may be beneficial. These recommendations alone typically only lead to significant change in self-report sleep satisfaction metrics, particularly subjective sleep onset latency (SOL), with changes rarely being captured in objective measures (K.-F. Chung et al., 2018; Waters et al., 2003).

Specialist Treatment. Many difficulties with sleep health require more specialist treatment over and above recommendations to self-apply sleep-related principles and lifestyle changes. These more unique disorders like hypersomnolence and narcolepsy: difficulties with staying awake and alert; breathing-related disturbances like obstructive sleep apnœa; parasomnia disorders like sleepwalking and night terrors; or sleep-related movement disorders like restless legs syndrome and rapid eye movement sleep behaviour disorder (Gauld et al., 2025; Harvey & Buysse, 2017; Vorster et al., 2024). Each of these specific disorders may require specialist support with specific approaches to treatment and management ranging from pharmacotherapy to continuous positive airway pressure for breathing related issues (Harvey & Buysse, 2017).

While specific pharmacotherapy is also often used to support people with sleep health related difficulties, supporting changes in environmental, behavioural, and cognitive aspects of sleep are more well tolerated and show more robust and enduring effects that medication alone (Kaplan & Harvey, 2014; Mitchell et al., 2012; van Straten et al., 2018). Cognitive and behavioural interventions for sleep health typically involve combinations of psychoeducation about sleep systems and sleep hygiene recommendations; behavioural interventions like progressive relaxation techniques, stimulus control to support associating bedtime stimuli and sleep, and sleep restriction interventions, that is restricting time in bed (TIB) to increase sleep efficiency (SE) through homeostatic processes prior to aiming to increase total sleep time (TST); along with cognitive therapy to support people to challenging unhelpful beliefs and worries about their sleep that can maintain sleep health difficulty (Edinger & Carney, 2015; Harvey, 2005; Harvey & Buysse, 2017). When offered in combination, these interventions are often called cognitive behavioural therapy for insomnia and have consistently shown high efficacy in improving subjective and objectively measures of sleep health and alleviation of insomnia (Mitchell et al., 2012; van der Zweerde et al., 2019; van Straten et al., 2018; Waters et al., 2003).

Insomnia refers to a predominant subjective complaint about sleep quality and quantity associated with difficulty falling asleep or staying asleep that is persistent for over six months and causes issues in someone's life (APA, 2022; Kaplan & Harvey, 2014). There are, however, other sleep health difficulties that can be effectively treated through cognitive and behavioural means including too much TIB; circadian rhythm disorders where timing of sleep causes issues in someone's life; and nightmares (Harvey & Buysse, 2017). As such, the transdiagnostic sleep and circadian intervention (Harvey & Buysse, 2017) was based on a broadening of cognitive behavioural therapy for insomnia principles and delineates broadly applicable cognitive, behavioural, and specialist supports for a wide range of sleep health difficulties that can operate independently or in conjunction with diagnosis specific treatment. As with many cognitive and behavioural interventions (e.g., Beck, 2020), psychoeducation is a core element in cognitive behavioural therapy for sleep health difficulties, typically involving similar sleep hygiene recommendations as described earlier (Harvey & Buysse, 2017).

Harvey and Buysse (2017) introduce their education component with specific reference to EMU and sleep:

> If a client understands the science behind a recommendation, he or she is much more likely to try it. For example, many people enjoy using technology before bedtime. One client with a severe mental illness, who lives in a board and care home, described her TV as “my only friend.” She slept with the TV on all night. It was positioned next to her bed, near her pillow. However, this client was willing to try turning the TV off when she learned that bright light and intermittent noise interfere with the biology of sleep. (p. 12)

There are many different extant recommendations on modifying EMU in service of sleep health, often recommending hardware-free time prior to sleep (Headspace, 2022; Health Navigator Editorial Team, 2017), or wearing blue light blocking glasses (American Sleep Association, n.d.). The science behind these recommendations is rarely clear, and some recommendations are contradictory, for example one resource recommended 30 – 60 minutes of device-free time before bed, though also recommended half an hour before of listening to light music during this time, an activity which typically involves EMU hardware and software (New Zealand Media and Entertainment, 2021; Suni, 2020). Moreover, Harvey and Buysse (2017) described that their client was “willing to try turning the TV off”, though they did not report whether she was successful. Below, I outline some of the interventions that have been developed for people who experience EMU-related addictions, which, at their core, involve difficulty with simply controlling or changing EMU.

Supporting EMU Health. In the inceptive book on internet addiction, Young (1998) recommended 20 recovery strategies to support people experiencing internet addiction. These self-help strategies ranged from measuring time spent and accounting for the impact on one's life because of the internet, to education and investigation into symptoms and causes of internet addiction such as loneliness, denial, and interpersonal difficulties. Strategies also included support with communication with loved ones, setting rules for children's internet use, tips for supporting others in their recovery journey, and recovery and relapse management support (Young, 1998).

Since the pioneering work by Young (1998), numerous interventions have been developed for other EMU-related addictions. Many of these interventions note principles aiming for adaptive, controlled use of EMU, the importance of recognising the benefits of EMU, and the impracticalities of complete EMU abstinence (Cash et al., 2012; de Abreu & Góes, 2011; Young, 1999). Davis's (2001) provided a cognitive-behavioural model of *pathological internet use* suggesting that internet addiction develops, in part due to inadequate social support in other facets of life. As such, therapy for internet addiction typically involves extensive therapy on both individual and group levels (de Abreu & Góes, 2011; Malak, 2017). De Abreu and Góes (2011) emphasised the benefit of group therapy for generalised internet addiction; they created an 18-week group program for internet addiction to support groups to connect, find shared understandings, and collectively adapt their internet use routines.

Malak (2017) described a protocol for individualised cognitive behavioural therapy adapted to internet addiction. Malak’s protocol appears typical of EMU-addiction interventions. This protocol begins with behaviour modification where a diary of internet use is kept by the client for assessment purposes by the therapist. Computer restructuring systems are put in place such as removing shortcuts and filtering certain websites, to remove their convenience, and setting timers to encourage other activities. The protocol then focusses on cognitive restructuring to investigate and challenge thoughts associated with triggers for internet-based behaviours, developing understanding of potential unfulfilled needs and problems that internet use causes in a client’s life to support motivation to change, and finally addressing understanding ætiology and coexisting problems. Similar interventions have been adapted to other categories of EMU-based problematic use and addictions. Reviews of these interventions have been conducted by Kim and Noh (2019), and Zajac et al (2017) for internet addiction and internet gaming disorder; Malinauskas and Malinauskiene (2019) for internet and smartphone addiction; and M. W. R. Stevens et al. (2019) for cognitive behavioural therapy for internet gaming disorder. To summarise across these reviews, while consistent effects were found, they were generally small for alleviating symptoms of addiction—cravings, triggers, tolerance, and neglect of other important activities—related to EMU. All emphasised that further research is required to clarify construct definitions and standardise methodologies to allow for more robust conclusions (see Zajac et al., 2017 for an exemplar of this discussion).

As yet, we do not know whether interventions on EMU improve sleep health, let alone how these improvements may support vigilance or mitigate fatigue. None of the abovementioned reviews of EMU related addiction interventions measured sleep health outcomes (Kim & Noh, 2019; Malinauskas & Malinauskiene, 2019; M. W. R. Stevens et al., 2019; Zajac et al., 2017). Moreover, “to date, experimental research that determines whether reductions in media use or other evidence-based interventions can clinically improve sleep is extremely rare.” (Exelmans & Van den Bulck, 2019, p. 525). There appears to be a singular exception to this dearth of reviews on EMU addiction interventions discussing sleep health: Martin et al. (2020) conducted a meta-analysis on screen use interventions with children aged 2-13 years old, finding on average, across 11 various intervention studies, that included interventions led to daily screen time reductions of approximately 33 minutes, and sleep duration increases of 11 minutes. However, Martin et al. (2020) noted that there were many confounding issues; their studied interventions were not solely focussed on EMU and sleep, but also focussed on general household routines, parenting behaviour, nutrition, and other activities. One cannot attribute the 11-minute increase in sleep duration to changes in EMU alone (Martin et al., 2020). To date, I have found no similar review on adults.

Summary

In summary, this chapter has discussed the changing face of EMU and introduced a new conceptual framework through which to understand EMU. This chapter has also developed understandings of sleep and sleep health, and unpicked some nuances involved in understanding the interactions between alertness, vigilance, sleepiness, fatigue, and fatigue propensity. Therapeutic support to mitigate fatigue, support sleep health, and intervene in EMU-related addictions were also described. Espie (2022) emphasised the importance of fundamental principles that people may adopt and adapt to their idiosyncratic situations to support sleep health. However, healthy sleep behaviour recommendations that mention EMU often take the form of specific recommendations which appear highly variable, might be difficult to apply, and which are rarely based on theoretical or empirical underpinnings. I return to this point in Chapters 3 and 4 in developing a theory of causal mechanisms potentially involved in the EMU–sleep health relationship and the development of a new intervention. Additionally, the impact of EMU interventions on sleep variables has not been adequately studied in the academic literature. Chapter 5 contributes to this sparse evidence space by assessing behavioural and subjective EMU, sleep, vigilance, and fatigue outcomes of the new intervention. The next chapter investigates an aggregation of the research on the EMU sleep health relationship in adults through an umbrella scoping review methodology. Note that as the following chapter is in preparation for publication independent of the entirety of this thesis, some discussion points from the above chapter will be repeated below.

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1

Doctoral Research Committee
May 2023

Chapter 2

An Umbrella Scoping Review Charting Electronic Media Use and Sleep Health in Adults.[1]

Structured Summary

Background. Despite a wealth of research into the relationship between electronic media use (EMU) and sleep in the past decade, it remains difficult to know how best to use (or not use) electronic media in the service of sleep health. ***Objective.*** To develop a clearer picture of the relationship between EMU and sleep health in adults.

Design. An umbrella scoping review is presented, mapping extant reviews on the relationships between EMU and sleep health in adults. Overlapping primary studies created a literal map of the literature. A novel framework for viewing EMU is applied, alongside the sleep health framework to assess concepts and knowledge gaps.

Results. Of 3261 records screened, 18 reviews were included. No reviews were found that synthesised multiple studies using behavioural measurement or on data from which causality can be inferred. Most studies investigated the intersection between user addiction variables and self-reported sleep satisfaction. Many reviews noted high between-study variance and tentative conclusions. ***Conclusions.*** Concepts, methods, and measurement of EMU–sleep health require refinement. Further investigation into causal mechanisms may support more consistent and generally applicable recommendations.

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[1] This paper is currently in preparation for publication; yet to be submitted.

An Umbrella Scoping Review Charting Electronic Media Use and Sleep Health in Adults.

With the ongoing explosion of electronic media use (EMU) over recent decades, a common belief perpetuated across academic and popular media, is that EMU has led to a change in sleeping patterns (Cabré-Riera et al., 2019; Gradisar et al., 2011; Magee et al., 2014; Matricciani et al., 2017). This belief may be fuelled by perceived trends of shortening sleep duration in the last 30 years (cf. Bin et al., 2012; Matricciani et al., 2017) concurrent with rises in EMU (Anderson & Perrin, 2017; Boniel-Nissim et al., 2015; Roberts & Foehr, 2008; Twenge et al., 2019). Theoretical links between EMU and sleep health (Bauducco et al., 2024; Snyder & Chang, 2019) along with these changing patterns understandably combine to form a general perception that EMU negatively impacts sleep. The latest consensus from the National Sleep Foundation has concluded EMU screen use impacts sleep in children and adolescents. For adults, however, consensus on the relationship between EMU and sleep remains elusive (Hartstein et al., 2024).

Typically, EMU is understood as interfering with sleep through light exposure, time displacement, and arousal mechanisms (Bauducco et al., 2024; Exelmans & Van den Bulck, 2017b; Heath et al., 2014; Kroese et al., 2016; Snyder & Chang, 2019; Zeitzer et al., 2000). EMU may also support sleep by facilitating detachment, recovery, and relaxation (Liu et al., 2020; Reinecke & Hofmann, 2016). Popular recommendations on presleep EMU reflect the lack of consensus in the science (e.g., Headspace, 2022; Health Navigator Editorial Team, 2017; Suni, 2020). Recommendations typically range from 30 minutes to one hour of no EMU before bed, though some also encourage EMU, for example by winding down by listening to light music (Suni, 2020). While these appear to align with current conceptualisation of EMU–sleep health mechanisms, few presleep EMU recommendations cite clear empirical evidence for their content, focussing on various limitations with vague delineation.

EMU and sleep are both incredibly complex subjects. Exelmans and Van den Bulck (2019) noted that when studying the sleep–EMU relationship, sleep may be well understood, but EMU requires better understanding. To unravel these topics' complexities, this umbrella scoping review draws on the sleep health framework (Buysse, 2014; Vorster et al., 2024), and introduces a novel framework for EMU in order to chart and synthesise the research field.

The sleep health framework, originally introduced by Buysse (2014) has been recently updated (Vorster et al., 2024). This framework sees sleep health as aspirational and multidimensional, currently containing eight dimensions: 1) satisfaction/quality; a person's holistic subjective assessment of their sleep; 2) alertness: their attention capacity and vigilance in waking hours; 3) timing: when in the day their sleep is set; 4) efficiency: the amount of sleep one gets over the time allocated for it; 5) duration; the total amount of sleep time in a 24h period (Buysse, 2014); further dimensions of 6) regularity: the consistency of sleep timing from sleep to sleep; 7) breathing: respiratory functioning during sleep; and 8) disordered sleep: capturing specific parasomnias not described by the other dimensions have recently been suggested for formal addition (Vorster et al., 2024). The sleep health perspective has been described as "a distinctively useful paradigm to facilitate interpretation of a multitude of sleep dimensions" (J. Chung et al., 2021, p. 1). Sleep health's expansion adds breadth and appears similarly useful.

In a prototypical review in this field, Cain and Gradisar (2010) grouped EMU based on specific use cases and niches: “television viewing” (P.736), “computer or electronic games” (p. 738), “mobile telephone use” (P. 739), and “music” (P. 740). Exelmans and Van den Bulck (2016) noted that with the diversity and convergence in EMU, the arbitrary nature of these kinds of groupings may become more problematic. Following the call by Exelmans and Van Den Bulck (2019) in refining understanding of EMU, a novel conceptual framework is introduced here to support with synthesising studies on the EMU–sleep health relationship. This framework is used to delineate EMU constructs within the current scoping umbrella review through five lenses depending on the review’s focus. These five lenses through which EMU could be studied or measured are 1) user: attributes of the person using EMU; 2) context: situational aspects of EMU; 3) hardware: variables of the EMU devices, their names, or attributes; 4) software; the algorithmic aspects of EMU that mediate between hardware and content and 5) content; descriptions of the sensory experiences of EMU.

Scoping reviews aim to map out and create an overview of scientific literature. Importantly, they are not designed to synthesize answers to specific questions, but rather investigate the types of evidence that are available, methodologies used, and provide an overview of conceptual understandings themes, concepts, and identify potential research niches that are yet to be filled (Arksey & O’Malley, 2005; Munn et al., 2018; M. D. J. Peters et al., 2022; Pham et al., 2014). Moreover, umbrella reviews focus specifically on secondary sources to broadly chart the evidence available in a particular field (Cant et al., 2022). The overarching question that guided this review was: What is the scope and nature of existing reviews on EMU and sleep health in adults? A key focus was on conceptualisations of EMU and whether new insights could be gained through applying the novel EMU framework. This umbrella scoping review also sought to provide summary and perspective on research challenges in this complex field. Given the potential, breadth, and complexity of research into EMU and sleep's relationship, an umbrella scoping review is presented below to chart reviews pertaining to the relationship between EMU and sleep health in adults.

Method

Protocol

The current review follows PRISMA-ScR guidelines (see Appendix A; Tricco et al., 2018), and traditional scoping review methodology (Arksey & O'Malley, 2005). The review was initially registered on Open Science Framework: https://osf.io/nv5dh/. Since registration, the protocol was updated to focus only on adults, and update the date range. Updated methodology is presented below.

Search Strategy

Search terms, developed in collaboration with Massey University's subject librarian (J. Duncan, personal communication, 28 April, 2023) were: ("cell* phone*" or "mobile phone*" or "smart phone*" or "computer*" or "laptop*" or "tablet" or "e reader*" or "e book*" or "electronic media" or "screen time" or internet or "information technology" or "information communication technology" or "social media" or "digital media" or "instant messag*" or "e mail*" or "video chat*" or "phone call*" or "television" or "movie*" or "video*" or "game*" or "gaming" or "console" or "e sport*" or "blue light" or "blue green light" or "light exposure" or "short wavelength" or "online learning" or "e learning" or "cyber leisure" or "e leisure" or "e ink" or "crt" or "lcd" or "led" or "oled" or "vr" or "virtual reality" or "augmented reality") AND ("sleep*" or "fatigue*" or "tired*") AND ("systematic review*" or "meta-analys*" or "narrative review*" or "scoping review*" or "qualitative synthesis" or "quantitative synthesis" or "integrative review*"). These terms were used within EBSCOHOST discover service to search MEDLINE, CINAHL Complete, and APA PsycINFO. They were also adapted for searches in the Cochrane Database of Systematic Reviews and SCOPUS. All searches were run on 12 May 2023. Further articles were found by scanning reference lists of included reviews. Search records were imported into Rayaan (Ouzzani et al., 2016) for deduplication, and manually screened to ensure accuracy. Titles and abstracts were assessed for potential inclusion. Full texts were retrieved and arranged in Zotero (Takats et al., 2022) for review against the inclusion and exclusion criteria and digesting included studies.

Eligibility Criteria and Study Selection

We included peer-reviewed meta-analyses, systematic reviews, scoping reviews, or reviews following similar methodologies published in English between 01 January 2010 and 12 May 2023 that either described, explained, commented on, or synthesised primary literature on the EMU–sleep health relationship, provided definitions of their EMU constructs and considered adulthood (age 18+) in their scope. Reviews were excluded if they did not synthesise multiple articles on the EMU–sleep relationship; did not provide searching and review methodology; were reviews of interventions delivered through electronic media; conflated EMU with sedentary behaviour or other environmental exposures (e.g. environmental lighting and electromagnetic radiation); did not include studies on adults, or focussed on specific medical conditions or mental health difficulties (unless they specifically and separately assessed the EMU–sleep health relationship). Reviews primarily focussing on changes during the COVID-19 pandemic were excluded given significant circumstantial confounds. Reviews focussing on *social media fatigue* were also excluded due to conceptual divergence from sleep health.

Charting the Data

Data charting was completed independently by the primary author. Data items included reviews aims, EMU definitions and assessment methods for EMU and sleep variables, summaries of outcomes, limitations, and commentaries from the reviews. Observations of types of evidence drawn on in the reviews were also compiled. Effect sizes in meta-analyses were extracted and summarised (Chen et al., 2010; Cohen, 1988; P. D. Ellis, 2010). If review studies provided unclear reference to measurement instruments used, primary sources were drawn on for clarity. Citations of all included primary studies on the sleep–EMU relationship were extracted, tabulated and arranged to create a literal map of the research using iGraph (Csardi & Nepusz, 2006) in R (Version 4.0.5).

Synthesis of Results

Prior research for this umbrella scoping review revealed no frameworks in the literature that described a foundational approach to what constitutes EMU. A novel framework was devised to delineate EMU constructs into five constituent lenses: *Context*, *User*, *Content*, *Software*, and *Hardware*. Intersections were drawn between EMU and relevant dimensions of sleep health. Studies could be intersected in multiple aspects of EMU and sleep health frameworks if they clearly addressed separate aspects.

Results

In total, 18 reviews were included in the umbrella review, which drew from 199 primary sources. These were distilled from 3232 records identified through academic databases, of which 15 were initially included; 29 records were identified from the reference lists of the 15 initially included articles, of which 3 met criteria. In total, 2166 records were scanned for relevance and 91 full texts were read to assess inclusion criteria. This process was completed by the primary author with consultation with other authors for less certain decisions. Figure 2 charts stages of record identification and refinement.

Characteristics of Included Reviews

Of the 18 included reviews, five were systematic reviews that also meta analysed the sleep–EMU relationship (Alimoradi et al., 2019; Chan et al., 2022; Kristensen et al., 2021; Li et al., 2020; Yang et al., 2020). Thirteen studied the sleep–EMU relationship in systematic reviews or similar methodology (Alonzo et al., 2021; Brautsch et al., 2023; C. Kemp et al., 2021; Kuss et al., 2021; Mac Cárthaigh et al., 2020; MacKenzie et al., 2022; Männikkö et al., 2020; Mihara & Higuchi, 2017; Ramjan et al., 2021; Ratan et al., 2021; Sadagheyani & Tatari, 2021; Sánchez-Fernández et al., 2023; Zhong et al., 2022). One of these systematic reviews (MacKenzie et al., 2022) focussed on qualitative research. The other 17 reviews were based primarily on quantitative correlational data. Details of the 18 included reviews are described in Table 1.

Mapping the Field

Figure 3 presents the network map that was drawn by overlapping primary studies used to describe the relationship between EMU and sleep health. The research ecosystem, when delineated by EMU–related variables contained four primary niches each with at least three reviews: gaming associated (n =5), social media associated (n = 3), internet associated (n = 3), and smartphone associated (n = 6) reviews. One further review (Brautsch et al., 2023) investigated *digital media*, which interestingly, contained no overlap with the gaming nor internet addiction studies, likely as Brautsch et al. investigated time spent on EMU, which addiction metrics tend not to capture. The prominence of (Alonzo et al., 2021) as a central link in Figure 3 indicated low specificity in their application of the *social media* construct.

Figure 2

Literature Search and Refinement Flow

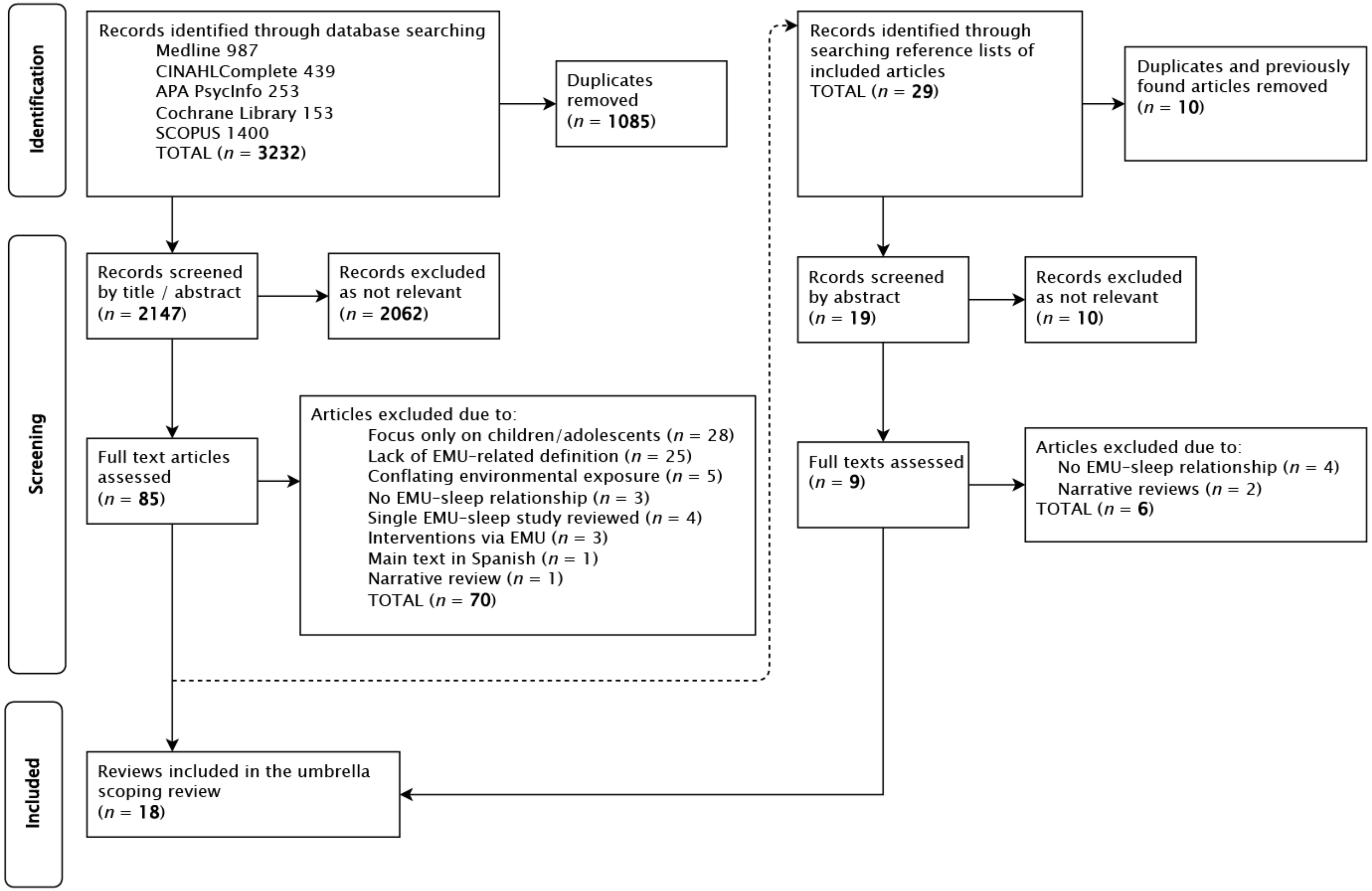


Table 1

Characteristics of Included Reviews

Code †, Author (Date). Review Type. Number of Studies*	EMU Aspects. EMU Definition. EMU Measures.	Sleep Aspects. Sleep Measures.	Main Outcomes on the Sleep & EMU relationship. Highlighted Limitations, Discussions and Commentary.
R01 Alimoradi et al. (2019). Systematic review / meta-analysis. 23 studies	Internet addiction symptoms: Tolerance, loss of control of use, escapism, deception, and neglect of consequences along with disturbances in other areas of life. DSM-5 IGD symptoms, YIAT, YDQ, s-IAT, CIAS, IOS.	Sleep disturbances: "Sleep problems based on the reported diagnosis or the assessment measure." (p. 53). Sleep duration: "sleep duration in mean hours with standard deviation" (p. 53). PSQI, ISI, AIS, ESS, SHQ, GHQ, CASC, researcher-devised questionnaires.	Pooled OR for sleep problems in presence of internet addiction: 2.20 (95% CI: 1.77 – 2.74). Pooled SMD for sleep duration for internet addiction group compared to normal internet users: -0.24h (95% CI: -0.38, -0.10) All analysed studies used self-reports in assessing internet addiction or sleep, influence of social desirability and memory recall bias.
R02 Alonzo et al. (2021). Systematic Review. 42 studies	Social media: Internet-based applications that facilitate exchange and exploration of user generated content. YIAT, YDQ, SAS, SAS-SV, CIAS, COS, BFAS, MTUAS smartphone usage subscale, SQAMPMU, OSNA. Self-reported: disturbance from phones in sleep diaries; combinations of hardware, internet, and Facebook use frequency, intensity, duration, timing, and impact estimates.	Synthesised under "sleep quality" included terms: sleep quality, sleep disturbances, sleep loss (defined as sleep duration shorter than 7-9 hours), poor sleep outcomes, sleep duration on weekdays and weekends, compensation, and sleep difficulties. PSQI, BIS, ISI, AIS, SSHS, KSQ, MOS-SS, GSAQ. Other self-report: sleep diaries, sleep quality/quantity/duration /loss/timing estimates. insomnia, sleepiness upon awakening.	23 studies found positive associations between frequent social media use and poor sleep quality. 5 cohort studies found excessive social media use at baseline as a risk factor for poor sleep quality at follow up. "Excessive internet use and mobile phone use were the most commonly examined forms of social media," (p. 6). Limitations: most studies used convenience samples, all studies used self-reported measures introducing potential biases. Suggested: "Future studies would benefit from the use of more objective methods of measuring sleep quality and technology use (actigraphy, screen time monitors on smartphones) as well as adopting longitudinal study designs to clearly establish temporality of the observed associations." (p. 10)

Code †, Author (Date). **Review Type.** **Number of Studies***	**EMU Aspects. EMU Definition.** **EMU Measures.**	**Sleep Aspects.** **Sleep Measures.**	**Main Outcomes on the Sleep & EMU relationship.** **Highlighted Limitations, Discussions and Commentary.**
R03 Brautsch et al. (2023) Systematic Review/rapid review. 42 studies.	Digital media: Devices or software examples: computer, smartphone, tablet, television, social media, internet, gaming, blogging, e-mail. Assessed time spent on any device or platform. Compiled all measures into "total screen use" (p. 3). In the narrative of results, they used the term "digital media use". The term "total screen use" was not mentioned after the introduction. Specific questionnaires used in studies not reported.	Sleep quality, sleep disturbances, daytime tiredness, sleep duration, delayed bedtime, sleep onset latency / problems falling asleep, early awakening, and discrepancy between wake-up times. KSQ, BIS, ESS, PSQI, ISI, single item self-reports, diary assessment, actigraphy.	Consistent evidence pointing to reduced sleep duration and satisfaction/quality when using some types of media (particularly smartphones) at nighttime. Inconsistent evidence for many sleep outcomes studied. Many studies showed lack of interactions between EMU variables and sleep variables. others showing interactions in some contexts. Limitations: Most studies used self-reported measurements of digital media use and sleep outcomes: noted a risk of misclassification, recall and social desirability bias.
R04 Chan et al. (2022). Systematic Review/meta-analysis. 8 studies	E-sports: a type of sport where actions and outputs are primarily mediated through human-computer interfaces. Included both players and audiences. None of the studies on sleep discussed e-sports specifically but were rather focused on video gaming. Two included studies defined video games: one provided examples of genres of video games, the other provided devices and software elements. Both focussed on gaming duration.	Sleep duration: assessed with self-report and fitbit. Sleep quality in meta-analysis included 3 studies that used global PSQI. Other measures included CSHQ, FAS, BIS. Insomnia complaints self-reports. single studies: sleep onset delay, weekday sleep duration, daytime sleepiness, fatigue, later bedtime, later rise time, sleep efficiency and daytime disfunction from PSQI.	Mixed-findings about the relationship between video-gaming and sleep. Systematic review described negative impacts of video gaming on sleep quality from 3 included studies, and on duration from 2 studies. Sleep quantity not in meta-analysis. Sleep quality relationship was meta-analysed: video gaming was not significantly associated with sleep quality. One study mentioned "intensity of video game playing" was related to sleep quality, however quantity was not. Limitations: Noted small sample sizes of included studies.
R05 Kemp et al. (2021). Systematic Review. 12 studies	Habitual gamers: Individual self-identification with regular game playing, either recreationally, competitively, or professionally. Gaming: Playing an electronic game on personal computer, game console, or mobile phone. Excluded arcade games. Studies	sleep quality: mostly assessed through PSQI, >5 cutoff score or correlations. Symptoms of insomnia: ISI, BIS, Interview. Self-report sleep duration & sleep timing. Single studies: restfulness of sleep, wake up time and delayed sleep phase syndrome, ESS.	Mixed results in relationship between sleep delay and video gaming volume: one study found association, two did not. Inconsistent small effect sizes between addiction and other sleep outcomes. Summarised one study that observed a

Code †, Author (Date). Review Type. Number of Studies*	EMU Aspects. EMU Definition. EMU Measures.	Sleep Aspects. Sleep Measures.	Main Outcomes on the Sleep & EMU relationship. Highlighted Limitations, Discussions and Commentary.
	generally on metrics of duration, although gaming intensity discussed in one study. Gaming addiction: assessed using measures aligned with DSM or ICD criteria for dependence/addiction: DAS, GAS-SF, YIAT-SF, IGDS9-SF, AIE-Q		significant (but small) odds ratio for lowered sleep quality: 0.969 (Altinas et al., 2019) as evidence for a "deleterious effect on sleep" (p. 11). Research gaps: Impact of sleep on gaming performance, difference in effects with different hardware. Limitations acknowledged: Self-report instruments, social desirability and recall biases, all studies cross sectional, online based survey collection methods & convenience samples reduce representativeness & potential of falsified data, heterogeny in measures for gaming and internet addiction, gaming duration inferring addiction may overlook gaming without functional impairment, sleep duration metrics do not consider timing, studies generally assumed homogeneity in other variables across their samples.
R06 Kristensen et al. (2021). Systematic review / meta-analysis. 34 studies	Problematic gaming: A pattern of gaming having negative influence on health and interference in daily activities. Assessed with adapted DSM/ICD criteria /addiction symptoms. Measures: AIE-Q, DAS, IGDS9-SF, KFN-CSAS-II, AICA-S, CESR, CGA, GAS(A), GASA, GASA-SF, IGD-20, IGDQ, IGDS, IGDT-10, OGASA, OVGA, PTU One study assessed problematic gaming through diagnostic interview. One based solely on time spent playing; problematic gaming ≥ 4 h playing a day.	Sleep variables in meta-analysis: sleep duration, sleep quality, daytime sleepiness, sleep problems. Majority of studies used self-report to assess sleep variables. One study used fitbit to measure sleep duration. One study used diagnostic interviews for insomnia & delayed sleep phase. Measures included: Neuro-QOL-SD-SF, SAMQ, SCL-90R, ISI, PSQI, PDSS, BIS, other researcher-devised measures.	Overall effects considered small in associations between problematic gaming and sleep factors. Sleep duration: small negative association: g = −0.238 [−0.364, −0.112]. Difference in mean TST (min): -20.79 [−27.31, −14.30]. Adolescent populations higher effect size than adult populations. Sleep quality: Higher odds of poor sleep quality OR = 2.02 [1.47, 2.78] Daytime sleepiness: Higher odds of reporting daytime sleepiness, OR = 1.57, [1.00, 2.47], single item questionnaires showed higher overall effect size, OR = 2.74 [1.84, 4.08]

Code †, Author (Date). Review Type. Number of Studies*	EMU Aspects. EMU Definition. EMU Measures.	Sleep Aspects. Sleep Measures.	Main Outcomes on the Sleep & EMU relationship. Highlighted Limitations, Discussions and Commentary.
			than multi-item questionnaires, OR = 1.01 [0.70, 1.44]. High between study variance. Sleep problems: Increased odds of reporting sleep problems OR = 2.60, 95% CI [1.94, 3.47]. High between-study variance. Multi item questionnaires, OR = 3.47 [2.51, 4.81] had a higher effect compared with single item studies OR = 1.77, [1.23, 2.65]. High heterogeny within subgroups & across studies. Noted "serious limitations" (p.13) in the literature: correlational studies on convenience samples of primarily western adolescents in educational facilities. Heterogeny in measurement. Genre of games, changing habits, motivations for playing not addressed. Loosened construct definition to improve analytic power.
R07 Kuss et al. (2021). Systematic review. 3 studies.	Generalised internet addiction: an umbrella term encompassing addictions to specific online behaviours incorporating symptoms of salience, mood modification, tolerance, withdrawal, conflict, and relapse. Measure: YIAT	poor sleep quality, sleep problems, sleep duration. not further defined.	Internet Addiction was significantly associated with poor sleep quality, sleep problems, and negatively associated with sleep duration. Cited one study for each sleep variable independently. Cited all three when reporting a positive correlation between internet addiction and sleep problems generally. Various cutoff scores for YIAT reportedly employed. Not described per study.
R08 Li et al. (2020). Systematic review/meta-analysis. 14 studies.	Mobile phone addiction: An inability to regulate use leading to negative consequences. Synonyms: smartphone addiction, problematic smartphone use, excessive smartphone use, problematic mobile phone use, mobile phone dependence.	Sleep quality PSQI global scores	Meta analysed mobile phone addiction association with sleep quality: summary r = 0.28, [0.22-0.33], P < 0.001 No significant subgroup variability for studies based on survey method, sampling strategy, measurement instrument for MPA, geographic

Code †, Author (Date). Review Type. Number of Studies*	EMU Aspects. EMU Definition. EMU Measures.	Sleep Aspects. Sleep Measures.	Main Outcomes on the Sleep & EMU relationship. Highlighted Limitations, Discussions and Commentary.
	Measures: MPAI, MPATS, SAS, SAS-SV, SPAI, SPAI-BR.		location, student's specialty, sample size and sex ratio of studies. Did not detect any publication bias amongst the sleep studies. Discussed that sleep quality could be a partial mediator for the impact that mobile phone use has on emotions. Based on correlational data, stressed possible reverse or bidirectional causality. All studies based on self-report. Restricted measurements to certain scales so noted possible underpowering of analyses. Despite restricted measures, noted substantial heterogeneity.
R09 Mac Cárthaigh et al, (2020). Systematic review. 9 studies	Problematic smartphone use: Overuse of smartphones to the extent that it disturbs daily life. Self-report measures: MPPUS, SAS-SV, SAPS, SPAI, MPAI. One study used a non-validated scale.	Sleep quality PSQI & translations. One of these studies also included actigraphy. Two studies not on sleep quality. One of these on daytime sleepiness (PDSS) and one on chronotype (CSM) and sleep duration (not further described).	7 studies compared subjective sleep of participants scoring high and low on measures of PSU. All supported hypothesis that PSU is associated with "poor sleep". Study that used actigraphy did not show significant effect. Weighting of quality of evidence below acceptable Limitations: Conceptual issues with the term "addiction" and difficulties operationalising problematic smartphone use. Reliance on subjective sleep measures, effect not supported by actigraphy study. No objective data to measure smartphone use. Time distortions during smartphone use distort self-report. All studies cross-sectional on homogenous samples within specific cultural contexts. Findings should be considered only tentative.

Code †, Author (Date). **Review Type.** **Number of Studies***	**EMU Aspects. EMU Definition.** **EMU Measures.**	**Sleep Aspects.** **Sleep Measures.**	**Main Outcomes on the Sleep & EMU relationship.** **Highlighted Limitations, Discussions and Commentary.**
R10 MacKenzie et al. (2022). Qualitative systematic review and thematic synthesis. 14 studies.	Primarily focussed on social interactions involved in nighttime social media use. examples: messaging friends, group chats, sending pictures. Given qualitative nature of studies, terminology and definitions were explored as part of method and results. Associated user attributes: fear of missing out, thoughts of phones, habitual use, & perceived lack of control.	Sleep timing, duration, daytime functioning interaction: qualitative analysis concerned patterns of delaying bedtime and sleep resulting in next day tiredness.	Three analytical themes, with 12 subthemes: 1. Social motivations (fear of missing out, social accountability, not subscribing to norms, enjoyment of bedtime social media use) 2. Habitual Smartphone use (strong urge to 'check' phone, automaticity of habitual use, difficulty in stopping electronic use, losing track of time, social media as a facilitator of sleep) 3. Recognition of a problem (negative effects, restrictions of electronics at bedtime, distraction from other priorities). Suggested that interventions need to find a balance between the facilitatory effect of social media use on sleep, and the drawbacks that simply imposing limits on social media use might have on sleep, calling for technology-based interventions. Two competing and essential parts of adolescent development; sleep and social acceptance. Limitations noted in studies: Absence of cultural / sociodemographic factors, primary researchers failing to place themselves culturally or theoretically. Inconsistent use of terminology between studies.
R11 Männikkö et al., (2020). Systematic review / meta-analysis. 3 studies in systematic review, 0 in meta-analysis	Problematic Gaming Behaviour: Experiencing withdrawal, loss of control and problems in personal relationships, at work and in school. Self-report assessment instruments: adapted DSM-IV-TR criteria for Substance Dependence, IGAS, KFN-CSAS-II.	Sleep disturbances (in discussion) and sleep problems (in results) used interchangeably with no further definition. Methods: One used open question, one unclear methodology, one unvalidated question on sleep disturbance and sleep time.	Noted an association between sleep problems and problematic gaming behaviour in the three studies. Not described further. Limitations noted: Sampling bias given many studies recruited from social media. Response bias given self-report nature of studies. Inconsistent cutoffs in scales used to

Code †, Author (Date). Review Type. Number of Studies*	EMU Aspects. EMU Definition. EMU Measures.	Sleep Aspects. Sleep Measures.	Main Outcomes on the Sleep & EMU relationship. Highlighted Limitations, Discussions and Commentary.
			determine problematic gaming behaviour. Heterogeneity of the data obtained. Studies mostly cross sectional.
R12 Mihara & Higuchi (2017). Systematic review. 4 studies.	Internet gaming disorder: defined with reference to DSM-5 criteria, though also included offline gaming. GADS, GAS, VGDS, PVGUS.	Sleep problems with no further definition or description of assessment methods. Described in table as: sleeping problems, sleep problems, and sleep disturbance.	Stated that internet gaming disorder is related to sleep problems, no further elaboration. Noted methodological inconsistencies in reviewed studies hindering identification of reliable associations or identification of prevalence rates. Noted cross sectional nature of many studies. All studies pertaining to sleep were cross sectional.
R13 Ramjan et al. (2021). Integrative literature review. 2 studies.	Smartphones: Tools used to access drug information, guidelines, sharing of visual data with colleagues, real-time access to the internet to support evidence-based care and connect with colleagues for isolated community nurses. Described as ubiquitous given portability and versatility. One study assessed smartphone use (methodology not described), the other used COS.	Sleep quality. PSQI	Concluded "the studies in this review have determined that smartphone use had a direct and indirect detrimental impact on students' physical (sleep quality)" (P.17) Quality appraisal rated both studies as "weak" Limitations noted: Only including English articles, excluding grey literature. The studies on sleep were correlational descriptive studies.
R14 Ratan et al. (2021). Systematic review. 6 studies	Smartphone addiction: behavioural addiction including symptoms of mood tolerance, salience, withdrawal, modification, conflict, and relapse. Measures: PUMP, SAS, SAS-SV, CSAI, SAS, Self-reported questionnaires.	Sleep quality: PSQI, AIS Daytime disfunction: PSQI Sleepiness: ESS One study mentioned reduced subjective sleep duration, though specific methodology not reported.	Five studies reported association between smartphone addiction and sleep quality. Outcomes of insomnia/sleepiness/daytime dysfunction not reported in narrative. Limitations: Studies were cross sectional. All papers were English, most studies from developed countries. Lack of standardised scales and cut-off scores for determining smartphone addiction.

Code †, Author (Date). Review Type. Number of Studies*	EMU Aspects. EMU Definition. EMU Measures.	Sleep Aspects. Sleep Measures.	Main Outcomes on the Sleep & EMU relationship. Highlighted Limitations, Discussions and Commentary.
R15 Sadagheyani & Tatari, (2021). General review. 8 studies.	Social media, classified into seven types: social networks, blogs, wikis, podcasts, forums, content communities and micro-blogs. Only defined social networks: a set of web-based services that allow individuals to create public or private descriptions for themselves, communicating with other members of the network, sharing their resources with them, and using this platform to find new connections. Methodologies of assessing social media not discussed.	Poor sleep quality / Poor sleep. Not further defined and methodologies of included studies not discussed.	Noted that social media at night on phones, laptops, and tablets associated with decreased sleep quality, also that greater social media use causes poor sleep which could increase depressive symptom scores. Suggested a warning system intervention: a message to high users of social media warning of harms of social media addiction. Suggested "we should try to use more active interactions in social media and use these interactions to strengthen communication in the real world." (p. 48) Also suggested education for students about the harms of social media. The authors stated that their study had limitations but did not say what they were other than that they only examined the relationship between social media and mental health.
R16 Sánchez-Fernández et al. (2023). Systematic review. 6 studies.	Problematic internet use: a maladaptive Internet use pattern characterized by loss of control, appearance of negative consequences and obsessive thinking when the Internet is inaccessible. Measure: YIAT	Poor sleep quality: an umbrella term lifestyle predictive factor for problematic internet use. Included sleep quality, "Sleeping less than 6h daily" (p.25) physical and mental fatigue, insufficient sleep, Sleep disturbance referring to "over six to 7 h or less than six to 7 h of sleep" (p.25). Methodologies for assessing sleep not described	Poor sleep quality: Of the six studies, five found significant effects between problematic internet use and sleep: One small, one medium, one large, two mixed effect sizes. One study mentioned "hours of sleep as a potential protective factor." (p.25) Limitations: Studies did not discuss specific behaviours. Authors called for future research to be done on specific use cases. Various YIAT cutoff points leading to heterogeny. Acknowledged dynamic nature and continuum of severity. Only studied direct effects: called for future research into indirect variables. Many of the studies were conducted in Asia.

Code †, Author (Date). Review Type. Number of Studies*	EMU Aspects. EMU Definition. EMU Measures.	Sleep Aspects. Sleep Measures.	Main Outcomes on the Sleep & EMU relationship. Highlighted Limitations, Discussions and Commentary.
			Lack of consensus around conceptualisation, criteria, and assessment tools for valid and reliable information about problematic internet use. Urged for more qualitative work to understand causes and symptoms to allow more precise instruments to be developed. Recommended further research using longitudinal designs controlling for possible confounds. Fact check: The authors claimed that internet gaming disorder "was officially recognized" (p. 2) in the DSM-5 "in the same chapter with substance use disorders" (p. 1). This is incorrect (cf. APA, 2013).
R17 Yang et al., (2020). Systematic review / meta-analysis. 8 studies	Problematic smartphone use: excessive use of smartphone, a strong internal drive for smartphone use, impaired ability to self-control, increased time given to smartphone use. continuation of use despite negative consequences. Measures: MPPUS-10, SAS-SV,K-SAS, MPPUS, COS, PCPU-Q.	Poor sleep quality. PSQI, PDSS, AIS	Significant association between problematic smartphone use and poor sleep quality, OR =2.19. [1.79, 2.67], moderate heterogeneity, I2 =56.9%, p = 0.023. Limitations: No universal consensus on problematic smartphone use definition. Heterogeny in PSU and outcome measures. Most studies cross-sectional, mainly focussed on students, self-report, unequal gender distribution, prone to recall and social desirability bias. Univariate analysis did not address potential moderators. Recommendations: network analysis for exploring mechanisms, use apps to log smartphone usage, studies with more participants to reduce sample biases, longitudinal studies to provide evidence for causal relationships.

Code †, Author (Date). Review Type. Number of Studies*	EMU Aspects. EMU Definition. EMU Measures.	Sleep Aspects. Sleep Measures.	Main Outcomes on the Sleep & EMU relationship. Highlighted Limitations, Discussions and Commentary.
R18 Zhong et al., (2022). Qualitative synthesis / Meta-analysis. 5 studies (0 in meta-analysis)	Smartphone addiction: Dependence on or addiction to smartphones and an "uncontrollable fear" (p.1172) of being without contact of their mobile phone. Synonyms: smartphone overuse, nomophobia, problematic smartphone use. Only included studies that used SAS or SAS-SV, Note: SAS and SAS-SV do not assess for uncontrollable fear.	Sleep quality PSQI	Overall prevalence estimate of smartphone addiction: 41.93% Range of significant correlations observed between smartphone addiction and poor sleep quality in three studies (r = .17—.31). Range of odd's ratios varying from OR = 3.19—2.12 for reporting poor sleep quality in the PSQI in context of meeting smartphone addiction criteria in SAS(SV). Limitations: Only including use of two smartphone addiction scales and one sleep scale. Significant heterogeneity between studies. Only included studies in Asian countries, and language restricted to English. Stressed that the findings should be interpreted with caution.

Note.

† These codes are used to identify references for Figure 3 and Table 2.

* Many of these studies also included other variables related to their EMU construct; only the studies that described the EMU–sleep relationship was counted.

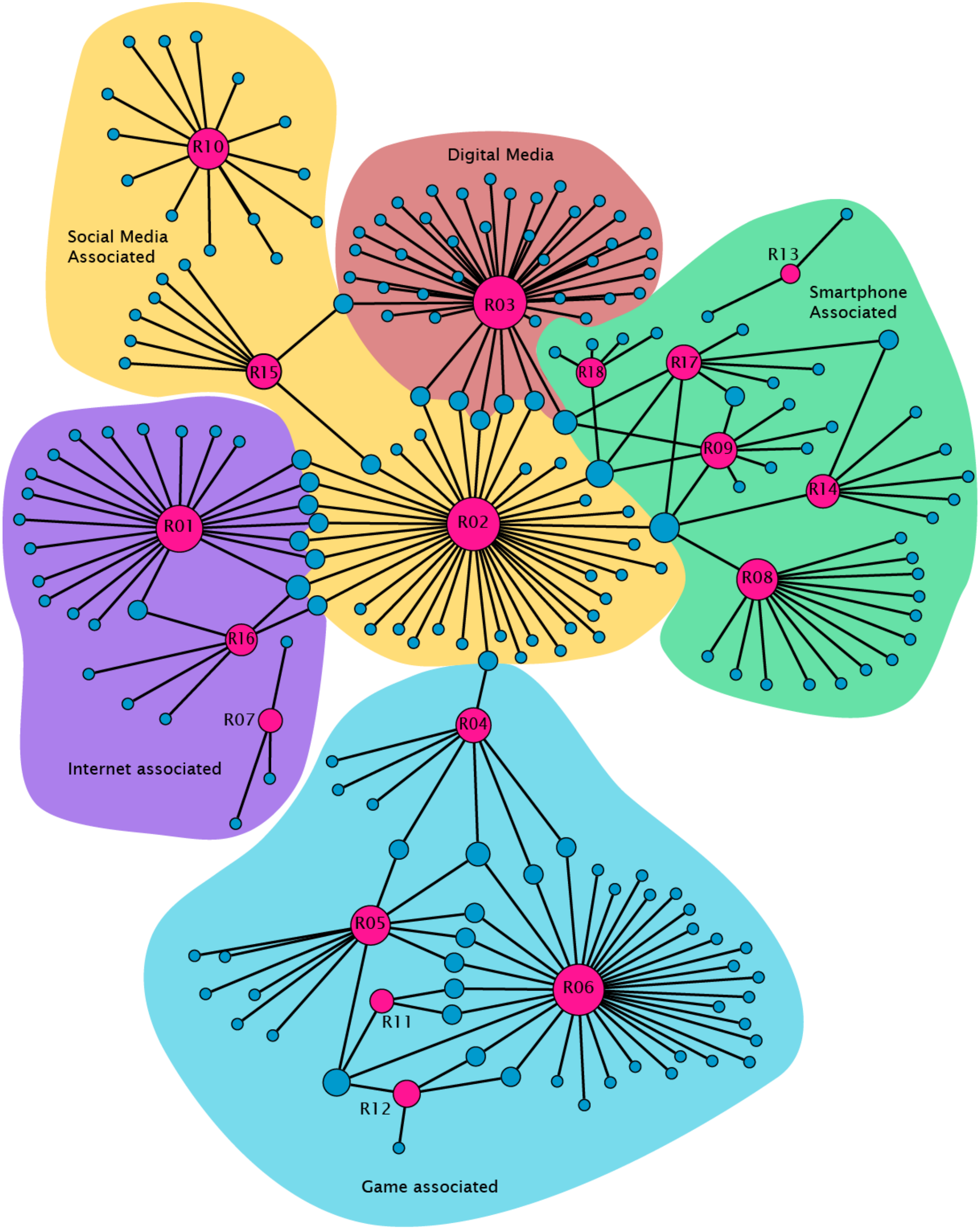
Acronyms: (SMD) Standard mean difference; (IGD) internet gaming disorder; (PSU) problematic smartphone use; (DSM-5) diagnostic and statistical manual of mental disorders, fifth edition (APA, 2013); (DSM-IV-TR) diagnostic and statistical manual of mental disorders, fourth edition, text revision (APA, 2000); (OR) odds ratio; square brackets ([a, b]) refer to 95% confidence intervals reported in meta analyses.

EMU measures: (AICA-S) assessment of internet and computer game addiction scale; (AIE-Q) addictive intensity evaluation questionnaire; (BFAS) Bergen Facebook addiction scale; (CESR) questionnaire of experiences related to videogames; (CGA) computer game addiction scale; (CIAS) Chen internet addiction scale; (COS) cell-phone over-use scale; (CSAI) Chen smartphone addiction inventory; (DAS) DSM-IV substance dependence adapted scale; (GADS) Goldberg internet addiction disorder scale; (GAS) gaming addiction scale; (GAS(A)) Persian gaming addiction scale; (GASA) gaming addiction scale for adolescents; (GASA-SF) game addiction scale for adolescents–short form; (GAS-SF) game addiction scale–short form; (IGAS) internet game addiction scale for Korean adolescents; (IGD-20) internet gaming disorder test; (IGDQ) internet gaming disorder questionnaire; (IGDS) internet gaming disorder scale; (IGDS9-SF) internet gaming disorder scale – short form; (IGDT-10) ten-item internet gaming disorder test; (IOS) internet overuse scale; (KFN-CSAS-II) German video game dependency scale; (K-SAS) Korean smartphone addiction proneness scale; (MPAI) mobile phone addiction inventory; (MPATS) mobile phone addiction tendency scale; (MPPUS) mobile phone problem use scale; (MPPUS-10) short version of the mobile phone problem use scale; (MTUAS) media technology usage and attitudes scale; (OGASA) online game addiction scale for adolescents; (OSNA) online social networking addiction scale; (OVGA) videogame addiction scale; (PCPU-Q) problematic cellular phone use questionnaire; (PTU) the pathological technology use checklist; (PUMP) problematic use of mobile phone scale; (PVGUS) pathological video game use scale; (SAPS) smartphone addiction proneness scale; (SAS) smartphone addiction scale; (SAS-SV) smartphone addiction scale - short version; (s-IAT) short form internet addiction test; (SPAI) smartphone addiction inventory; (SPAI-BR) Brazilian version of the smartphone addiction inventory; (SQAPMPU) self-rating questionnaire for adolescent problematic mobile phone use; (VGDS) video game dependency scale; (YDQ) Young's 8-item diagnostic questionnaire; (YIAT) Young's internet addiction test; (YIAT-SF) Young's internet addiction test – short form.

Sleep measures: (AIS) Athens insomnia scale; (BIS) Bergen insomnia scale; (CASC) child and adolescent sleep checklist; (CSHQ) children's sleep habits questionnaire; (CSM) composite scale of morningness; (ESS) Epworth sleepiness scale; (FAS) fatigue assessment scale; (GHQ) general health questionnaire; (GSAQ) global sleep assessment questionnaire; (ISI) insomnia severity index; (KSQ) Karolinska sleep questionnaire; (MOS-SS) medical outcomes study sleep scale; (PDSS) paediatric daytime sleepiness scale; (PSQI) Pittsburgh sleep quality index; (SAMQ) sleep activity and media questionnaire; (SHQ) sleep habit questionnaire; (SSHS) school sleep habits survey.

Figure 3

Categorising Overlap of Studies and Reviews of EMU and Sleep Health



Note. Pink nodes represent review studies. Blue nodes represent primary studies that were drawn on in reviews. Node size is proportional to number of links. See Appendix B for a full map of study overlap along with primary study references. See Table 1 (above) for reviews reference "R" codes.

Synthesis of Results

EMU construct definitions and sleep health dimensions were extracted from included reviews and charted in a table of intersect (Table 2). If reviews also discussed clearly delineated aspects of EMU and sleep health in their results, evidenced by at least two studies, regardless of specific definitions being present, these were also presented in the table. For example, Brautsch et al. (2023) described that most consistent evidence they found was for reduced sleep duration when using some types of media at nighttime specifically. Although *timing of media use* was not operationally defined in their study, an entry for Brautsch et al., (2023) was included in the table in the intersect of sleep duration and EMU context. Studies on problematic use and addiction variables for EMU–related topics were aligned with the *user* aspect as measurement of addiction and problematic use focussed on user attributes rather than measuring *use* per se. Within sleep health dimensions, insomnia scales were often drawn on in the reviews interchangeably with subjective sleep quality measures. If reviews discussed EMU and insomnia using global scores of measures like the insomnia severity index and Athens insomnia scale, these were intersected through *satisfaction*, as subjective satisfaction with numerous sleep health dimensions is the unifying sleep health aspect for these scales (Buysse, 2014; Shahid et al., 2012). If sleep duration and efficiency were explicitly discussed separately, then they were also intersected with their respective dimensions. If Pittsburgh Sleep Quality Index (PSQI Buysse et al., 1989) global scores were reported, this was identified as *satisfaction*, though if PSQI subscales were independently reported, then they were each identified with their respective sleep health dimensions.

Table 2

Intersecting Reviews by Sleep Health and the Five-Lens EMU Frameworks

	Sleep Health Dimensions							
EMU Lens	Satisfaction	Duration	Timing	Efficiency	Alertness	Breathing	Regularity	Disorder
Context	R03, R15	R03	R03, R10		R03			
User	R01, R03, R05, R06, R08, R09, R14, R16, R17, R18	R01, R06, R16	R10		R06			
Content			R10					
Software	R02, R03, R04, R05, R15	R03, R04	R10					
Hardware	R03, R15	R03	R03	R03	R03			

Note. This table utilises codes for each reviewed study that are listed in Table 1. Four reviews were excluded from this table. Three (Mihara & Higuchi, 2017; Kuss et al., 2021; & Männikkö et al., 2020) discussed *sleep problems* without further delineation. One (Ramjan et al., 2021) discussed sleep quality related to smartphones in two studies, one of which used the cell phone overuse scale (user lens); the methodology of the other was not reported, thus the EMU intersect was unclear. Only one study (Garmy & Ward, 2018) found in one review (Brautsch et al., 2023) assessed variability in wakeup times associated with night time texting. Sleep health dimensions of regularity, breathing, and other sleep disorders are clear areas for further research or review. See Appendix C for description of decisions in this table's creation. Colours within the table show a heat map relating to number of reviews in each intersection.

Summarising Evidence

In meta-analyses, relationships between EMU and sleep health constructs were assessed through pooled odds ratios, correlations, or Hedge's *g*. Overall, small to medium effect sizes were found between addiction and problematic use constructs (user lens) and sleep quality, sleep duration, and alertness dimensions of sleep health. The one meta-analysis that was not on addiction variables was Chan et al. (2022), who based their meta-analysis on reported time spent playing video games (software lens) and found no significant correlation between video gaming quantity and sleep quality.

Small to medium pooled effect sizes were reported in studies that investigated the relationship between poor sleep quality and EMU-related variables: problematic smartphone use (pooled odds ratio [OR] = 2.19, 95% confidence interval [CI]: [1.79, 2.67]; Yang et al., 2020), mobile phone addiction (r = 0.28, 95% CI [0.22–0.33], P < 0.001; Li et al., 2020) problematic gaming (OR = 2.02, 95% CI [1.47, 2.78]; Kristensen et al., 2021). Similar odds were summarised for reporting general sleep problems in cases of internet addiction (OR = 2.2; Alimoradi et al. 2019), and problematic gaming (OR = 2.60, 95% CI [1.94, 3.47]; Kristensen et al. 2021). The only study that meta-analysed quantity of EMU, rather than addiction or problematic use symptoms in relation to sleep quality was Chan et al (2022) who reported small and nonsignificant correlation between quantity of video gaming and sleep quality (r = 0.13, 95 % CI [0.05, 0.32], p = 0.149). Kristensen et al. (2021) noted a small correlation between problematic gaming and sleep duration (g = −0.238, 95% CI [−0.364, −0.112]), where the standard mean difference of total sleep time in those identified as problematic gamers was 20.79 minutes (95%, CI = [27.31, 14.30, min.]) shorter than those not identified as problematic gamers. Alimoradi et al. (2019) also reported a standard mean difference in sleep duration where people who were identified as having an internet addiction slept on average approximately 14.4 minutes less than those that were not. While these may appear minimal, they may also represent meaningful differences if they represent a pattern of accumulating chronic sleep deprivation. Kristensen et al. (2021) reported a small increased odds (OR = 1.57, 95% CI [1.00, 2.47]) of reporting daytime sleepiness for cases identified with problematic gaming.

Conceptual Issues

Thirteen of the 17 quantitative studies (Alimoradi et al., 2019; Alonzo et al., 2021; Brautsch et al., 2023; C. Kemp et al., 2021; Kristensen et al., 2021; Kuss et al., 2021; Li et al., 2020; Mac Cárthaigh et al., 2020; Männikkö et al., 2020; Mihara & Higuchi, 2017; Ratan et al., 2021; Sánchez-Fernández et al., 2023; Yang et al., 2020) cautioned against inferring causality based on correlational data alone. Interestingly, three of these 13 studies that cautioned against inferring causality (C. Kemp et al., 2021; Kristensen et al., 2021; Ratan et al., 2021) concurrently made causal inferences in their reporting. For example, Kemp et al. (2021) reported on a correlational study that showed “high intensity of video game playing was associated with a greater risk of having low sleep quality (OR: 0.969, 95% CI: 0.946–0.993, p = 0.01)” (Kemp et al., 2021, p. 7). In their discussion, this same primary study (Altintas et al., 2019) was cited after the following claim: “gaming intensity is complementary to gaming duration in its deleterious effect on sleep” (Kemp et al., 2021, p. 11). Three studies implied causality from correlational data without noting caution in causal inference (Chan et al., 2022; Ramjan et al., 2021; Sadagheyani & Tatari, 2021). One study (Zhong et al., 2022) neither inferred causality nor cautioned against it.

Among introduction and discussion passages, nine reviews discussed possible causal mechanisms that could be responsible for the sleep EMU relationship. However, these discussions neither formed nor guided the structure of any study's results. All mechanisms that were discussed pertained to potential causal direction from EMU negatively impacting sleep health (Alonzo et al., 2021; Brautsch et al., 2023; C. Kemp et al., 2021; Kristensen et al., 2021; Li et al., 2020; Mac Cárthaigh et al., 2020; MacKenzie et al., 2022; Ratan et al., 2021; Zhong et al., 2022). While six articles acknowledged the possibility of EMU being caused by sleep difficulties or the relationship being bidirectional, mechanisms of this causal direction were neither elaborated nor specified (Alimoradi et al., 2019; Brautsch et al., 2023; Kuss et al., 2021; Li et al., 2020; Mihara & Higuchi, 2017; Yang et al., 2020). None of the included reviews speculated on a possible maintenance cycle involved in the EMU–sleep health relationship.

Thirteen reviews were explicit in describing significant conceptual and methodological limitations, urging caution in the interpretation of their results (Alonzo et al., 2021; Brautsch et al., 2023; C. Kemp et al., 2021; Kristensen et al., 2021; Li et al., 2020; Mac Cárthaigh et al., 2020; MacKenzie et al., 2022; Männikkö et al., 2020; Mihara & Higuchi, 2017; Ratan et al., 2021; Sánchez-Fernández et al., 2023; Yang et al., 2020; Zhong et al., 2022). The five reviews that did not make the tentative nature of their conclusions clear (Alimoradi et al., 2019; Chan et al., 2022; Kuss et al., 2021; Ramjan et al., 2021; Sadagheyani & Tatari, 2021) did not demonstrate any obvious methodological or conceptual advantages.

Ten reviews included studies that based their results on self-report EMU variables that contain explicit reference to sleep problems (Alimoradi et al., 2019; Alonzo et al., 2021; C. Kemp et al., 2021; Kuss et al., 2021; Li et al., 2020; Mac Cárthaigh et al., 2020; Ratan et al., 2021; Sánchez-Fernández et al., 2023; Yang et al., 2020; Zhong et al., 2022). Some examples of scales that contain sleep items within their assessments of EMU include the commonly used Young internet addiction test (YIAT; Young, 1998), the game addiction scale (GAS; Lemmens et al., 2009), the mobile phone problem use scale (MPPUS; Bianchi & Phillips, 2005), the smartphone addiction inventory (SPAI; Lin et al., 2014), the smartphone addiction scale (SAS; Kwon et al., 2013), and the problematic use of mobile phone scale (PUMP; Merlo et al., 2013). Each of these scales introduce a hidden logical tautology into their assessment of the EMU–sleep health relationship, an issue that was not noted in any of the reviews.

Discussion

This umbrella scoping review aimed to summarise and synthesize a broad understanding of the EMU–sleep health relationship, focussing on reviews that considered adults, and from which EMU definitions could be gathered. Eighteen reviews were included. These were mapped by charting the overlap of primary studies and the research field was synthesised according to facets of sleep health and a novel five-lens framework for understanding EMU. The preponderance of the reviews researched the intersection between addiction symptoms (user lens) and sleep satisfaction. Reviews rarely discussed EMU content and sleep efficiency. Most of the reviewed data in this field was correlational. Despite causal statements being common and conceptually sensible, no evidence of a causal effect was found in these reviews. Many reviewers noted conceptual issues in the primary research, limitations of their reviews and advised caution in their interpretation.

EMU and sleep health constructs were studied through diverse viewpoints that appeared to elude consistent definition across reviews. The difficulty with forming coherent, simple, and cross-applicable understandings of the relationship between EMU and sleep health may explain inconsistency in popular presleep EMU recommendations. Clear, consistent, cross-applicable, and evidence-based recommendations for managing EMU to support sleep health requires an increase in clarity of concepts and methodologies in this research field.

S. S. Stevens (1935) discussed the need to constantly update and test construct validity and operational utility "if we are to be rid of the hazy ambiguities which result in ceaseless argument and dissension." (S. S. Stevens, 1935, p. 517). *Hazy ambiguities* were frequent in many of the above articles. For instance, the YIAT (Young, 1998) was a common measure that was variously used to provide evidence for *internet addiction* (Alimoradi et al., 2019; Kuss et al., 2021), *problematic internet use* (Sánchez-Fernández et al., 2023), *social media use* (Alonzo et al., 2021), *habitual videogaming* (C. Kemp et al., 2021), and *problematic gaming behaviour* (Männikkö et al., 2020). Many EMU concept names, such as *problematic internet use* and *problematic smartphone use*, on the surface, given the verb "use" in their construct, appear to be referring to *behavioural determinants*, that is actions and activities that influence the person or environment (Bandura, 1986). However, their respective scales refer to *personal determinants* (Bandura, 1986), or in the EMU framework, *user* variables, that is the presence of symptoms of addiction in a person's life.

The inclusion criteria for the current umbrella scoping review required studies to define their EMU concepts of interest. While definitions were present in each review, they were rarely operational and sometimes inconsistently applied. For example, Alonzo et al. (2021) defined social media "as Internet[*sic*]-based applications that facilitate exchange and exploration of user-generated content" (p. 1). In their discussion they stated: "excessive internet use and mobile phone use were the most commonly examined forms of social media" (p.6). The subsummation of these undefined constructs made of verb phrases (*excessive internet use*, or *mobile phone use*) within constructs represented by a noun phrase (*social media*) indicate a *hazy ambiguity* that requires resolution. Finding consistent operational definitions for EMU constructs is difficult. For example, two studies, (C. Kemp et al., 2021; Kristensen et al., 2021) on gaming-associated variables used the word *game* within their game-related construct definitions. Concepts like games are notoriously difficult to define in a way that encompasses all common aspects. Wittgenstein (1953/1986) discussed the conundrum of trying to form an accurate definition of a fuzzy concept with reference specifically to the difficulty to define the concept of a *game*. There is not one quality that is universal across all games; they consist of groups of overlapping traits, not common to all, but interlinked *family resemblances* (Wittgenstein, 1953/1986, Sections 66–77). To understand better the relationship between EMU and sleep health, these resemblances and attributes require more thorough and focussed research to resolve ambiguity.

The resolution of these nebulous constructs requires ongoing effort. S. S. Stevens (1935) suggested:

> The ultimate success of such efforts depends upon the diligence with which the concepts are kept under observation so that they may be constantly revised to accord with new discoveries or to adjust to new demands of simplicity and utility. No concept can be defined once and for all: every concept of science requires constant purging to keep it operationally healthy. (p. 527)

The current umbrella scoping review aimed to build on this effort by delineating EMU constructs into a new framework for more clearly understanding the categories of EMU under investigation. In order to develop consistent statements about how EMU impacts sleep health, sharper delineation of EMU constructs are necessary. By delineating hardware, software, content, context, and user variables of EMU from each other, and clearly describing which aspects are the objects of reference, future research may be more accurately and easily synthesised, and understood within a consistent categorical framework.

In applying the five-lens framework for understanding EMU along with the latest (Vorster et al., 2024) delineation of sleep health dimensions, a majority, 10 of the included reviews provided evidence on the relationship between user variables associated with EMU, and the subjective satisfaction dimension of sleep health. One possible reason for this is the methodological ease for gathering mass subjective data from survey studies. Measures of EMU-related addiction capture symptoms that, while subjectively associated with EMU, are not necessarily due to the effect of EMU.

Addiction symptoms are often attributed to countless other ætiologies which researchers in addictions spaces work to conceptualise (e.g., Maté, 2018). An early conceptualisation of internet addiction stressed the many related personal and circumstantial influences associated with addictions (Young, 1998) . When discussing EMU-related addictions, the relationship with sleep health could be influenced through other addiction-related variables, with EMU perhaps being spurious. While addictions may manifest in usage, EMU related addiction measures rarely assess actual use.

Many EMU-related addiction scales also included sleep constructs in their items (e.g., Young, 1998). A recent network analysis found that the strongest link between an EMU-related addiction scale, the YIAT and the PSQI was between the subjective sleep quality item in the PSQI sleep health item in the YIAT (Lu et al., 2023). Many studies included in the above reviews drew conclusions based on correlations between these two scales. When sleep satisfaction items are nested within EMU addiction scales, correlations between EMU addiction scales and sleep satisfaction scales might simply be measuring overlapping sleep satisfaction constructs. This conceptual overlap was not noted in any of the reviews.

In a recent narrative review of mechanisms involved in the EMU–sleep health relationship, Bauducco et al. (2024) noted that “correlational studies are not necessarily adding to our knowledge going forward” (Bauducco et al., 2024, p. 8). In the current umbrella scoping review no effect size was found to indicate that any other EMU construct domain, other than addiction symptoms correlated with sleep health. While that there certainly have been tremendous volumes of correlational data, and no reviews found that could determine causality, from intersecting studies between the sleep health and EMU frameworks, many areas of potential correlational research remained undocumented. Table 2 showed a lack of reviews of sleep efficiency when relating to EMU context, user, content, and software, as well as reviews of alertness relating to software, and reviews of EMU content's relation to sleep satisfaction, duration, efficiency, and alertness. Research investigating the recently included breathing, regularity, and specific sleep disorders dimensions (Vorster et al., 2024) were also not synthesised in the included reviews. More work could be done to form understandings on the relationships between the content of EMU and sleep health as well as how sleep efficiency relates to various aspects of EMU, and how software aspects relate to alertness. We may still achieve new insights in these domains through correlational studies and downstream reviews. Their interpretation should be cautious in inferring causality, though they may give further insight into mechanisms for experimental studies which the current set of review literature consistently noted was lacking in the field.

Limitations of the Current Review

This review only included reviews that included adults aged over 18 years in their criteria. However, some of these included studies still gathered information from adolescent populations, which may have influenced conclusions (e.g., MacKenzie et al., 2022). The selection of studies, data extraction, analysis, charting, and mapping was all completed by one person, thereby increasing the chance that potentially eligible studies were missed, and bias may have been introduced into the judgemental tasks of mapping and categorising the literature. Mitigation of this was attempted by having a relatively relaxed inclusion criteria initially, checking all possibly included studies with co-authors, and running tough decisions past co-authors to discuss and find consensus. The five-lens framework for understanding EMU was applied to delineate the viewpoints that different reviews took in their conceptual understandings. As understanding of EMU develops, the five-lens framework is likely to require further development and refinement. In this umbrella scoping review, the five-lens framework proved useful for identifying research oversampling and niches in the EMU–sleep health relationship that either still require review or that require further primary research. More reviews on primary studies will be required to investigate whether it is the primary research that is lacking. We anticipate the frameworks utility for quickly identifying what exactly researchers are investigating when discussing EMU. However, given the framework's categorical spin, researchers may also disagree on the specific lens through which their EMU-related construct is seen. We anticipate utility of the framework also for diagnosing and clarifying these possible dissensions.

Conclusions

The EMU–sleep health relationship research field in adults appears mostly focussed on addiction symptoms and subjective sleep quality, with most EMU-related variables delineated through arbitrary definitions that lack foundational delineation. These constructs are colloquially meaningful, and the measurement of them methodologically and statistically convenient. However, if we are to debate over the impact of these EMU concepts like "social media", "smartphone", and "internet", while they develop, change, and blur at an ever-increasing pace, our understanding of them will be continually outpaced by developments in the area that we seek to conceptualise (Exelmans & Van den Bulck, 2016, 2019). It is anticipated that application of this five-lens EMU framework will resolve inconsistencies in construct definitions and lead to an increase in the conceptual health of this research field.

Practice Points

1. When investigating correlations between sleep health and electronic media use, use metrics for assessing electronic media use that are not explicitly confounded with sleep health items.
2. Delineate electronic media use constructs by user, context, hardware, software, and content categories for more consistent narratives of electronic media use.
3. When publishing recommendations for EMU to support sleep health, where possible, reference empirical literature to support these recommendations.

Research Agenda

1. The relationship between addiction symptoms and subjective sleep quality has been oversampled. Further investigation and review of other aspects of electronic media use particularly software, hardware, and content and intersects with other sleep health dimensions such as timing, alertness, variability, efficiency, breathing, and disordered sleep is required.
2. Causal mechanisms through which EMU and sleep health may interact require further study. This requires development and application of relevant theories to frame understanding, and reviews of experimental studies to support the development of empirically-based recommendations for those who experience EMU–sleep health difficulties.

3. Most of the reviewed research is correlational. Further experimental studies are required on how modification of EMU might support sleep health.

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Chapter 3

Investigating Interrelated Influences: A Potential Maintenance Cycle of Electronic Media Use, Sleep Health Difficulty, and Fatigue

This chapter outlines a maintenance model of the relationships between EMU, sleep health difficulty, and fatigue. It begins by distilling complex influences of EMU on sleep health into intertwining time displacement and arousal mechanisms. The impact of sleep health difficulty on fatigue propensity is also discussed, and fatigue's role as a motivation controller is described along with motivation principles that frame a regulatory draw towards EMU. This narrative review of empirical and theoretical literature culminates in the description of a causal maintenance model of EMU, sleep health difficulty, and fatigue that links the three variables of interest in this thesis.

Importantly, this chapter merely represents a perspective afforded by the culmination of my own investigation into this literature and therefore is "the initial stage, the act of conceiving or inventing a theory" (Popper, 1968, p. 7). While many of the ideas integrated into this chapter formed a conceptual base for the intervention introduced in Chapter 4, and tested in Chapter 5, the test of the intervention makes no claim to potentially falsify the maintenance model presented here, only to test the usefulness and efficacy of the intervention itself. Testing the practical implications of the links of this new maintenance model will require further investigation beyond the scope of this thesis, as such, this chapter concludes with mention of some areas for further research.

How EMU Could Lead to Sleep Health Difficulty

There are many frames through which the relationship between EMU and sleep health can be seen (see Bauducco et al., 2024; Cain & Gradisar, 2010; Exelmans, 2020; Hale & Guan, 2015; LeBourgeois et al., 2017 for overviews). Below, I attempt to distil the causal impact of EMU on sleep health into two primary and intertwining mechanisms: time displacement, and arousal. These mechanisms are difficult to disentangle from each other, and also difficult to delineate from the influence of other environmental, personal, and behavioural determinants, as such, this chapter has developed a certain unavoidable complexity and non-linearity that echoes the likely complexity of these interwoven causal influences. This section begins with an investigation into *time displacement*, delineating EMU's facilitation of displacement of biological time: EMU's influence on the circadian timekeeping system via light exposure; and displacement of behavioural time: the fundamental idea that spending time on one activity displaces time available for others. Social and environmental influences on time displacement are also discussed as EMU's may facilitates social contact within and across other time contexts that can influence both behavioural and biological time displacement. Following an investigation into these time displacement mechanisms, studies on EMU's influence on arousal and subsequent impacts on sleep health are reviewed, and a compromise is described between EMU facilitated arousal and psychological detachment.

Time Displacement

Biological and behavioural time displacement mechanisms are closely intertwined with each other and confounding to tease apart (Czeisler, 1995). The impact of social influence on time use decisions contributes to their interweaving (cf.

Khalsa et al., 2003; Wever, 1979). Time displacement can occur independently from EMU, though may also be facilitated by electronic media. Furthermore, isolating the independent functioning of these mechanisms to EMU is particularly difficult as this involves controlling for other social, behavioural, and environmental influences that users may experience. EMU provides many opportunities for individuals to control and assimilate light exposure, while experiencing social and parasocial content, and spending time doing so. The relationships between these time displacement mechanisms are complex. In this section I attempt to unpick some of their complexity as a key mechanism through which EMU may lead to difficulties with sleep health.

Biological Time Displacement. The circadian timekeeping system in humans is primarily conducted by cells in the SCN (Lydic et al., 1980). A key mechanism of biological timekeeping is the oscillation of clock gene transcriptions and translations whose resulting protein complexes repress their own transcription factors, leading to upregulation and downregulation of clock and clock-controlled gene expression over the course of the endogenous circadian day and night (Hastings et al., 2018). These oscillations occur in all cells throughout the body, though the ones in the SCN primarily synchronise the rest through hormonal secretions and neuronal activity, the key control mechanisms of the biological clock (Grosjean et al., 2023; Hastings et al., 2018; Roenneberg et al., 2019). Peripheral clocks throughout the body provide local mediation of this system which ultimately influences all daily patterns of human biology from temperature and metabolism, to potentiating wakefulness and sleep (Grosjean et al., 2023; e.g., Hastings et al., 2018; Smies et al., 2022). This biological clock is endogenous, with the innate cycle length typically extending slightly beyond the 24-hour period of day and night, though for some, this *free running period* may be shorter than 24 hours (Gander, 2023; Roenneberg et al., 2019). The biological clock promotes wakefulness during the biological day and sleep during the biological night (Czeisler, 1995; Exelmans & Van den Bulck, 2019; Roenneberg & Foster, 1997). When sleep and wake behaviour is synchronised to biological time, sleep health is enhanced; when behaviour is desynchronised from biological time, this can lead to difficulties with sleep health and wake functioning (Matheson et al., 2014; Vlasak et al., 2022).

The biological clock can be shifted depending on the system's exposure to light (Czeisler, 1995, Roenneberg & Foster, 1997). Light synchronises the biological timekeeping system by being detected through ganglion cells in the retina that express melanopsin; photosensitive proteins that initiate signals to the SCN through the retinohypothalamic tract (Berson et al., 2002; Grosjean et al., 2023). These light signals result in increases to the firing rates of SCN neurons which lead to a biological time displacement with effects depending on when the signals occur (Gander, 2023). Biological time shifts later if light exposure occurs between dusk and the body's temperature minimum in the very early morning, and earlier if light exposure occurs between the temperature minimum and dawn (Gander, 2023; Khalsa et al., 2003; McGlashan et al., 2018; Rea et al., 2012). If local *sun time* is somehow desynchronised from biological time, then light cues, zeitgebers from the sun typically resynchronise the biological clock to keep it in tempo (Roenneberg et al., 2019). However, light from the sun are not the only kind of light that synchronises the biological clock. Artificial ambient light, and light from EMU can also influence this photic entrainment, or biological time displacement mechanism.

Biological time displacement effects depend on many complex mechanisms and individual differences (Chellappa, 2021; Grosjean et al., 2023). The duration of light exposure, and light's brightness and its wavelength are crucial dimensions of this environmental determinant (A. Chang et al., 2012; Khalsa et al., 2003). Photic entrainment of the circadian timekeeping system in humans is particularly sensitive to short, blue-cyan-green light wavelengths, peaking in sensitivity between around 470–510 nm (Rea et al., 2012). EMU hardware, particularly screens, typically emit this wavelength of light (Gringras et al., 2015). Bright artificial light of around 9000 lux can induce biological time displacement that exceeds its length of exposure, though with the amplification of effect decreasing in potency as exposure time lengthens: When presented close to peak time for biological time displacement for 15 seconds, this bright light can lead to around a 35 minute biological phase delay (Rahman et al., 2017); 12 minutes of exposure to this light at this time can lead to biological time displacement of around one hour, and the temporal amplification drops to around two hours and 40 minutes of biological time displacement for a four hour bright light exposure (A. Chang et al., 2012). Lower light intensities also impact the system. Phillips et al. (2019) found that when exposed to dimmer light of varying brightness for five hours in the evening, this can lead to biological time displacement of approximately 22 minutes for 10 lux, 77 minutes for 30 lux, and 109 minutes for 50 lux, though noted that these responses are highly variable between individuals (Phillips et al., 2019; see also Chellappa, 2021). To put these brightness levels in perspective, outdoor daytime light is frequently over 10,000 lux (e.g., Stothard et al., 2017); recommended indoor lighting levels range from 100 lux for ambient lighting, 300 lux in bathrooms, and 500–800 lux for reading physical media (Adams, 2019);

and a first-generation iPad set to full brightness and held 25cm away from the eyes delivers approximately 40 lux to the cornea (Wood et al., 2013). Light from artificial sources, including EMU can therefore lead to biological time displacement, potentially desynchronising our biology from the local day-night cycle.

The biological time displacement that EMU may induce, is very difficult to isolate from the influences of ambient light and other sources of behavioural and social influence. Green et al. (2017), however, provided experimental evidence of the impact of blue light from EMU alone on indications of displaced biological time. Green et al. conducted a crossover study comparing the impact of EMU light exposure across nights when participants engaged in text-based EMU tasks from 2100h to 2300h while isolated to a dark room and sleeping soon after. Green et al. found that, if only blue LEDs were active on computer screens, normal melatonin and temperature changes—measures used to infer the biological clock's functioning overnight—were relatively suppressed when compared to when only red LEDs illuminated the EMU tasks. While tightly controlling context and behaviour, a biological time displacement from EMU can be directly assessed, though, as Green et al.'s experiment showed, the biological time displacement effect depended primarily on the wavelength of light emitted by EMU. EMU software can modify light emissions from EMU to mitigate this effect while keeping other environmental variables relatively constant (f.lux Software LLC, 2008; Gringras et al., 2015; Warren, 2016).

Behavioural Influences on Biological Time Displacement. The experiment mentioned above by Green et al. (2017) also made the amount of time participants spent using electronic media prior to bed consistent between their experimental conditions. This control was in order to isolate a biological time displacement effect that depended on the wavelength of light emitted by electronic media screens. While these tight controls are useful for verifying that EMU can have a direct effect on the circadian timekeeping system (cf. Mook, 1983), outside of the laboratory, other variables may lead to other forms of time displacement, interacting with, or independently from the influence of light on the central circadian timekeeper.

The interactions between behaviour and biological time displacement are complex. Non-photic social and behavioural synchronisation of biological clocks was initially thought of as the primary mechanism through which the human circadian timekeeping system entrained to the environment (Wever, 1979), while the photic entrainment system is now relatively well understood, how social and behavioural influences impact circadian biology is less clear (cf. Czeisler, 1995; Honma et al., 2003, 1995; Khalsa et al., 2003) and is an outstanding question for chronobiology (Chawla et al., 2024). Within current understandings, behavioural and social time displacement is generally thought of as entraining the biological clock *through* associated light exposure, or leading to a desynchrony, or displacement *between* biological, social, and sun clocks (e.g., Roenneberg et al., 2019).

Many of the behaviours that people engage in while doing EMU are not under the strict controls like the study by Green et al. (2017). In naturalistic settings, adults generally regulate their own EMU timing. In investigating the impact of self-regulated EMU on biological time displacement, Chinoy et al. (2018) compared sleep timing and melatonin rhythms of participants between nights where they read printed materials and nights where they used a tablet computer before bed. Chinoy et al. found that, overall, when participants were in the unrestricted-tablet-use condition, their self-selected bedtimes, and their sleep onset were around half an hour later, and biological time displacement as measured through blood serum melatonin assays was on average just under an hour later than in the printed material reading condition. Chinoy et al. emphasised the close interactivity between EMU facilitated behavioural time displacement, and biological time displacement. If people stay up later on EMU, they may be exposed to more light and displace their biological time. However it is worth noting that in the study by Chinoy et al. (2018), when reading printed materials, participants were exposed to only very dim lighting conditions, averaging at 0.7 lux; far below recommended brightness for reading printed materials (cf. Adams, 2019; Chinoy et al., 2018), whereas in the tablet conditions illuminance was closer to 40 lux; so the impact of some behavioural time displacement mechanisms on biological timing may still, for example, permeate into reading printed material under brighter lighting prior to sleep, or other activities that people may engage in using artificial light.

Behavioural Time Displacement. A simple behavioural time displacement mechanism that EMU can facilitate centres on the topic of procrastination, in particular, procrastination of sleep. When first introduced, bedtime procrastination was defined independently from EMU as "failing to go to bed at the intended time, while no external circumstances prevent a person from doing so" (Kroese et al., 2014, p. 1). Since then, this concept has expanded to *sleep procrastination*, including both procrastination of going to bed, and while-in-bed procrastination of going to sleep, in favour of other evening activities, each possibly facilitated by EMU (Exelmans & Van den Bulck, 2017a; Liu et al., 2020; Magalhães et al., 2020). This behavioural time displacement appears tightly knit with other aspects of a user's life. For example, when people have days filled with highly structured activities, or high responsibility, the precious opportunity that the relatively unstructured post work time provides can be particularly precious (L. Müller, 2023). People may be drawn to prolong this time, and through prolonging this time, before or while in bed, they displace time available for sleep (L. Müller, 2023). EMU, particularly portable and bed-compatible hardware can lead to periods of extended wakefulness that displaces time available for sleep (Exelmans & Van den Bulck, 2017a). Liu et al. (2020) described bedtime procrastination as a key variable through which EMU may lead to sleep health difficulty. Bauducco et al. (2024) described behavioural time displacement as simply *time displacement* and noted that this may lead to the greatest threat from EMU to sleep health. Engaging in bedtime procrastination may expose one to more artificial light and lead to synchronous delays in both behavioural and biological time (Chinoy et al., 2018). However, EMU does not always displace time available for other activities, nor does it always result in light exposure. For example, people may listen to music while engaging in other activities (Hesmondhalgh et al., 2023), and people may also use electronic media while trying to go to sleep (e.g., Exelmans & Van den Bulck, 2016; Wang et al., 2021). Social influences may be a key environmental determinant of the kinds of EMU one engages in, likely influencing both behavioural and biological systems in their complex interaction.

Social Influences on Time Displacement. EMU may be a facilitator of social contact, which can strongly influence behaviour (Bandura, 1986). EMU may also be a facilitator of parasocial experience, that is, one-directional interactions that seem social to the user (Forster, 2023). Time displacement may be encouraged by social commitments from local peers accessed through EMU (e.g., MacKenzie et al., 2022; H. Scott et al., 2019); time displacement may also be facilitated by social and parasocial EMU experiences, which can occur across time zones, or even in embedded relatively timeless contexts where a seemingly forever awake community awaits (Seung-A, 2010; Wienrich et al., 2021; Young, 1998).

An early temporal isolation bunker study documented by Wever (1979) showed that if people have access to the ability to completely control the light that they are exposed to and are removed from interfering cues of the local sun time, biological time ran free, typically lengthening, sometimes to around 26 hours per day, suggesting the extremes to which the free running period of our biology and behavioural clocks may run. When self-adjusted lighting is possible, and when isolated from the local day night cycle, continual biological time displacement from sun time may occur freely (Czeisler, 1995). Extremes of EMU in the form of virtual reality may replicate these settings (Wienrich et al., 2021) and possibly lead to similar time displacement patterns.

Wever (1979) also described another unique experiment of two individuals living together in the temporal isolation bunker where either participant could turn the lights on or off at will. Wever found that their rhythms entrained to each other; the last to go to bed turned the lights off, shifting the other's behavioural and biological time later, and the first to get up turned the lights on, shifting the other's behavioural and biological time earlier. This (Wever et al., 1979) study showed a neat example of the interaction between social and biological timekeeping; a coregulation of social behaviour and light exposure leading to a mutual synchrony of social and biological time that ran free, continually displaced from local sun time. Most people, however, do not live in time isolation laboratories where this pure mutual social influence is possible. Instead, many are faced with a mixed light cues from artificial light and the sun clock, as well as social commitments on the consensus *social clock* determined by the tempo and rhythm of industrialised society (Roenneberg et al., 2019, see also Postman, 1985).

As humans can typically control artificial light in the evening, there is a tendency towards delayed biological clocks for all the but the earliest chronotypes (Roenneberg et al., 2003). Morning commitments, however, rarely adjust to these delays, rather, staying on the consensus *social clock* and leading to what Wittman et al. (2006; see also Roenneberg et al., 2019) described as the phenomenon of *social jetlag*: a pattern of shorter and earlier sleep on weekdays and longer and later sleep in weekends to compensate for partial sleep deprivation when morning commitments tend to be lacking. Roenneberg et al. (2019) describe this as uniquely facilitated by the combination of a lowered salience of the night–day cycle, an ability to control artificial lighting in local environments, and social commitments associated with the roughly seven-day pattern of work and rest (see also Reinberg et al., 2017). Social jetlag leads to significant variability in sleep timing, challenging sleep regularity, and is also associated with shortened sleep and desynchronised biological, social, and behavioural clocks that challenge the synchronicity of all the systems that contribute to healthy sleep (Roenneberg et al., 2019). Therefore, while EMU may not be causal to time displacement, EMU may facilitate time displacement, desynchronising behaviour from central and peripheral biological clocks, truncating sleep, and disorientating the harmonies of the body's rhythms, leading to difficulties with sleep health and the cognitive faculties that sleep restores (Gander, 2023; Hebl et al., 2022; Vlasak et al., 2022).

Impacts of Time Displacement on Sleep Health

When isolated from contextual influences, the causal impact of biological time displacement from EMU on sleep health, was found in the study by Green et al. (2017). After participants' blue light nights, their sleep duration and continuity, as measured by polysomnography, and next day difficulties with subjective sleepiness, and early wake functioning measured by a response inhibition task were all significantly impacted. However, the practical magnitude of this impact was difficult to quantify. Moreover, the control for this study was also EMU, of a similar duration, and with similar content, only different light wavelength exposure. In addressing this issue, Duraccio et al. (2021) were interested in the practical effects of modifying light exposure from EMU on sleep. Duraccio et al. gave 167 young adult iPhone users actigraphy watches to measure their sleep in a field study, while instructing them to either use software to suppress short wavelength light on their phones, use their phones as normal, or not use their phones at all in the hour before bed. Duraccio et al. found that there were no significant differences in TST nor SE metrics measured by actigraphy between any of these groups. Practically, the biological time displacement mechanism from EMU that Green et al. were able to view in isolation, may be flooded out by other contextual determinants.

Attenuating short-wavelength light emissions that impact the circadian timekeeping system from EMU can increase the comfort of night-time EMU (Zukerman, 2013). If people are able to engage in EMU more comfortably for longer periods prior to sleep, then photic entrainment may still occur through other ambient lighting in the evening. Other time displacement mechanisms like sleep procrastination might exert a greater relative influence on sleep health than light exposure specifically from phone screens. A recent systematic review of sleep procrastination noted a negative association with sleep duration and a positive association with daytime fatigue (Hill et al., 2022). When people must wake up at a certain time of day, sleep delays inevitably impact TST, resulting in a chronic partial sleep deprivation during the week and an attempt to catch up on the weekend (Roenneberg et al., 2019). Chronic partial sleep deprivation can lead to limitations in the faculties of cognition that healthy sleep supports, moreover, the two day weekend typical of social jetlag may fail to bring functioning back to baseline, despite possible subjective readaptation (Axelsson et al., 2008; Van Dongen et al., 2003). In addition, the impact of sleep variability that time displacement can lead to has far reaching consequences, from cardiovascular and metabolic health, to alertness and safety (Sletten et al., 2023).

Photic zeitgebers available from EMU are difficult to detach from those of other artificial photic zeitgebers, furthermore, access to social cues via EMU, or sleep procrastination likely lead to social jetlag (Roenneberg et al., 2019). Either way, as many in modern life have quick access to artificial light, from ambient lighting to EMU, social and behavioural time displacement may lead to strong influence on endogenous rhythms through consequential changes in light exposure (Czeisler, 1995). Given their interwoven nature, biological and behavioural time displacement mechanisms are conjoined as a link in the model of EMU–sleep health difficulty with the general label of *time displacement*.

Arousal and Psychological Detachment

The time displacement mechanism described above may be seen, in its essence as similar to what Przybylski (2019) likened to *food time* when discussing nutrition. Arousal and psychological detachment may be seen as simplified elements of the impacts of the nutrition itself. Time displacement, while interacting with content, does not capture the effects of the content itself on sleep. As discussed in Chapter 2, EMU content is rarely mentioned in reviews of the EMU–sleep health relationship. This may be due to the idiosyncratic nature of user's relationship to content, leading to high variability of responses and likely difficulty with comprehensively or accurately quantifying its impacts. For example, "after watching a violent show with a friend, a viewer could feel fine, but the friend might be too hyped up to sleep." (Medoff & Kaye, 2017, p. 546).

Similar to the various threads through the time displacement mechanism, arousal, psychological detachment, and time displacement may also be closely intertwined and difficult to tease apart (Chinoy et al., 2018). For example, light emitted by electronic media can directly stimulate alertness, a kind of arousal that may lead to a psychological detachment from cues of sleepiness, impacting sleep timing by limiting people being able to receive cues about how tired they are (Axelsson et al., 2020; Chinoy et al., 2018; Figueiro et al., 2007; Xiao et al., 2021). When lighting is kept relatively controlled, however, EMU content may differentially impact on arousal.

Arousal

In an early study on the impacts of EMU facilitated arousal on sleep health, Weaver et al. (2010) studied 13 male adolescents each subject to two conditions, either actively playing a video game before sleep for 50 minutes or watching a tranquil movie for the same duration. While physiological arousal measured by heart rates did not significantly differ between conditions, for participants in the video-gaming condition, cognitive alertness was higher, subjective sleepiness before bedtime was lower, and sleep-onset latency (SOL) was longer: 7.5-minute median SOL after video gaming, versus a 3-minute median SOL after the movie. In a later study, King, Gradisar, et al. (2013) investigated the impact of length of time spent gaming while in bed and before sleep, comparing the impact of 50 minutes versus 150 minutes before usual bedtime of gaming with 17 male adolescents (mean age 16 years) who were regular gamers, all late chronotypes, and who had no preexisting sleep complaints. Similar to Weaver et al., King, Gradisar et al. found no significant differences in heart rate between conditions suggesting that the mechanism through which EMU impacts sleep health might be more abstract than physiological arousal. Nevertheless, in the longer gaming sessions, King, Gradisar et al. observed an objectively measured seven-percentage point decrease in SE, and around half an hour reduced TST. Although King, Gradisar et al.'s participants reported a significant difference in SOL, averaging an estimated 17 minutes longer after the extended gaming condition; this extended SOL, however, was not reflected in polysomnography.

Recently, Baselgia et al. (2023) conducted a complex study that addressed the interaction between EMU content, arousal, and sleep. In their experiment, 50 young adults watched suspenseful TV series and a documentary on different nights. For half the participants, the suspenseful series was unedited and ended with a *cliffhanger* where the show stopped before the action had fully resolved (cliff group). The other group witnessed the same series though the ending was edited to conclude at the resolution of action (no-cliff group). Baselgia et al. also measured heartrates and cortisol levels throughout the study as a measure of physiological arousal, along with other metrics of subjective stress, subjective sleep metrics, and polysomnography throughout the night. As was expected, participants generally rated subjective stress levels higher when they watched the suspenseful show compared with the control documentary. However, an interesting interaction was found. Compared with the control documentary night, the cliff group's physiological arousal before sleep was higher when they watched the suspenseful show, though the no-cliff group showed *lower* arousal after the suspenseful show than after the documentary. Self-reported sleep quality, SOL, wake after sleep onset (WASO), and number of awakenings, were not significantly impacted. In objective sleep measures, only SOL showed a significant effect. Surprisingly though, across both groups, the suspenseful show was generally associated with shorter SOL than the documentary. Moreover, higher arousal metrics predicted shorter SOL on the suspenseful show night, whereas higher arousal predicted longer SOL on the documentary night. Although SOL was shorter, Baselgia et al. highlighted that after witnessing the suspenseful show with cliffhangers, the cliff group showed less deep slow wave sleep in polysomnography for their first two sleep cycles. Baselgia et al. (2023) suggested "in this case, the association between pre-sleep mental activity and sleep onset latency… cannot simply be explained by increases in pre-sleep arousal, as the exact content of the pre-sleep mentation might be relevant." (p. 194). Even though cliffhangers left early sleep disrupted, after more arousing EMU, SOL was shorter. In contrast, after the documentary, higher stress predicted longer SOL. The results of this study indicated that EMU may facilitate arousal that interferes with sleep, however its impact on sleep depends on its cognitive impact. The cognitions that people have are known to have arousing and sleep disrupting impacts (Harvey, 2005). The more arousing suspenseful show was perhaps more effective at helping people detach from their other life stresses. This pattern suggests a delicate balance between arousal and psychological detachment that EMU can facilitate, which may lead to difficulties with sleep health.

Psychological Detachment

People may be drawn to engage in EMU in efforts to detach from unpleasant emotional experiences. In an early study of motivations behind television viewing, Kubey (1986) proposed that heavier television use would be associated with more dysphoria in time spent doing idle activities as "it is during idle time that one is most likely to be confronted by the self" (Kubey, 1986, p. 111). Kubey found significant negative correlations between time spent watching TV and four affect dimensions: "'happy-sad,' 'cheerful-irritable,' 'friendly-hostile,' and 'sociable-lonely' (Kubey, 1986, p. 112) during the following identified idling activities: "staring into space, waiting, walking, pacing, standing, sitting, riding in a car or bus or train (not driving), lying in bed, trying to sleep, fantasizing, daydreaming, and thinking" (Kubey, 1986, p. 117). The strongest correlation that was observed by Kubey between television use time and affect while idling was for the sociable-lonely dimension: r = -.35, p<.001, indicating that people who felt lonelier (amongst other negative affective experiences) in idle or in unstructured time, were more likely to be heavier users of television. They noted that while their conclusions could not indicate causal direction (i.e., television may make people less tolerant of unstructured time), theoretical accounts at the time (Rubin, 1984; Rubin & Windahl, 1986), and Kubey's social and demographic analyses of the participants strongly suggested that people were using television as a tool to escape.

> Television programs and commercials, after all, provide parasocial experiences and are constructed to keep the viewer's attention focused on the TV and not on the self. The medium thus provides a much welcome and soothing alternative to the gaping voids of solitude and unstructured time. It is the fulfillment of this function that accounts, perhaps more than any other single factor, for the enormous and worldwide popularity of television. (Kubey, 1986, p. 120).

Kubey's (1986) study is particularly important as it captures experience in a time when easily portable electronic media have not yet filled these idle moments. Nowadays, many forms of EMU may be available on demand through portable connected media, allowing for detachment on demand (L. Scott, 2015). The often-unstructured time occurring while one is in bed and waiting for sleep to come, may be a time where one is most focussed on the self and where worries and associated anxiety can permeate, leading to arousal and potentially extended SOL (e.g., Harvey, 2005). During this time, people may be drawn to EMU as a way to combat negative affect and associated cognitions, with the aim of providing pre-sleep comfort (Exelmans & Van den Bulck, 2016). In investigating this, Exelmans and Van den Bulck (2016) found that those who engage in EMU as a comforting sleep aid were apparently equivalent in subjective sleep duration to those who do not. However, they appear to report later bedtimes, later rise times, and higher trait levels of subjective fatigue and reduced sleep quality. This could mean either that EMU as a sleep aid is detrimental, or people who engage in EMU as a sleep aid might be benefitting from it; their sleep may be even worse, and they may have been more fatigued if they were not using electronic media to try and support their sleep (Exelmans & Van den Bulck, 2016).

Impact of Arousal on Sleep Health

The arousal mechanism appears to exude a nuanced impact on sleep health. For example, the effect of arousal from EMU on SOL may be subtle but significant (E. Weaver et al., 2010; King, Gradisar, et al., 2013), though the arousal of other aspects of life, contained within users' cognitions, or interacting with nuanced aspects of EMU content such as cliffhangers may also exert a great influence on sleep health (cf. Baselgia et al., 2023; Harvey, 2005). People may use EMU to detach from unpleasant emotions that unstructured time may leave room for (Kubey, 1986) and may therefore engage in EMU as a sleep aid (Exelmans & Van den Bulck, 2016), though its efficacy as such is questionable, EMU could support sleep health if, for example, enough arousal is invoked by EMU that people can successfully detach from other life stresses, and not too much arousal, or unfinished narrative is experienced by which it may lead to further sleep difficulty (Baselgia et al., 2023). There is also the interaction that EMU facilitated psychological detachment may have with the alerting effects of light, leading to a detachment from signals of sleepiness (Chinoy et al., 2018) which may otherwise motivate behaviour towards sleep (Axelsson et al., 2020). In addition, if people are experiencing cliffhangers or unfinished narratives in social life, they may be drawn to engage in further EMU in efforts to resolve them so as not to miss out (e.g., H. Scott et al., 2019). The arousal mechanism appears intertwined with time displacement mechanisms where decisions that are made about EMU experiences may exude nuanced, though important effects on sleep health and resulting wake functioning.

The interactions between arousal and time displacement mechanisms are complex, and as has been shown above, difficult to disentangle from each other. Liu et al. (2020), however, found simple clarity between these mechanisms that can serve as an overall summary for these mechanisms. Liu et al. described a *dual-path model* that saw psychological detachment as beneficial for sleep quality and quantity, and bedtime procrastination as detrimental to sleep quality and quantity, each impacting on subjective ratings of performance and vitality at work the next day. The study by Liu et al. is unpacked further in Chapter 4. Below, the consequences of sleep health difficulty are focussed into their potentiating of fatigue (See Chapter 1); the functioning of fatigue is described through the lens of the self-regulatory motivational control theory (Hockey, 2013), and an account is given to the draw of EMU, and the ways in which some EMU software in particular can lead to a self-regulatory difficulty that is captured in the maintenance model presented at the end of this chapter.

Fatigue, Utility, and Coercion

Many activities can lead to fatigue. Often fatigue results from the impact of having some demands placed on behaviour that seems out of our control, however these demands may range from engaging in work and maintaining vigilance, to using social media or other EMU, or even for some, whose fatigue experiences are more prolonged, the ongoing strenuous task of maintaining functioning of everyday life (Balkin & Wesensten, 2011; Belenky et al., 2014; Bright et al., 2015; Fortes et al., 2019; Gantois et al., 2021; Hockey, 2013; Williamson & Friswell, 2013). This section situates fatigue as a potentially key motivational experience (Hockey, 2013) that is positioned as a possible maintenance factor of EMU and sleep health difficulty. As described in Chapter 1, sleep health crucially impacts on wake functioning, particularly if tasks are of long enough duration for the effect of fatigue to manifest (e.g., Balkin & Wesensten, 2011; Dawson & McCulloch, 2005; Kleitman, 1963; Lisper & Kjellberg, 1972). Time on some task is typically seen as crucial for the fatigue experience to occur (e.g., Balkin et al., 2023; Balkin & Wesensten, 2011; Belenky et al., 2014), in the causal model presented towards the end of this chapter, sleep health difficulty is seen therefore as exacerbating the effect of time on task on fatigue.

The Experience of Fatigue in Goal Selection

Hockey (2013) situates fatigue as a crucial motivational and self-regulatory experience that occurs during ongoing tasks. Hockey's (2013) motivation control theory of fatigue describes a model of three interlinked regulatory loops involved in regulating goals, regulating effort, and controlling routine behaviours. Within the goal regulation system, many different personal goals compete for selection and cognitive, somatic, and environmental events determine which goal is active at any point in time. Within the effort regulation system, the effort that one puts into achieving a goal is monitored and adjusted. Both goal and effort regulation systems respond to performance evaluations. That is, the results of behaviour and the effort required to achieve those results are evaluated against expectations. If discrepancies are noticed, depending on the judged importance of continuing the behaviour, goal or effort regulation is instigated to resolve discrepancies. The third regulatory loop, routine control describes the processes of producing relatively automatic behaviours when the executive regulatory mechanisms are not active. In Hockey's (2013) model, the experience of fatigue is a regulatory emotion that emerges from the intensity and frequency of activation of goal regulation, or effort regulation processes, each responding to perceived reduction in the success one has of fulfilling their goals, or ongoing increased effort required to maintain expected performance.

According to Hockey's (2013) theory, fatigue interrupts ongoing activity when it becomes more effortful than originally intended, or if results fail to meet expectations. Fatigue then acts as an emotion to broaden the view of possible behaviour away from the current task, to facilitate reorientation of behaviour so that tasks with greater utility—lower perceived cost and higher perceived reward—may be considered. Recent investigations into the functioning of this self-regulatory system of fatigue associate this fatigue experience with activation in neural substrates associated with effort-based decision making and subjective value judgements such as the rostral cingulate zone, the ventral striatum, the middle and superior frontal gyri, and the frontal pole (T. Müller et al., 2021). T. Müller et al., (2021) concluded: "fatigue states shift how much value we ascribe to working on a momentary basis" (p. 7). Bijleveld (2023), in reviewing the cognitive neuroscience study by T. Müller et al. (2021), emphasised the importance of viewing fatigue as a dynamic and complex process and an *adaptive signal* that supports a review of current activity and urges switching to higher utility; less effortful and more rewarding alternatives.

The practical outcomes of this fatigue-based decision making has been shown to be the case for decision making on the utility of physical effort (van As et al., 2021). Though, as yet, similar studies for decision making based on cognitive effort have not been found and are a clear area for future research. This effect may be intertwined in the complexity of self-control and ego-depletion studies (see Chapter 4), that is an ongoing area of research (Audiffren et al., 2023). Therefore, in the causal model introduced in the end of this chapter, the link between fatigue leading to EMU remains speculative. Testing this link would require a study that somehow induces and measures cognitive fatigue (e.g., van As et al., 2021), and then assesses perceived utility of either free or perhaps constrained choices when users are faced with various EMU or nonEMU activities to select from. This study may then check the hypothesis that when fatigued, users will choose activities that they see as providing high perceived benefit and low perceived costs. A further hypothesis would be that EMU may frequently be selected in these circumstances. To my knowledge this study is yet to be undertaken. While this study was not completed over the course of this thesis, it is a possibility for further research. The next section describes the draw of EMU, explains why EMU may sit as a particularly salient goal category within the goal regulation system, and may provide a good framework through which to understand the utility of EMU.

The Balance of Utility and Coercion of EMU

Basic psychological needs theory (Deci & Ryan, 2000; Ryan & Deci, 2017) posits that individual wellbeing, functioning, and motivation are most supported by the meeting of three core psychological needs: *autonomy*, the extent to which one is self-directed in action and aspiration; *competence*, the extent to which one believes they can accomplish their aims; and *relatedness*, the extent to which one feels connected to others. The potential meeting of these needs also motivates behaviour: Individuals tend to pursue situations and activities where their needs may be met (Deci & Ryan, 2000). Understanding how EMU can meet needs of autonomy, competence and relatedness in immediate and predictable ways gives insights into the potential allure of EMU (Adachi et al., 2018; Przybylski et al., 2010; Rigby & Ryan, 2011).

An understanding of these needs has also been commercially adopted in the generation of EMU software and content, often to increase engagement with commercial electronic media software platforms. For example, an article posted by a user experience design consulting firm referenced basic psychological needs theory and emphasised the importance of fostering a sense of autonomy, competence, and relatedness for promoting user engagement on software: “Designs that accommodate people’s fundamental needs will be both pleasant and easy to use. These qualities are what motivate users to continue using any product or service” (Kohler, 2022, Section 2). Rigby and Ryan (2011) stress the importance of carefully understanding the ease with which EMU meets basic psychological needs, compared to the more difficult, distant, and sparse meeting of these needs in the *molecular world*—referring to nonEMU contexts (Rigby & Ryan, 2011). Rigby and Ryan suggested that if EMU systems are designed to fulfil basic psychological needs, especially when not met in the molecular world, users will likely be motivated towards EMU.

D. Peters and Calvi (2023) highlighted that understanding these needs as they relate to EMU can be seen through both positive and negatively oriented lenses, highlighting ethical tension between “those interested in leveraging this impact (e.g., via motivational design and behaviour change) and those concerned by it (e.g., by manipulation, attention-hijacking, addiction)" (D. Peters & Calvi, 2023, p. 979). Adachi and Rigby (2023) noted the ways in which users may experience fulfilment of autonomy needs via EMU varying from a direct autonomy, for example controlling a character in a video game, to a vicarious autonomy experience through relating to characters in television shows. Wu et al. (2020) provided an account of the ways in which users might feel an experience of autonomy while engaging in various EMU software platforms, though their choices being subtly influenced by design.

> Social media, web portals, and contracted technical platforms on the back-end seem to direct traffic in ways that require little or no conscious planning or choosing on the part of the user. The corresponding online choice architectures involved are difficult for people to discern in increasing degrees. Institutions routinely manage online flows with integrative hypertexts, browser configurations, and back-end bundling, all of which are essentially invisible. (Wu et al., 2020, p. 15)

Electronic media software being designed to capture attention and foster engagement or manipulate users in the financial interests of the platform business owners has been termed *deceptive design* (Poell et al., 2022; Wray, 2019; see also https://www.deceptive.design). Zuboff (2015) termed the more general economic model of EMU software amassing data on users, monitoring their behaviour, and adjusting software parameters for personalising content and advertising as *surveillance capitalism*: "This new form of information capitalism aims to predict and modify human behavior as a means to produce revenue and market control"

(Zuboff, 2015, p. 75; see also Bandura, 2009; Figueiredo & Bolaño, 2017; Lauer, 2021; Wynn-Williams, 2025). Though, of course this has its roots in historic advertising practices.

> No group of sociologists can approximate the ad teams in the gathering and processing of exploitable social data. The ad teams have billions to spend annually on research and testing of reactions, and their products are magnificent accumulations of material about the shared experience and feelings of the entire community (McLuhan, 1964, p. 279).

While the *ad teams,* that McLuhan (1964) discussed, tailored products to entire communities, nowadays, recommender software regulates itself automatically (Hesmondhalgh et al., 2023; Jannach et al., 2016), and the products of the software, the tuning of the algorithms, have become an accumulation of the exploitable, personal experience of individual single users. The adaptation of these algorithms to tune with user's behavioural patterns may lead to a sense of identification and internalisation of the experience of interacting with them. If external regulators are in line with personally held values and identity, they may share many qualities with intrinsic motivation and therefore promote engagement (Ryan & Deci, 2000). In a sense, while Ryan and Deci (2000) described the processes through which external motivators are integrated into personal motivation systems, within these coercive media software systems, the reciprocal seems to occur: Personalised motivation is inferred by the surveillance of the user's EMU, and these are integrated into the environmental determinant of the software and the content that the software curates.

Recent developments in EMU software include the evolution of highly responsive algorithmic content recommendations (Heuer, 2021; Jannach et al., 2016) which curate the content that is accessed on various online media platforms in the interests of promoting user engagement on their platform (Wu et al., 2020). Whereas online EMU in the 1990s and 2000s was characterised by user-generated content and manual searching (Young, 1998), recommender systems on software platforms lead to more passive consumption of users, making them more like the audiences that interact with more traditional or top down media content from TV and radio (Berman & Katona, 2016; McLuhan, 1964; Medoff & Kaye, 2017; Napoli, 2010).

> The algorithms that tend to be of greatest public concern today, such as those that lie behind Google's search engines, Facebook's News Feed or Spotify's playlists... are constantly adjusted by people working for organisations that seek to create profit in order to pay shareholders and creditors (Hesmondhalgh et al., 2023, Section 1.3).

The passivity that recommender systems induce in their audiences is balanced with an increase in *utility*, as content delivery can be readily tuned for relevance to the user (Hesmondhalgh et al., 2023). EMU may now readily permeate into situations where intentional content seeking behaviour might be impractical or unwanted (Hesmondhalgh et al., 2023; see also J. Webster et al., 2016). Of all the user impacts that EMU may create, the source of the most widespread and insidious influence may be through how software can monitor and adapt to users, determine the content that users are presented with and likely lead some EMU to hold high status amongst the goal regulation system.

> Like when you're done talking to someone or you're done checking Snapchat or something, the stories, you're done with that. Then you go on to Instagram, you have to look at everything there. Then you have to go back on Snapchat because someone has messaged you or there's more stuff. So this keeps on happening and then there is like Facebook or something you have to check. It's stuff like that, it just keeps going until like 12. (H. Scott et al., 2019, p. 542)

This quote from a 14-year-old participant in a recent qualitative study described the allure of EMU, its utility and the self-regulatory difficulty, in particular a sense of obligation that EMU might induce. This quote also summarises the impact of this allure with the time displacement, arousal, psychological detachment and unfinished narratives that high-utility EMU may provide.

Summary

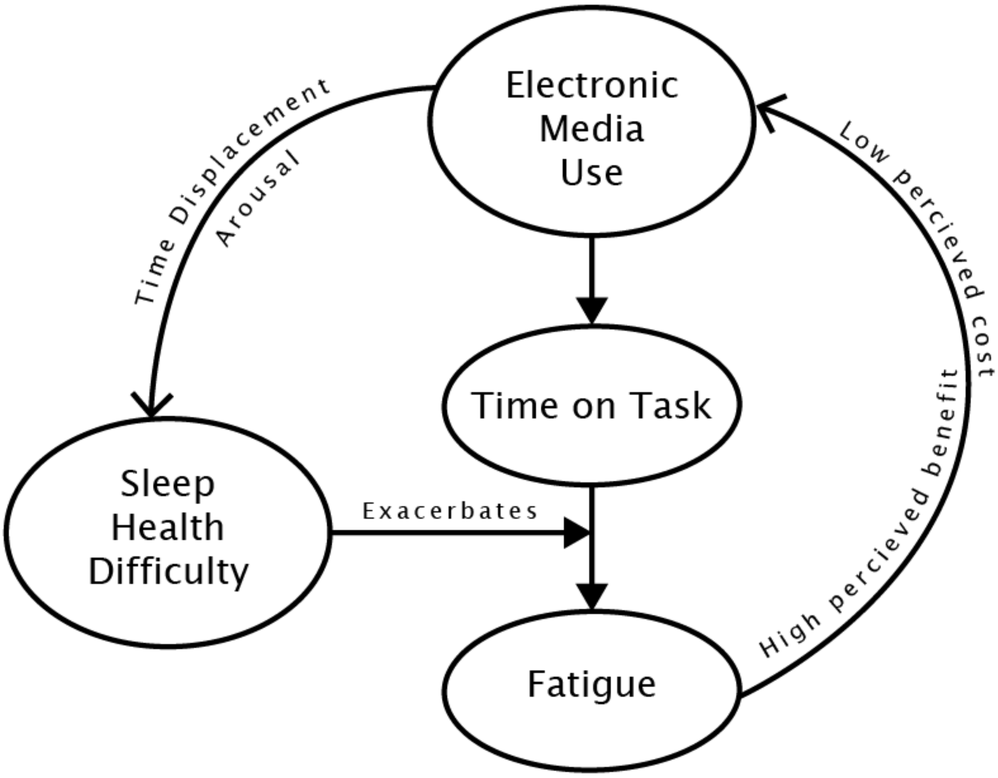
These potential interrelated influences are mapped out in the maintenance model presented in Figure 4 at the end of this chapter. In this figure, the impact of EMU on time displacement and arousal mechanisms are seen as causing difficulties with sleep health. The time displacement mechanism is seen as holistic given the complex intertwining of biological, social, and behavioural influences on different kinds of time. The time displacement mechanism spans from the simple behavioural time displacement as captured through the idea of sleep procrastination (e.g., Exelmans & Van den Bulck, 2017a; Kroese et al., 2016), to the interacting complex desynchrony of biological time, social commitments, the associated difficulties with sleep health that these may lead to (e.g., Chinoy et al., 2018; MacKenzie et al., 2022; Roenneberg et al., 2019). The arousal mechanism captures the impacts that alertness from light (e.g., Chinoy et al., 2018; Figueiro et al., 2007), cognitive arousal from stimulating EMU (e.g., King, Gradisar, et al., 2013) or unfinished narratives from EMU or from the molecular world may have on sleep health (e.g., Baselgia et al., 2023), as well as the potential support for sleep health that psychological detachment may bring (e.g., Exelmans & Van den Bulck, 2016; cf. Harvey, 2005; Liu et al., 2020). These mechanisms are seen in the model as leading to *sleep health difficulty* to frame the EMU–sleep health relationship as a problem that can possibly be negotiated (cf. Bandura, 1997). Given the impacts that issues with sleep health has on wakeful performance, sleep health difficulty is seen in the model as exacerbating the effect of time on task on fatigue (e.g., Balkin & Wesensten, 2011; Belenky et al., 2014; Dawson & McCulloch, 2005; Hockey, 2013). Fatigue is then seen in its motivation control function (Bijleveld, 2023; Hockey, 2013), leading to selection of high utility behaviour, which EMU is a likely example of (e.g., Rigby & Ryan, 2011; Young, 1998; Hesmondhalgh et al., 2023; see also Audiffren et al., 2023). While not explored in depth in the above section, EMU is also seen as a task in itself which people spend time on, and which may lead to an experience of fatigue (see Zheng & Ling, 2021 for an overview of *social media fatigue*) and may also include work-related EMU (Lanaj et al., 2014). Given the many possibilities that EMU may contain, a reselection of goals may also lead to a change from one EMU activity to another EMU activity (e.g., MacKenzie et al., 2022; H. Scott et al., 2019), perpetuating time displacement and arousal, difficulties with sleep health, and increased fatigue propensity.

Future Research

This current chapter rests on a review of broad literature, some of which remains to be empirically tested. For example, an outstanding question in chronobiology asks, “How do communities of circadian organisms rhythmically interact with each other?” (Chawla et al., 2024, p. 1) suggesting possibly reemerging study into *social zeitgebers* (e.g., Wever, 1979) that could contribute to biological time displacement, particularly when photic zeitgeber strength is low (see Roenneberg et al., 2019). Recent evidence suggests metabolic inputs to the SCN through which non-photic zeitgebers may exert their influence (Grosjean et al., 2023). Another example of speculation is that of fatigue leading to decisions for high utility cognitive experiences. Recent developments based on motivation control principles of fatigue have focussed on physical activity decisions (e.g., van As et al., 2021, 2022), and while neurocognitive research has found potential biological substrates for fatigue’s association with effort-based decision making (cf. Hockey, 2013; T. Müller et al., 2021), practical implications of decisions over cognitive effort remain to be empirically validated.

Figure 4

Model of Interrelated Influences between EMU, Sleep Health, and Fatigue



Chapter 4

Interrupting the Cycle: Introducing an Intervention and a Hypothesis

The previous chapter discussed a broad overview of mechanisms that appear to permeate into the relationship between EMU, sleep health and fatigue. This culminated in the description of a model of maintenance of EMU, sleep health difficulty, and increased fatigue propensity. The current chapter suggests a possible solution for breaking this cycle by introducing a new EMU self-reflection intervention (EMU-SRI) and discussing its foundations.

When directly controlled in experimental settings, acute changes to EMU appear to only lead to minor, if any, short-term changes to sleep outcomes (Combertaldi et al., 2021; Mahalingham et al., 2023; Sennock et al., 2024). For example, in a between-subjects study, Mahalingham et al. (2023) assigned participants to either cessation of smartphone-based social media for one week or continuing normal use and found no significant differences in subjective sleep quality after one week. Under tighter experimental controls and each using within-subjects designs, Sennock et al. (2024) assigned adolescents to 45 minutes of either social media use, reading a book on a smartphone, or reading from a paper-based book prior to sleep with take-home polysomnography kits. Combertaldi et al. (2021) assigned adult participants to 30 minutes of either social media use with blue-light blocking glasses, progressive muscle relaxation, or neither prior to three sleep nights in a sleep laboratory with polysomnography measures. Both Sennock et al. and Combertaldi et al. also assessed next-day memory consolidation and Combertaldi et al. also assessed next morning PVT performance. Taken together, these results all suggested that when pre-sleep EMU is directly restricted, reduced, or replaced by non-EMU activities, few immediate changes to sleep or wake functioning occur.

However, the relationship between EMU and sleep may be more complex than what might be solved by simple reduction in EMU. For example, both Sennock et al. (2024) and Combertaldi et al. (2021), each noted that in their experimental condition, engaging in EMU prior to sleep was still time-limited, so they were unable to assess behavioural time displacement, a likely crucial element in the EMU–sleep health relationship. Moreover, Mahalingham et al. (2023) noted that other EMU hardware and software may have displaced smartphone-based social media use time during participants' experimental weeks. Additionally, EMU, depending on its content and interaction with other life stresses, may be used as an aid to support sleep (Baselgia et al., 2023; Combertaldi et al. 2021; Exelmans & Van den Bulck, 2016) so simple reductions to EMU might limit its potentially beneficial impact. A potentially subtle immediate impact of EMU on sleep health may accumulate over time spans far greater than the above experiments could assess (e.g., Hökby et al., 2025). Longer-term improvements to EMU patterns might be required to observe potentially cumulative improvements in sleep health and fatigue. This may require interventions designed to produce enduring changes to EMU and studies to assess their outcomes on sleep health.

There are already many EMU and sleep health interventions (see Chapter 1). However, existing EMU interventions have focussed primarily on addiction models, and typically involve lengthy cognitive, behavioural, or group therapy processes (e.g., Cash et al., 2012; de Abreu & Góes, 2011; Malak, 2017), or self-help strategies for controlling use and reflecting on difficulties in one's life that EMU may contribute to (e.g., Young, 1998). EMU components within sleep health interventions typically take the form of educational sleep hygiene recommendations (e.g., Harvey & Buysse, 2017; Sleep Health Foundation, 2016; Suni, 2020). No studies have been found that assessed the independent utility of these kinds of EMU–sleep health recommendations, nor any that addressed whether longer term interventions on EMU can improve sleep health (cf. Martin et al., 2020). Furthermore, best practice administration of cognitive behavioural therapies for sleep health difficulties requires a clinician who is an experienced clinical psychologist and also has a firm background in behavioural sleep science (B. Sweeny, personal communication, 7 September, 2020). EMU-SRI is intended to be a brief intervention that may lead to possible cascades of improvement for those who may be struggling with EMU and sleep health difficulty, though for whom the other interventions described in Chapter 1 may be unsuitable.

EMU-SRI was developed during the investigation of mechanisms interacting between EMU and sleep health outlined in the previous chapter, as well as investigations into self-control and self-regulation theories, described later. This current chapter begins with a critical eye on self-control as a mechanism that has previously been discussed as a protective factor for the EMU-sleep health relationship (e.g., Bauducco et al., 2024; Exelmans, 2019). Following this, the social cognitive theory of self-regulation (Bandura, 1991) is drawn on to describe a reframe of self-control, and the principles that frame the new intervention. A paper (Liu et al., 2020) that provided primary inspiration to the intervention's development is also described in this overview. This chapter concludes by introducing the new self-reflection intervention for EMU and sleep health, and hypothesising its efficacy.

EMU-SRI has been designed to be applied independently, and could also potentially be adapted to interact with already existing intervention frameworks to bridge the gap between EMU and sleep health specific interventions.

Self-Control and Ego-Depletion Theory

Self-control refers to a faculty to regulate or inhibit immediate proponent behaviour in the interest of long-term benefit over immediate reward (e.g., Baumeister et al., 2007). In a recently published overview of mechanisms involved in the EMU–sleep health relationship, Bauducco et al. (2024) discussed parental limits to EMU and sleep supporting self-control as two protective factors. Regarding self-control, Bauducco et al. (2024) suggested, “similar to a battery, self-control can be recharged after a good night’s sleep and last until bedtime. Thus, forming a protective loop of self-control, conscious use of technology, and preserved sleep quality and quantity” (p. 7). The idea that self-control as a faculty may be depleted and recharged like a battery stems from ego-depletion theory (e.g., Baumeister et al., 1998; Muraven et al., 1998) which centres on the idea that self-control capacity draws on a general, limited resource that can be trained like a muscle, or charged and discharged like a battery. The general paradigm for studying ego-depletion involves an experimental manipulation that requires participants to *exercise self-control* to inhibit a proponent response, and afterwards test how long they persist on a challenge without an obvious end point; the cessation of effort on this unending task is assumed to assess a depletion of self-control resources (Baumeister et al., 1998).

Recently, the ego-depletion effect has been at the forefront of the replication crisis, where effects preponderantly found by classic social psychology research paradigms have failed to be reliably reproduced when subject to replication studies (Inzlicht & Friese, 2019). Two recent large-scale replication studies have comprehensively challenged ego-depletion theory. The first of these found small to no evidence of a depletion of self-control resources (see Hagger et al., 2016), although its experimental manipulation was soon challenged (Baumeister & Vohs, 2016). The more recent replication study with refined methodology, however, was also unable to detect a significant ego-depletion effect, suggesting self-control to be potentially unlimited (Vohs et al., 2021). While the self-control based protective loop described by Bauducco et al. (2024) may be useful for forming a broad idea of the maintenance of sleep health and EMU difficulties, its theoretical underpinnings have been challenged, and as described next, the utility of proposing self-control as a limited resource may also be questionable.

Individuals' beliefs about their own willpower, or self-control ability might influence their expression. Job et al. (2010) conducted four studies variously measuring and modifying individuals' theories about their own self-control and found that self-control only diminished for those who held or were induced to hold beliefs that self-control is a limited resource. Later, this research was applied to understanding bedtime procrastination with results suggesting that if individuals hold a belief that their self-control is an unlimited resource, they are less likely to procrastinate bedtime after stressful days (Bernecker & Job, 2020).

Within the last two replication studies of the ego-depletion effect, subjective fatigue was suggested as a potentially important moderator, as across conditions, participants who reported higher subjective fatigue during replication studies tended to give up on the unending tasks earlier (Dang, 2016; Vohs et al., 2021). The reframe that the motivational control theory of fatigue supplies, indicates that the cessation of the ego-depletion tasks is not necessarily a depletion of the ego, or self-control resources, but instead an implicit reevaluation of priorities associated with the subjective fatigue experience; a utility-motivated choice to stop (Hockey, 2013). Fatigue as a possible variable involved in the self-control, sleep, and EMU relationship was also suggested by Exelmans (2019) in the inceptive paper on self-control in the EMU–sleep health relationship. In an early study on bedtime procrastination, Kroese et al. (2016) viewed bedtime procrastination as a self-regulation issue, though saw self-control, an ability to resist temptations, as a key indicator of "self-regulation skills" (p. 854). While self-control and self-regulation terms may be seen as broadly compatible (Kroese et al., 2016; Vohs & Baumeister, 2004), empirical evidence for sleep's support of self-control is limited when it is viewed as a "basic cognitive process" (Baron & Culnan, 2019, p. 366). The social cognitive theory of self-regulation (Bandura, 1991) adds complexity and nuance to understanding more deeply the more executive processes that people may engage in when they exercise self-control, and, as described later, clarifies avenues through which EMU–sleep health behaviour may be supported.

The model from the previous chapter ultimately saw the maintenance of EMU, sleep health difficulty, and fatigue as being a self-regulatory issue, wherein high-utility EMU experiences are continually chosen, motivated by the experience of fatigue (Hockey, 2013). The social cognitive theory of self-regulation (Bandura, 1991) was chosen as a complementary theory to understand how to support self-efficacy and self-directed EMU. Both the social cognitive theory of self-regulation and the motivational control theory of fatigue broadly describe motivation for behaviour; how goals, effort, and behaviour are dynamically updated and adjusted; and the cognitive components involved in these adjustments. However, whereas the motivation control theory of fatigue applies within the flow of ongoing tasks, the social cognitive theory of self-regulation applies more broadly across people's lives (cf. Bandura, 1991; Hockey, 2013). The controversy of the ego-depletion and self-control studies described above converged on the idea that the nuanced picture of fatigue provided by Hockey's (2013) motivational control theory may be useful in better understanding the relationship between EMU and sleep (see Chapter 3). Furthermore, while not explicitly mentioned in the studies by Bernecker and Job, (2020), their manipulation of willpower beliefs appeared to align well with Bandura's concept of self-efficacy (Bandura, 1991, 1997); that an individual's beliefs about their own abilities pervasively influences their self-regulation system, and, for Bernecker and Job's participants, were associated with lower bedtime procrastination. While Hockey's (2013) motivation control theory of fatigue may be key to understanding the maintenance of EMU–sleep health difficulty, Bandura's (1991) social cognitive theory of self-regulation may be key to understanding how to break the cycle of EMU–sleep health difficulty and fatigue.

Social Cognitive Theory of Self-Regulation

The concept of *self-regulation* describes the active cognitive processes through which individuals adapt their personal and behavioural determinants over time to fit in with and influence their environmental determinants (Bandura, 1991). Bandura's (1991) social cognitive theory of self-regulation can be seen as holding two broad components. The first, *self-reflection* is a process of monitoring and evaluating actions and results. This is achieved by self-monitoring behaviour and comparing perceived occurrences to what is expected. From this comparison individuals judge their activities and resulting outcomes according to personal standards that are informed through observational learning (Bandura, 1991). The second broad component of self-regulation is *self-reactive influence*. People react to their judgements of discrepancies from self-reflection and, to reduce the reactions that these discrepancies elicit, they act to reduce the discrepancies by modifying their efforts, their goals, or shifting their internal standards (Bandura, 1991).

These processes in Bandura's (1991) theory broadly reflect the motivational and goal maintenance systems of Hockey's (2013) motivational control theory of fatigue, both models also describe a reevaluation of internal standards of performance to maintain equilibrium. While broadly similar, they function in different ways: Hockey's model describes a process of regulation while in the flow of a task, whereas Bandura's model describes the processes of regulation more broadly where people may aspirationally seek and then resolve discrepancies between expectations and performance. Bandura (1991) centres the idea of *self-efficacy* as influential to each component of the self-regulation system. Self-efficacy refers to the beliefs that one holds about their influence over the environment. Self-efficacy determines what goals are selected, whether people persist and increase their efforts, or are discouraged in response to setbacks (see also Bandura, 1997). Self-efficacy is seen as a core personal determinant of how the discrepancy between expected and observed outcomes are interpreted and managed and can improve *self-directedness* of behaviour, referring to the extent to which personal determinants, as opposed to environmental determinants lead behaviour. Self-efficacy, and thereby self-directedness can be improved through success in discrepancy reduction (Bandura, 1991).

Bandura's (1991) social cognitive theory of self-regulation applies broadly across people's lives and contexts and describes the long-term affective, behavioural, and cognitive processes through which symbiosis is maintained between a person and their contexts, while also explaining how people can exert agency in their actions. Self-reflection and self-reactive influence are understood as conscious processes through which self-regulation occurs before, during, and after certain tasks, as an activity that can be promoted to support adaptation.

Balancing Bedtime Procrastination and Psychological Detachment

In discussing the interaction between people's beliefs about their willpower and bedtime procrastination, Bernecker and Job (2020) highlighted a balance between engaging in activities that promote recovery from stress, and the potential for these activities to displace sleep time. Concurrently with these discussions, Liu et al. (2020) studied this balance between psychological detachment and bedtime procrastination. Liu et al. found that *mindfulness* as a trait variable supported the sleep enhancing benefit of EMU-facilitated psychological detachment, while buffering EMU facilitated bedtime procrastination. Liu et al. (2020) defined mindfulness as "a tendency to be attentive to and aware of what is taking place in the present" (p.4). In assessing mindfulness, Liu et al. employed the Reduced Mindful Attention Awareness Scale (Van Dam et al., 2010), which was truncated from the Mindful Attention Awareness Scale (Brown & Ryan, 2003). In developing their reduced scale, Van Dam et al. (2010) also criticised its construct validity, noting that while its items “may reflect a broad psychological construct” (p. 809), they do not simply represent *mindfulness*, indeed Van Dam et al. concluded their paper by challenging the idea of measuring the nuance and complexity of mindfulness through the use of a scale at all. Perhaps they show face validity for another construct? These scale items that individuals in Liu et al.’s study answered included “It seems I am ‘running on automatic,’ without much awareness of what I’m doing. … I rush through activities without being really attentive to them. … I do jobs or tasks automatically, without being aware of what I’m doing. … I find myself doing things without paying attention” (Van Dam et al., 2010, p. 809). Liu et al. (2020) found that affirmative answers to these items were associated with increased EMU facilitated bedtime procrastination, and decreased benefits of psychological detachment via EMU. While no studies have been found equating the Reduced Mindful Attention Awareness Scale with self-regulation, its items appear akin to assessing the functioning of the self-monitoring subfunction in Bandura’s (1991) account of self-regulation. To reinterpret the results found by Liu et al (2020) in this light, it appears that higher quality self-monitoring may be associated with reduced bedtime procrastination, increased benefit of psychological detachment from EMU, and possibly increased sleep health as a result.

Introducing an EMU Self-Reflection Intervention (EMU-SRI)

The EMU self-reflection intervention (EMU-SRI) introduced here seeks to encourage user self-directedness and increase intentionality of EMU through encouraging explicit self-monitoring that, in turn, increases awareness of discrepancies between *expected* and *extra* EMU activities. Through a self-reflection exercise, these discrepancies are evaluated. Users are encouraged to reduce discrepancies in two ways: (1) by devising alternative behaviours, or (2) by expecting to do their typical extra activities, thereby shifting their internal standards. EMU-SRI, in its current inceptive form, has been tailored towards the context of sailors in active duty in the RNZN (see Chapter 5). EMU-SRI's details have been captured in a manual (see Appendix D) and workbook (see Appendix E). The intervention study described in the next chapter is an initial test of its efficacy. EMU-SRI comprises three core elements:

1. Education in EMU–sleep health–fatigue relationship, and recommendations about healthy sleep behaviours.
2. Documenting and reflecting on bedtime routine; and
3. An EMU diary to nest EMU within a self-reflection exercise.

Educational Component

The intervention begins by introducing an educational component to participants. This component includes an introduction to the two-process model of sleep, the upstream effects that sleep health may have on performance, and hypothesised mechanisms and mediators through which EMU may impact sleep and fatigue. This education component also includes basic healthy sleep behaviour recommendations that were drawn from the Australasian Sleep Health foundation resources (Sleep Health Foundation, 2011, 2016, 2020) and adapted with supervision to the likely requirements of sailors in active duty with the RNZN. This educational component functions as a social environmental determinant through which personal standards of participants may be influenced.

Bedtime Routine Development

The second component of the intervention begins with documenting and then later editing a pre-bedtime routine. This provides an operationalisation of the healthy sleep behaviour recommendations and educational component in a way that provides some structure while still encouraging autonomy. First, participants document their current bedtime routine (self-monitoring), and at a later session, they are asked to consider the recommendations provided in order to improve their pre-bedtime routine and engage in self-reflection on any discrepancies of their chosen changes. Any behavioural changes remain entirely up to the individual. This component was developed based on findings that consistent, habitual prebedtime activities, whether they incorporate EMU or not, are associated with lower sleep procrastination (Exelmans & Van den Bulck, 2017b; Liu et al., 2020).

EMU Diary Component

The core component of the intervention contains a diary to facilitate self-monitoring of EMU as “success in self-regulation partly depends on the fidelity, consistency, and temporal proximity of self-monitoring” (Bandura, 1991, p. 250). Users are provided with a pocketable EMU diary to complete before and after engaging in EMU. Given that the diary is to be interacted with prior to EMU, the diary serves as an operationalisation of goal regulation, and an external memory reference to aid in accurate *discrepancy production* from a user’s perspective. As was discussed in Chapter 3, coercive flows of many EMU software may lead individuals to engage in EMU activities that they had not initially intended, so they are also encouraged to use the diary again following conclusion of EMU and document *extra activities*; what they did that they did not initially intend to do, thus increasing awareness of discrepancies in their behaviour. This diary serves as a vehicle for an explicit self-reflection exercise, which is facilitated during an intervention session after they have been using it for a week. During the facilitated self-reflection exercise, the user is instructed to reflect on their discrepancies, and either anticipate and intend to do these behaviours prior to EMU, a reevaluation of internal standards, or devise alternative behaviours that might meet the same needs.

Hypothesis

Theoretically, EMU–sleep health–fatigue difficulties can be framed as an issue of self-regulation. Self-directedness of EMU might be fostered through intentional self-monitoring and self-reflection and lead to improvements to sleep health and waking performance (e.g., Bandura, 1991, 1997; Liu et al., 2020). EMU-SRI aims to encourage these faculties of self-monitoring and self-reflection. Therefore, the hypothesis is that engaging in EMU-SRI will lead to improved sleep health and reduced fatigue propensity for users.

Chapter 5

Testing an Electronic Media Use Self-Reflection Intervention in the Navy: A Multiple Baseline Single Case Experimental Study

Personal and workplace wellbeing form a complex symbiotic relationship. A person's wellbeing impacts their performance at work; their performance at work also impacts their wellbeing (Bennett, 2021; Bevan, 2010). When someone is at work, they are likely to be in an environment, or engage in tasks that require them to be attentive for longer than they may autonomously choose, exposing them to a higher likelihood of fatigue (Hockey, 2013; Williamson & Friswell, 2013). Fatigue likelihood can be increased by exposure to risky environments that require sustained vigilance, and these risky environments can become more risky when people in them are fatigued (Williamson & Friswell, 2013). Mitigating fatigue-related risk requires mutual interest and shared responsibility of legislators, regulators, employers, and employees (Gander, 2005). Fatigue-related behaviours have been legislated as a hazard to be minimised or eliminated as far as reasonably practical across all workplaces in Aotearoa New Zealand (Health and Safety at Work Act 2015, Sections 16 & 30). Mitigating fatigue is particularly crucial within high-risk and high-consequence occupations like those within Te Taua Moana O Aotearoa - Royal New Zealand Navy (RNZN; Wray, 2019).

The topic of this thesis was encouraged by the RNZN, who were interested in the potential impacts that EMU has on fatigue, to try mitigating downstream risks to health and safety (Health and Safety at Work Act 2015; Wray, 2019). At that time, research in the intersects of these constructs was rare in the RNZN. A recent report by

LTCDR Marianne Wray (Wray, 2019) suggested increased research into this domain was required for the RNZN. That same year, Exelmans and Van den Bulck (2019) released a paper calling for increased multidisciplinary research into the relationships between EMU and sleep. Wray's (2019) report noted that EMU appeared to be increasingly prevalent in the RNZN during rest periods, and suggested that effective fatigue mitigation required ongoing investigation and understanding of the EMU, sleep, and fatigue relationship. At the conclusion of the report by Wray (2019) into EMU, and fatigue in the RNZN, Wray recommended "Development, distribution and implementation of resources and low level intervention tools," (Wray, 2019, p. 62). This suggestion was supported by the Maritime Component Commander of the RNZN, CDR Mathew Williams, and has led to the current project's development.

This study trials EMU-SRI, a brief self-reflection intervention developed for EMU–sleep health based in self-regulation principles. EMU-SRI encourages self-reflection and self-directedness of EMU (see Chapter 4). This intervention was primarily developed based on the understanding that EMU is nuanced and can support or detract from sleep health, and that self-monitoring and self-reflection appear to support EMU's possible benefits, while buffering EMUs possible detriments (e.g., Bandura, 1991; Liu et al., 2020). In this study, EMU-SRI is applied for sailors in active duty in the RNZN abord HMNZS Wellington, with the hypothesis that sleep health metrics will improve, and that fatigue may be mitigated. To assess these outcomes, subjective and behaviourally measured EMU, sleep quality and quantity metrics, and sleepiness, vigilance and fatigue metrics were assessed. Longer-term changes were measured with a six-month follow-up survey as it was expected that improvements to EMU, sleep, and fatigue will be enduring.

Rationale for Multiple Baseline Single Case Experiment Design

The effect of EMU on recovery, sleep, and the resulting effects of this on fatigue and performance is hypothetically significant (e.g., Exelmans & Van den Bulck, 2019; Liu et al., 2020). In practice, the extent of this effect in RNZN sailors was yet unknown (Wray, 2019). Much of the research into the relationship between EMU, and sleep has stemmed from large-scale correlation studies (see Chapter 2), none were found addressing the EMU–sleep health–fatigue relationship, and causal studies on EMU interventions supporting sleep health are “extremely rare” (Exelmans & Van den Bulck, 2019, p. 525).

MBDs can support developing understanding of interventions that are expected to show gradual and enduring behaviour change (Krasny-Pacini & Evans, 2018). In MBDs, participants act as their own controls with outcomes measured repeatedly before and after the introduction of an intervention (Krasny-Pacini & Evans, 2018). MBDs provide a powerful approach for gaining in-depth understanding of causal relationships between an interventions and outcomes (Aydin, 2024). MBDs have a small number of participants so is appropriate for assessing the process of a novel intervention, and to limit the spread of any unexpected or potentially harmful outcomes. Consistent outcome changes after intervention introduction, if replicated across time and across participants provides evidence of intervention efficacy within their contexts; MBDs are often used for developing and determining evidence-based practice (Aydin, 2024; Greenwood, 1989; Kratochwill et al., 2010; Willis, 2014). To meet best practice guidelines, MBDs should involve at least three participants with measurement beginning at different times between participants and at least three measures per phase to account for coincidental contextual influences and to allow for observing inter-case replication of any effects (Byiers, 2018; Kratochwill et al., 2010). This MBD study was designed to be practically feasible to implement on board an RNZN ship alongside the regular duties of the participants, to see whether EMU-SRI could show efficacy with sailors in active duty. While generalisability is nuanced, findings from single case research can also provide insight into potential application in other contexts (Lincoln & Cuba, 2009; Mook, 1983; Willis, 2014). Given the complexity and nuance of the EMU–sleep health–fatigue relationship, the infancy of EMU-SRI, and the unique setting of the RNZN for studying its efficacy, an MBD was decided on to test whether EMU-SRI would be effective for improving sleep health and mitigating fatigue for sailors in active duty in the RNZN to develop insights into its utility in this setting, and understand the dynamics of any benefits that may be observed.

The Context of the Study

Together, with enabling agencies, Te Ope Kātua O Aotearoa, The New Zealand Defence Force (NZDF) provides citizens of Aotearoa New Zealand with constant assurance of military defence and security (NZDF, 2022). NZDF contains three primary branches: Ngāti Tūmatauenga O Aotearoa, New Zealand Army; Te Tauaarangi O Aotearoa, Royal New Zealand Air Force; and RNZN. RNZN plays a pivotal role in maintaining the security of communities in Aotearoa New Zealand and the Pacific, as well as involvement in numerous international operations. As of 31 December 2024, the RNZN employed 2,895 personnel including 2,153 regular force and 742 reserve force; 1566 identified as male and 587 identified as female (RNZN, 2024). HMNZS Wellington, the context of the current study, is an offshore patrol vessel of the RNZN. One of RNZN's smaller ships, she has a complement of 80 individuals including 42 core crew and 12 flight personnel (NZDF, n.d.). HMNZS Wellington primarily operates in the New Zealand Exclusive Economic Zone and mostly conducts operations and training in the Pacific Region. Recently, her crew has been involved in various rescue, health service delivery, and sustainability management operations in the Pacific (NZDF, 2022). The current study took place in late 2021 with selected volunteer participants that form part of her crew.

The Navy Environment and its Impact on Sleep Health and Fatigue

While at sea, RNZN ships require a constant presence of personnel awake and on watch with varying rotations between shifts depending on operational and staffing circumstances (Personal communication, LT Egidia Bernerius, March 1, 2021). As such, typical sleeping schedules may be frequently disrupted, contributing to likely downstream issues with fatigue (e.g., Kilding & Bonetti, 2017; United States Government Accountability Office, 2024b). Routines on board RNZN ships require personnel to present at work activities during the day even after completing night shifts (Personal communication, LT Egidia Bernerius, March 1, 2021). As an analogue to the RNZN environment, recent research of 994 active duty personnel in the United States Navy indicated that their personnel generally achieve less than recommended sleep hours (mean 6.60h, standard deviation [SD] 1.01h), would be classified as poor sleepers and often split their sleep (Matsangas & Shattuck, 2020). The United States military have reported that many of its personnel are not getting recommended daily sleeping hours and have urged ongoing research into causes of, and ways to manage fatigue to ensure relative safety of its personnel (United States Government Accountability Office, 2024a). While no literature was found that addresses these issues in the RNZN specifically, these findings and recommendations likely apply to the current context (Wray, 2019).

In disciplined and controlled working environments, as it found within the RNZN, motivation and effort are required for adequate performance (Kilding & Bonetti, 2017). Within these kinds of structured settings, where performance is most crucial, particularly in situations of stress and high potential consequence, current goals may have high importance and require active maintenance of effort in order to adequately complete them, leading to higher risk of fatigue (Hockey, 2013).

Safety risks due to fatigue have been widely acknowledged as particularly concerning across high-risk industries such as maritime, aviation, and transportation (Gander, 2005; Gander et al., 2014; Rudin-Brown & Filtness, 2023). Errors associated with performance impairments range from immediate and strategic to insidious, tactical, and systemic (Reason, 1991). To mitigate the consequences of fatigue, workplaces benefit from encouraging wellbeing practices within and beyond the workplace to encourage effective recovery (Colten & Altevogt, 2006; Dawson & McCulloch, 2005). The NZDF Health Directorate guide to supporting health in the defence community is an example of this effort (Defence Health Directorate, 2023). The guide contains recommendations for RNZN personnel to support their health, wellbeing, and safety. The guide outlines consequences of fragmented, restricted, or deprived sleep, and offers relaxation, cognitive distraction and breathing exercises for personnel to try. The guide also notes the potential impact of EMU on sleep by acknowledging the importance of EMU for social communication and relationship maintenance, as well as its potential displacement of sleep time (Defence Health Directorate, 2023, pp. 143, 78).

There are many benefits that EMU provides for users such as social connection, leisure, facilitating productivity, fostering creativity, and supporting psychological detachment (Liu et al., 2020; Reinecke & Hofmann, 2016; van Dijck, 2013). Therefore, the aim for any EMU intervention should be a controlled and balanced use, rather than enforced abstinence (Cash et al., 2012; Young, 1999). EMU-SRI shares these aims by encouraging self-reflection and self-directed EMU to promote sleep health. The current study assesses whether this can lead to mitigation of fatigue.

Method

Ethics

This study was reviewed and approved by the Massey University Human Ethics Committee: Southern A, Application 21/34; and Organisational Research at NZDF: reference 5000/PB/5/3; and the NZDF Research Ethics Committee: 21 July 2021. The study was run with the aid of the medic stationed with HMNZS Wellington as a research representative (RR). Confidentiality agreements (see Appendix F) were signed by RR and the second rater of the actigraphy data. RR oriented participants to the study with the aid of an orientation guide (see Appendix G) and facilitated data collection, resource provision, and interfaced with participants in the delivery of the study's orientation and the four intervention sessions. Participants were compensated with supermarket vouchers totalling $160 NZD each for their time in the study. As part of the ethical considerations for this study, the privacy of participants within this relatively small population was paramount. Any information that could be used to identify participants or differentiate them from one another, for example, specific working patterns, sleep timing, and identifiably unique EMU hardware, software, and activities, were not reported. Participants used self-generated identification codes throughout all components of the study to obfuscate their identities in the interest of anonymity.

Participants

Participants were recruited by way of advertising flyers (see Appendix H) alongside and onboard ship. Organisational emails were also sent to the crew of HMNZS Wellington calling for expressions of interest. After reading information sheets (see Appendix I) and completing a consent form (see Appendix J), participants completed an intake survey (see Appendix K) through which eligibility for the study was assessed. Thirteen participants expressed interest, of which, eight completed the intake surveys. Eligibility for the study was based on global Pittsburgh Sleep Quality Index (PSQI) scores being greater than five, the originally described "sensitive and specific measure of poor sleep quality" (Buysse et al., 1989, p. 205). Seven participants were initially assessed as eligible based on this cutoff, though one of these was no longer sailing after completing the survey, so was excluded from the study. The six participants that participated in the MBD are referred to as P1, P2, P3, P4, P5, and P6 throughout this study. Following conclusion of the study and doublechecking scores early February 2024, a scoring error was found in one of the intake surveys which mistakenly included P6 in the MBD, though they did not meet the cut off point for PSQI score. Because of this, only P1–P5's MBD data was analysed to determine immediate intervention outcomes. Three participants completed the follow-up survey, one of which (P6) was the one whose PSQI scores were miscalculated. The intake and follow-up survey data for P6, as well as exploratory analysis of their EMU diary data are still presented herein and included in the grouped exploratory analysis of EMU diaries.

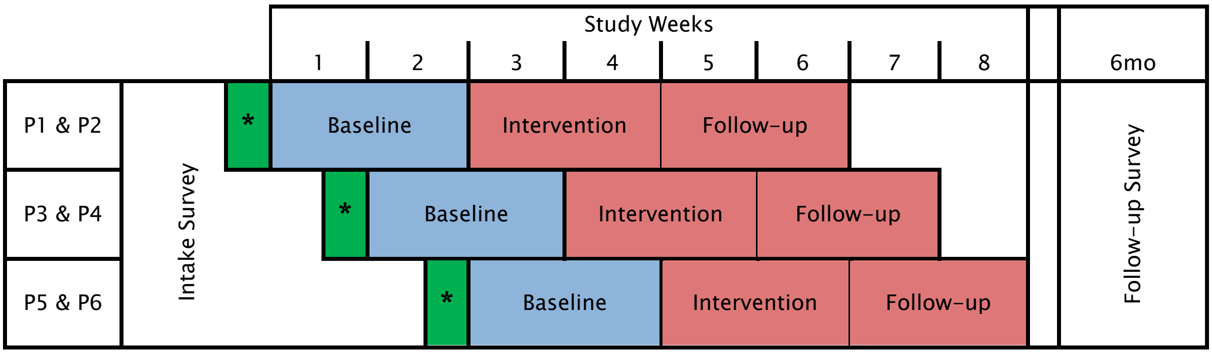
The five participants eligible for MBD analysis (P1, P2, P3, P4, and P5) included four participants who identified as male, and one who did not report their gender. Four identified as New Zealand European/Pākehā ethnicity, and one as Māori. They had a median age of 27 years (interquartile range 12 years) and they held a variety of responsibilities on board ship ranging from technicians to officers. All of the participants were day workers and some occasionally worked early morning, into the evening, or on call. Deviations from standard daytime hours were infrequent. Two night shifts were the most that any participant in this study worked over the course of the participation in the six-week MBD. To preserve anonymity, further specifics of working patterns are not reported.

Structure

Structurally, the study was split into two components. One component was the intake and follow-up questionnaire which assessed eligibility and longer-term changes in intake measures six months after the study's conclusion. The core of the study was the MBD which consisted of three series, staggered one week apart. Two participants participated in each series, though they went through each component of the study independently of each other. This allowed for attrition of one participant per series while maintaining the minimum guideline of three participants at three times for demonstrating evidence of an effective intervention with MBD (Kratochwill et al., 2010). The beginning of baseline measurement was staggered to mitigate the confounding effect of long baseline phases for participants in later series (Byiers, 2018). Each series contained three phases. From a single participant's perspective, after the intake assessment and orientation, they were in baseline measurement phase for two weeks, intervention introduction phase for two weeks, and a follow up phase for two weeks. In structuring the methods to facilitate communication with RR and participants, intervention and follow up phases were described separately in the method. In analysing MBD results, visual analysis also considered differences between the intervention introduction phase and the follow up phase. For final decision making on the outcomes of the study, intervention introduction and follow up phases were concatenated, as they both represented the period of time after the intervention was introduced, which could not be withdrawn. The protocol for this study and intervention manual as given to RR working with the participants on board ship is provided in Appendix E. Below, Figure 5 graphs the temporal design of the study.

Figure 5

A Chart Showing the Series and Phases of The Study



Note. *Indicates study orientation session.

Measures

When measuring EMU, sleep, and performance, behaviourally measured and subjectively reported data can vary independently (Bernstein et al., 2019; Lin et al., 2015; Mac Cárthaigh et al., 2020; Van Dongen et al., 2003). Therefore, both behavioural and self-report data was gathered throughout the timeseries component of the study for EMU-, sleep-, sleepiness/vigilance-, and fatigue-related variables. All measures were daily assessment, apart from the PVT which was assessed thrice weekly. Therefore, for assessing outcomes, approximately 14 datapoints per phase per participant were gathered for daily measures and six datapoints per phase were gathered for PVT. Intake and follow up assessment consisted of self-report trait EMU, sleep health, and fatigue measures.

Intake and Follow-up Survey. Interested participants were emailed an information sheet and a link to complete the intake survey on Qualtrics (https://www.qualtrics.com/). Given difficulties with internet stability on board ship, a pen and paper survey was also created for participants to fill out for scoring (see Appendix K). Four participants completed this survey on Qualtrics, and four in paper-and pencil format. The final follow-up survey (see Appendix L) was administered only through Qualtrics. The intake survey contained the media use questions of the media and technology usage and attitudes scale (MTUAS), and questions to assess whether potential study candidates would be able to utilise the screen timing applications on their smartphones. These surveys also included the full scored section of the Pittsburgh sleep quality index (PSQI), the fatigue assessment scale (FAS), and demographic questions. The follow-up survey contained a reevaluation of the MTUAS, the PSQI, the FAS, and a chance for participants to provide feedback. Internal consistency was calculated for these three metrics using Cronbach's α assessment with an aggregate of the 11 total responses to both the intake and follow-up surveys.

Media and Technology Usage and Attitudes Scale. The MTUAS (Rosen et al., 2013) contains nine subscales totalling 40 items measuring EMU frequency, two subscales with two questions each on online friendship metrics, and four subscales comprising 16 items that measure attitudes towards EMU (Rosen et al., 2013). The nine subscales assessing EMU frequency were administered to the participants during the intake and follow-up surveys. These subscales—smartphone usage, general social media usage, internet searching, e-mailing, media sharing, text messaging, video gaming, phone calling, and watching television—are each answered on 10-point scales indicating frequency ranging from 1 = "Never" to 10 = "All the time". Often studies employ specific subscales of the MTUAS such as the smartphone usage subscale (Amez et al., 2020, 2021; D. A. Ellis et al., 2019; Khoo & Yang, 2021; Rashid & Asghar, 2016), and social media usage subscale (Barton et al., 2021; K. Burke et al., 2021; Jun et al., 2020). An internal consistency estimate for the entire EMU frequency section was not found in the literature, though internal consistency estimates for each of the nine frequency subscales independently ranged from Cronbach's α = 0.6–0.9 (Rosen et al., 2013). Subscale scores of the MTUAS are derived by calculating a mean of the scores that participants answered to their constituent items. For this study, an overall EMU frequency score was calculated by taking a mean of the subscale scores. Cronbach's α = 0.703 was calculated, treating subscale scores as individual items within the overall MTUAS frequency score (hereafter referred to as MTUAS).

Pittsburgh Sleep Quality Index. The PSQI (Buysse et al., 1989) contains 19 self-report items relating to participants' subjective assessment of their sleep health. Extra unscored questions to be answered by sleeping partners were omitted. The PSQI is commonly used in research to assess sleep quality across a multitude of clinical and nonclinical settings, including with Navy sailors in the United States of America and as a self-report sleep assessment in EMU-related studies (e.g., Exelmans & Van den Bulck, 2016; Matsangas & Shattuck, 2020; Mollayeva et al., 2016). The PSQI total score is calculated as a sum of seven components (each scored from 0-3): subjective sleep quality, sleep latency, sleep duration, habitual sleep efficiency, sleep disturbances, use of sleep medication, and daytime dysfunction (Buysse et al., 1989). PSQI scores range from 0–21, with 0 indicating the best sleep quality and 21 indicating the worst sleep quality. The original cutoff score of >5 was used as an eligibility cutoff to select participants for the study. In the PSQI inception study it showed a sensitivity of 89.6% and a specificity of 86.5% for identifying sleep disturbance (Buysse et al., 1989). In this initial validation study, PSQI demonstrated adequate internal consistency, Cronbach's α = .83 (Buysse et al., 1989). Cronbach's α = 0.79 in the current study.

Fatigue Assessment Scale. The FAS (Michielsen et al., 2003, 2004) contains 10 items measured on seven-point Likert-type scales designed to measure subjective fatigue. The FAS comprises a combination of items from other fatigue related scales: the checklist individual strength (Bültmann et al., 2000; Vercoulen et al., 1994), the

World Health Organization quality of life assessment instrument (The WHOQOL Group, 1998), the fatigue scale (Chalder et al., 1993) and a unique item related to mental fatigue (Michielsen et al., 2003). The scale has demonstrated good internal consistency as a unilateral measurement of fatigue: Cronbach's α = .87–.90 (Michielsen et al., 2003, 2004). The FAS has shown discriminant validity from scales of depression and emotional stability (Michielsen et al., 2003) and has been used to assess fatigue in a study on shift workers in the US military aviation sector (Tvaryanas & Thompson, 2006). The FAS was featured in a review by Sagherian and Geiger Brown (2016) as an appropriate and well validated scale for measuring unidimensional fatigue in shift workers. It was also employed by Exelmans and Van den Bulck (2016) in their study on EMU as a sleep aid. This scale was administered to assess longer-term fatigue experiences as part of the intake and follow-up assessments for the current study. Cronbach's α = 0.81 in the current study.

Timeseries component. Participants completed ongoing measures through the three phases of the study. Most of these were daily measures compiled into Daily measures books (Appendix M), and a sleep/duty/EMU logbook (Appendix N). Participants also wore an actigraphy watch for the duration of their time in the timeseries component and completed three 10-minute PVTs per week. Actigraph and PVT logs (Appendices O & P) facilitated data parsing and identification.

Samn Perelli Fatigue Scale. Initially named the Samn Perelli Crew Status Check (Samn & Perelli, 1982), now generally named the Samn Perelli fatigue scale (SPFS; e.g., Centofanti et al., 2020; Gregory et al., 2021), the SPFS is a single-item, seven-point scale with lexical anchors for each point originally designed to measure acute fatigue of aircrew in the United States Air Force (Samn & Perelli, 1982). The form and content of this scale has subtly changed since its inception with an unclear history (e.g., removing "Extremely Peppy" from the anchor for a score of one and removing the "workload estimate" section of the scale; cf. Gander et al., 2014; Samn & Perelli, 1982). Nevertheless, SPFS is a widely used assessment instrument in sleep and fatigue studies (e.g., Y.-H. Chang et al., 2019; Gander et al., 2013, 2014; Gregory et al., 2021; Powell et al., 2011 see also Centofanti et al., 2020; Dorrian et al., 2011; Lamp et al., 2019). Scores in the SPFS are sensitive to changes in acute fatigue levels and have shown convergent validity with PVT performance (Arsintescu et al., 2020; Baulk et al., 2009; Samel et al., 1997). Higher scores indicate more acute fatigue and scores greater than four are commonly associated with significant safety concerns in high-risk occupations (International Civil Aviation Organization, 2016, Chapter 5). The SPFS was selected to be a useful brief assessment of subjective fatigue and included in participants' daily measures books (Appendix M), labelled simply as "Fatigue Scale".

Karolinska Sleepiness Scale. The Karolinska Sleepiness Scale (KSS; Åkerstedt & Gillberg, 1990) is a single-item, nine-point measure of subjective sleepiness. The scale contains lexical anchors for odd numbered scale items, with opportunity for participants to rate their sleepiness between each anchor. Higher scores indicate greater sleepiness. In its inception study, Åkerstedt and Gillberg (1990) revealed a curvilinear relationship between ratings on KSS and physiological sleepiness: alpha and theta activity patterns associated with sleepiness were observed in electroencephalogram assessment when participants reported scores of seven—"sleepy – but no difficulty remaining awake"—and above. Recent developments have shown evidence for electroencephalogram changes associated with lower KSS scores (Putilov et al., 2019). The KSS is a benchmark scale by which other scales of similar constructs are validated (e.g., Putilov et al., 2019). The KSS has been used for measuring sleepiness across various contexts and experimental protocols (Baulk et al., 2001; Bjorvatn et al., 2021; Geiger Brown et al., 2014; Kaida et al., 2006; Maghsoudipour et al., 2018; Waage et al., 2012). There are two versions of the KSS in wide circulation, one with anchors on each step, and one with anchors on odd numbered steps. In a comparison study the two versions were found to be essentially equivalent (Miley et al., 2016). Due to the time saved by having participants only needing to read five rather than nine lines in order to make their rating decision, the original KSS, with anchors on the odd numbered steps was used for the current study. In the daily measures books (Appendix M), KSS was labelled “Sleepiness Scale” and used as a subjective daily measure of acute sleepiness.

Duty / Sleep / EMU logbook. A “Duty / Sleep / EMU logbook” (Appendix N, hereafter *logbook*) was provided for participants to report bed/wake times, working periods, and EMU periods exceeding 10 minutes. These logbooks were used to support actigraphy analysis, and also contributed to subjective understandings of sleep, work, and EMU time. The use of a visual scale to capture time periods was decided upon for its brevity, compactness, and ease of administration. Each hour of the visual time scale was designed to be 10mm, to allow for quick conversion between spatial log marks and time measurement. Accompanying these on each page, a morning measurement section prompted participants to perform a daily note down of the previous day’s total screen time from any native screen timing application available on their smartphones. The morning measurement section of the logbook also contained a truncated PSQI widely used for rapid daily reporting of subjective sleep quantity and quality (e.g., Lanaj et al., 2014; Liu et al., 2020; Sonnentag et al., 2008). In the truncated PSQI, participants estimated their TST from the night just been in hours and minutes and rated their sleep quality on a four-point scale: “Very good”, “Fairly good”, “Fairly bad”, and “Very bad”. These were scored from 1–4, respectively; higher scores indicated worse subjective sleep quality.

Psychomotor Vigilance Tasks. For a behavioural measure of vigilance and fatigue propensity, participants completed a 10-minute PVT three times per week, on Tuesday, Thursday, and Friday afternoons during the MBD. PVTs (Dinges & Powell, 1985) are serial reaction time tests that require participants to respond as rapidly as they can to stimuli that appear at randomised intervals within certain parameters (See Appendix D for setup instructions and Appendix G for participant instructions). The portable PVT-192 (Ambulatory Monitoring, n.d.-b) was used. PVT-192 is a standalone portable hardware to run, collect and store automatic PVTs and their data. PVT-192 has been described as the "gold standard" in PVT administration (Reifman et al., 2018, p. 39). Two PVT-192 units were provided for the current study by the Sleep Wake Research Centre at Massey University. In these 10-minute tasks, participants respond as rapidly as possible to visual stimuli as they appear on a small LCD screen. Interstimulus intervals were set to 2,000ms minimum and 10,000 maximum. A PVT log (see Appendix O) was placed next to the PVT-192 so that participants could write down their time of use and their identification codes to facilitate data identification.

Actigraphy. To provide behaviourally measured sleep data, participants wore a Micro-Motionlogger (Ambulatory Monitoring, n.d.-a) on their non-dominant hand for the duration of the 6-weeks they were in the MBD component (See Appendix D for setup instructions and Appendix G for participant instructions). Micro-Motionloggers employ a calibrated tri-axial accelerometer, along with a light sensor, temperature sensor, and event marker button to infer rest and activity periods (Ambulatory Monitoring, Inc., n.d.-a). Actigraphy has been described as an effective method for capturing behavioural data as it relates to sleep (Buysse, 2014). Wrist worn actigraphy has been employed to measure sleep parameters in US Navy in rough seas (Matsangas et al., 2015). The Micro-Motionlogger hardware specifically has been effectively used in previous studies with NZDF personnel (Edgar et al., 2021) and more recently with US Navy submariners (Chabal et al., 2024). An Actigraph assignment log (See Appendix P) was kept by RR so that participant identification codes could be linked to their Actigraphy watch serial numbers.

EMU Diary. During the intervention phase, participants were introduced to the EMU diaries (see Appendix Q) as part of the intervention, and through which more fine-grained EMU data were reported. They continued to use this diary during follow-up phase. As EMU diaries were not captured at baseline phase, these were not used as outcome measurement. However, EMU diaries were collected for exploratory analysis. Accompanying EMU diaries, in the intervention workbook, participants completed an EMU audit to document the hardware they were using to support categorising EMU diary entries. The EMU diaries themselves were A6 sized pocketbooks with spaces for participants to report beginning and end use times, intended hardware and activities, and extra hardware and activities.

Procedure

From each participants perspective, the study began with the intake survey, following which they met with RR for an orientation session just prior to beginning the MBD component. An actigraphy watch was provided during orientation and they were trained in the use of the PVT. They were given the first of the daily measures books to be carried with them and given the logbook to keep in their quarters. Day 1 for each participant began on the Monday following their orientation session. Beginning day 1 and running through to the final Sunday six weeks later (day 42), participants wore their actigraphy watches, filled out their logbooks, and completed daily measures and thrice weekly PVTs on Tuesdays, Thursdays, and Fridays, aiming for PVT measurement and daily KSS and SPFS ratings at the same time each day.

After two weeks of their baseline measurement phase were complete, each participant began the two-week intervention phase. In the first intervention session on Monday, day 15 for each participant, the EMU diaries were introduced. Participants attended a total of four half-hour sessions—two per week—with RR, scheduled on Mondays and Wednesdays, so that they did not overlap with days that they completed their PVTs. Two weeks of follow-up assessment followed while participants continued to complete their EMU diaries to assess for stability of changes in the absence of ongoing intervention sessions. This continued until midway through each participant’s day 42, when materials were collected and stored by RR. Follow-up surveys were emailed to participants to complete approximately six months later.

Data Treatment

Clarifying Temporal Terminology. For describing time in the MBD component, clarification is required for terminology used in the results: *Night n* denotes the 24h period beginning at midday on *day n* and concluding midday on *day n+1*. The term *study* before *day* and *night* refer to the time course of the entire MBD component of the study, that is, excluding the intake and follow up assessments. Study day 1 began at 0000h on 25 October 2021, and the MBD component concluded at 2359h on study day 56, 19 December 2021. The terms *day* or *night* used independently of *study* refers to an individual participant's perspective on their MBD component. P1 and P2 began day 1 on study day 1, 25 October 2021; P3 and P4 began day 1 on study day 8, 1 November 2021; P5 and P6 began their day 1 on study day 15, 8 November 2021. Each participant completed the follow-up phase of the MBD on their day 42. For P1 and P2 this was on study day 42, 5 December 2021, for participants 3 and 4 this was on study day 49, 12 December 2021, for P5 and P6 this was on study day 56, 19 December 2021. Night 41 was the last night of data collection; for P1 and P2, from the 4–5 December 2021, for P3 and P4 from the 11–12 December 2021, and for P5 and P6 from the 18–19 December 2021. For MBD charts, one day was subtracted from the day on which *yesterday's screentime* was reported in order to create a *screentime* variable that was associated with the day the screentime occurred rather than the day when it was reported from inbuilt screen timing software. All duration metrics were converted to minutes to facilitate comparisons. Participants were instructed to maintain measurement according to the time set on their actigraphy watches in case of time zone changes while on duty. Time zone changes were accounted for as study events (see Appendix R).

Calculating Reliable Change. A reliable change Index (RCI) was calculated for the MTUAS, PSQI, and FAS following the method outlined by Blampied and Fitzgerald (2016). The RCI is a cutoff threshold for identifying reliable change in clinical measures for single cases such as the intake/6-month-follow-up assessment from the current study. Importantly, RCI cannot establish causal effects of an intervention as other uncontrolled variables may change scores, though RCI can evaluate whether changes in an outcome measure may be due to random measurement error. To calculate RCI, subscale SDs were retrieved from the original study for the MTUAS (Rosen et al., 2013) and a pooled SD = 2.27 for the MTUAS was approximated based on the analysed and compiled subscales for the MTUAS in the current study (Cohen, 1988). Cronbach's α = 0.703 based on the current estimate meant an RCI of 3.42 indicated reliable change between the intake and follow-up surveys for the MTUAS. For the PSQI, an RCI = 6.4 was calculated from the current study's Cronbach's α = 0.79, and the SD from the original PSQI study = 5.1 (Buysse et al., 1989). For the FAS, an RCI = 7.87 was calculated from the current study's Cronbach's α = 0.81, and the SD from the initial FAS validation study = 6.52 (Michielsen et al., 2003).

Actigraphy Data Analysis. Actigraphy data was analysed with Action-W (Ambulatory Monitoring, n.d., -a). To estimate behavioural sleep metrics, *down intervals*, the period of time where a participant is assumed to be in bed and attempting sleep, were inferred by triangulating data from sleep logs, and the activity, light, temperature, and event marker data from the actigraphy watch. To assess the accuracy of this triangulation, 20% of nights' data (41 nights) from the final analysis of P1–P5 were randomly selected to be subject to interrater reliability assessment. An independent trained rater who signed a confidentiality agreement (see Appendix F) provided a second estimate of down intervals which were then compared to the original estimates. Down interval boundaries occurring within 15 minutes were considered as in agreement. Initial interrater reliability was 81.70%. Disagreements were discussed and reconciled. Interrater agreement following discussion was 100%. There was one night measured by P5 where the actigraphy data indicated that the watch was not worn, this night (study night 23) was marked as a bad period and treated as missing data. Aside from that night, P1–P5 appeared to have worn their actigraphy watches consistently throughout their sleep periods. The Cole-Kripke sleep estimation algorithm was applied with rescoring rules to the down intervals (Cole et al., 1992; Fekedulegn et al., 2020; J. B. Webster et al., 1982). With actigraphy, the following sleep-related metrics were assessed: TIB, TST, WASO, SE, and SOL.

PVT Data Analysis. Data from the PVTs were parsed and analysed with the aid of REACT software (Ambulatory Monitoring, n.d.-b). As lapses were rare, reaction time data was used as the primary vigilance metric. The reaction time data in milliseconds was transformed to its reciprocal, and multiplied by 1000 for an index of response speed; the reciprocal reaction time (RRT; e.g., Basner & Dinges, 2011). Four metrics were calculated from the RRT. The first was a mean RRT over the whole 10-minute PVT, the second was the mean RRT of the slowest 10% of responses, and the third was the mean RRT of the fastest 10% of responses, each respectively giving insight into overall, and lower-, and upper-ends of vigilant performance (Basner & Dinges, 2011; Dorrian et al., 2011; Gander et al., 2014; Van Dongen & Dinges, 2005).

The regression slope of RRT as a function of time over the course of the 10-minute test was used to assess the time on task effect of the RRT, as a behavioural measure of fatigue accrual as a function of time on task and so was used to infer fatigue propensity (e.g., Balkin & Wesensten, 2011).

Time of Day Influence for Time Sensitive Measures. Time-of-day is likely to impact vigilance/sleepiness and fatigue metrics (e.g., Balkin & Wesensten, 2011; Gander et al., 2015). The influence of time of day of assessment was investigated for trends within participants' SPFS, KSS and PVT mean RRT and RRT vs minute slope scores. These scores were each charted as a function of time of day to assess this influence. Time of day as a function of study day was also charted to assess for systematic time of day patterns over the timeseries component. In self-report measures, P2's scores showed a correlation between time of day and scores on the KSS and SPFS, though they did not show any systematic timing changes over the study. Conversely, P3 showed a systematic change in the time of day over the study, though did not show any relation between time of day and their self-report scores. Therefore, no adjustments were made, nor any outliers removed for any self-report data. In the PVT metrics, P1's RRT vs minute slope showed a marked curvilinear relationship when plotted against time of day of testing as well as systematic change in time of day of testing over the course of the study. A binomial trendline approximating this effect of time of day on testing was calculated for each of the RRT vs minute slope scores of each participant in Microsoft Excel (Version 2406, Build 17726.20160). The best-fitting binomial functions were subtracted from the observed scores to provide a further variable, named *RRT vs minute slope corrected for time of* *day* to be analysed alongside the raw score timeseries charts (see Appendix S for an account of this process).

Single Case Research Design Data Analysis Method.

With MBD, visual analysis is the primary way of judging the presence of a relationship (Krasny-Pacini & Evans, 2018; Kratochwill et al., 2010). Traditional conventions for MBDs require having three clear effects measured at three different times in order to demonstrate evidence of a causal relationship (Dowdy et al., 2022; Kratochwill et al., 2010). To facilitate understanding the relationships between the intervention and outcome measures, timeseries graphs were drawn up, printed, and analysed by hand according to level changes, monotonic trends, variability of scores, overlap between phases, immediacy of any observed effects, and consistency of any patterns of change between participants in similar phases in the study. Visual analysis considered both intervention introduction and follow-up phases separately and conjointly to assess for patterns of change.

Major study events reported by RR are presented along with the study phase shifts in Appendix R. The chart in Appendix R was designed to be printed at the same scale as the timeseries charts that were used in visual analysis. Eighty-five timeseries charts were created, 17 for each of the five participants that were eligible for timeseries analysis. The following outcome measures charted for each participant in the MBD analysis (see Appendices T-X): logged EMU time, phone screentime, estimated sleep duration, sleep quality, TIB, TST, WASO, SE, SOL, KSS score, PVT RRT means for fastest 10% of responses, PVT RRT means overall, PVT RRT means for the slowest 10% of responses, SPFS score, RRT vs minute slopes, and RRT vs minute slopes corrected for time of day. Duty time was also assessed for each of the five included participants when analysing data, however, save for duty times of P1 and P2—who both showed a sharp increase in duty time at the beginning of their intervention phases, likely due to the beginning of a new sailing coinciding with their beginning intervention phase—no substantial patterns were noted in the duty time charts that warranted their presentation over the interests of anonymity.

Baseline phase stability was algorithmically determined by evaluating whether more than 80% of points fell within 15% of the median baseline score (Lobo et al., 2017). Percentage nonoverlapping data (PND) analysis (Scruggs et al., 1987; Scruggs & Mastropieri, 1998) was employed to supplement visual analysis. PND analysis involved a calculation of how many datapoints fell outside of the lower or upper extremes of data from the baseline phase. PND provided a consistent and objective means of evaluating the intervention outcomes to augment visual inspection with a reliable metric (Scruggs & Mastropieri, 2013). For PND calculations, intervention introduction and follow-up MBD phases were conjoined as they both represented the time after the intervention—the independent variable in this study—was introduced. PND scores above 50% was the cutoff for considering that any effect had occurred within the MBD component, unless visual analysis clearly indicated otherwise (Scruggs et al., 1987; Scruggs & Mastropieri, 2013).

Exploratory Analysis Method

Participants returned their EMU diaries to RR at the conclusion of their MBD component. Data from these diaries were collated and subject to descriptive analyses. Data from P6 was also analysed as part of this process. For each participant, activities engaged in were simplified from their notes. Time spent on each activity was tabulated, separated by hardware used. From the EMU diary data, the time spent on extra activities compared with intended activities could not be measured. Therefore, only the intended activities were tabulated from entries that time spent was able to be inferred. This resulted in a measure of how much time was spent when intending to engage in certain EMU. For time duration reporting of individual results, identifiable activities were obfuscated, for example if only one participant played a certain game, names of these were changed to “game” in order to protect anonymity as participants could possibly be identified by the specific games that were played.

A Sankey diagram was created for each participant, and for an aggregate of all participants’ EMU diary entries. Sankey diagrams are flow charts that show flows of energy (e.g., Bostock, 2023). In this case, the Sankey charts graphed links between intended hardware, intended activities and extra hardware and extra activities. These flow charts were based on all EMU diary entries, including ones where timing was not reported, to show a flow of attention, rather than time spent. Sankey charts were created in R (Version 4.4.1) using the Network D3 package (Allaire et al., 2014). EMU diary entries were also used to create two donut charts. For one donut chart, entries with start and end times were categorised based on whether the hardware was identified as communal in the EMU audits to display the amount of time spent using communal vs non-communal electronic media. For the other donut chart, all entries were grouped and categorised based on how they documented their activities. This categorisation employed the five-lens EMU framework (see Chapter 1) to gain insight into how participants described their EMU in the diaries.

Results

The results of this study are summarised in aggregate below. As there were many outcome measures in this study totalling approximately 70 pages of graphs, these have been reported for each participant independently in the appendices. Major study events are charted in Appendix S; Individual results including MBD results for P1–P5 are presented in Appendices T–X. Results for P6 are presented in Appendix Y.

Intake and Follow-up Surveys

In the intake and follow-up surveys, all participants noted that they regularly use a smartphone, and all answered that they have social media accounts. There was no missing data from these surveys. P1 and P6 were not able to access screentime recordings from their mobile phone screen time applications. The two MBD eligible participants that completed both intake and follow-up questionnaires (P2 & P3) each showed reliable decrease in fatigue as measured by the FAS in the follow-up survey. P6 also showed substantial decrease in the FAS, though this decrease was less than RCI threshold. P2 also showed reliable improvement in sleep quality as measured by the PSQI. P3 showed improvement in PSQI, though under RCI threshold. While MTUAS measures of EMU decreased for all participants that completed both surveys, these were all below RCI threshold. Table 3 charts intake and follow up survey scores for the six participants.

Multiple Baseline Design Timeseries Results

All six participants completed the study in their expected timeframes. The only change in schedule reported by RR was the fourth intervention session for P3 and P4 being postponed by one day (occurring on study day 32 rather than 31). Allowance for slightly delayed sessions was built into the study design, and intervention sessions were not expected to have immediate effects, so this time shift would not have substantially influenced results. Despite P1 not reporting inbuilt screentime application data in their intake survey, they were able to report this in the MBD component. There were few instances of missing data across the timeseries measures. None of the missing data led less than three datapoints per phase to be assessed for any participants. There appeared to be no systematic patterns influencing missingness so these missing datapoints were treated as missing completely at random and ignored (Aydin, 2024). Percentage of missing data for P1 = 2.85%; for P2 = 0.57%; for P3 = 1.14%, for P4 = 0.57%; and for P5 = 1.71%.

Table 3

Intake and Follow-Up Scores

Measures	Participants					
	P1	P2	P3	P4	P5	P6
MTUAS	6.09	5.79 (5.03)	7.02 (4.66)	6.15	6.4	4.77 (4.35)
PSQI	9	10 (3) *	12 (8)	7	14	3 (4)
FAS	28	31 (22) *	29 (20) *	25	26	19 (12)

Note. Brackets denote scores on the 6-month follow-up survey.

*Reliable change based on RCI.

EMU. Overall, the intervention appeared to only exert a subtle effect on any of the daily EMU measures. While EMU as measured through screentime applications showed a surprisingly sharp immediate drop for P1 and P2 between baseline and intervention phases, this same drop was seen in the middle of baseline EMU measurements for P3 and P4. This was best explained through the ship leaving for a new sailing on study day 15. P2 also increased their use of other EMU as reported in their time logs after intervention introduction, though this was not reflected in their screentime measures, likely as audio content was apparently not captured in their screen timing application. P5 showed a slight decrease in both subjective and objective EMU following the introduction intervention session, however this was in line with a decreasing trend and consistent with highly variable baseline data. Figure 6 shows a compiled MBD graph for P1–P5 EMU time variables.

Sleep. Estimated nightly sleep duration and sleep quality showed minimal change from baseline into the intervention phase for P1 and P2. Trends for these participants were approximately even. While highly variable, the sleep outcomes scores for P1 and P2 did not show any consistent changes that could be attributed to the intervention's impact. For P3, a highly variable TST in baseline did not reach above baseline measurements after intervention introduction. For P3, the upwards trend in subjective TST was seen in actigraphy TIB measurements, although was not reflected in actigraphy TST. P3's WASO increased from baseline during intervention introduction and their SE showed a downward trend after intervention introduction, jumping back to above baseline again two weeks later, appearing to reflect a fortnightly duty time pattern. For P4, no changes were noted in subjective sleep satisfaction following the introduction of the intervention. For P4, one marked outlying night with long SOL, WASO, and lowered SE noted in actigraphy occurred following the ship leaving cell phone reception, and approximately when "clocks moved back one hour" twice in two days as reported by RR. For P4, EMU log time and phone screentime estimates were relatively low on these days, so the disrupted sleep was likely due to other factors. Interestingly, subjective reporting of sleep quality and TST impressions for P4 did not reveal these anomalous nights. For P5, subjective TST and sleep quality remained variable and similar across phases. While in baseline, P5 did not note that their sleep quality was "very good" for any nights. After the intervention was introduced, there were two nights where P5 rated "very good" sleep. For P5, actigraphy results reflected a relatively stable pattern, with some disrupted sleep later in the study. In actigraphy assessed TST for P5, there was one sleepless night in baseline, and six relatively sleepless nights after the intervention was introduced, one of which had extended SOL, and short TST. These anomalous nights were not echoed in their estimated TST, so may have been measurement error in the actigraphy. Overall, no consistent effect of the intervention on sleep metrics was able to be found for any of the participants sleep health outcomes. As an example, Figure 7 graphs logbook's estimated TST and actigraphy assessed TST for P1–P5 over the course of the MBD component of the study.

Sleepiness and Vigilance. KSS scores were highly variable within phases for all participants and showed no marked between phase changes, save for P1 and P5 who showed slightly increased sleepiness scores at the very beginning of intervention introduction phase. These effects coincided with increased duty at that time. For the average RRT in the PVTs, P1's speed showed a relatively stable baseline, an increasing trend during intervention introduction, and a downward trend during follow-up phase. This same pattern was more exaggerated in their mean RRT for their slowest 10% of responses, and subtler in their fastest 10% of responses. P2 showed a similar pattern to P1, though P2 showed no trend during intervention introduction phase. While P2's overall mean RRT and mean RRT of slowest 10% of responses declined at the end of follow-up phase, their mean RRT for the fastest 10% of responses remained high and at level with baseline. P3 showed stable within phase variability for mean RRT, with one marked lower RRT at the end of intervention introduction phase for both mean RRT and mean RRT of slowest 10% of responses, although fastest 10% RRT was more robust to this fluctuation. P4, on the other hand, showed a declining trend in mean RRT measures over baseline measurement, which appeared to become an upward trend during intervention introduction phase, although stabilising at a lower level in follow-up phase. P5 showed a similar pattern of increased mean RRTs comparing baseline to intervention introduction phase, and then slower and more variable metrics in follow-up phase for mean RRT, although similar variability between phases was observed for each slowest and fastest 10% of responses. As a summary, Figure 8 shows mean RRTs timeseries charts graphed against KSS scores for P1-P5. Note that in Figure 8, Mean RRTs are mapped on a reverse scale so that elevated lines for both measures indicate higher sleepiness and lower vigilance.

Fatigue. SPFS scores for P1 and P2 were highly variable across the study, with no notable changes that could be attributed to the intervention. While P3 showed a highly fatigued measure (SPFS score of 7) on the second day of intervention phase, this was a singular occurrence and balanced with a downward trend after intervention phase. P4 showed an increasing trend of SPFS estimated fatigue over both baseline and intervention introduction phase, with the trend stabilising during follow-up phase, their scores hovering around their overall median of 5 and overlapping completely with the variable and upwards trending scores in baseline measurement, though showing no ceiling effect. P5 showed no trend within phases in subjective fatigue scores, with similar medians (SPFS score 5) in baseline and intervention introduction phases, though their median SPFS score increased to 6 in follow-up phase. Fatigue propensity as evaluated through RRT vs minute slopes for P1 showed increased fatigue propensity after intervention introduction. When correcting P1's scores for time of day of assessment, this declining performance disappeared, so may have been due to change in measurement time between these phases. P2 and P3 showed high within-phase variability and relatively unchanged fatigue propensity from baseline to after intervention introduction. P4 showed an increase in variability of fatigue propensity from baseline to after intervention introduction though no other marked changes. P5 showed increased fatigue propensity after intervention introduction. Figure 9 presents SPFS scores plotted alongside PVT RRT vs. minute slopes.

Percentage of Nonoverlapping Data. To supplement and simplify the results of the timeseries component, PND in the direction of anticipated effects is presented in Table 4. Table 4 shows that overall, no consistent effect of the intervention was found on any of the outcome measures for P1–P5 during the MBD component of the study.

Figure 6

EMU Outcomes Multiple Baseline Design Chart

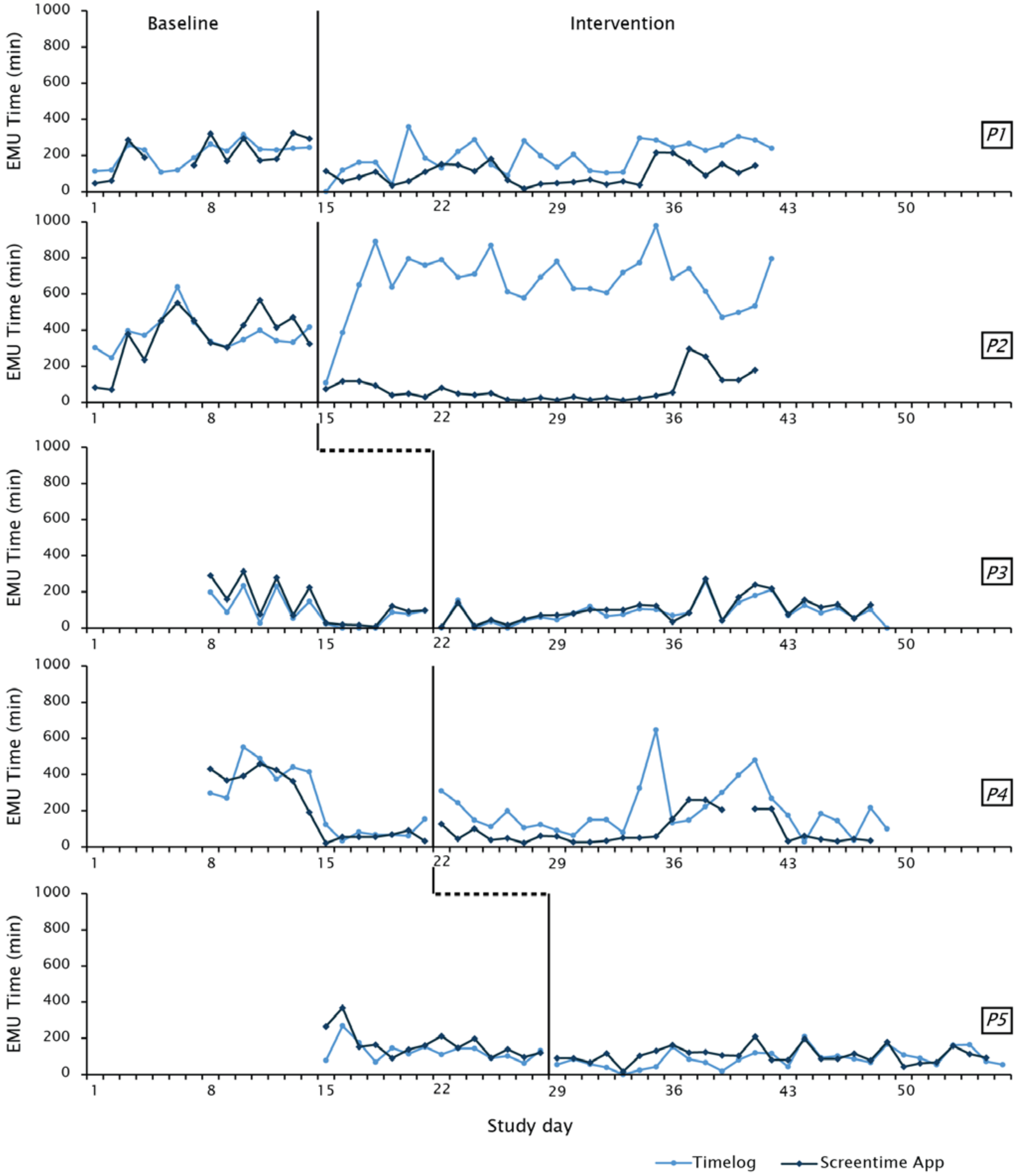


Figure 7

Total Sleep Time Multiple Baseline Design Chart

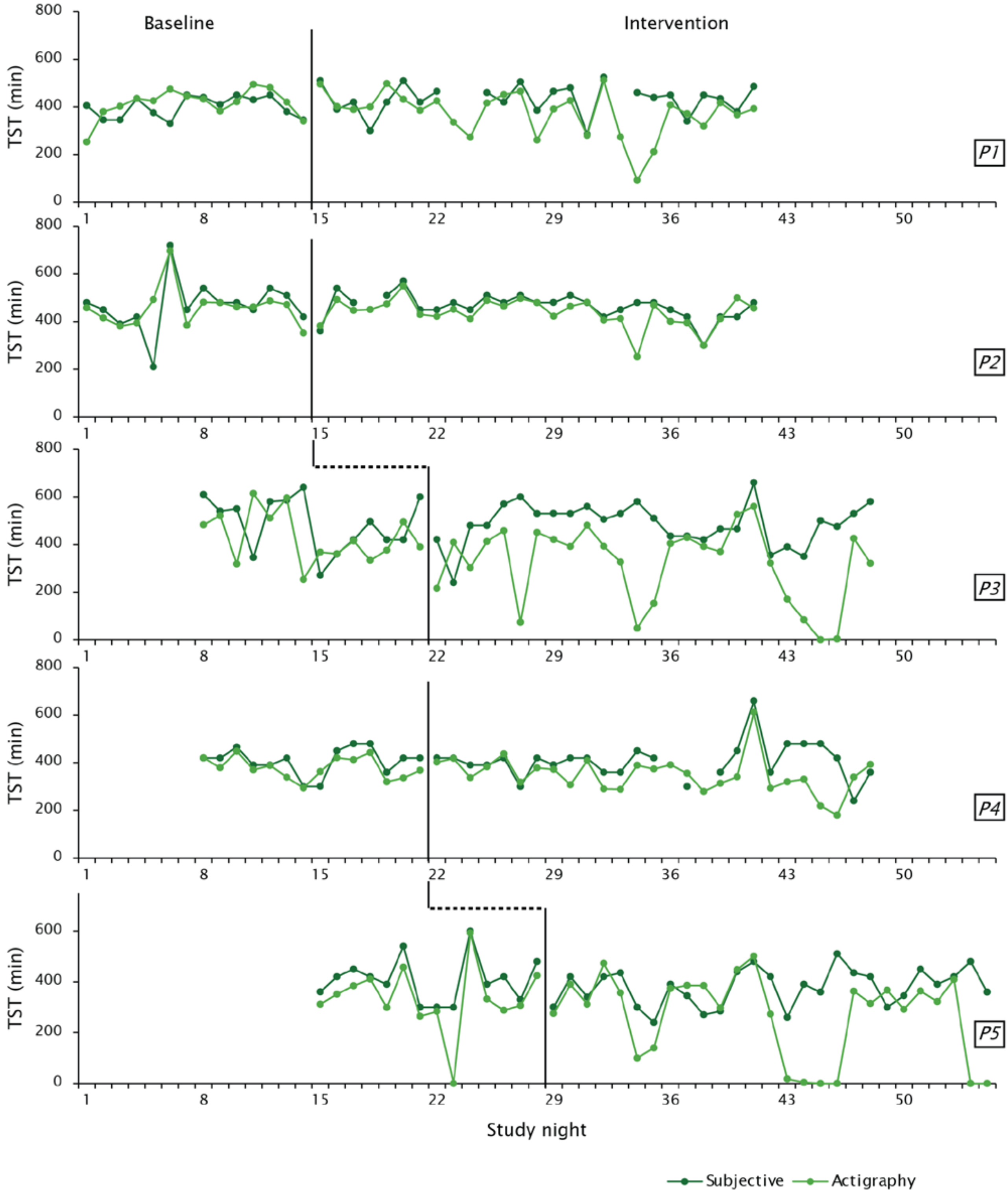
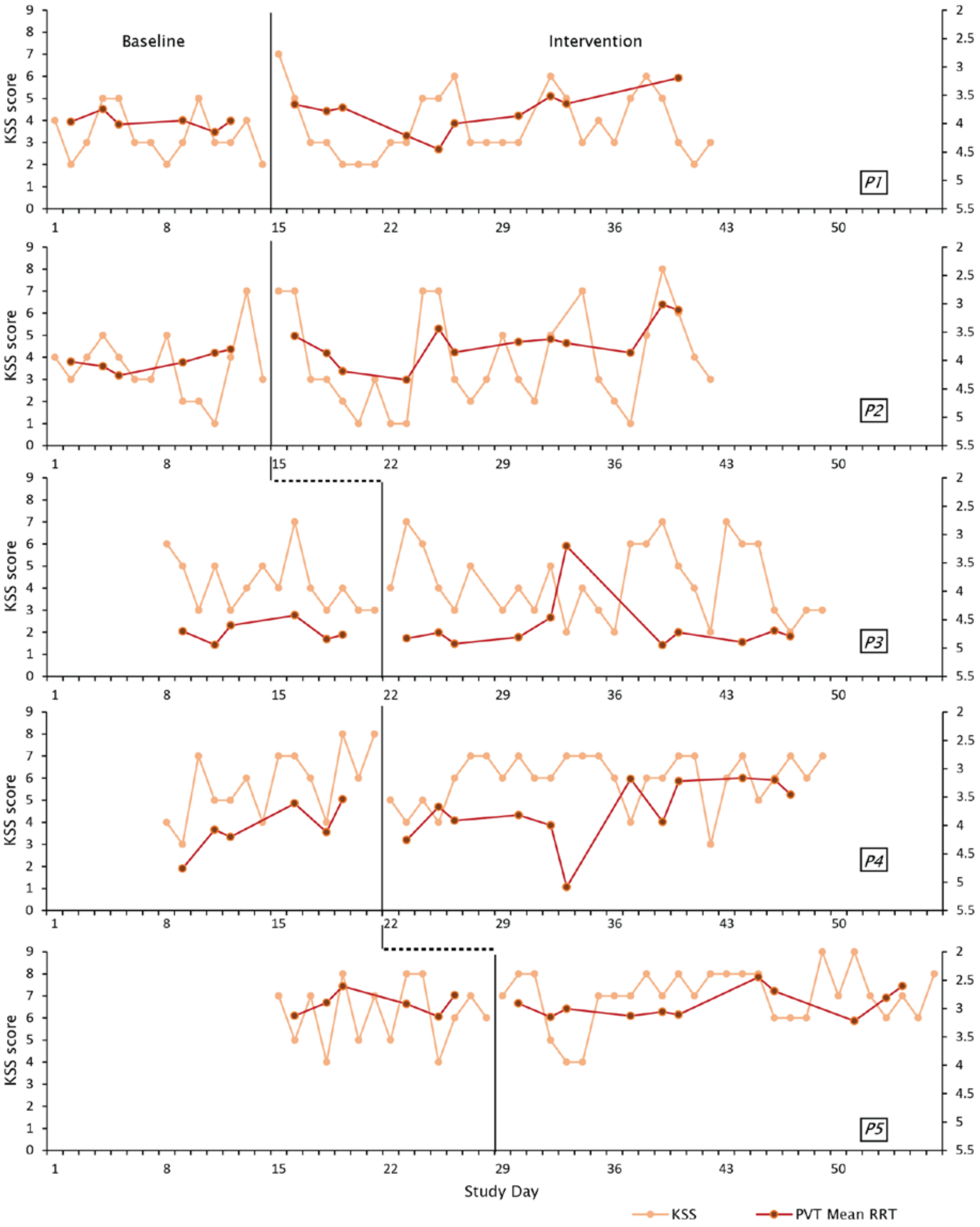


Figure 8

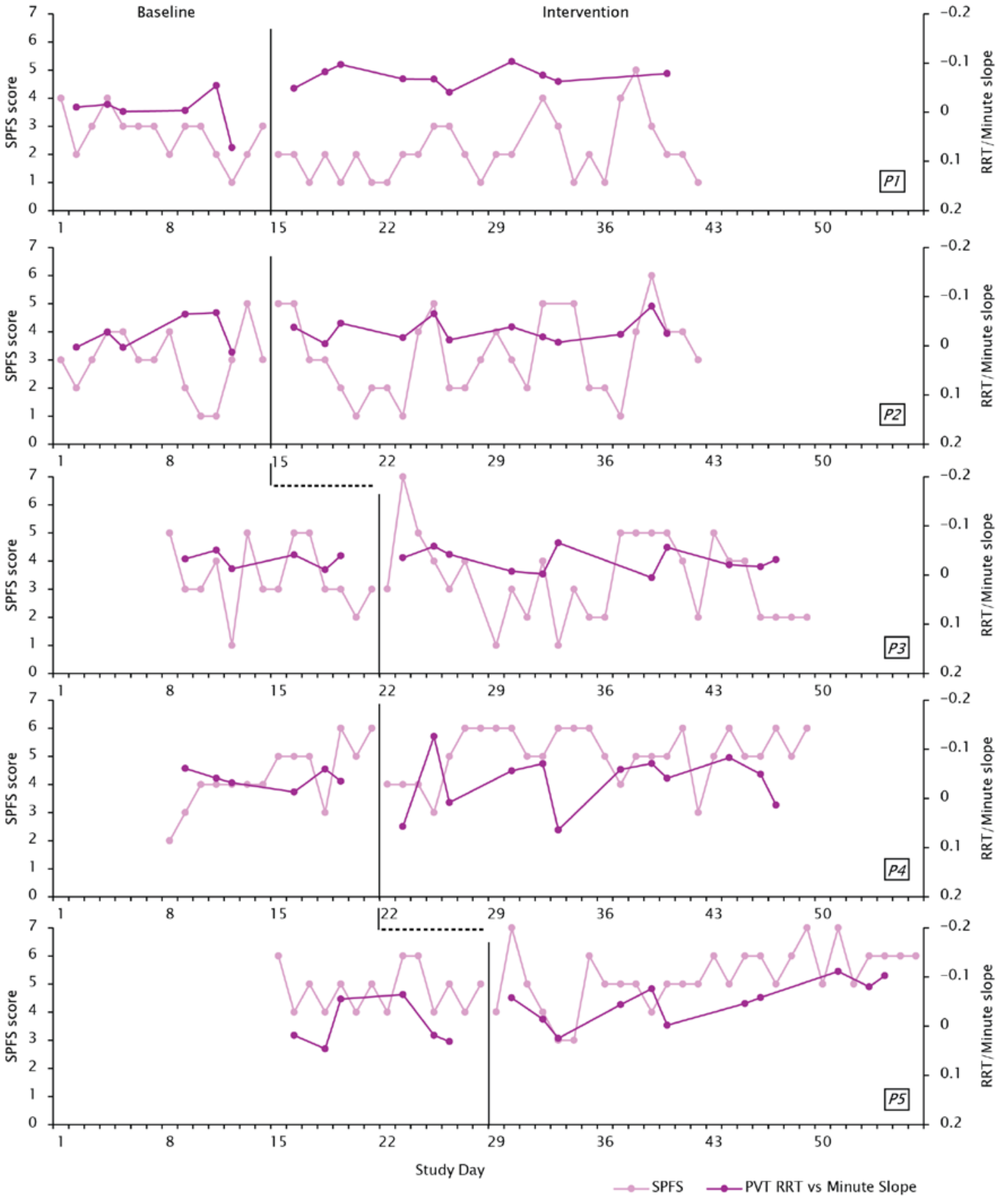
Sleepiness and Vigilance Multiple Baseline Design Chart



Note. (KSS) Karolinska Sleepiness Scale; (RRT) reciprocal reaction time, response speed; (PVT) psychomotor vigilance task. Mean RRTs mapped on a reverse scale so that elevated lines for both measures indicate higher sleepiness and lower vigilance.

Figure 9

Fatigue Multiple Baseline Design Chart



Note. RRT vs minute slopes are plotted on a reverse axis so that higher marks represent greater fatigue propensity (i.e., more negative RRT slopes over the course of the 10 minute PVT).

Table 4

Percentage of Nonoverlapping Data in Direction of Expected Effect

Outcome	+/− [a]	Participant					
		P1	P2	P3	P4	P5	Effect
EMU		%	%	%	%	%	
Subjective							
Logged EMU time	–	14	**4***	0	4	36	No
Objective							
App screentime	–	19	**63**	4	0	37	No
Sleep							
Subjective (modified PSQI)							
Subjective sleep duration	+	42	0	4	4	0	No
Subjective sleep quality	–	0	0	26	4	7	No
Objective (actigraphy)							
TIB	+	22	0	0	26	0	No
TST	+	11	0	0	4	0	No
WASO	–	7	30	4	0	5	No
SE	+	11	30	12	0	5	No
SOL	–	0	4	12	0	0	No
Vigilance/Sleepiness							
Subjective daily measures							
KSS	–	0	0	15	0	0	No
Objective PVT metrics							
Mean RRT	+	**20***	**8***	9	8	18	No
Mean RRT Slowest 10%	+	20	8	9	8	36	No
Mean RRT Fastest 10%	+	20	0	0	16	0	No
Fatigue							
Subjective daily measures							
SPFS	–	0	0	0	0	7	No
Objective PVT metrics							
RRT/Minute slope	+	**0***	0	28	33	0	No
RRT/Minute slope corrected for time of day	+	0	0	28	25	**0***	No

Note. [a] "+" and "-" signal whether we expected values to increase above baseline, or decrease to below baseline, respectively. Percentages of nonoverlapping data are reported in this direction though were measured in both directions (see Appendices T-X).

"*" indicates greater than 50% PND in the opposite direction to expected.

PND values over 50%, indicate at least a questionable effect in either direction; signalled through bold typeface. PND was rounded to the nearest whole number value in this table. Underlined entries denote stable baselines calculated as >80% of baseline data falling within ±15% of median baseline value (Lobo et al., 2017). The final column headed with *Effect*, is based on the requirement that a stable effect be observed across three time periods to provide robust evidence of an effect (Kratochwill et al., 2010). See Appendices T–X for timeseries charts for P1–P5. PND for both directions are reported in full in the notes of the charts of respective appendices for each participant.

Exploratory Analysis of the EMU Diaries' Contents

Table 5 documents, for P1–P6, the number of entries noted in their EMU diaries, the percentage of entries from which EMU time spent could be inferred, and the total number of minutes accounted for by these entries after intervention introduction for each participant. Analysed qualitative EMU diary data, as well as pre- and post-test analyses are presented for P6 in Appendix Y.

Documenting EMU Activities. In their EMU diaries, participants were asked to identify any expected and extra activities that they engaged in while they were engaging in EMU. In Chapter 1 of this thesis, a framework was introduced for understanding different frames through which EMU could be understood. For interest, all entries that were made in the activities columns in the EMU diaries were analysed and categorised into the different aspects of this five-lens EMU framework to ascertain how participants generally described their EMU. Figure 10 shows this aggregated analysis in a donut chart.

Communal or Personal. In their EMU audits, participants were asked to identify the hardware that they would be noting in their EMU diaries and whether the hardware was communal or personal. Figure 11 charts time spent on intended hardware, categorised based on weather audits identified it as being personal or communal. Figure 11 was created from entries that included both start and end times so that time spent could be inferred on a donut chart. Figure 11 shows that the majority of time spent on EMU was when participants were engaging with personal, noncommunal hardware; 30% of EMU time was spent using communal hardware. These entries often included watching TV or movies or engaging in or watching other people gaming on communal hardware such as the TV in the mess.

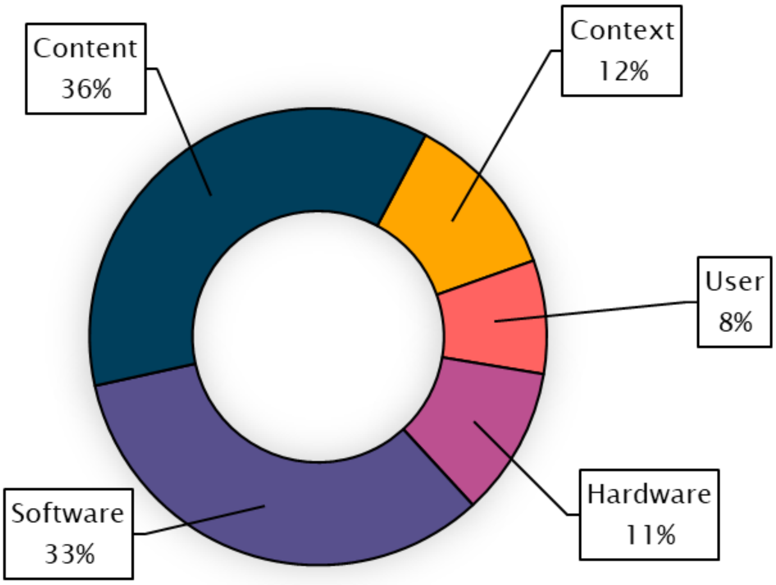
Table 5

Number of EMU Diary Entries and Time Accounted for by Participants

Participant	Total number of entries (n)	% of entries where time can be calculated	Total time From time-calculatable entries (min)
P1	93	17%	1,420
P2	111	98%	19,062
P3	106	100%	3,663
P4	79	100%	4,681
P5	21	95%	540
P6	36	97%	2,559

Figure 10

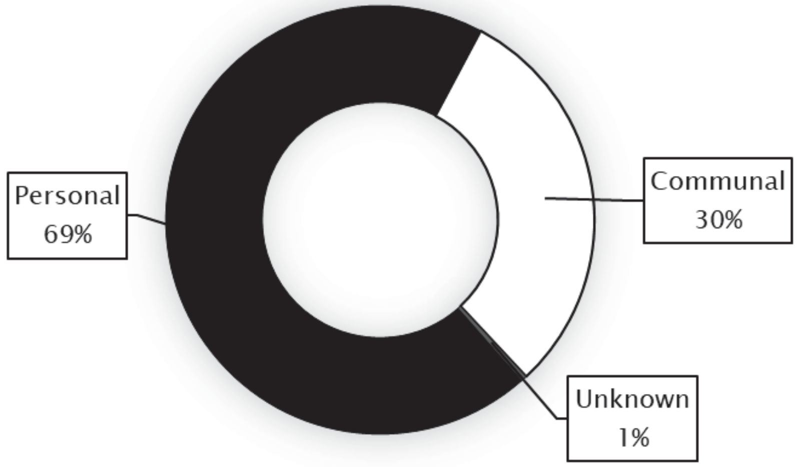
Entries in EMU Diaries Categorised by the Five-Lens EMU Framework



Note. The largest portion by of EMU described in the diaries by a small margin was through the content lens with a slightly smaller portion viewed through the software lens. Each word or phrase in the entries were categorised once. If entries had multiple elements (e.g., “watching movie” then each element of the listing was categorised, for example, *User* (watching) and *Content* (movie).

Figure 11

Time Spent when Intending to Engage in Personal or Communal EMU



Note. Approximately 1% of data was unknown as the hardware listed in the EMU diary was not accounted for in the EMU audit sheets.

Flow of Activity. A Sankey chart showing the flows of EMU activity from intended to extra is presented in Figure 12 – fold out. Figure 12 is an aggregate of all six participants' EMU diary entries. Figure 12 shows that overall, TV and phones were the most used intended hardware, with fewer, though still prominent use of game consoles and iPads. The majority of intended activities were movies, TV, Netflix, and gaming, with less common though still prominent white noise and social media amongst other intended activities. Phones predominated extra hardware, and a diversity of activities were engaged in as extra activities, most commonly, though only by a small margin was gaming as an extra activity.

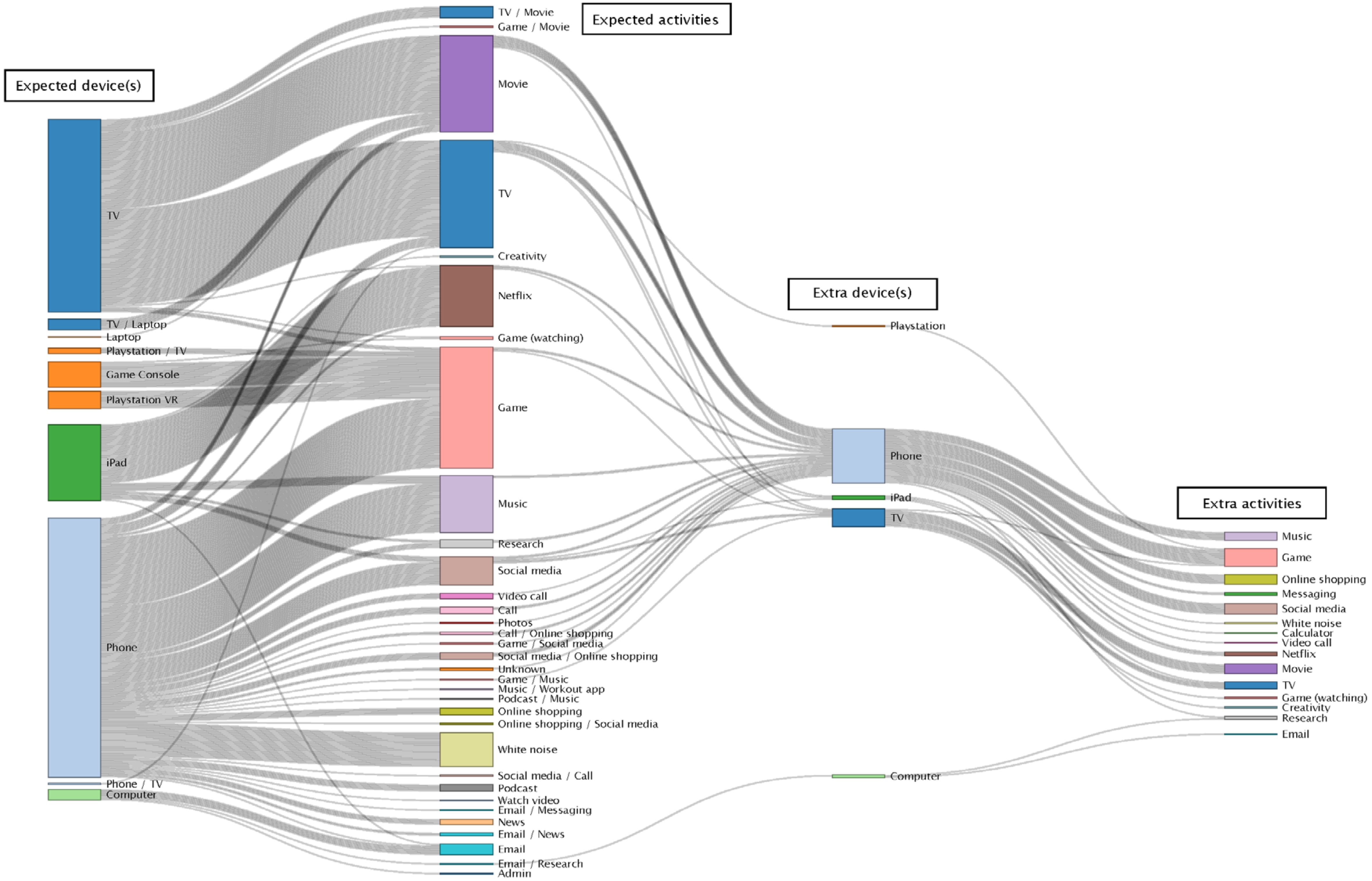
Figure 12

A Sankey Diagram Summarising the Entries of the EMU diaries for all Participants

(unfold)

Figure 12

A Sankey Diagram Summarising the Entries of the EMU Diaries for all Participants



Note. This diagram was based on an aggregate of the 450 total entries made in EMU diaries by P1, P2, P3, P4, P5, and P6. Some reported activities and devices used were obfuscated and grouped to protect anonymity. Some extra activity entries consisted of multiple activities (e.g., Online shopping / Social media). These were unfolded for simplifying the display. Expected activity entries that were multiple (denoted by "/") were retained so that the nuance of links between expected activities and extra devices remained. 548 total links are documented here. Created in R using the NetworkD3 package.

Feedback

Participant Feedback. In the follow up questionnaire, participants were asked what they found the most helpful about the intervention or study. One answered that they found it helpful that the intervention was balanced in its view of EMU. One noted that they found it helped noticing passive vs active EMU and constructing a bedtime routine. One noted that they were surprised by realising how much time they actually spent engaging in EMU. Two participants noted less helpful aspects of the intervention or study or what could be improved. One stated that they preferred the passive monitoring of using their inbuilt screen time application to tracking their EMU in the diaries. One participant critiqued that some questions were wordy and not straight to the point, and that the many different books in the study were complex to keep track of. One participant made a general comment that their EMU is very different between being ashore and at sea, and that their time during the study was mostly at sea. One participant stated that they considered the study overall useful and informative.

Research Representative Feedback. RR also provided their feedback and perspective at the conclusion of the study. They echoed that people's habits tend to change when at sea compared to on shore and at home. RR noted that participants mentioned a number of things influence EMU habits, including sea state and daily routine, and suggested that these extra factors be recorded more thoroughly in future studies. RR also observed that participants had difficulty with keeping PVT assessment consistent across days due to their work schedule and suggested ensuring PVT assessment time be kept to out of usual working hours in any further studies. They also noted that sea sickness medication, which the participants regularly took while at sea caused “drowsiness and slower reaction times,” and suggested that this be specifically documented in future studies. They also reported that some participants had work computers in their cabins right by their beds: “it is easy to be swayed into checking emails late at night or before bed”. Finally, RR noted a trend that individuals did not have many extra activities to log in their EMU diaries, indicating that most of their use was intentional.

Discussion

The objective for this study was to trial EMU-SRI with participants in active duty with the RNZN, and to assess whether EMU-SRI could modify participants’ EMU, support their sleep health and vigilance, and mitigate fatigue. The study was run in late 2021 with the support of RR on board HMNZS Wellington. To assess outcomes, the study primarily employed an MBD methodology, augmented with exploratory analysis of EMU diaries and assessment of longer-term changes by comparing intake measure scores with those from a six-month follow up survey. Subjective and objective measures were gathered to assess for changes in EMU, sleep, sleepiness/vigilance, and fatigue outcomes. Six volunteer participants were each in the timeseries portion of the study for six weeks: two weeks baseline, two weeks intervention introduction, two weeks follow-up. The majority of the study occurred while HMNZS Wellington was at sea. Due to a calculation error in the PSQI assessment in intake, only P1–P5 were deemed eligible for MBD assessment. However, data from P6 was still included in qualitative analysis of the EMU diaries and their intake and follow-up surveys were also analysed. From analysing the MBD data collected from P1–P5, no consistent effect of the intervention was able to be detected. There was, however, a reliable decrease in subjective fatigue observed at six-month follow-up from P2 and P3. Both P2 and P3 also showed evidence of improvement in their sleep, with their PSQI scores each improving seven points and four points, respectively. Though this change was below the RCI threshold, P2 and P3's reported improvements in subjective sleep quality were larger than the mean improvements noted for both sleep hygiene interventions and cognitive behavioural therapy for insomnia in a recent meta-analysis (Chung et al., 2018). P6 showed no reliable change between their intake and follow-up surveys, though a trend toward decreased fatigue was noted. The majority of intended EMU identified in the EMU diaries was on personal hardware, although 30% was communal. Participants mostly identified their use through noting types of software and content that they were engaged in. Feedback from participants was generally positive, some helpful feedback about the study's complexity was given. There was no attrition, implying that the intervention was generally well received.

Environmental Influences on Observed Variables

The lack of effect of intervention effect during the MBD indicated that EMU-SRI was not powerful enough to elicit consistent improvements to sleep and fatigue variables in this naturalistic setting. As is common in sleep and wake performance studies, uncontrolled environmental influences likely influenced outcomes and overshadowed clear results (Axelsson et al., 2008; Greenwood, 1989). Work demands, environmental noise, motion sickness, and motion sickness medications may have influenced aspects of participant's EMU, sleep, and vigilance and potentiated fatigue over the course of the study (Hockey, 2013; Leung & Hon, 2019; Seokjin et al., 2024; Zhang et al., 2016). Light exposure aspects of EMU, for instance, may produce measurable influences on sleep in an isolated laboratory environment; however, in naturalistic settings, the effects might be more subtle than measurement tools may sensitively measure as they can be obscured by contextual influence (cf. Duraccio et al., 2021; Green et al., 2017). By early December the research assistant noted “cabin fever creeping in” (see Appendix S). Cabin fever is a colloquial concept often associated with being stuck in certain bounded circumstances. Cabin fever is often accompanied with a sense of a lack of enthusiasm, or listlessness, cabin fever may be reduced by a change in environment or change of routine (Rosenblatt et al., 1984). When the ship is at sea, broad changes in environment might not always be possible. Cabin fever experience closely resembles the circumstances of low autonomy and control that Hockey (2013) noted are most likely to potentiate fatigue and for some participants, fatigue did appear to subtly increase over the course of the study. Many of the timeseries results showed high variability within phases. Given that the study was run in this naturalistic setting while sailors were in active duty, circumstantial and environmental aspects likely influenced results and precluded stable pattern observation.

RR noted that participants commonly engaged in work-related EMU close to bedtime on their computers. To ensure that the study did not interfere with working demands, and to preserve information security, participants were not required to document specifics of work-related EMU. Therefore, work related EMU may have influenced sleep health without being captured in EMU journals, and participants may have not engaged in intentional self-reflection of their work-related EMU. Post-work work-related EMU has recently been shown to significantly impact fatigue and sleep health through higher alertness before bed in office workers (Ikeda et al., 2023). Work-related EMU before bed may impair the sleep-enhancing benefit of psychological detachment that leisurely EMU may facilitate (e.g., Liu et al., 2020). Participants may have been engaged in problem solving unfinished work-related business while in preparation for sleep leading to a sense of unfinishedness that could influence their sleep (e.g., Baselgia et al., 2023). In any future studies, assessment of post-work work-related EMU may be a useful specific avenue for investigation. However, the impact of this might also be overshadowed by the more general environmental challenges that these participants faced while living at their workplace.

The relationship between EMU and sleep is nuanced, influenced by the interaction between EMU context, content, software, hardware, users' cognitions, and self-regulation. It is possible that EMU in general might also not be having much of an impact on sleep. For example, in a recent media diary study, Ellithorpe et al. (2022) suggested that that non-multitasking EMU in the hour before bed, if not engaged in for too long, was surprisingly associated with earlier bedtime, more TST, and unimpaired sleep quality. A large-scale time use diary study digesting data from 17,247 adolescents (Orben & Przybylski, 2019) concluded that there was little evidence to suggest any negative effects of EMU on wellbeing in general. A later, similar study found only an overall very small association between teenagers' screen time and sleep delays (Orben & Przybylski, 2020). If individuals are struggling with their sleep and fatigue, and their EMU is only contributing a small effect when compared with other influences, then modifying their EMU approach, as this intervention intended, may only lead to small benefits in sleep and fatigue, even if the EMU modification is significant. Furthermore, if the intervention did improve awareness and intentionality of EMU, this might not have improved sleep and fatigue over and above the fatigue that sailors' working demands and the idiosyncrasies of their working environment might precipitate (e.g., Allen et al., 2008; Baulk et al., 2009). The longer-term decreases in fatigue and trend towards improved satisfaction in the follow-up survey was encouraging, however no substantial changes were observed that could be confidently or consistently attributed to the intervention.

EMU as a Sleep and Alertness Aid

One may think of modifying EMU in the service of sleep to mean engaging in less EMU, however, EMU can also benefit sleep health in ways that may apply to the environment on board ship. For instance, the psychologically detaching effect of EMU (e.g., Liu et al., 2020) might stave off cabin fever through providing an EMU-facilitated change in scene (e.g., Wienrich et al., 2021). Environmental noise on board ship, well known to be a cause of sleep disruption and fatigue for seafarers (Seokjin et al., 2024), may also be alleviated through the use of *white noise* EMU content (Ebben et al., 2021), or background music to improve sleep duration and efficiency (e.g., Tan, 2004). Some participants noted in their EMU diaries that they listened to music or white noise close to bed or while sleeping. As this was not in any of the healthy sleep behaviour recommendations of the intervention, it is likely that they had independently found this EMU supported sleep adaptation.

EMU might also promote arousal and alertness, increasing performance and reducing tiredness through content and light exposure effects (e.g., Baselgia et al., 2023; Bauducco et al., 2024; Silvani et al., 2022). While EMU, may, through its impact on sleep health, lead to greater fatigue propensity, EMU might also buffer this effect through increasing alertness. The impact of EMU on wake functioning might be insidious and short-term improvements in fatigue propensity may therefore only observed to be moderate. Subjective adaptation to chronic partial sleep deprivation, and the slow rate by which performance variables recover following improvement in sleep health (Axelsson et al., 2008; Van Dongen et al., 2003) may buffer and delay vigilance recovery. This buffering may also explain the lack of effect noted in the timeseries component, and the subsequent improvement to fatigue noted in six-month follow-up.

Difference Between Objective and Subjective

Subjective interpretation of EMU timing and sleep timing tends to be inaccurate to objectively measured equivalents (Bernstein et al., 2019; Lin et al., 2015; Young, 1998). There were a few nights where actigraphy data did not reflect what was reported subjectively. This data may have been an artifact of rough seas which has been known to influence actigraphy results in similar circumstances (Matsangas et al., 2015). Other discrepancies were noted between subjectively logged EMU and data collected from screentime applications. These differences were likely due either to passive screen timing applications only preexisting on smartphones, the EMU logs only requesting EMU periods of 10 or more minutes to be recorded, or misestimation of EMU time by participants.

Limitations

Single case experimental designs such as MBDs come with threats to internal validity. As participants act as their own controls, the shift from baseline to experimental condition might coincide with uncontrolled environmental determinants that influenced results. This was, for example seen in the changes in

EMU for P1 and P2 from baseline to intervention phases coinciding with the beginning of a new sailing (see Figure 6). In MBDs, replication across series attempts to assess for these coincidental changes to increase confidence in any observed effects (Krasny-Pacini & Evans, 2018). For example, the changes in EMU in the middle of baseline for P3 and P4 directly showed an assessment of coincidental change to EMU due to the new sailing's beginning. If P1 and P2 alone were assessed without assessing for environmental effects, this spurious result may have appeared significant. Nevertheless, other spurious influences on results that were not made apparent by the staggering of series might have also influenced the results of this study as well as its conclusions.

This study had limitations that may have contributed to moderation of the current results. For example, work requirements led to inconsistency in the time of day of PVT assessment. Control for this was attempted (see Appendix S). In applying this control, for one participant the observed increase in fatigue propensity over the timeseries component disappeared, though, for another participant this control meant a pattern of increasing fatigue propensity was exaggerated, revealing increasing fatigue propensity from baseline. These discrepant results indicated the complexity of gathering these measurements with idiosyncratic cases in such a unique and complex environment.

Participants were compensated with supermarket vouchers for their participation in the study. Given this extrinsic compensation for significant time investment in the study, they may have experienced lowered intrinsic motivation for change (e.g., Deci et al., 1999; Deci & Ryan, 1980). Furthermore, participants EMU, sleep, and fatigue scores were being intentionally monitored, and participants were aware of this from the beginning of the study; they may have initially changed normal habitual behaviour from beginning of baseline measurement (Wickström & Bendix, 2000). The requirement of some degree of self-monitoring for filling out the logbooks in baseline measurement may have led to behaviour change prior to the intervention's introduction (see Bandura, 1991). If this were the case, perhaps only basic EMU logging is required for adequate self-reflection and accompanying behaviour change to achieve the effect that was seen in the follow-up survey.

The purposive sampling of participants who self-identify with sleep challenges, and the positive changes observed in the six-month follow-up survey may also be due to regression to the mean, were extreme scores in measures tend to become more moderate upon reassessment (Bland & Altman, 1994b, 1994a; Peacock & Peacock, 2020). For instance, the mean FAS score found in the FAS validation study by Michielsen et al. (2003) was 19.26. P2 and P3 remained marginally above this score—with scores of 22 and 20, respectively—in the six-month follow-up. Although the positive changes over the 6-month period for P2 and P3 was promising to see, these scores may have improved simply due to regression to the mean. However, the accidental inclusion of P6 in the study fortuitously supports dismissing the effect as being solely regression to the mean; as P6's FAS score began below the mean of the FAS from the initial FAS study (Michelsen et al., 2003, p. 348), and at the 6 month follow up, their score had dropped to further than 1SD below the mean FAS score that was found by Michelsen et al. (2003), suggesting that other variables, perhaps having participating in EMU-SRI, may have influenced this longer term improvement in subjective fatigue.

In the methods of the study, SPFS was assessed prior to engaging in the PVTs. As fatigue is a function of personal determinants as well as task demands (e.g., Belenky et al., 2014), SPFS assessment will have been influenced by the uncontrolled preSPFS activities. This limitation of these self-assessments was observed by Axelsson et al. (2008). To standardise preSPFS activities for future studies, capturing SPFS assessment after PVTs may have made SPFS scores more stable.

At the outset of this project, I was working alongside a PhD candidate, and we agreed to separate our research priorities into two streams. They were to investigate a cross-sectional account of the prevalence of EMU and sleep health difficulty within the RNZN, and, given the importance of application to clinical practice required for the Doctor of Clinical Psychology degree, my focus became on the conceptual and mechanistic aspects of the EMU–sleep health–fatigue relationship, and the development and testing of an intervention. The focus on conceptual understanding, theory, and intervention development for this study remained despite structural changes to the project team. The cross-sectional investigation is, to my knowledge, yet to occur. This study's discussion is therefore limited in being unable to further assess the potential applicability of EMU-SRI in other arms of the RNZN. However, insights drawn from the current study might support conceptual and methodological integrity of broader investigations of EMU and sleep health difficulty in the RNZN. For example, the time required to potentially assess changes in subjective fatigue metrics after intervention delivery.

The process of ascertaining feedback from the participants lacked scientific rigour. However, these processes captured valuable insight about participants' and

RR's experiences in the study. A key difficulty with the study was the sheer volume of data that needed to be collected to adequately assess behavioral and subjective estimates of all the relevant variables. One participant noted that the many booklets were difficult to keep track of. Installing EMU monitoring software on participant's hardware (cf. Lin et al., 2019) might somewhat support with simplifying some of the data collection in future studies.

This studies single case experimental design invoked a specific set of circumstances under which the intervention was trailed and within which any outcomes were constrained (Lincoln et al., 2009). In order to assert any generalisation, or any chance of efficacy or inefficacy when applied more generally, broader research is required into the intervention's outcomes across other contexts and population samples.

Future Directions

The task of ascertaining further understanding in the causal links between EMU, sleep, and fatigue will require more experimental studies in less noisy environments. For inspiration, this MBD could be replicated in environments where participants may have more consistent EMU and more consistent settings for habitualising behaviour change. For even higher isolation of extraneous variables, a laboratory study might be useful to test more thoroughly the dynamics of the intervention, of course, with adequate caution in its interpretation given to generalisability to external contexts (Greenwood, 1989). Future studies would benefit from considering the impact of baseline monitoring on behaviour. This could be assessed by incorporating a longer period of passive monitoring to establish a more stable baseline prior to the active monitoring baseline phase that was used in the current study, then introducing the intervention after the active monitoring phase.

Further research is required to better delineate the kinds of EMU that might impact sleep positively or negatively. More refined gathering of data regarding EMU, for example by way of body cameras to assess light exposure and categorise EMU hardware has shown promise (Lowe et al., 2023). Their use could be extended to enhance understandings of user engagement with software and content aspects of EMU. Ecological momentary assessment (e.g., Parsey & Schmitter-Edgecombe, 2019) may be useful to capture experiences of intentionality, mood, and more frequent fatigue metrics. Incorporating performance variables (Reifman et al., 2018), and integrated passive monitoring of EMU software and content use and sleep variables (e.g., Lin et al., 2019) may also support developing further insight into these variable relationships as well as contribute to ongoing efforts to find ways of monitoring and moderating their impact. An EMU software that works across various hardware, and potentially supports intervention administration as well as outcome measurement might facilitate this effort. While this software's development would require significant resources, this hypothetical software could also facilitate a longitudinal study with a larger sample size, extended passive baseline measurement, and extended follow up assessment that could gather a more precise understanding of the longer-term improvement to fatigue that was observed in the six-month follow-up survey.

EMU-SRI's efficiency may also be improved, and its tenets expanded upon through development of a group educational intervention—as has had success in other EMU associated therapy for addictions (see Chapter 1)—or a module in other individualised interventions that consider more thoroughly individual formulation and support (e.g., Harvey & Buysse, 2017). EMU-SRI might also be refined through encouraging participants to specify more thoroughly the exact content that they wish to access, to increase self-monitoring moment to moment, and mitigate simply intending to be caught within software-based coercive flows that might be content ambiguous (e.g., Wu et al., 2020). Furthermore, the intervention may be further enhanced by having people identify expected finish times when they begin their EMU and compare this with actual finish times in a daily reflection exercise for greater insights into discrepancies.

Cross-hardware passive EMU timers (e.g., Lin et al., 2019) could be incorporated to support an objective and quantitative aspect to self-reflection. Through developing the EMU diaries presented herein into this same software, data input by individuals into their EMU diaries, possibly set as an automatic prompt for self-reflection upon EMU commencement, could lead to automatic creation of Sankey charts (see Figure 1 in each of Appendices P-Y and Figure 12 in this chapter) may be able to be automatically created with automated precision to support weekly reflection about attention flows and to visually show changes in patterns over time. With these future directions, caution should be exercised in the impact of *too much monitoring* leading to an increased entanglement between sleep and EMU (Coveney et al., 2023). Perhaps the use of the physical EMU diaries, framing EMU with a brief self-monitoring nonEMU activity is all that is needed.

Conclusion

While the intervention was not immediately effective in the MBD component, for the participants that completed the follow up questionnaire, fatigue reliably improved for two, and sleep reliably for one. Based on feedback from the participants who completed the follow-up questionnaire, the intervention supported awareness raising and self-reflection regarding EMU. The longer-term changes observed may have been due to some long-term impact of the intervention, or they may be circumstantial. Further studies over longer timeseries and in other contexts may support understanding the intervention's potential longer-term impacts.

Epilogue: Reflections

Through the course of this thesis, I have investigated conceptual difficulties and clarified understandings of EMU, sleep, and fatigue to frame a perspective on the relationship between them. I have applied these conceptual frames to an umbrella scoping review of the EMU–sleep health relationship and discussed areas in need of deeper understanding. I have proposed a theoretical maintenance cycle of sleep health difficulty, EMU, and fatigue through reviewing experiments conducted in these fields and relevant theoretical underpinnings. I have created a brief intervention aimed to support self-directed EMU through engaging in self-monitoring and self-reflection on EMU. This intervention was captured in a manual and was trailed with sailors in the RNZN. Using MBD, I assessed for resulting changes to EMU, sleep health, vigilance and fatigue through both subjective and objective measurements and analyses. While I was unable to observe immediate measurable benefits for sleep and wake functioning in the cases that were studied, some longer-term improvements were noted in the six-month follow-up, particularly for subjective fatigue.

During early developments of this project, I met with my supervision team at the Sleep Wake Research Centre. Early in our conversation we attempted to draw a boundary around what counts as a *screen* when discussing *screen time*. I had recently used the microwave and asked my supervisors whether I had just engaged in screen time as I input the time into the microwave. We agreed that, for the purposes of this project, that kind of screen time would not be applicable, though we all failed to express exactly how come with any degree of satisfaction. Whether it was the size of the screen or the number of pixels or the relatively short length of time I interacted with it? Though it may not colloquially be understood as EMU when inputting cooking times into a microwave, these kinds of appliances are also participating in convergence: many everyday objects are integrating into broader connected electronic media ecosystems (Medoff & Kaye, 2017; Stair et al., 2020; Tate, 2024). It is important to monitor and regulate the utility of the constructs under investigation (S. S. Stevens, 1935).

Colloquial understandings typically permeate prior to their scientific definition. While most people may implicitly know what *electronic media use* is, operational definitions of related constructs were surprisingly absent from published literature. This parallels discussions by Buysse (2014) on the lack of an operational definition of *sleep health* prior to the introduction of the sleep health framework, and also reflects similar discussions by Balkin et al. (2023) on the numerous definitions and re-definitions of *fatigue* that have led to a nebulous construct. I found that EMU had no specific form for study outside of assumed colloquial understandings, potentially indicating the infancy of this topic. When we rely on inconsistent and often colloquial understandings of EMU or its subconstructs such as *social media*, this can easily lead to misrepresentation and can become overgeneralised in the literature and difficult to interpret. A highlighted example from Chapter 2 was Alonzo et al.'s (2021) review of social media and its impacts. In this, the term *social media* was used in their review to cover many ideas that would lie outside their definition's scope, though were nevertheless included in their review. When applied, allowing other attached constructs, the relationships between them became diffused and difficult to interpret. While we all may have experienced electronic media and intuitively know what EMU entails, by delineating EMU into its constituent parameters it can more readily become an object of consistent study for deriving useful insight. The five-lens EMU framework was iteratively developed and refined over the course of this thesis' writing. Ultimately, lenses of context, user, hardware, software, and content, and combinations of these lenses, appeared to comprehensively capture the lenses through which EMU had been discussed in the research field.

Over time, clarified constructs in the literature may change their meaning. For instance, Young (1998) described an actively accessed and fragmented *internet* marked by a dominance of chat rooms. This *internet* from the nineties seemed to hold a different experience to more recent internet experience marked by passive consumption of algorithmically curated content: the "online attention economy" (Wu et al., 2020, p. 16; see also Harris & Cho, 2023). EMU experience may also change rapidly: "a contemporary algorithm is, in a strict sense, a multiple of itself: because programmers promote constant efficiency tweaks, the same algorithm has different versions over time and is thus a persistently ephemeral socio-technical entity" (Vicente & Burnay, 2024, p. 1260). By the time that we fully understand the EMU landscape, it may shift again, as it has in early 2025, with, for example declining uptake the dominant social media software that use top-down content moderation and algorithmic curation, and increasing userbase in chatroom-based software, and customisable algorithms (cf. Kumar, 2024, 2025; Marriott, 2024). While these shifts may just be a brief, correlational, and possibly transient phenomenon, they may nevertheless signal a resurgence of relevance to many of the case studies on active chatroom use of the nineties described by Young (1998). More research is required to thoroughly understand the more difficult-to-construct-and-measure user experiences on various software platforms from a sleep wake science perspective (Exelmans & Van den Bulck, 2019).

The definition of colloquially nested EMU subconstructs will likely remain fuzzy. Wittgenstein's (1953/1986) difficulties with defining a *game* was mentioned in Chapter 2's discussion of operationally defining EMU constructs. From talking about games, Wittgenstein described the *language games* that must be played in order to allow language to serve its various functional purposes. Chapter 2 served to indicate that when the rules of these language games lean too closely to the side of practicality over accuracy of definition, then our insights may be conceptually limited. The critical balance between practicality and accuracy is so hard to strike in this field, evidenced by the identical note in the last two editions of the APA's diagnostic and statistical manual of mental disorders released close to a decade apart (APA, 2013, 2022) pertaining to the condition for further research, *internet gaming disorder*: "The literature suffers, however, from lack of a standard definition from which to derive prevalence data" (cf. APA, 2013, p. 796, 2022, p. 914).

Psychology seeks to gain generalised and adaptable understandings that can accurately be applied to specific instances. Psychology's clinical practice seeks often to encourage this search in clients. In cognitive behavioural therapy, for example, a therapist works with clients to identify and challenge thoughts and behaviours, with emphasis on accurate and evidence-based thinking (e.g., Beck, 2020). To support individuals who seek support for their EMU, psychologists should be able to have sensitive, nuanced, and open conversations about EMU. If our research relies on nonspecific and pathologizing language to describe EMU, underlying mechanisms supporting formulation and treatment planning may be missed. When we speak about EMU potentially impacting sleep, without delineation of the actual parameters of the EMU that is the topic of study, it is as useful as saying that *behaviour* impacts sleep. The methods through which the problem has been generally investigated, as discussed in Chapter 2, were reminiscent of the critical difficulty that psychology as a science must constantly work to address, summarised by Wittgenstein (1953/1986) that "problem and method pass one another by" (p. 232). Chapter 3 revealed that there are nuanced and specific aspects of EMU that have been studied through experimental methodologies that can ground evidence-based formulation of EMU–sleep health difficulties. The heuristic causal maintenance model described in Chapter 3 captured functional relationships between EMU, sleep health, and fatigue that may be useful in clinical practice for framing discussions with those who seek support. Further experimental research, including for example more in-depth assessment and adaptation of EMU-SRI would be required to further understand its clinical utility.

Understandings and judgements of abstract concepts can influence behaviour. For example, Hockey (2013) discussed the influence of the industrial revolution on limited energy theories of fatigue. These metaphors have permeated into likening self-control to a battery (e.g., Bauducco et al., 2024), or the *recharging* faculties of psychological detachment and sleep (e.g., Liu et al. 2020). If people are under the impression that self-control is limited in this way, their behaviour may manifest their belief (Bernecker & Job, 2020; Job et al., 2010). Many of the criticisms levied at the changing face of EMU and how it impacts us in the past years may simply be new forms of similar anxieties levied against other forms of media, both electronic and physical (Hesmondhalgh, 2022), and could represent an electronic-media-facilitated *moral panic* that has historically accompanied technological development (Walsh, 2020). In the prologue of this thesis, I mentioned that despite subjective accounts, there was limited objective evidence for decreased sleep durations from the past few decades (Bin et al., 2012; Matricciani et al., 2017). Perhaps other environmental and social determinants that predate electronic media's prominence may exert a greater impact on sleep health than EMU (Paine & Muller, 2023; Roenneberg et al., 2019; Stothard et al., 2017), though, as EMU permeates into many contexts (Figueiredo & Bolaño, 2017; L. Scott, 2015) EMU may be easily seen as the common thread and culprit of sleep health difficulty. Focussing on EMU as a locus of blame for sleep health difficulties may remove focus from other, possibly more powerful environmental determinants (Grandner, 2019).

The encouragement of self-reflection of EMU may theoretically support self-regulation, and consequentially support sleep health, and mitigate fatigue, though this may take longer than the four weeks that the MBD study in Chapter 4 was able to capture. EMU may also only be a small aspect in the complexity of an individual's life through which many sources will exert their influence, and which may require more systemic approach. It remains likely that the social and parasocial utility and influence of EMU remains prominent (e.g., MacKenzie et al., 2022; see also Hoffner & Cohen, 2023). Supporting individual and group education, assessing, and promoting readiness to change, facilitating self-directed EMU, and addressing other environmental determinants (cf. Grandner, 2019) may help with fostering individual and community EMU health. An ability to intentionally interact with electronic media hardware, software, and content may support user's thriving in their various contexts. Such efforts as have been undertaken by the Center for Humane Technology (2025) to educate software hardware, and content designers in user-wellbeing principles suggest the multisystemic approach that is required. Throughout these efforts, to ensure that our insights remain useful, it is important that our science aspires for accuracy and embraces the complexity of the changing experience of EMU.

Postface

I began developing this thesis on a camping trip, removed from electronic media by the shores of Te Manganui o Te Ao. My companion on this trip created a sundial with a tent peg and together we tuned into the rhythms of the sun and earth for a week (see Jamieson, 2020). This week for me was the most satisfied I had been with my sleep for a long while before, and the most satisfied I would be with my sleep for the next half decade. Shortly after returning, I found an interesting study by Stothard et al. (2017) that experimentally showed the impact on sleep of being able to behaviourally control light exposure. Students were taken on a weeklong winter camping trip in the Rocky Mountains of Colorado, with limited opportunity for artificial light exposure and strong photic zeitgebers. In a night in the sleep lab after the camping trip, the participants' dim light melatonin onset was around two hours and forty minutes earlier, and they slept for around two hours and twenty minutes longer (and earlier) than they did on the night before the camping trip, after a week of industrialised life.

To avoid biasing my judgements, I have not yet used EMU-SRI on myself. During the course of writing this thesis, I have formed the opinion that it may be helpful for supporting sleep health in contexts where electronic media permeate. After these many late and sleepless nights to conclude this thesis, I imagine a camping trip will be a more powerful immediate intervention.

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Appendix A

Preferred Reporting Items for Systematic reviews and Meta-Analyses extension for Scoping Reviews (PRISMA-ScR) Checklist

This Appendix contains the Preferred Reporting Items for Systematic reviews and Meta-Analyses extension for Scoping Reviews Checklist (Tricco et al., 2018). This checklist refers to page numbers in Chapter 2 where each aspect of the scoping umbrella review that meets checklist criteria can be found.

SECTION	ITEM	PRISMA-ScR CHECKLIST ITEM	REPORTED ON PAGE #
TITLE			
Title	1	Identify the report as a scoping review.	41
ABSTRACT			
Structured summary	2	Provide a structured summary that includes (as applicable): background, objectives, eligibility criteria, sources of evidence, charting methods, results, and conclusions that relate to the review questions and objectives.	41
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of what is already known. Explain why the review questions/objectives lend themselves to a scoping review approach.	42
Objectives	4	Provide an explicit statement of the questions and objectives being addressed with reference to their key elements (e.g., population or participants, concepts, and context) or other relevant key elements used to conceptualize the review questions and/or objectives.	44–45
METHODS			
Protocol and registration	5	Indicate whether a review protocol exists; state if and where it can be accessed (e.g., a Web address); and if available, provide registration information, including the registration number.	45
Eligibility criteria	6	Specify characteristics of the sources of evidence used as eligibility criteria (e.g., years considered, language, and publication status), and provide a rationale.	46–47
Information sources*	7	Describe all information sources in the search (e.g., databases with dates of coverage and contact with authors to identify additional sources), as well as the date the most recent search was executed.	46
Search	8	Present the full electronic search strategy for at least 1 database, including any limits used, such that it could be repeated.	45–46
Selection of sources of evidence†	9	State the process for selecting sources of evidence (i.e., screening and eligibility) included in the scoping review.	46
Data charting process‡	10	Describe the methods of charting data from the included sources of evidence (e.g., calibrated forms or forms that have been	47

		tested by the team before their use, and whether data charting was done independently or in duplicate) and any processes for obtaining and confirming data from investigators.	
Data items	11	List and define all variables for which data were sought and any assumptions and simplifications made.	47
Critical appraisal of individual sources of evidence§	12	If done, provide a rationale for conducting a critical appraisal of included sources of evidence; describe the methods used and how this information was used in any data synthesis (if appropriate).	N/A
Synthesis of results	13	Describe the methods of handling and summarizing the data that were charted.	47
RESULTS			
Selection of sources of evidence	14	Give numbers of sources of evidence screened, assessed for eligibility, and included in the review, with reasons for exclusions at each stage, ideally using a flow diagram.	48, 50
Characteristics of sources of evidence	15	For each source of evidence, present characteristics for which data were charted and provide the citations.	48
Critical appraisal within sources of evidence	16	If done, present data on critical appraisal of included sources of evidence (see item 12).	N/A
Results of individual sources of evidence	17	For each included source of evidence, present the relevant data that were charted that relate to the review questions and objectives.	51–61
Synthesis of results	18	Summarize and/or present the charting results as they relate to the review questions and objectives.	62–68
DISCUSSION			
Summary of evidence	19	Summarize the main results (including an overview of concepts, themes, and types of evidence available), link to the review questions and objectives, and consider the relevance to key groups.	68–73
Limitations	20	Discuss the limitations of the scoping review process.	73–74
Conclusions	21	Provide a general interpretation of the results with respect to the review questions and objectives, as well as potential implications and/or next steps.	74

FUNDING			
Funding	22	Describe sources of funding for the included sources of evidence, as well as sources of funding for the scoping review. Describe the role of the funders of the scoping review.	76

Note. JBI = Joanna Briggs Institute; PRISMA-ScR = Preferred Reporting Items for Systematic reviews and Meta-Analyses extension for Scoping Reviews.

* Where *sources of evidence* (see second footnote) are compiled from, such as bibliographic databases, social media platforms, and Web sites.

† A more inclusive/heterogeneous term used to account for the different types of evidence or data sources (e.g., quantitative and/or qualitative research, expert opinion, and policy documents) that may be eligible in a scoping review as opposed to only studies. This is not to be confused with *information sources* (see first footnote).

‡ The frameworks by Arksey and O'Malley (6) and Levac and colleagues (7) and the JBI guidance (4, 5) refer to the process of data extraction in a scoping review as data charting.

§ The process of systematically examining research evidence to assess its validity, results, and relevance before using it to inform a decision. This term is used for items 12 and 19 instead of "risk of bias" (which is more applicable to systematic reviews of interventions) to include and acknowledge the various sources of evidence that may be used in a scoping review (e.g., quantitative and/or qualitative research, expert opinion, and policy document).

Reference

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Appendix B

Full Map of Primary Study Overlap Including References to Primary Studies from Umbrella Scoping Review

This appendix contains two elements. First is an A3 sized map documenting the reviewed studies contained in the umbrella review, along with labels for the primary studies that were drawn on in the creation of those reviews. This map, like its simplified version (see figure X in Chapter 2) uses pink and blue nodes with size depending on the number of links attached. Pink nodes represent review studies, and blue nodes represent primary studies that were drawn on in the reviews. The second part of the appendix is a key which contains references for each of the nodes.

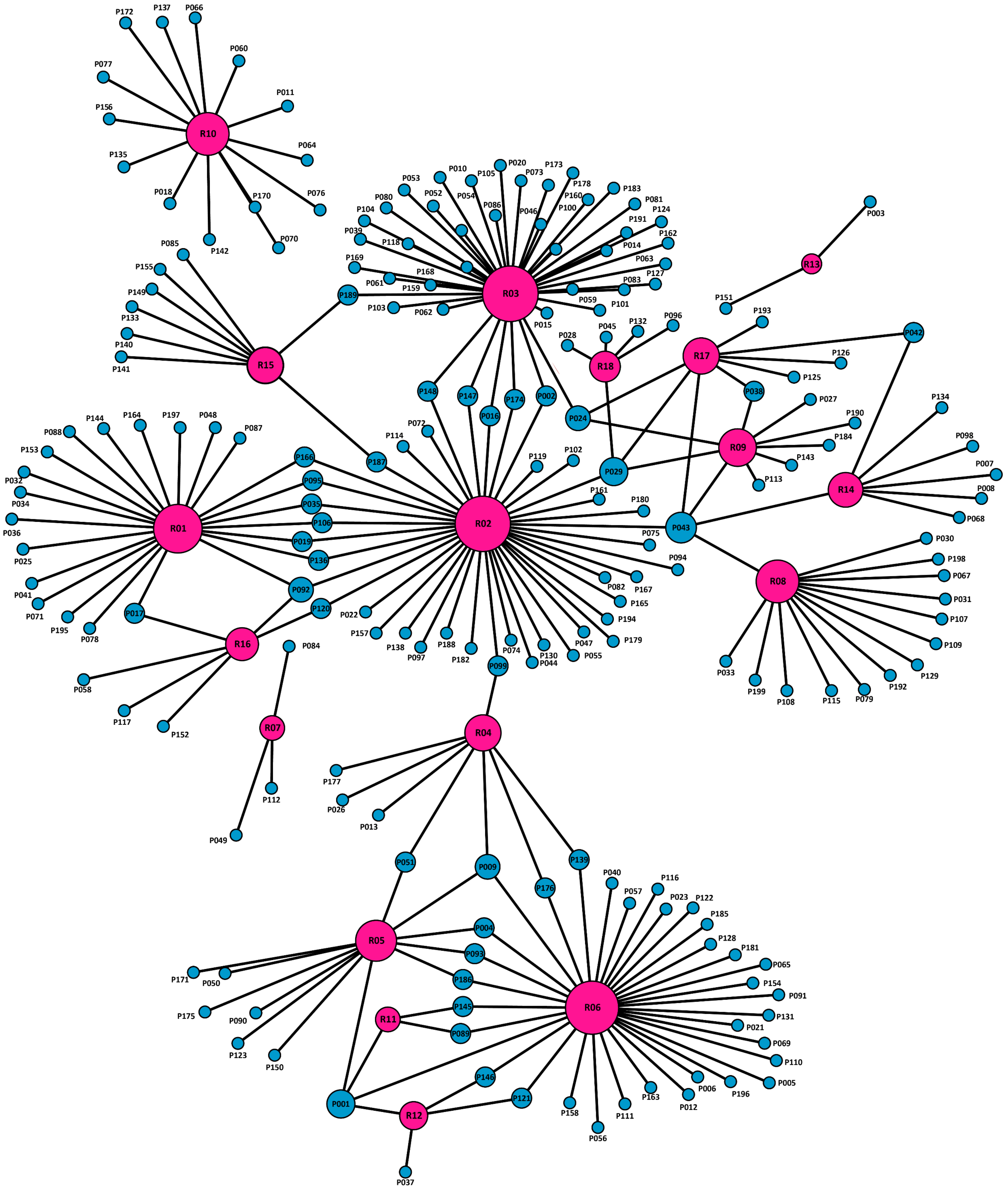
Figure B1

Overlap Map of Studies with Primary Study Labels from the Umbrella Scoping Review

(unfold)

Figure B1

Overlap Map of Studies with Primary Study Labels from the Umbrella Scoping Review



Note. Pink nodes (codes beginning with "R") indicate the included review studies. Blue notes (codes beginning with "P") indicate primary studies drawn on in the reviews. A key containing references for each study represented on this map are documented in Table B1 (below).

Table B1

A Key for Figure B1 Including References to All Reviews and Primary Studies

Code	Reference
R01	Alimoradi, Z., Lin, C.-Y., Broström, A., Bülow, P. H., Bajalan, Z., Griffiths, M. D., Ohayon, M. M., & Pakpour, A. H. (2019). Internet addiction and sleep problems: A systematic review and meta-analysis. *Sleep Medicine Reviews*, *47*, 51–61. https://doi.org/10.1016/j.smrv.2019.06.004
R02	Alonzo, R., Hussain, J., Stranges, S., & Anderson, K. K. (2021). Interplay between social media use, sleep quality, and mental health in youth: A systematic review. *Sleep Medicine Reviews*, *56*, Article 101414. https://doi.org/10.1016/j.smrv.2020.101414
R03	Brautsch, L. A., Lund, L., Andersen, M. M., Jennum, P. J., Folker, A. P., & Andersen, S. (2023). Digital media use and sleep in late adolescence and young adulthood: A systematic review. *Sleep Medicine Reviews*, *68*, Article 101742. https://doi.org/10.1016/j.smrv.2022.101742
R04	Chan, G., Huo, Y., Kelly, S., Leung, J., Tisdale, C., & Gullo, M. (2022). The impact of eSports and online video gaming on lifestyle behaviours in youth: A systematic review. *Computers in Human Behavior*, *126*, Article 106974. https://doi.org/10.1016/j.chb.2021.106974
R05	Kemp, C., Pienaar, P. R., Rosslee, D. T., Lipinska, G., Roden, L. C., & Rae, D. E. (2021). Sleep in Habitual Adult Video Gamers: A Systematic Review. *Frontiers in Neuroscience*, *15*, Article 781351. https://doi.org/10.3389/fnins.2021.781351
R06	Kristensen, J. H., Pallesen, S., King, D. L., Hysing, M., & Erevik, E. K. (2021). Problematic Gaming and Sleep: A Systematic Review and Meta-Analysis. *Frontiers in Psychiatry*, *12*, Article 675237. https://doi.org/10.3389/fpsyt.2021.675237
R07	Kuss, D. J., Kristensen, A. M., & Lopez-Fernandez, O. (2021). Internet addictions outside of Europe: A systematic literature review. *Computers in Human Behavior, 115*, Article 106621. https://doi.org/10.1016/j.chb.2020.106621

Code	Reference
R08	Li, Y., Li, G., Liu, L., & Wu, H. (2020). Correlations between mobile phone addiction and anxiety, depression, impulsivity, and poor sleep quality among college students: A systematic review and meta-analysis. *Journal of Behavioral Addictions, 9*(3), 551-571. https://doi.org/10.1556/2006.2020.00057
R09	Mac Cárthaigh, S., Griffin, C., & Perry, J. (2020). The relationship between sleep and problematic smartphone use among adolescents: A systematic review. *Developmental Review, 55*, Article 100897. https://doi.org/10.1016/j.dr.2020.100897
R10	MacKenzie, M. D., Scott, H., Reid, K., & Gardani, M. (2022). Adolescent perspectives of bedtime social media use: A qualitative systematic review and thematic synthesis. *Sleep Medicine Reviews, 63*, Article 101626. https://doi.org/10.1016/j.smrv.2022.101626
R11	Männikkö, N., Ruotsalainen, H., Miettunen, J., Pontes, H. M., & Kääriäinen, M. (2020). Problematic gaming behaviour and health-related outcomes: A systematic review and meta-analysis. *Journal of Health Psychology, 25*(1), 67-81. https://doi.org/10.1177/1359105317740414
R12	Mihara, S., & Higuchi, S. (2017). Cross-sectional and longitudinal epidemiological studies of Internet gaming disorder: A systematic review of the literature. *Psychiatry & Clinical Neurosciences, 71*(7), 425-444. https://doi.org/10.1111/pcn.12532
R13	Ramjan, L. M., Salamonson, Y., Batt, S., Kong, A., McGrath, B., Richards, G., Roach, D., Wall, P., & Crawford, R. (2021). The negative impact of smartphone usage on nursing students: An integrative literature review. *Nurse Education Today, 102*, Article 104909. https://doi.org/10.1016/j.nedt.2021.104909
R14	Ratan, Z. A., Parrish, A.-M., Zaman, S. B., Alotaibi, M. S., & Hosseinzadeh, H. (2021). Smartphone addiction and associated health outcomes in adult populations: A systematic review. *International Journal of Environmental Research and Public Health, 18*(22). Article 12257. https://doi.org/10.3390/ijerph182212257
R15	Sadagheyani, H. E., & Tatari, F. (2021). Investigating the role of social media on mental health. *Mental Health & Social Inclusion, 25*(1), 41-51. https://doi.org/10.1108/MHSI-06-2020-0039

Code	Reference
R16	Sánchez-Fernández, M., Borda-Mas, M., & Mora-Merchán, J. (2023). Problematic internet use by university students and associated predictive factors: A systematic review. *Computers in Human Behavior, 139*, Article 107532. https://doi.org/10.1016/j.chb.2022.107532
R17	Yang, J., Fu, X., Liao, X., & Li, Y. (2020). Association of problematic smartphone use with poor sleep quality, depression, and anxiety: A systematic review and meta-analysis. *Psychiatry Research, 284*. Article 112686. https://doi.org/10.1016/j.psychres.2019.112686
R18	Zhong, Y., Ma, H., Liang, Y.-F., Liao, C.-J., Zhang, C.-C., & Jiang, W.-J. (2022). Prevalence of smartphone addiction among Asian medical students: A meta-analysis of multinational observational studies. *The International Journal of Social Psychiatry, 68*(6), 1171-1183. https://doi.org/10.1177/00207640221089535
P001	Achab, S., Nicolier, M., Mauny, F., Monnin, J., Trojak, B., Vandel, P., Sechter, D., Gorwood, P., & Haffen, E. (2011). Massively multiplayer online role-playing games: Comparing characteristics of addict vs non-addict online recruited gamers in a French adult population. *BMC Psychiatry, 11*, Article 144. https://doi.org/10.1186/1471-244X-11-144
P002	Adams, S. K., & Kisler, T. S. (2013). Sleep quality as a mediator between technology-related sleep quality, depression, and anxiety. *Cyberpsychology, Behavior, and Social Networking, 16*(1), 25-30. https://doi.org/10.1089/cyber.2012.0157
P003	Ahn, S.-Y., & Kim, Y.-J. (2015). The influence of smart phone use and stress on quality of sleep among nursing students*. Indian Journal of Science and Technology, 8*(35), 1-6. https://doi.org/10.17485/ijst/2015/v8i35/85943
P004	Akçay, D., & Akçay, B. D. (2020). The effect of computer game playing habits of university students on their sleep states. *Perspectives in Psychiatric Care, 56*, 820-826. https://doi.org/10.1111/ppc.12497
P005	Al Asqah, M. I., Al Orainey, A., Shukr, M. A., Al Oraini, H. M., & Al Turki, Y. A. (2020). The prevalence of internet gaming disorder among medical students at King Saud University, Riyadh, Saudi Arabia. A cross-sectional study. *Saudi Medical Journal, 41*(12), 1359-1363. https://doi.org/10.15537/smj.2020.12.05584

Code	Reference
P006	Al Gammal, M., Ali Elsheikh, M., & Abozahra, A. (2019). Internet addiction and internet gaming disorder and associated insomnia among a sample of Al-Azhar University students, clinical study. *The Egyptian Journal of Hospital Medicine, 77*(5), 5718-5726. https://doi.org/10.21608/ejhm.2019.63227
P007	Alageel, A. A., Alyahya, R. A., Bahatheq, Y. A., Alzunaydi, N. A., Alghamdi, R. A., Alrahili, N. M., McIntyre, R. S., & Iacobucci, M. (2021). Smartphone addiction and associated factors among postgraduate students in an Arabic sample: A cross-sectional study. *BMC Psychiatry, 21*, Article 302. https://doi.org/10.1186/s12888-021-03285-0
P008	Alosaimi, F.D.; Alyahya, H.; Alshahwan, H.; Al Mahyijari, N.; Shaik, S.A. (2016). Smartphone addiction among university students in Riyadh, Saudi Arabia. *Saudi Medical Journal. 37*(6), 675-683. https://doi.org/10.15537/smj.2016.6.14430
P009	Altintas, E., Karaca, Y., Hullaert, T., & Tassi, P. (2019). Sleep quality and video game playing: Effect of intensity of video game playing and mental health. *Psychiatry Research, 273*, 487-492. https://doi.org/10.1016/j.psychres.2019.01.030
P010	Amez, S., Vujić, S., Soffers, P., & Baert, S. (2020). Yawning while scrolling? Examining gender differences in the association between smartphone use and sleep quality. *Journal of Sleep Research, 29*(6), Article e12971. https://doi.org/10.1111/jsr.12971
P011	Amiri, M., & Dowran, B. (2020). Smartphone overuse from Iranian university students' perspective: A qualitative study*. Addiction & Health, 12*(3), 205-215. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7679485/
P012	Arnesen, A. A. (2010). *Video game addiction among young adults in Norway: Prevalence and health* [Master's thesis, University of Bergen]. Bergen Open Research Archive. https://bora.uib.no/bora-xmlui/handle/1956/4114
P013	Arora, T., Hussain, S., Lam, K. H., Yao, G. L., Thomas, G. N., & Taheri, S. (2013). Exploring the complex pathways among specific types of technology, self-reported sleep duration and body mass index in UK adolescents. *International Journal of Obesity, 37*(9), 1254-1260. https://doi.org/10.1038/ijo.2012.209

Code	Reference
P014	Baiden, P., Tadeo, S. K., & Peters, K. E. (2019). The association between excessive screen-time behaviors and insufficient sleep among adolescents: Findings from the 2017 youth risk behavior surveillance system. *Psychiatry Research, 281*, Article 112586. https://doi.org/10.1016/j.psychres.2019.112586
P015	Bartel, K., Williamson, P., van Maanen, A., Cassoff, J., Meijer, A. M., Oort, F., Knäuper, B., Gruber, R., & Gradisar, M. (2016). Protective and risk factors associated with adolescent sleep: Findings from Australia, Canada, and The Netherlands. *Sleep Medicine, 26*, 97-103. https://doi.org/10.1016/j.sleep.2016.07.007
P016	Bélanger, R. E., Akre, C., Berchtold, A., & Michaud, P.-A. (2011). A U-shaped association between intensity of internet use and adolescent health. *Pediatrics, 127*(2), e330-e335. https://doi.org/10.1542/peds.2010-1235
P017	Bener, A., Yildirim, E., Torun, P., Çatan, F., Bolat, E., Alıç, S., Akyel, S., & Griffiths, M. D. (2019). Internet Addiction, Fatigue, and Sleep Problems Among Adolescent Students: A Large-Scale Study. *International Journal of Mental Health and Addiction, 17*(4), 959-969. https://doi.org/10.1007/s11469-018-9937-1
P018	Bergner, E. M., Williams, R., Hamburger, E. R., Lyttle, M., Davis, A. C., Malow, B., Simmons, J. H., Lybarger, C., Capin, R., & Jaser, S. S., (2018). Sleep in teens with type 1 diabetes: Perspectives from adolescents and their caregivers. *The Diabetes Educator, 44*(6), 541-548. https://doi.org/10.1177/0145721718799086
P019	Bhandari, P. M., Neupane, D., Rijal, S., Thapa, K., Mishra, S. R., & Poudyal, A. K. (2017). Sleep quality, internet addiction and depressive symptoms among undergraduate students in Nepal. *BMC Psychiatry, 17*, Article 106. https://doi.org/10.1186/s12888-017-1275-5
P020	Billari, F. C., Giuntella, O., & Stella, L. (2018). Broadband internet, digital temptations, and sleep. *Journal of Economic Behavior & Organization, 153*, 58-76. https://doi.org/10.1016/j.jebo.2018.07.001
P021	Bonnaire, C., & Phan, O. (2017). Représentations des risques associés à l'usage des jeux vidéo chez les jeunes adolescents : Une étude exploratoire pour aider à penser la prevention [Negative perceptions of the risks associated with gaming in young adolescents: An exploratory study to help thinking about a prevention program]. *Archives de Pédiatrie, 24*(7), 607-617. https://doi.org/10.1016/j.arcped.2017.04.006

Code	Reference
P022	Brunborg, G. S., Mentzoni, R. A., Melkevik, O. R., Torsheim, T., Samdal, O., Hetland, J., Andreassen, C. S., & Pallesen, S., (2013). Gaming addiction, gaming engagement, and psychological health complaints among Norwegian adolescents. *Media Psychology, 16*(1), 115–128. https://doi.org/10.1080/15213269.2012.756374
P023	Brunborg, G. S., Mentzoni, R. A., Molde, H., Myrseth, H., Skouverøe, K. J. M., Bjorvatn, B., & Pallesen, S. (2011). The relationship between media use in the bedroom, sleep habits and symptoms of insomnia. *Journal of Sleep Research, 20*(4), 569–575. https://doi.org/10.1111/j.1365-2869.2011.00913.x
P024	Cabré-Riera, A., Torrent, M., Donaire-Gonzalez, D., Vrijheid, M., Cardis, E., & Guxens, M. (2019). Telecommunication devices use, screen time and sleep in adolescents. *Environmental Research, 171*, 341–347. https://doi.org/10.1016/j.envres.2018.10.036
P025	Canan, F., Yildirim, O., Sinani, G., Ozturk, O., Ustunel, T. Y., & Ataoglu, A. (2013). Internet addiction and sleep disturbance symptoms among Turkish high school students. *Sleep and Biological Rhythms, 11*(3), 210-213. https://doi.org/10.1111/sbr.12022
P026	Chan, H. S. (2014). *The associations between video gaming, sleep, and neuropsychological functioning in Hong Kong children* [Master's Thesis, The University of Hong Kong]. The HKU Scholars Hub. http://hdl.handle.net/10722/209534
P027	Chang, A. K., & Choi, J. (2016). Predictors of sleep quality among young adults in Korea: Gender differences. *Issues in Mental Health Nursing, 37*(12), 918–928. https://doi.org/10.1080/01612840.2016.1235636
P028	Chatterjee, S., & Kar, S. K. (2021). Smartphone addiction and quality of sleep among Indian medical students. *Psychiatry, 84*(2), 182–191. https://doi.org/10.1080/00332747.2021.1907870
P029	Chen, B., Liu, F., Ding, S., Ying, X., Wang, L., & Wen, Y. (2017). Gender differences in factors associated with smartphone addiction: A cross-sectional study among medical college students. *BMC Psychiatry, 17*. Article 341. https://doi.org/10.1186/s12888-017-1503-z
P030*	Chen, B., Ying, X., Fang, L., Li, F., & Yue, N. (2016). Relationship between smartphone addiction, sleep and depression in college students from a medical school (In Chinese). *Journal of Chifeng University (Natural Science Edition), 32*(6), 191–193. https://doi.org/10.3969/j.issn.1673-260X.2016.06.074

Code	Reference
P031*	Chen, X. (2018). Correlation study between mobile phone dependence syndrome and sleep quality and personality traits among college nursing students (in Chinese). *Chinese Nursing Research, 32*(21), 3440–3443. https://caod.oriprobe.com/articles/55169661/Correlation_study_between_mobile_phone_dependence_.htm
P032	Chen, Y.-L., & Gau, S. S. (2016). Sleep problems and internet addiction among children and adolescents: A longitudinal study. *Journal of Sleep Research, 25*(4), 458–465. https://doi.org/10.1111/jsr.12388
P033*	Cheng, L., Zhang, H., Chen, Y., & Pang, X. (2020). Relationship of mobile phone dependence, resilience and sleep quality among private college students (in Chinese). *Occupation and Health, 36*(10), 1407–1410. http://www.zyyjk.com.cn/EN/1004-1257/home.shtml
P034	Cheng, S. H., Shih, C.-C., Lee, I. H., Hou, Y.-W., Chen, K. C., Chen, K.-T., Yang, Y. K., & Yang, Y. C. (2012). A study on the sleep quality of incoming university students. *Psychiatry Research, 197*(3), 270–274. https://doi.org/10.1016/j.psychres.2011.08.011
P035	Cheung, L. M., & Wong, W. S. (2011). The effects of insomnia and internet addiction on depression in Hong Kong Chinese adolescents: An exploratory cross-sectional analysis. *Journal of Sleep Research, 20*(2), 311–317. https://doi.org/10.1111/j.1365-2869.2010.00883.x
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P198	Zhang, Y., Lv, S., Li, C., Xiong, Y., Zhou, C., & Li, X. (2020). Smartphone use disorder and future time perspective of college students: The mediating role of depression and moderating role of mindfulness. *Child and Adolescent Psychiatry and Mental Health, 14*, Article 3. https://doi.org/10.1186/s13034-020-0309-9

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P199*	Zhou, L., Jin, J., & Wang, C. (2019). Study on the relationship between sleep quality and mobile phone dependence among college students (in Chinese). *Psychological Monthly, 14*(18), 25–27. https://doi.org/10.19738/j.cnki.psy.2019.18.013

Note. *Eleven of the above primary sources were written in Chinese, and only translated English titles were provided in the source article: R08 (Li et al, 2020). These articles—P030, P031, P033, P079, P107, P108, P109, P115, P129, P192, and P199—were unable to be found. Best efforts were given to find useful links to these articles, their journals, or databases where they could be found. Otherwise, the references are as reported in the source article (R08; Li et al., 2020).

Appendix C

Intersecting Frameworks to Map the Reviews

This Appendix documents the decisions made for Table 2 in Chapter 2, the intersection between the frameworks in the umbrella scoping review.

Table C1

A chart documenting decision making of intersection chart between facets of sleep health EMU Framework.

Code	Reference	Intersect	Notes
R01	Alimoradi et al., 2019	User / satisfaction	Internet addiction (user reported symptoms) / Sleep disturbances & sleep quality assessment
R01	Alimoradi et al., 2019	User / Duration	Internet addiction / sleep duration (Mean hours) – self report
R02	Alonzo et al., 2021	Software / Satisfaction	Social media applications / Sleep quality including various self-report measures subsumed.
R03	Brautsch et al., 2023	Context / Alertness	Media use at night time (context), alertness (e.g. ESS)
R03	Brautsch et al., 2023	Context / Duration	Media use at night time (context), sleep duration
R03	Brautsch et al., 2023	Context / Satisfaction	Media use at night time (context), sleep satisfaction
R03	Brautsch et al., 2023	Context / Timing	Media use at night time (context), timing of sleep (Early awakening, delayed bedtime)
R03	Brautsch et al., 2023	Hardware / Alertness	Specific hardware use, alertness (e.g. ESS)
R03	Brautsch et al., 2023	Hardware / Duration	Specific hardware use (mobile phones computers, tablets, game console, television), sleep duration
R03	Brautsch et al., 2023	Hardware / Satisfaction	Specific hardware use e.g. use of mobile phone / smartphone, sleep quality
R03	Brautsch et al., 2023	Hardware / Efficiency	Specific hardware use (mobile phone, screens, game console etc.), Efficiency (SOL) + tablets and sleep disruptions.
R03	Brautsch et al., 2023	Hardware / Timing	Specific hardware use, timing of sleep (Early awakening, delayed bedtime)

Code	Reference	Intersect	Notes
R03	Brautsch et al., 2023	Software / Duration	Social media use and short sleep duration
R03	Brautsch et al., 2023	Software / Satisfaction	Social media and sleep quality
R03	Brautsch et al., 2023	User / Satisfaction	Measure of smartphone addiction and poor sleep quality
R04	Chan et al., 2022	Software / Satisfaction	Quantity of video game playing / Sleep quality (and insomnia complaints)
R04	Chan et al., 2022	Software / Duration	Quantity of video game playing / Sleep duration self report/fitbit
R05	Kemp et al., 2021	Software / Satisfaction	Video gaming volume and sleep quality (PSQI)
R05	Kemp et al., 2021	User / Satisfaction	Video gaming addiction, sleep quality (including insomnia self report)
R06	Kristensen et al., 2021	User / Satisfaction	Problematic gaming (addiction/dependence criteria), sleep quality (PSQI) / insomnia "problems"
R06	Kristensen et al., 2021	User / Alertness	Problematic gaming (addiction/dependence criteria), daytime sleepiness
R06	Kristensen et al., 2021	User / Duration	Problematic gaming (addiction/dependence criteria), sleep duration metrics
R08	Li et al., 2020	User / Satisfaction	Smartphone addiction metrics, PSQI sleep quality
R09	Mac Cárthaigh et al., 2020	User / Satisfaction	Smartphone addiction metrics, PSQI sleep quality
R10	MacKenzie et al., 2022	Context / Timing	Night time use / restriction of use, bedtime delays
R10	MacKenzie et al., 2022	User / Timing	Habits, FOMO, bedtime delays

Code	Reference	Intersect	Notes
R10	MacKenzie et al., 2022	Software / Timing	Social media platforms, bedtime delays
R10	MacKenzie et al., 2022	Content / Timing	Social interaction, bedtime delays
R14	Ratan et al., 2021	User / Satisfaction	Smartphone addiction / PSQI
R15	Sadagheyani & Tatari, 2021	Context / Satisfaction	At night, decreased sleep quality
R15	Sadagheyani & Tatari, 2021	Hardware / Satisfaction	On phones, laptops, tablets, decreased sleep quality
R15	Sadagheyani & Tatari, 2021	Software / Satisfaction	Social media, decreased sleep quality
R16	Sánchez-Fernández et al., 2023	User / Satisfaction	Internet addiction test, sleep quality
R16	Sánchez-Fernández et al., 2023	User / Duration	Internet addiction test, duration (less than 6 h daily in one study and “over six to 7 h or less than six to 7 h of sleep” in another.)
R17	Yang et al., 2020	User / Satisfaction	Problematic smartphone use (addiction scales / symptoms), sleep quality (mostly PSQI)
R18	Zhong et al., 2022	User / Satisfaction	Smartphone addiction (SAS / SAS-SV), sleep quality PSQI

Note. R7, R11, R12, and R13 were not included in the chart due to unclear definitions for sleep variables

Appendix D

Study Protocol and Treatment Manual

EMU
Electronic Media Use

Study Protocol
&
Treatment Manual

This Appendix contains the Study Protocol and Treatment Manual that was given to the research representative who ran the study with the select participants of HMNZS Wellington

Welcome

This is the Study Protocol and Treatment Manual for the 2021 study on Electronic Media Use (EMU), Sleep, and Fatigue. This research is being conducted by Jonathan Peters as part of a Doctor of Clinical Psychology degree and is sponsored by The Maritime Component Commander.

Six participants are expected to be recruited for the study. There are three starting points for the study, staggered by a week each, so two participants will begin the protocol at a time. There are three main phases to the study. These are baseline measurement phase, intervention phase, and follow up phase. The day before baseline measurement phase is an orientation session with participants. There are various booklets that will need to be given to participants during orientation and throughout the study. These booklets are both for outcome measurement and also serve as a part of the intervention.

This book contains a treatment manual which details the protocol for the four intervention phase sessions with participants to be run during intervention phase. These sessions are expected to take approximately 30 minutes each. They are expected to be run on Mondays and Wednesdays. Please also refer to the Workbook which Participants are to be given at the beginning of session 1 of the intervention phase. This Workbook contains resources and worksheets sorted by session number, and spaces for notes and reflections for participants. It would be helpful to familiarise yourself with its contents so that its use can be integrated into the intervention sessions.

Throughout the study, participants will also be wearing actigraph watches, and be regularly completing Psychomotor Vigilance Tasks (PVTs) to measure their sleep and fatigue levels. This book contains instructions for setting up and running the PVTs, the actigraph watches, and their computer interface software to set them up and download data. At the end of the current book is a sheet which contains the scheduling for the study to help with keeping track of where participants are up to in the study and to aid in planning and scheduling meetings.

Outline

Part 1: Study Orientation and Protocol p. 4

Part 2: Treatment Manual p. 17

Part 1: Study Orientation and protocol

Introduction to the Study

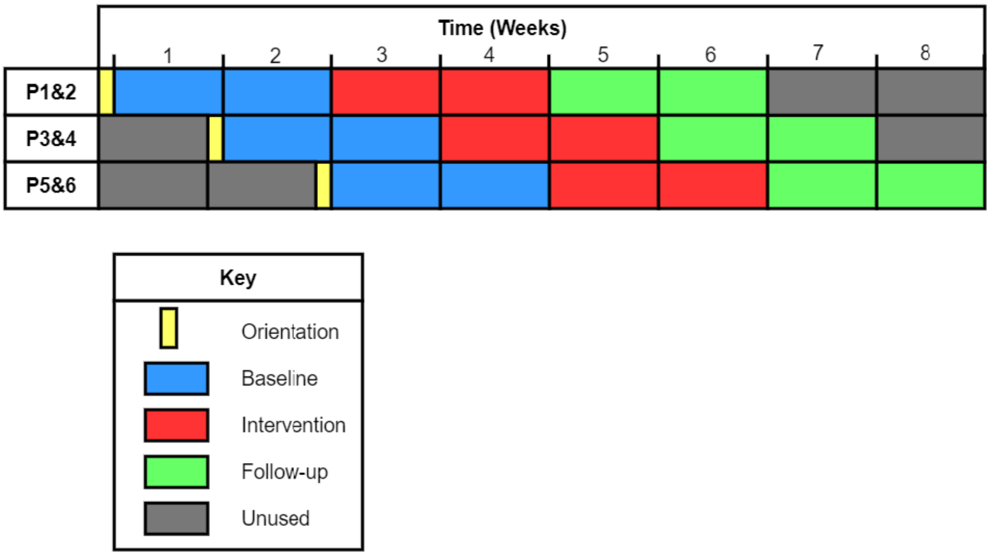
This study has been created in response to three pressing issues. The first is the hazard that fatigue poses to Royal New Zealand (RNZN) operations; the second is the pervasive and increasing use of electronic media in the lives of many, including sailors in the RNZN; the third is a hypothesised relationship that electronic media use has on functioning and fatigue, through its effect on sleep. The size of this effect, and the amount that it can practically be intervened in RNZN personnel is yet unknown. This study seeks to explore these unknowns.

The purpose of the study is to provide a practical intervention to select sailors in the RNZN that identify as struggling with sleep and fatigue and who also experience high levels of electronic media use. The details of the intervention are outlined in the current book. This study also involves extensive measurement of electronic media use, sleep, and fatigue through both behavioural monitoring and participant self-report. As the research representative, your role in this study is multi-faceted. It involves:

- Providing participants with the books in which they will report daily sleep, fatigue, and electronic media use data, and orienting them to the study.
- Collecting and filing completed measurement books.
- Providing participants with actigraphy watches. Changing batteries and backing up their data half way through the study (or as needed).
- Ensuring that the psychomotor vigilance tasks are available and running for participants.
- Running intervention sessions for participants following the Treatment Manual (contained in this book)

Study Layout / Timetable

This study is run over the course of approximately 8 weeks. 6 participants will be selected for the study. There are staggered start times for participants: 2 participants begin the study at one time. Each participant will stay in the study for 6 weeks. The first 2 weeks is baseline measurement phase, the next 2 weeks is intervention phase where the intervention is introduced, and the final 2 weeks is follow-up phase to assess for longer term changes. Start times for each pair of participants are spaced 1 week apart. The following diagram illustrates this staggered layout for the timing of the study. In the diagram below, P refers to participants (e.g. P1&2 refers to participants 1 and 2). Even though 2 participants begin the study at the same time, throughout the study you will be working with each participant individually.



Materials List

Throughout this study there are many different outcome measurements we are collecting from participants. These are organised into books which you supply to participants throughout the study. The following is a list of the materials given to participants at each phase.

- **Orientation day & Baseline measurement phase**
    - Orientation guide
    - Daily Measures Book 1
    - Sleep/Duty/Electronic Media Use Logbook
    - Actigraph watch
- **Intervention phase**
    - Workbook
    - Electronic Media Use Diaries
    - Daily Measures Book 2
- **Follow-up phase**
    - Daily Measures Book 3
    - Electronic Media Use Diaries as requested

There are also the psychomotor vigilance tasks (PVTs) which are to stay in a location that is quiet, free from distractions, and accessible to all participants. Participants share the PVTs. The actigraph watches are worn by participants throughout the study to measure their sleep.

Supplied with the Actigraph watches and the PVTs are log sheets for you to keep track of which Actigraph was given to which participant, and for participants to write when they complete their PVTs so that data can be matched up following the study's conclusion. Prior to orienting participants to the study, it is important that you familiarise yourself with the operation of the actigraph watches and the PVT devices.

Actigraph Watches

The actigraphs are wrist-watch sized devices that participants will be asked to wear on their wrist throughout the six weeks that they are in the study. It is used in conjunction with information from the Sleep/Duty/Electronic Media Use Logbook to measure daily total sleep time and estimates of sleep quality. The actigraph contains an accelerometer and memory chip to detect and record arm movement. This is recorded as activity counts per minute. It also records light intensity and keeps track of its own temperature to determine whether it's being worn or not. It does not and cannot record biological information such as heart rate. People generally move less when asleep, so sleep length and distribution can be determined from participants movement record stored on the actigraph. The actigraph only tells us whether participants are wearing it and are moving, not what they are doing. It also tells the time and the date.

Participants start wearing the actigraph during orientation day and continue wearing it until Sunday 6 weeks later when follow-up phase concludes for them and measurement book 3 is complete.

The actigraph should always be worn on the non-dominant wrist (the hand participants don't write with). It is important that they do not change wrists. It should not be too loose; if it does move about, tighten the strap slightly. It shouldn't be worn when showering, swimming, or bathing -but should be put back on as soon as possible afterwards.

The event marker is the left-hand button on the face of the device. Participants are instructed to press firmly on the event marker (the letter E and a green light will appear) whenever they start trying to sleep (lights out) and whenever they stop trying to sleep (lights on). This can further help to distinguish wake periods from rest periods.

Participants are instructed to write down in their daily measurement books the times they remove the actigraph, and when they put the actigraph back on. If they forget to put it back on after removing it, they are instructed to put it back on as soon as they remember and note down the time that they put it back on in their daily measurement book.

Due to the length of the data collection period, you will need to change participants' watch batteries about 20 days after it starts recording. This aligns with session 2 of the intervention phase: The battery change will happen during session 2.

What do I need to do?

You will be provided with a full manual that details the running of the actigraph watches. You should only need to interact with each watch three times. Once for initialising the watch, once when changing the battery halfway through the study, and once at the end when you collect the watch. The instructions for changing the batteries are summarised in Session 2 of the treatment manual (later in this book), as that is when the batteries will need to be changed.

The instructions that you need to follow for the initialisation of watches will be summarised below. In order to follow these instructions, it is assumed that you will have installed the WatchWare program on your computer and have IrDA support activated and the drivers for the ACTiSYS IR wireless interface are installed also. The installation of these will be organised when you meet with the primary researcher. During the orientation session with each participant. Pick an actigraph watch from the container and install a CR2430 battery into it. Then initialise the watch…

Initialising the watch

Plug in the ACTiSYS IT wireless interface into your computer. Open the Motionlogger WatchWare Software. Click on the menu item “Motionlogger” and click on “Initialize”. Ensure that the “actigraph type” is set to “Micro MotionLogger” all “Data Modes” are ticked. “Epoch Length” is set to “1 minute”, “Wake up” is set to “Immediate”. “User Time Display Edit” is not ticked. “Date display” is ticked, “Light on Event” is ticked. These are often the default settings for the program. Click continue. Ask for participants Self Generated Identification Code and enter it in the ID box that appears. Write the participant’s SGIC and note the serial number (SN) of the watch (the last four digits of the bottom number on the back face of the watch) on the Actigraph log sheet to aid in data identification. Then click “initialise” on the software and follow the instructions on the “Prepare Watch For Communication” window that pops up. Then click “OK”. After initialisation is complete the watch will be set to the computer’s time and date, after a short while (usually about a minute) a bar will be seen moving up and down on the right-hand side of the watch screen. This means that the watch is now collecting movement data.

Changing the battery

In session 2 of the intervention, in order to ensure ongoing actigraph measurement, the battery of the participant’s watch will need to be changed. Before changing the battery, ensure that the data from the watch has been downloaded. Following battery change the watch will have to be re-initialised. More detailed instructions for this process are contained in the intervention session 2 section of this book.

Psychomotor Vigilance Tasks

The Psychomotor Vigilance Task (PVT) is essentially many reaction time tests contained within a 10-minute block of time. Participants respond to a stimulus as quickly and accurately as they are able whenever the stimulus appears. You will be provided with two PVT machines. If there are a mix of left and right handers in the study, one will be set up for left handers, and one will be set up for right handers. If the dominant hand for all participants in the study is the same, then both machines will be essentially identical. Participants will be completing these tasks on Tuesdays Thursdays and Fridays in the afternoons. There will be a log sheet next to the actigraph machines where participants log their SGIC and the time and date of their PVT measurements.

What do I need to do?

To set up the PVT devices: plug the USB to Serial Converter into the USB port of your computer. Then plug the serial port end into the bottom of the PVT device. Switch on the PVT device. Push the left button on the PVT so that the cursor is on “Setup” then press the right button to select “setup”. Then using the left button to scroll and the right button to select each character, enter the “supervisory code” labelled on the side of the PVT. The device should now read “Supervisory Mode”.

Open the PVTCOMM software. Check that the port at the bottom left of the software screen (e.g. “Comm4”) is the same number as the port of the USB-to-Serial Comm Port. This can be read by opening up the device manager in Windows and viewing the Ports (COM & LPT) list. If the number at the end does not match, then on the PVTCOMM software click the “Configure” menu, then select “Port” and select the appropriate port from the drop-down menu. This will ensure that the PVTCOMM software and the PVT device will be able to communicate.

On the PVTCOMM software: Click the “PVT” drop down menu then select “Initialise”. The PVT software will then prompt for the current time. It will automatically get this from the computer’s clock. Check that this is the correct time, then click “Continue”. This will lead you to the “PVTComm Initialization Form”. Fill this out as follows:

- **Study:** the PVT device number, 1 or 2
- **Experimenter's initials**: *your initials*
- **Trial Length seconds:** 600
- **ISI MINIMUM:** 2000
- **ISI MAXIMUM:** 10,000
- **Task**: Visual
- **Mood, Subject initials, Subject ID number, and Trial number:** are all left blank

If there are both left and right handers in the study, one PVT will need to be initialised as a “Left” handed device, and one will need to be initialised as a “Right” handed device. In the left-handed device participants respond to the stimulus using the button on the left, and in the right-handed device participants respond using the button on the right. If participants are ambidextrous, then they may select which hand they use, but this must be kept consistent throughout the study. Click OK. A window will pop up prompting you to ensure that the PVT is in supervisory mode. Click OK again. A series of windows will pop up following which a pop-up window will confirm “Initialisation Finished” The PVT device will beep and restart.

If there are both a left-handed and right-handed device, then label each one so that you and the participants will know which one to use. With each PVT is also contained a PVT log. This is to be kept with the PVT so that participants can write their SGIC and the start time and date for each PVT that they complete. This will allow us to match tests taken with participants.

Each PVT device contains enough memory for approximately 29 10-minute PVTs. As the PVT data is crucial outcome data for the study, it is best to save the data off each PVT and re-initialise the PVTs at the end of each week.

Saving PVT data

Connect the PVT to the computer and put it into supervisory mode as per the instructions above. Open PVTCOMM software and click the PVT dropdown menu, then Click "Download" a pop-up window will appear to remind you to put the PVT into supervisory mode. Click OK. Next is another pop-up stating the "current memory status". Click the OK button. The PVT will beep when the download is finished. Click "OK" when the "download complete" box appears. This will take you to a "Save As" window. Save the PVT data into an appropriate folder on your computer. Name the file with the PVT machine number (1_ or 2_) and the date (dd_mm) for example for PVT device 1, data downloaded on the 28th of June: 1_28_06.pvt. Once data is saved, turn the PVT off and on again and restart the PVTCOMM software. Enter supervisory mode on the PVT. Then click on the PVT drop-down menu in the PVTCOMM software and select "Clear" to clear the PVT memory and free it up for future tests.

Charging the battery of the PVT

The PVT-192 devices are charged using the chargers labelled "SWRC PVT charger" They were designed to be charged for 14-18 hours at a time. The devices need to be switched off while charging. The charge cord plugs into the base of the PVT, near the ON/OFF switch. As participants do not complete PVTs on Mondays, this day would be appropriate to ensure that the PVTs have a full charge for the week ahead. There is also a low battery signal which consists of on-screen messages and an audible beep. If this occurs during the testing, then participants can plug in the device for further testing if necessary. However, usually there will be enough battery after this signal to complete the current test prior to the PVT device needing to be plugged in for charging / further use.

Books

Along with Actigraphy watches and PVTs, there are many books which make up much of the outcome data of the study, and two books which are also used as part of the intervention. These are described below.

Orientation Guide

The ORIENTATION GUIDE book is for participants to keep. It contains instructions for the study. You can also look through the orientation guide with participants to get oriented to the study together during the orientation session. As you look through the orientation guide, instructions for the PVTs and the Actigraph watches from the participants point of view will prompt you to give the participant an actigraph, and take them through the demo PVT.

Daily Measures Books

The Daily Measures Books contain the fatigue scale and sleepiness scale. They also contain a reminder on Tuesdays, Thursdays, and Fridays to complete the PVT. As fatigue and sleepiness levels, and PVT performance change quite a lot throughout the day, it is important that participants complete these measures at around the same time every day. The books are small and intended to be pocketable so that participants can complete their measures no matter the location they are in. In the ORIENTATION GUIDE there is a page devoted to finding and committing to a consistent afternoon measurement time. Participants fill out each page of their daily measurement books as close as they can to this time. Participants are given their Daily Measures Book 1 during the orientation session, then, in session 1 of intervention phase, it is collected, and they are given Daily Measures Book 2. At the end of intervention phase, Daily Measures Book 2 is collected and they are given Daily Measures Book 3 which is collected at the end of the study.

Sleep/Duty/Electronic Media Use Logbook

This is a larger book and is intended to be kept next to the participant's bed. This contains a brief morning questionnaire for participants to complete each morning just after waking up where they self-report how many hours they think they slept and how well they think they slept. It also asks for data from their screentime/digital wellbeing application on their phone from yesterday. There are also visual logs of sleep, duty, and electronic media use in this book. The visual sleep log is to be completed by participants every time they go to sleep and wake up. Participants mark the time that they begin and finish trying to sleep. The duty diary is similar: Participants mark the beginning and end of each shift. The electronic media use log is to be used by participants to note the beginning and end of periods of electronic media use. Later in the study, during the intervention phase, participants are to be provided with a more detailed electronic media use diary. When this is introduced, participants are expected to complete both the visual electronic media use log, and the electronic media use diaries. In the Sleep/Duty/Electronic Media Use logbook participants are only expected to report periods of Sleep/Duty/Electronic Media Use that exceed 10 minutes.

Workbook

The Workbook is given to participants at the beginning of the intervention phase, during session 1. It contains resources and activities sorted by session number of the intervention. It is used by participants both during session and between sessions for reflection / "homework" purposes. The Workbook also contains an audit sheet for electronic media on a tear off sheet. This is the only part of the Workbook that is collected as research outcome data. The rest of the Workbook is the participants to keep.

Electronic Media Use Diary

This diary forms a core part of the intervention. Participants are given this book during intervention session 1. They are to use it to keep track of and reflect on electronic media use over the intervention and follow-up phases of research. This is collected back when it is complete, or the study is over. You will be provided with spare copies should participants need more for during the study or want more for after to continue keeping track of their use.

Phases of study

Orientation day with participants

The orientation session takes place on the Friday before day one of the study (Monday) for each of the participants. So, for three Fridays in a row at the beginning of the study you will be orienting the next pair of participants to the study, one at a time. During the orientation day participants are provided with the orientation guide, the Daily Measures Book 1, the sleep/ duty/ electronic media use diaries, they are fitted with an actigraph watch, and are oriented to the PVTs. Begin with giving the books to the participant, then, in the orientation guide, you can work through the orientation to the study together.

Baseline measurement

During this phase participants will be filling out their Sleep/Duty/Electronic Media Use Logbook every day. They will be filling out the Daily Measures Book 1 every afternoon. They will be wearing the actigraph watches throughout, and completing PVTs on Tuesdays, Thursdays, and Fridays throughout the study.

Intervention phase

At the beginning of intervention phase, on the Monday, participants have their first intervention session with you. They return their Daily Measures Book 1 to you and collect Daily Measures Book 2. Daily Measures Book 1 is essentially the same as Daily Measures Book 2. Participants also collect the EMU electronic media use diaries during this session and are taken through the operation of this book as part of intervention session 1. Instructions for this are in the treatment manual later in this book. PVTs, actigraph measurement, and Sleep/Duty/Electronic Media Use Logbooks continue to be completed as before.

Follow-up measurement

Participants are provided with Daily measures book 3, they continue completing all measures as in previous phases and also continue filling out the electronic media use diaries. When participants run out of pages in their electronic media use diaries, they are to be returned to you. Ensure that this is labelled with their SGIC, and a new copy will be provided.

Treatment Manual

This treatment manual has been created specifically for the current study. It contains instructions and content for running the four intervention sessions individually with each participant. Each participant's actigraph watch must have its data uploaded and batteries changed in session 2. For convenience the instructions for this are in the Session 2 section of this guide.

Session 1

Session Contents

- Whanaungatanga, Confidentiality and Informed Consent
- Education in Electronic Media Use, Sleep, Fatigue
- Instruction in Electronic Media Use Diaries
- EMU Audit Sheet
- Bedtime Routine

Workbook Contents

- EMU Audit Sheet (loose page)
- The Relationship between Electronic Media Use and Sleep
- Good Sleep Habits
- Current Bedtime Routine

Whanaungatanga, Confidentiality and Informed Consent

This is the beginning of the intervention phase. This session will be run on the Monday, two weeks after orientation and baseline measurement began. Allow space for whanaungatanga (establishing/re-establishing a connection) at this time, operationalise this with each client individually and allow them to express their wants and needs for active participation in sessions with you. For example, participants may choose how they open/close each session. During this time it is also important to acknowledge with individuals what time they have already put into the data collection and troubleshooting any issues that they have noticed with this so far.

Although ***confidentiality and informed consent*** would have been discussed with each participant around the beginning of the study at the Orientation session and they will have read contents regarding what will happen to their data in the information sheet, it will be important to discuss this further at the beginning of the intervention sessions as this is the first time they will be sharing data interpersonally rather than via surveys/outcome measurement which are all available to the researchers as research data. Most of what is discussed in sessions with you will be confidential: The researchers will generally not have access to the content of the sessions. The contents of the Workbook also, are not shared with researchers apart from the electronic media audit sheet which we will get to later.

In order to be able to evaluate the current intervention, problem solve and tweak the intervention as it is being run, some general information about how the sessions are going, and particularly any feedback or questions from participants on the study, may be shared with the researchers in a supervision-style relationship. This needs to be made explicit to participants

Although you may wish to take notes during sessions for your own practice, these will not be made available to the researchers. There is an exception to this also, if there is a situation which arises which you or the participant believe could impact results, then this is to be noted down for feeding back to the researcher to aid in data interpretation.

Also, if in special circumstances, particular situations are deemed particularly important for helping understand how individuals are interacting with the content, then you can use your judgement to discuss with the participant whether they consent to sharing notes regarding this and summaries with the researchers. Still at this point no guarantee is given that these situations will be published, and individuals' specific story will only be published in correspondence with them and can be edited in such a way to ensure that upon reading the final publication they will, to their satisfaction, not be identifiable. Any questions participants have about the process should be given due space for answering at this stage. If you do not have a clear answer, but it is something that the researcher and supervision team may be able to answer, write the question down to consult with the researcher prior to session 2.

In the Electronic Media Use Diary booklets, there is no need for participants to disclose or record any specific activities that they do not wish to discuss in session. For example, the current study is not specifically investigating the use of pornography. A participant may wish to record for example "video watching" in their Electronic Media Use Diaries to discuss this activity more broadly. Ensure participants understand that information that they share in session will be confidential (except in the case of risk to self or others, discussed below), and write ups of results of Electronic Media Use Diaries will handled sensitively. Care will be taken in writing up all results to make information non-identifiable.

A ***discussion around risk*** will integrate into the confidentiality discussion. The individuals that are involved in this study are employed in an inherently high-risk occupation. It is expected that you have been trained in standard RNZN protocol for handling reports of risk of harm. Any risk due to particularly high levels of fatigue/sleepiness/sleep deprivation, if warranted, should be handled following standard RNZN reporting procedures. Any immediate danger to self or others or other notifiable reports that participants in this study might disclose are also to be also handled via normal RNZN reporting procedures. At this stage it is important to remind participants that if they do report extensive fatigue that either they or you perceive to be putting themselves or others at risk, or if there are any other experiences that participants or you believe to be risking harm to themselves or others, then you will still need to act within your normal duty to report this up the chain of command if necessary and other interventions may be put in place following normal RNZN protocol. It is expected that normal processes for dealing with risk are to be followed and the current study does not seek to supersede any normal protocol.

Informed consent to treatment: This involves an orientation to the layout of the sessions and their contents, and what to expect from them. Part of this is important to emphasise: that participants are encouraged to make their own decisions around what they want to use electronic media for, and how they do it. Participants may find it confronting to reflect on their own use of electronic media and this may cause discomfort. Let them know of supports that are available to them. The NZDF4U Wellbeing support line is available on 0800 693 348, or text 8881 or +64 9 414 9914 if calling from overseas for 24/7 confidential support over the phone or to organise further face-to-face support.

Details for these support lines that individuals can contact are written in the information sheet which participants would have read prior to beginning the study. If there is a standard flyer with this information, then you can provide this to participants at this stage also. Depending on work demands, it is hoped you also might be an available ongoing support independent of administering the intervention. The researchers may also be available for support and fielding questions. Their contact details are in the information sheets provided to participants in the study. You will be provided with spare information sheets to supply to participants if they have misplaced theirs or want a second copy. Participants will at this stage have been filling out measures for two weeks. Ask participants to continue to complete their afternoon measurements at the same time every day. It is expected that they attend each session with you and make an ongoing commitment to completing the measures.

Hand out the Workbook to the participant and read through the general overview to the sessions written in the Workbook. Ask participants if they have any further questions at this stage and whether they would like to begin.

Education in Electronic Media Use, Sleep, Fatigue

This is the psychoeducation component of the intervention and predominantly covers the effects of EMU on sleep. There are many different resources and beliefs that people have about sleep. It is important for the consistency of this study that the ideas presented here are stuck to closely. It is written in such a way that it can be read through verbatim if you wish. This section is also copied into the participant's Workbook (slightly edited) along with some practical healthy sleep recommendations from the Australasian Sleep Health Foundation for participants' ongoing reading and reflection.

Sleep introduction

The amount of sleep that everyone needs is different from person to person. Most people need around 7-9 hours of sleep per night. Healthy sleep behaviours can result in more sleep, sleep that is a better quality, and sleep that has more consistent timing. This can have positive effects on your daily wellbeing both mental and physical. You will be able to focus for longer, have faster reaction times and sustained attention, you will be able to work more efficiently, and you will be safer. Although having a healthy sleep habit can have many positive impacts on your wellbeing, sleep doesn't need to be perfect every single night. If you have a single bad night's sleep your next day performance probably won't be affected by too much, that is why this study is going for six weeks, so that we can assess any longer-term changes.

Light and sleep systems

There are two main systems that control sleep. The first is the homeostatic drive for sleep. This is determined by how long it has been since we have slept. The need for sleep increases the longer we are awake, and it decreases if you've had a substantial sleep. The second system is called the circadian clock. Essentially, we have an internal clock which is roughly timed to the day and night cycle. This clock programs typical sleep and wake time, and also programs many other physiological patterns such as body temperature and alertness. The way that the clock is kept in step with the day and night cycle is through light exposure.

Bright light is alerting. How alert we are can influence how long it takes to fall asleep. If you are exposed to bright light in the evening you will tend to fall asleep later. Light exposure in the evening also shifts the timing of your circadian clock to later which can make it harder to fall asleep. Even small amounts of light can have an effect on the circadian clock. If pressure to fall asleep from the first system, the homeostatic drive for sleep is high then you will probably be feeling tired. If the circadian clock is out of sync though, then that can prevent you from falling asleep.

Many electronic media now come equipped with a night mode which dims the screen and shifts colours away from the kinds of light that most disrupt the circadian clock. This night mode would be helpful to switch on if it's not activated by default on the various electronic media that support it. However, light is not the only way that our sleep can be disrupted so this won't completely cancel out any effect that electronic media may be having on sleep.

Stimulating content

Many electronic media that we interact with contain content which is stimulating, exciting, and possibly unsettling. There is also many media which can be calming and relaxing to interact with. Some electronic media are interactive, for example gaming or interacting with others on social media, and some are more passive for example reading an e-book or watching a movie. Although the light exposure may be similar, people who watch, for example, March of the Penguins just before bed tend to have better sleep than those who play Counter-Strike for the same length of time just before bed. Prioritising calming and more passive electronic media use activities in the evening can lead to our nervous system being more ready for sleep. This can lead to less difficulty falling asleep, and sleep which is better quality and more efficient. Stimulating content on electronic media can also be very distracting, and we can often end up in a state of flow, particularly when using more active electronic media, which can also lead to delaying our bedtime.

Decision making and bedtime procrastination

Through our days and into our evenings we are often making decisions. A particular decision that is crucial to sleep health is the one we make when we go to bed and decide to try and go to sleep. Many forms of electronic media are designed in to reward us for staying on that platform for long periods of time. For example, this can be in the form of in-game rewards and a sense of achievement or scrolling social media in the hopes of finding an interesting and satisfying post. This can lead to many positive, satisfying feelings, and it can also lead to a decision to keep up the activity even if we know that we really should be making that decision to go to bed and try go to sleep.

Sleep deprivation and fatigue can also have an impact on decision making ability. This means that it is harder to make that decision to get ready for bed. From this we can see a cycle of delayed bedtimes, which, if we must get up at a certain time the next day, leads to getting insufficient sleep. This insufficient sleep can lead to a loss of decision-making ability, particularly when we are tired in the evenings, which makes it easier to be swayed by the draw of electronic media and a difficulty with deciding to go to bed, leading to delayed bedtimes, which begins the cycle again. By interacting with electronic media in a goal directed way and noticing when we are using electronic media for longer than we intended when we started, we can become aware of the kinds of activities that might be interfering with our decision to go to sleep. Then we can more easily notice when we are doing those activities and the decision to go to bed instead might become easier.

Recent research has also shown that if we interact with electronic media in a way that is intentional and goal-oriented, it can be more effective for unwinding, is more satisfying, and can help lessen the negative impacts it might be having.

Summary

So, in summary, electronic media can impact sleep through light exposure which increases alertness, through stimulating and interactive content, and by distracting us from making the decision to go to bed. By disconnecting from bright screens or bringing in night-mode before bed this can allow for our circadian clock to be in sync with our need for sleep. By bringing in calming activities before going to sleep, the nervous system will be more ready for a better-quality sleep. Finally, by increasing the control we have over electronic media use and becoming aware of the activities we do for longer than we intended, or the activities that might draw us in without intending to do them, we can either more readily choose not to do them and go to bed instead, or they will be more satisfying if we become aware of and do those activities intentionally.

There is a summary of the education section, along with sleep recommendations derived from the Australasian Sleep Health Foundation's resources for further practical tips in the participants Workbook.

Instruction in the Electronic Media Use Diaries

Give the participant the Electronic Media Use Diary. The diaries form the essence of the intervention. The point of these diaries is to have participants become aware of their habits and to strengthen a goal-oriented use of electronic media. Recent research suggests that intentional use of electronic media can strengthen the positive aspects of Electronic Media Use (EMU) while lessening the negative impacts that it may have on sleep health.

Electronic media, in this study is defined as any electronic device that people use for accessing, creating, interacting with, and/or transmitting information, for example, phones, computers, tablets, gaming devices, televisions. Both active interaction with the electronic media (for example typing a text message or notes, scrolling through social media posts, phone calls, and gaming), and passive consumption of electronic media (for example, watching a movie, watching a friend play a video game, listening to music or audiobooks) count as EMU and should be noted into the Electronic Media Use Diary.

Before undertaking any form of electronic media use, participants are instructed to write the time and expected activities in their appropriate fields of the diaries. Upon putting down the electronic media and deciding to finish that session, they write down the time and any extra activities that were engaged in in their appropriate columns too.

Work through an example with the participant in their Electronic Media Use diary (label this with an e.g. in the margin so that it is not added into the analysis). Ask an opening question to begin: When did you last use electronic media for an extended period of time? Can you remember what you were intending to do when you started? Do you remember when you finished? How about any other activities that you did when you were using electronic media in that session?

It is important that at least most activities are captured by an individual in the Electronic Media Use Diaries. Even if they are brief interactions like checking messages. Prioritise recording longer activities and those closest to sleep. The time captured here does not have to strictly correspond to the screen time data from native screen timing applications which participants are hopefully able to capture but ask participants to try and make it as accurate as possible practical for accurate reflection on actual use. Although discussion so far has been around light exposure, also record activities like music listening, and eBook use – as these are also electronic media and this study is interested in all different types of EMU. The Electronic Media Use Diaries will be collected when complete and given back to the researcher for analysis at the conclusion of the study. If and when it gets filled out completely, participants are to return it to you, and are provided with another.

EMU Audit Sheet

Open the Workbook. There will be a perforated page under session one: ***Electronic Media Use Audit Sheet (tear off).*** the electronic media audit is to help identify the electronic media that participants will be writing in their Electronic Media Use Diaries. Participants may be using shorthand terms such as “phone” or “tablet” to fill out their Electronic Media Use Diaries. As many various devices could fit into either of these classes, it is important for the research to be able to summarise what kinds of technologies participants in the study are engaging with and when. This can be done in session. If there are media which have not been brought to the session, but which the participant regularly interacts with, for example communal televisions and game consoles, instruct them to fill out the details of these devices in the remainder of the worksheet before session 2. This audit form will be the only part of the Workbook which will be fed back to the researcher at the conclusion of the study.

Pre-Bedtime Routine

An important aspect to this intervention is a reflection on pre-bedtime routine. This is where these recommendations are put into practice. To begin with, for homework before the next session, participants are to note down their current pre-bedtime routine accounting for roughly the hour before they go to sleep. There is space in the Workbook for noting this down.

Give participants the Daily Measures Book 2 and receive the Daily Measures Book 1. Ensure that this book is labelled with their SGIC. They should from this session take the Workbook, the Daily Measures Book 2, and the Electronic Media Use Diary. Now would be a good time to check if participants have any further questions before finishing up session 1. If questions need to be fielded to the researcher or supervisors, throughout this process, note them down and email the research team who will endeavour to answer any questions prior to the next session so that answers can be fed back.

Schedule in next session. According to current study scheduling this will be on the day after tomorrow (Wednesday). Ask participants to fill out and bring their Electronic Media Use Diary to each session, to complete the bedtime routine notes and the electronic media audit form in their Workbook, and to also bring the Workbook to the next session.

Session 2

Session Contents

- Recap and Check in
- Discussion around the Positive Aspects of EMU
- Creating a Pre-Bedtime Routine
- Actigraph Battery Change

Workbook Contents

- Positives of Electronic Media Use
- Bedtime Routine Plan Space

Recap and Check in

The session begins with a recap of last session. Last session was about light exposure, healthy sleep behaviours, and bedtime routine, and we worked through a demonstration for the electronic media diaries. Allow for any questions that participants may have on the content of the session or the homework. If you are unable to answer at present, write these down and you can email the research team who will endeavour to answer questions. Also, during this time, if participants had questions that were unable to be answered last session, and they have been answered by the research team, feedback any answers for discussion at this stage too. Check in on homework

- Has the Electronic Media Audit Form been completed? Collect this document from the participant and ensure that it is labelled with their SGIC (there are instructions for this on the back)
- Have the Electronic Media Use Diaries been completed?
- Has the bedtime routine been noted down?

Discussion Around the Positive Aspects of EMU

The next part of the session involves a discussion around the positive aspects of EMU. Try to elicit these from the participant and make a list in the Workbook. If not forthcoming from the participant, participants might be able to engage with some examples which are written below. If you have any personal examples to share too, that might be helpful for building rapport and normalising this experience. During this discussion, collect the participant's actigraphy watch so that the data can be downloaded, and the battery changed.

Examples of positive aspects of EMU include: Psychological detachment to escape from stressful situations at work, unwind from the day, and experience pleasure, mastery, excitement, social connection, leisure, information access, research, general knowledge. These positive aspects to EMU can actually help with fostering good sleep and recovery from work. There is evidence that if you are aware of and goal oriented about your use you get the most out of it. When using electronic media, try and check in with yourself and notice what you are experiencing. If you are active in deciding what and when you use electronic media, you may get the most benefit out of it.

Creating a Pre-Bedtime Routine

Use the previously written bedtime routine in the Workbook as a starting point and try follow guidance from the healthy sleep behaviours resource in Workbook under session 1. Note this is for a typical day i.e., it is not relevant if participants have an overnight watch. The participant then may write this routine plan in the appropriate section of their Workbook (under Session 2).

Actigraph Battery Change

- Plug in the ACTiSYS IR wireless interface into a USB port on your computer.
- Open the WatchWare program. Click OK on the welcome screen.
- Select the Motionlogger drop down menu and click on Download then follow the on-screen instructions.
- Once the records have been downloaded, save the AMI file using the default filename onto a secure folder on your computer. It is fine to save all AMI files to the same folder.
- Once the data has been saved, with the provided Phillips screwdriver unscrew the 4 screws on the back plate of the actigraph watch. Hold the plate down while unscrewing them.
- Remove the DL2430 battery and replace it with a new one. There will be a container for you to put the old batteries in.
- Ensure that the rubber O-ring is still in place and screw the back plate back on. Tighten the screws in an "X" formation.
- The watch will need to be re-initialised following the same method as during the orientation session.

During initialisation, ensure that the "actigraph type" is set to "Micro MotionLogger" all "Data Modes" are ticked. "Epoch Length" is set to "1 minute", "Wake up" is set to "Immediate". "User Time Display Edit" is not ticked. "Date display" is ticked, "Light on Event" is ticked.

Ask for the participant's Self-Generated Identification Code and write that into the ID box that pops up.

Schedule in next meeting (Next Monday). Remind participants to bring in their Electronic Media Use Diary again and their Workbook for session 3.

Session 3

Session Contents

- Recap and Check in
- Reflection Exercise on the Electronic Media Use Diaries
- Alternative Behaviours to EMU
- Troubleshooting Pre-Bedtime Routine

Workbook Contents

- Electronic Media Use Diary reflection exercise
- Pre-Bedtime Routine Plan Edit

Recap and Check in

The first part of this session is a recap of last session. For example, "Last session was a looser discussion thinking about the positive aspects EMU activities have in your life. The actigraph watch battery was also switched out, so that was a main focus for the time, you also thought about your pre-bedtime routine and wrote down an idea of a new pre-bedtime routine which might work for you." Allow space for any questions that participants may have at this stage. Again, if you are unable to answer at present, write these down and you can email the research team who will endeavour to answer questions. Also, during this time, if participants had questions that were unable to be answered last session, and they have been answered by the research team, feedback any answers for discussion at this stage too.

Reflection Exercise on the Electronic Media Use Diaries

The session moves to a reflection exercise on Electronic Media Use Diaries. In particular, this exercise focuses on the extra activities engaged in column from the diaries. These would be activities that individuals engaged in without having planned to do so when they began their EMU. This allows for reflection on what sorts of activities the participant may unintentionally engage in. Reflect with the participant on what the positive aspects of these activities might be. What needs are they fulfilling? There are tables in the Workbook for noting specific activities, and the needs that they meet. Remember in order to make the most of the EMU time, it is best if activities are scheduled, planned, and intended. It is important to note that in the case of receiving and interacting with direct communications from whānau, family and friends, this can often take the form of unplanned use of electronic media, so these kinds of direct communication, if they are important to the participant, shouldn't be discouraged. However, it might be helpful to reflect on whether this could be impacting their sleep and whether they could be done earlier, or if notifications from group chats and various applications are interfering with their ideal evening routine.

Now that the participant has a reflection on what they are unintentionally doing, they have two options: Firstly, they can intend to do these activities if they want to. For example, if a participant wrote "scrolling Facebook/social media checking" in their extra activities, they could now be aware that this is something that they tend to do unintentionally. If they wish to still do it, they can now plan to do this in advance by writing it into the intended activities section of the Workbook before they begin doing the activity. Secondly, they can do alternative behaviours. This is framed around a discussion on the needs that these activities fill.

Alternative Behaviours to EMU

The session moves into coming up with alternative behaviours to EMU. Space for this activity is also in the Workbook. In this activity participants look at the needs that they recognised that EMU meets from their Electronic Media Use Diaries and copy them into the appropriate column in the Workbook. They then can come up with non-EMU/calming alternative EMU activities that might similarly fill those needs. Examples could be:

- Social media scrolling: Need – information and entertainment psychological detachment. Alternative – read a book/eBook. Need – keeping in touch with friends & whānau. Alternative – write a letter.
- Video gaming: Need – social connection and mastery. Alternative – play cards/ boardgames with others.
- Read the news online: Need – staying up to date. Alternative – listen to the radio/ podcasts. (Note that this is still an EMU activity, but one which is probably going to be less stimulating and also result in less light exposure. Alternatives like these can be encouraged). See also the healthy sleep behaviours section in the Workbook for discussion around active and passive electronic media for further insights.

Are there any patterns to the needs that participants identify that these EMU activities meet? What alternative sleep-friendly activities can be brought in to fill those needs instead of the EMU activity?

Troubleshooting Pre-Bedtime Routine

Discuss with participants how well they believe they have been sticking to their pre-bedtime routine, and whether there have been any changes that they have noticed in their sleep. Acknowledge and validate their experience with this. It is important to acknowledge also that it might have been difficult to make any changes, particularly if they are trying to break long habits, this is not expected to be able to happen in a week. Habits often can be expected to form after 10 weeks, following which consistently done behaviours tend to become more automatic. It is understandable that any habit change before this time will be more effortful. Use this opportunity to problem solve scheduling issues that participants have for their ideal bedtime routine. There is space for reworking their bedtime routine in the Workbook. If getting the bedtime routine going at night is one of the difficulties, the workbook suggests setting a reminder alarm in the evening to begin the bedtime routine. For this to be most effective, name the alarm with the specific activity that begins the bedtime routine.

Set a time for session 4. Session 4 is a review and closing session.

Session 4

Session Contents

- Summary of Sessions, Space for Questions
- Feedback
- Guidance into Follow-Up Phase

Workbook Contents

- Summary of Intervention

Summary of Sessions, Space for Questions

This session is a summary of the previous sessions' content. Begin by asking the participant to summarise for themselves as best they can what the content of the sessions has been. In this way you are able to check understanding and clarify any questions participants have. If there are gaps in the knowledge or rationale for any of the activities, then these can be addressed here.

Use this time also to discuss your shared understanding of the relationship that electronic media has with sleep; the healthy sleep behaviours recommendations; the bedtime routines that participants have made; the positive aspects that EMU has, what needs EMU fills in their life and potential alternative behaviours that they could be engaging in to fill those needs. Reinforce the purpose of the Electronic Media Use Diaries: Firstly, so that people can plan their use to make it goal directed (planned use can be more effective for unwinding than automatic or non-goal directed use), and secondly that it can help to increase awareness of EMU habits so that people are able to improve their decision making around electronic media and take control over their use. Reiterate the importance of consistent use of the Electronic Media Use Diaries to break automatic or non-goal directed use patterns and facilitate reflection on unintended EMU.

If participants are lacking in motivation, perhaps feeling as though it's not making a difference, let them know that sometimes we don't realise how tired we are, and subtle changes to alertness, or fatigue might be outside of their own awareness. They might be able to see changes once the PVT data is analysed and sent back to them.

Allow for participants to have an opportunity to reflect on any patterns that they might have noticed about their own use. This will be less directive than the past few sessions. Ask participants what they have learned about any attempts to change EMU patterns. Reinforce any positive changes and acknowledge and collaboratively problem solve any difficulties.

Feedback

This session also provides a chance for individuals to give immediate feedback on the intervention. Explicate that feedback at this stage will be, with permission, given back to the researcher and ask participants for consent to share this. Ask them generally how they found the content of the sessions, whether it had relevance for them, if they had any constructive feedback on the content, layout, or any of the resources, or any insights that they would like to share. It would be also helpful for the researcher to find out what elements of the intervention resonated most strongly with the participant, and what did not resonate as well. Ask participants also for an estimate on the likelihood that they will continue to complete Electronic Media Use Diaries after the conclusion of the study. Extra Electronic Media Use Diaries can be provided. Ensure that feedback is noted separately from the main session notes so that it can be given back to the researcher without compromising privacy of participants.

Guidance into Follow-Up Phase

On next Monday, follow up phase officially begins when participants complete Daily Measures Book 2 and begin Daily Measures Book 3. Plan a time next Monday when the participant can drop off Daily Measures Book 2 and you can give them Daily Measures Book 3. Ensure that the participant's SGIC is written in Daily Measures Book 2 when it is returned.

In Follow Up Phase, participants will proceed with another two weeks of measurement. Electronic Media Use Diaries are still to be completed during this stage to pick up any changes in use patterns. Instruct participants to hand Daily Measures Books and Electronic Media Use Diaries back to you once they are complete. If the study is still ongoing when the Electronic Media Use Diary is finished, participants are to be provided with another one. Following the conclusion of the study they can then collect a further Electronic Media Use Diary to keep filling out if they wish.

Ask the participant if there is any way that they would like to close the sessions. The instructions for returning the Daily Measures Book 3 are at the end of that book.

Study Calendar

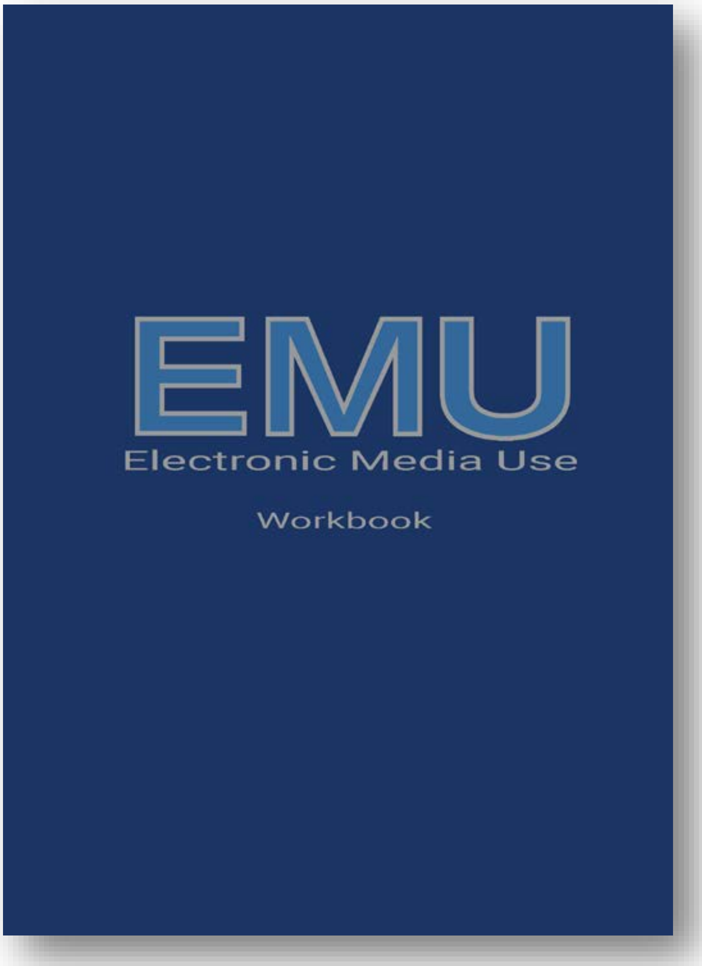
	Mon	Tue	Wed	Thu	Fri	Sat	Sun
Week 0					P1 Orientation P2 Orientation		
Week 1					P3 Orientation P4 Orientation		
Week 2	P1 S1 P2 S1		P1 S2 P2 S2		P5 Orientation P6 Orientation		
Week 3	P3 S1 P4 S1 P1 S3 P2 S3		P3 S2 P4 S2 P1 S4 P2 S4				
Week 4	P5 S1 P6 S1 P3 S3 P4 S3		P5 S2 P6 S2 P3 S4 P4 S4				
Week 5	P5 S3 P6 S3		P5 S4 P6 S4				P1 End P2 End
Week 6							P3 End P4 End
Week 7							P5 End P6 End

Note: S refers to session number, P refers to participant number

	Mon	Tue	Wed	Thu	Fri	Sat	Sun
Week 0							
Week 1							
Week 2							
Week 3							
Week 4							
Week 5							
Week 6							
Week 7							

Appendix E

Electronic Media Use Self Reflection Intervention Workbook


EMU
Electronic Media Use
Workbook

This Appendix contains the Intervention Workbook that was given to the participants of the single case research design study on HMNZS Wellington.

Welcome

Kia ora and welcome! This is the workbook for the Electronic Media Use, Sleep, and Fatigue study. This workbook is for you to use as you go through meetings with the ship's medic/research representative. It contains resources, activities, and notes on the intervention which you and the medic will work through as part of this study. There are four face-to-face sessions, there are also four sections of this book, labelled by session number. In each section, you will find worksheets and activities to either go through during session or in between sessions. This book can be kept by you for future reference and its contents will not go back to the researchers, so use it as you wish. The EMU audit sheet in session 1 however, will be given back to the ship's medic at session 2 or once it is complete. This audit sheet will then go back to the researcher as part of the rest of the data collected for the study. I hope you find value in some of the resources and the reflection activities contained in here, and that the sessions are useful and informative.

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2

Outline

Session 1

Session 2

Session 3

Session 4

Session 1

4

Electronic Media Use Audit Sheet (tear off)

Device name	Device model	Other connected devices / screens	Is device communal?

[Back page of Electronic Media Use audit sheet]

Please Enter your SGIC in the box below

SGIC instructions

Spaces 1 & 2: Your **birth month** (e.g. For April, you would write 0/4)

Spaces 3 & 4: The first two letters of your **first middle name** (e.g. for Maria, you would write M/A. If you don't have a middle name write X/X).

Space 5: The **first letter** of City/Town you were born in (e.g. for Tauranga, you would write /T/

___ ___ ___ ___ ___

The Relationship Between Electronic Media Use and Sleep

The amount of sleep that everyone needs is different from person to person. Most people need around 7-9 hours of sleep per night. If you bring healthy sleep behaviours into your life it can result in more sleep, sleep that is a better quality, and sleep that has more consistent timing. This can have positive effects on your daily wellbeing both mental and physical. You will be able to focus for longer, have faster reaction times and sustained attention, you will be able to work more efficiently, and you will be safer. Although having a healthy sleep habit can have many positive impacts on your wellbeing, sleep doesn't need to be perfect every single night. If you have a single bad night's sleep your next day performance probably won't be affected by too much, that is why this study is going for six weeks, so that we can assess any longer-term changes.

There are two main systems that control sleep. The first is the homeostatic drive for sleep. This is determined by how long it has been since you have slept. The need for sleep increases the longer you are awake, and it decreases if you've had a substantial sleep. The second system is called the circadian clock. Essentially, we all have an internal clock which is roughly timed to the day and night cycle. This clock programs typical sleep and wake time, and also programs many other physiological patterns such as body temperature and alertness. The way that this clock is kept in step with the day and night cycle is through light exposure.

Bright light is alerting. How alert we are can influence how long it takes to fall asleep. If you are exposed to bright light in the evening you will tend to fall asleep later. Light exposure in the evening also shifts the timing of your circadian clock to later which can make it harder to fall asleep. Even small amounts of light can have an effect on the circadian clock. If pressure to fall asleep from the first system, the homeostatic drive for sleep is high then you will probably be feeling tired. If the circadian clock is out of sync though, then that can prevent you from falling asleep.

Many electronic media now come equipped with a night mode which dims the screen and shifts colours away from the kinds of light that most disrupt the circadian clock. This night mode would be helpful to switch on if it's not activated by default on your electronic media devices. However, light is not the only way that our sleep can be disrupted so this won't completely cancel out any effect that electronic media may be having on sleep.

Stimulating content

Many electronic media that we interact with contain content which is stimulating, exciting, and possibly unsettling. There is also many media which can be calming and relaxing to interact with. Some electronic media are interactive, for example gaming or interacting with others on social media, and some are more passive for example reading an e-book, or watching a movie. Although the light exposure may be similar, people who watch, for example, March of the Penguins just before bed tend to have better sleep than those who play Counter-Strike for the same length of time just before bed. Prioritising calming and more passive electronic media use activities in the evening can lead to our nervous system being more ready for sleep. This can lead to less difficulty falling asleep, and sleep which has better quality and is more efficient. Stimulating content on electronic media can also be very distracting, and we can often end up in a state of flow, particularly when using more active electronic media, which can also lead to us delaying our bedtime.

Decision making and bedtime procrastination

Through our days and into our evenings we are often making decisions. A particular decision that is crucial to sleep health is the one we make when we go to bed and decide to try and go to sleep. Many forms of electronic media are designed in a way to reward us for staying on that platform for long periods of time. For example, this can be in the form of in-game rewards and a sense of achievement or scrolling social media in the hopes of finding an interesting and satisfying post. This can lead to many positive, satisfying feelings of achievement and entertainment, and it can also lead to a decision to keep up the activity even if we know that we really should be making that decision to go to bed and try go to sleep.

Sleep deprivation and fatigue can also have an impact on decision making ability. This means that it is harder to make that decision to get ready for bed. From this we can see a cycle of delayed bedtimes, which, if we must get up at a certain time the next day, leads to getting insufficient sleep. This insufficient sleep can then lead to a loss of decision-making ability, particularly when we are tired in the evenings, which makes it easier to be swayed by the draw of electronic media and a difficulty with deciding to go to bed, leading to delayed bedtimes, which begins the cycle again. By interacting with electronic media in a goal directed way, and noticing when we are using electronic media for longer than we intended when we started, we can become aware of the kinds of activities that might be interfering with our decision to go to sleep. Then we can more easily notice when we are doing those activities and the decision to go to bed instead might become easier.

Recent research has also shown that if we interact with electronic media in a way that is intentional and goal-oriented, it can be more effective for unwinding, is more satisfying, and can help lessen the negative impacts it might be having on sleep. This is the purpose of the electronic media use diaries provided in Session 1. In these, write what you intend to use electronic media for when you first decide to use it, and write down the time and the device that you will be using. Then when you've finished doing that activity write the end time. If you used any other devices or did any other activities during that time, then write them down in the extra activities section. This can help with keeping your electronic media use goal-directed, and make you more aware of the things that you are doing that you might not have intended when you first decided to use that electronic media.

Good Sleep Habits

The following practical recommendations are adapted from The Australasian sleep health foundation's recommendations.

- Technology use in the evenings may delay bedtime and interfere with sleep.
- Using a bright screen can increase alertness, so you might not realise how tired you are.
- Dimming the screen as much as possible for evening use may help mitigate some of the effects of the light hitting your eyes. In many e-readers you can even invert the screen colour (i.e., white font on black background). A free software program for PCs and apple computers decreases the amount of blue light in computer screens during the evening and increases orange tones instead. This program is called f.lux and is at https://justgetflux.com
- Activities on electronic media can be stimulating and make us less ready to sleep.
- People can also become absorbed and continue using technology beyond their usual bedtime.
- Not all people are affected by technology use in the same way.
- Your sleep will be affected differently depending on how you use electronic media.
- In the evening, use technology in moderation. Switch from interactive use (e.g., phones and games) to passive devices (e.g., e-readers or listening to calming music).

Current Pre-Bedtime Routine

In the space below, draw or write an account of your current pre-bedtime routine, activities that you typically engage in in the hour before going to bed for your main sleep of the day.

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Notes

Session 2

Positives of Electronic Media Use

Electronic media use has many positive attributes and you can meet many needs and wants by using electronic media. Examples are staying in contact with others, gathering information and research, distraction, and leisure. Have a think about the positive aspects of electronic media use that you experience and the needs that electronic media meets for you. Any ideas that you have can be written below while the actigraph watch battery is changed. This could also be a good time to have a think about sleep-friendly and calming electronic media use that you might want to incorporate into your bedtime routine. See if there are any changes that you would like to make, or you think would be helpful for your sleep health.

Pre-Bedtime Routine Plan Space

On this page and the next page is space for being able to write a specific step-by-step pre-bedtime routine that works for you. Try and thoroughly think through the 1 hour before trying to actually go to sleep. Be as specific as possible and write estimated time markers for each of your pre-bedtime activities. Remember to focus on activities that are calming, soothing, and help you unwind from your day, as well as the more practical aspects of getting ready for bed.

Try and find activities that you can do in every setting, and ones that are simple. Examples could be reading a book, brushing your teeth, listening to a podcast. If this routine doesn't happen every night that's okay too, just try and bring it in when you can.

Have a think about what we know so far could be the relationship between electronic media and sleep from last session. This is a time for experimenting and there will be space for thinking about what worked and what didn't next session. For now, on the next page, write down a bedtime routine that you think works for you and might help you with your sleep.

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Notes

Session 3

Electronic Media Use Diary Reflection Exercise

Look at the “Extra activities engaged in” column in your electronic media use diary from the past few days and copy any you see into the box below.

These extra activities are ones that you engaged in without having planned to do them when you decided to use your electronic media. This is a normal part of electronic media use that many of us experience. Sometimes when using electronic media, we may get reminded of tasks and activities that we wanted to do, and then we do them. Other times when we use electronic media we can get distracted by the variety of activities and information that is available to us and can end up forgetting what the reason was why we picked up the device in the first place. Sometimes it’s as simple as responding to, or checking a message or a phone call. These are all normal parts of using electronic media. Often these unintentional activities can lead us to using electronic media for longer than we would like, which can interfere with other life activities. Becoming aware of these unintentional activities can help lessen that interference. Now that you can see what extra activities you used electronic media for that you were not intending you can have a think about what needs these extra activities are meeting. Copy some extra activities into the table below and write the needs that these activities meet next to them.

Activity	Needs

Now have a look at the needs that these activities meet. Think about whether there are alternative activities you could do to meet those needs in your life which you can intend to do instead. It might be that the original activity you listed is actually a really good way of meeting that need for you, and that is fine. If it's possible, experiment with planning this activity in advance. You might notice that by planning to do the activity you get more enjoyment out of it and it becomes a more fulfilling activity. For example, recent research suggests that scheduling habitual use of electronic media (e.g., watching a TV show at the same time every day) and allowing yourself to be fully present with the media you're engaging in can help you detach from work, relax, and unwind. However, if you can, try also come up with some alternative behaviours to meet these needs. This is particularly important for more stimulating activities you might be doing close to sleep, or activities that delay your bedtime. Write the needs from the previous box into the first column of the first one of the next page, then think of some alternative behaviours that you could try to meet these needs.

Needs	Alternative activity

Here is a bigger table that’s slightly more compressed. You can use it to address any more actives that don’t fit into the previous tables or to summarise what you have written on them.

Extra activity	Needs	Alternative activity

Pre-Bedtime Routine Plan Edit

Have a think about the bedtime routine that you came up with last session and, if there are any further changes that you would like to make, re-write it below. It might also be helpful to set a gentle alarm to remind you to begin the routine if you have been having trouble getting it started. Remember to keep the activities simple, calming and ones that you could do in any situation. For inspiration you could look at the alternative activities that you came up with in the previous exercise.

Notes

Session 4

Summary of Intervention

Over the course of the past 2 weeks, you have learned what we know so far about how electronic media use relates to sleep, the importance of having good sleep routines, and you have designed a new bedtime routine that works for you. You have also been keeping track of your electronic media use through the electronic media use diaries and you have been keeping track of unintended or extra activities that you hadn't been planning to do when you decided to pick up or begin using that particular electronic media. By monitoring and learning about your own electronic media use, I hope that you feel like you are able to take more control over your electronic media use and lessen its influence on your day-to-day life. This includes its influence on your sleep. You have also been completing many outcome measurements related to your sleep and fatigue over the course of the past few weeks to measure any long-term changes. Even if it feels that there might only have been small changes, sometimes these can have positive echoes and gradually become bigger positive changes. Thank you again for your ongoing commitment to this study.

There are 2 weeks left of the main measurement component in the study. During these 2 weeks please continue to fill out your daily measures and completing your PVTs. Please also continue to fill out your Electronic Media Use Diaries. In around a month, you will also be sent a follow-up questionnaire which will be similar to the intake questionnaire you answered at the beginning of this study. It will also ask for any further feedback and insights you have on the study.

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Appendix F

Confidentiality Agreement

This Appendix contains the template confidentiality agreement that was signed by the research representative and the second rater for the actigraphy data.

MASSEY UNIVERSITY
COLLEGE OF HUMANITIES
AND SOCIAL SCIENCES
TE KURA PŪKENGA TANGATA

Electronic Media Use, Sleep, and Fatigue:

CONFIDENTIALITY AGREEMENT

I .... (Full Name - printed) agree to keep confidential all information concerning the project: Electronic Media Use, Sleep, and Fatigue.

I will not retain or copy any information involved in the project, over and above what is expected of me in my normal duties as a medic in the Royal New Zealand Navy.

Signature: .... **Date:** ....

Appendix G

Orientation Guide

EMU

Electronic Media Use

Study Orientation Guide

This Appendix contains the orientation guidebook that the research representative worked through with the participants to introduce them to the procedures of the single case research design study prior to their beginning the timeseries component.

Electronic Media Use, Sleep, and Fatigue Study Orientation Guide

Contents

Welcome

Kia ora and welcome to the study on electronic media use, sleep and fatigue. The purpose of this study is to test out a newly developed intervention that is intended to give you greater control over electronic media use, and sleep. Thank you for participating! There are many measurements needed throughout the study in order for us to get an idea of the relationship between electronic media use, sleep and fatigue in your daily life, and how this may change due to the intervention. The main measurement of this study will take 6 weeks.

During this time, you will be provided with measures books to log your sleep, your fatigue levels, your hours worked, and your electronic media use. You will also be provided with an **ACTIGRAPH**, a small wristwatch which has a movement sensor to measure your sleeping activity.

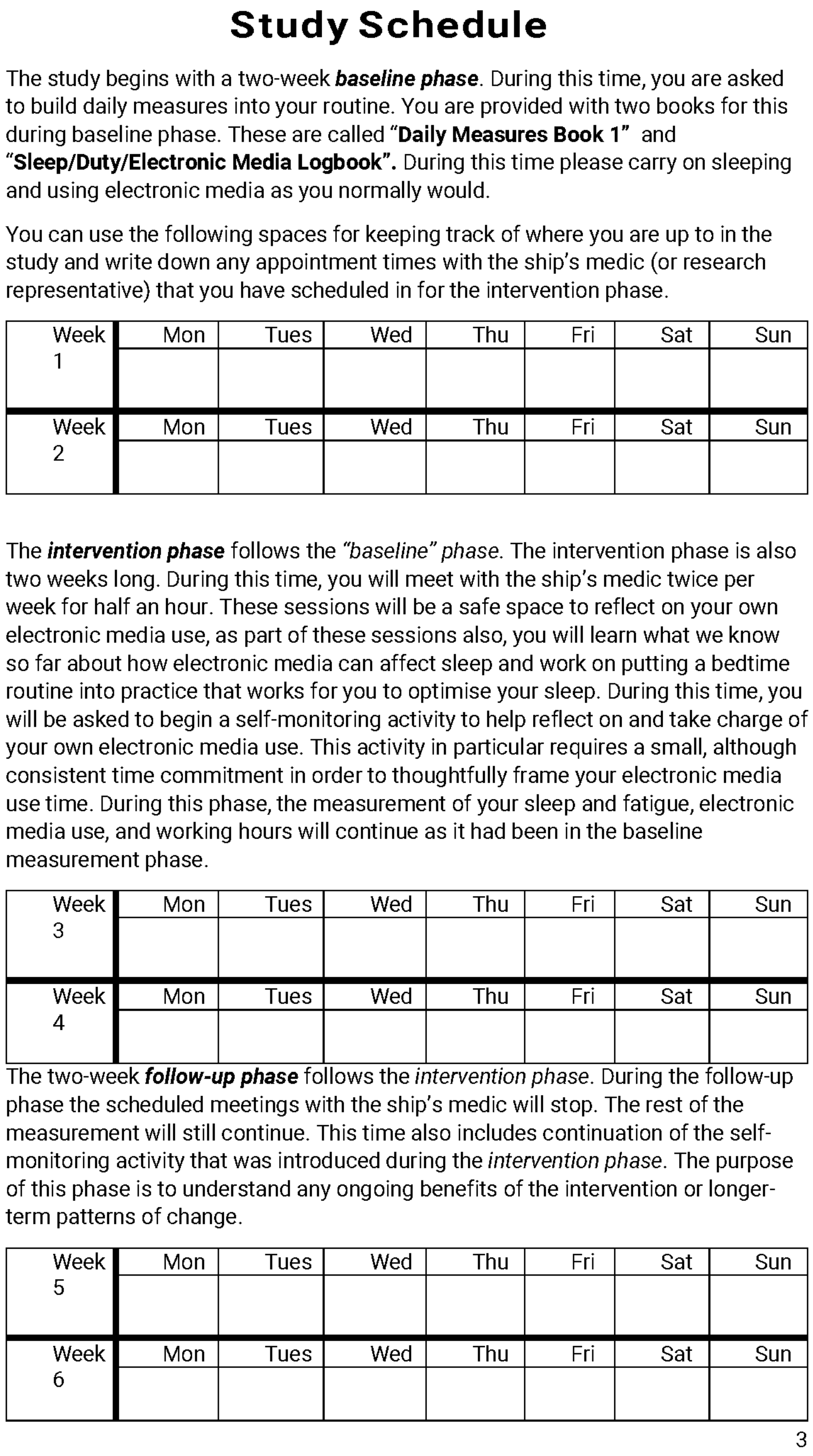
You will also be provided with a **SLEEP / DUTY / ELECTRONIC MEDIA LOGBOOK**. This is for noting down every period of sleep, work, and electronic media use that you had during the day. From these we'll be able to get a good estimate of your sleep, work, and electronic media use timing.

You will also be given a **DAILY MEASURES BOOK,** where every afternoon you report your sleepiness and fatigue levels that you experience. This is so that we can find out whether you noticed changes to your energy levels and experience of fatigue over the course of the study. There are three of these, one for every fortnight of the study.

You will also be asked to complete **PSYCHOMOTOR VIGILANCE TASKs (PVTs)** three times per week. PVTs are effectively a 10-minute-long reaction time test, which will provide a measure which reflects your fatigue levels, or performance. Scores on the PVT might change differently to how fatigued you feel, and scores might also change very subtly. It is important to measure these as they give us insight into how your performance might change in subtle ways from changing electronic media use and sleep habits. As these are quite long measures to complete (They take 10 minutes), you will only be asked to complete them three times per week.

Daily Measures Book measures of fatigue and sleepiness and PVT scores can change lots over the course of the day. So, it is important that these are completed **at the same time each day** in order for any changes over the course of the next few weeks to be accurately measured. The PVT should be completed straight after the questions in your Daily Measures Book (Although only 3 times per week). This orientation guide contains instructions for finding the ideal time for you to be able to consistently complete these measures. There is also a reminder in the daily measures books to complete the PVT on the right days.

Thank you for your interest in and commitment to the study. From the information that you provide we will be able to more thoroughly assess the role that electronic media has in people's lives, how it may affect sleep and fatigue, and find out whether the intervention is helpful for helping lessen unwanted electronic media use, and improving sleep and fatigue levels.



Study Schedule

The study begins with a two-week ***baseline phase***. During this time, you are asked to build daily measures into your routine. You are provided with two books for this during baseline phase. These are called **"Daily Measures Book 1"** and **"Sleep/Duty/Electronic Media Logbook".** During this time please carry on sleeping and using electronic media as you normally would.

You can use the following spaces for keeping track of where you are up to in the study and write down any appointment times with the ship's medic (or research representative) that you have scheduled in for the intervention phase.

Week 1	Mon	Tues	Wed	Thu	Fri	Sat	Sun
Week 2	Mon	Tues	Wed	Thu	Fri	Sat	Sun

The ***intervention phase*** follows the *"baseline" phase*. The intervention phase is also two weeks long. During this time, you will meet with the ship's medic twice per week for half an hour. These sessions will be a safe space to reflect on your own electronic media use, as part of these sessions also, you will learn what we know so far about how electronic media can affect sleep and work on putting a bedtime routine into practice that works for you to optimise your sleep. During this time, you will be asked to begin a self-monitoring activity to help reflect on and take charge of your own electronic media use. This activity in particular requires a small, although consistent time commitment in order to thoughtfully frame your electronic media use time. During this phase, the measurement of your sleep and fatigue, electronic media use, and working hours will continue as it had been in the baseline measurement phase.

Week 3	Mon	Tues	Wed	Thu	Fri	Sat	Sun
Week 4	Mon	Tues	Wed	Thu	Fri	Sat	Sun

The two-week ***follow-up phase*** follows the *intervention phase*. During the follow-up phase the scheduled meetings with the ship's medic will stop. The rest of the measurement will still continue. This time also includes continuation of the self-monitoring activity that was introduced during the *intervention phase*. The purpose of this phase is to understand any ongoing benefits of the intervention or longer-term patterns of change.

Week 5	Mon	Tues	Wed	Thu	Fri	Sat	Sun
Week 6	Mon	Tues	Wed	Thu	Fri	Sat	Sun

Afternoon Measurement Time

During this upcoming 6 weeks, it is important that you are able to complete the measures of fatigue and sleepiness that are in Daily Measures Books 1, 2, and 3 **at the same time every day**. On most days this is a task that takes less than 2 minutes. Also, the Psychomotor Vigilance Task (PVT) is required on Tuesdays, Thursdays, and Fridays and this will take over 10 minutes and should also be completed around this same time. As the Psychomotor Vigilance task is cognitively fatiguing in its' administration, it would be ideal to find a time at the end of your main block of work for the day, which allows space for rest following its administration. If you have consistency in your daily shift, at the end of your main block of work for the day is ideal. Otherwise, as close to 1400h-1500h as possible would be preferable. There is a natural dip in energy levels around this time, so it is the place where the most noticeable effects are likely to be picked up.

The Commanding Officer of the ship will know that there is a study ongoing on the ship and be aware that space and time is required for this consistent measurement. Please now take a moment to decide on a suitable time to aim for completing these measures:

- The Sleepiness Scale
- The Fatigue Scale
- The Psychomotor vigilance task (PVT).

Please write down your preferred time for these measures here.

If possible, please set a daily alarm to remind you to complete your afternoon measures.

These Measures will be outlined and organised in your **MEASURES BOOKS 1, 2, and 3.** These will be given to you as you progress through the study.

The Actigraph

The actigraph is a wrist-watch sized device that you will be asked to wear on your wrist throughout the data collection period. We will use it to measure daily total sleep time across all days of your study period. Start wearing the actigraph today and continue wearing it until Sunday 6 weeks from now when measurement book 3 is complete.

The actigraph contains an accelerometer and memory chip to detect and record arm movement. This is recorded as activity counts per minute. People generally move less when asleep, so sleep length and distribution can be determined from your movement record.

Actigraph data will be used in conjunction with information from the duty/sleep diary to determine sleep length and quality.

The actigraph records only arm movement, light intensity and the temperature of the actigraph. It does not and cannot record biological information such as heart rate. Arm movement data is used to infer sleep and wake (like a FitBit or similar device would).

Light intensity is also used to help identify periods of sleep (most people sleep in a dark environment) and The temperature of the watch is used to identify periods when the actigraph is not worn.

The actigraph should always be worn on the non-dominant wrist (the hand you don't write with). It is important that you do not change wrists. It should not be too loose; if it does move about, tighten the strap slightly. It shouldn't be worn when showering, swimming or bathing – please remember to put it back on afterwards.

The event marker is the left-hand button on the face of the device. Please press firmly on the event marker (the letter E and a green light will appear) whenever you start trying to sleep (lights out) and whenever you stop trying to sleep (lights on). This further helps to distinguish wake periods from rest periods.

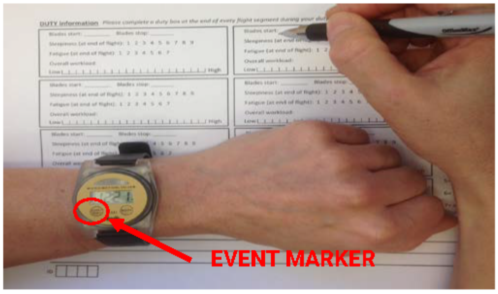
Please write down in your duty/sleep diary the times you remove the actigraph

If you forget to put the actigraph back on after removing it:

- Put it back on as soon as you remember
- Write down in your diary the time you put it back on

Remember that the actigraph only tells us whether you are wearing it and are moving, not what you are doing.

Due to the length of the data collection period, we will need to change your watch battery about 20 days after it starts recording. This aligns with session 2 of the intervention phase, and the research representative is aware of this need. The battery change will happen during session 2 of the intervention.



The Psychomotor Vigilance Task

Performance will be measured using a psychomotor vigilance test (PVT), a simple reaction time test completed on a specialised device. Work performance will not be assessed.

The research team has loaned 2 PVT devices to the RNZN and these are kept in the office of the research representative.

The PVT needs to be completed at your chosen afternoon measurement time, on Tuesdays, Thursdays, and Fridays. The devices will be numbered and programmed ahead of time.

The button you press (left if you are left handed, right if you are right handed) will have been pre-set so make sure you select a device that is programmed for your dominant hand.

Make sure you record the time of your test in the sheet provided next to the PVT.

The PVT devices will be downloaded and reprogrammed daily.

The PVT tests last 10 minutes and measures reaction time by recording the amount of time it takes you to respond to a visual stimulus by pressing a button.

The visual stimulus is presented in the form of red numbers appearing on the top screen. These represent the time since they have appeared on the screen. Respond to their presence as quickly as you can. Try to respond as quickly and as accurately as possible, avoid 'jumping the gun' if you can.

Instructions on how to start the test are taped to the device and provided in the study manual which should be located with the devices in the office of the research representative.

It is important that when you take the test you always hold the device in the same way and use the same finger of your dominant hand. It is important that you do this throughout each individual test and across all tests.

Please try to take the test in an environment that is as quiet and distraction free as possible. Take a small break after completing the test in order to help with recovery. To help you familiarise yourself with the PVT, you will be asked to take a practice PVT when possible.

The practice PVT takes about 3 minutes and the data from that test is not recorded or analysed; it is purely for practice purposes. To take the practice PVT follow the instructions on the next page.

The practice test only takes a few minutes and is a good way for you to get a feel for what the full test is going to be like.

Data from the practice PVT is not saved by the device. It is purely for practice purposes.

- Hold the device in your non-dominant hand or place it on a flat surface in front of you if that is more comfortable. During the test you will need to respond to the stimulus by pressing either the left (if left hand dominant) or right (if right hand dominant) button. You may use your thumb or finger, but you must use the same finger for the duration of all tests.
- Turn on the PVT by flipping the 'POWER' switch at the front of the device to the 'ON' position. The serial number of the PVT will scroll across the screen before the screen displays 'Select Test Setup'. The cursor should automatically highlight the 'Test' option but if it doesn't use the left button to move the cursor onto it.
- Press the right button to select the 'Test' option. The screen will then display 'Select Test Real Demo Ret'. Use the left button to scroll across to 'Demo' then select this option by pressing the right button.
- The screen will then display 'Alert? No………………Yes'. This scale must be completed before you can begin the test and requires you to indicate how sleepy you feel at that time. Use the left button to move the cursor along the scale and then use the right button to submit your response.
- The screen will then display 'Ready to test…press any button to start'. Once you have pressed a button, the practice test will begin.
- Watch the screen at the top of the device and press the appropriate button (e.g., right side button if right hand dominant) whenever you see red numbers appear. The numbers in the display show how fast you responded each time (the smaller the better). Always try to do your best and get the lowest number possible.
    - If you 'jump the gun' and press the button before a stimulus appears you will see 'FS' flash across the screen but the test will continue.
    - If you press the wrong button the letters 'ERR' will flash across the screen but the test will continue.
    - If you forget to release the button, the device will beep at you and the screen will display a reminder to release the button before continuing the test.
- At the end of the practice test, you will need to complete the scale again to indicate how sleepy you feel at that time. Use the left button move the cursor and the right button to submit your response.
- Once you have finished, you can turn off the device by flipping the 'POWER' switch to the 'OFF' position.
- None of the data from this test will have been recorded so you can practice as many times as you want.

Book List

These are the books that will be provided to you throughout the study, followed by brief descriptions of their function.

Daily Measures Book 1

This contains self-report sleepiness and fatigue measures to be completed daily at afternoon measurement time in baseline phase. Each Daily Measures Book also contains reminders to complete PVTs on Tuesdays, Thursdays, and Fridays.

Sleep/Duty/Electronic Media Use Logbook

This book contains morning measures to be completed upon waking, and visual log of sleep, duty, and electronic media use times exceeding 10 minutes. This is to be kept close to your bed and completed daily throughout the study. It also contains space for reporting data from any inbuilt screentime / digital wellbeing applications you may have available on your smartphone.

Daily Measures Book 2

This book, like Daily Measures Book 1, contains self-report sleepiness and fatigue measures to be completed daily at afternoon measurement time during the intervention phase. It also contains PVT reminders.

Workbook

This contains activities and resources matched up with the intervention sessions for working on during and between sessions.

Electronic Media Use Diary

This book is a reflection and intention setting exercise to keep track of and reflect on each time you use electronic media. It is introduced during the intervention phase.

Daily Measures Book 3

This book, like Daily Measures Books 1 and 2, contains self-report sleepiness and fatigue measures to be completed daily at afternoon measurement time during the follow-up phase. It also contains reminders to complete PVTs on their allocated days.

Project Contacts

The research representative/medic on board ship will be on hand to work with and support you during the study.

The Commanding Officer of the ship will also know that there is a study ongoing on the ship and be aware that space and time is required for consistent measurement and meetings.

Others who you can contact include colleagues and leaders, chaplains, social workers, SAPRAs, and psychologists.

The researcher and supervision team are also available for contact if you have any questions. Their contact details are below. Their emails are also listed in the daily measures books.

If you need to contact someone urgently, the NZDF4U Wellbeing support line is available on 0800 693 348, or text 8881 or +64 9 414 9914 if calling from overseas for 24/7 confidential support over the phone or to organise further face-to-face support. In case of emergency dial 111.

Jonathan Peters, jonathan.peters.2@uni.massey.ac.nz

Dr Ian de Terte, I.deTerte@massey.ac.nz, 04 49793603

Prof Leigh Signal, T.L.Signal@massey.ac.nz, 04 49793257

LT Egidia Bernerius, Egidia.Bernerius@nzdf.mil.nz, Internal: 3977715

Mrs Helen Kilding, H.Kilding@dta.mil.nz, 09 4455877

Notes

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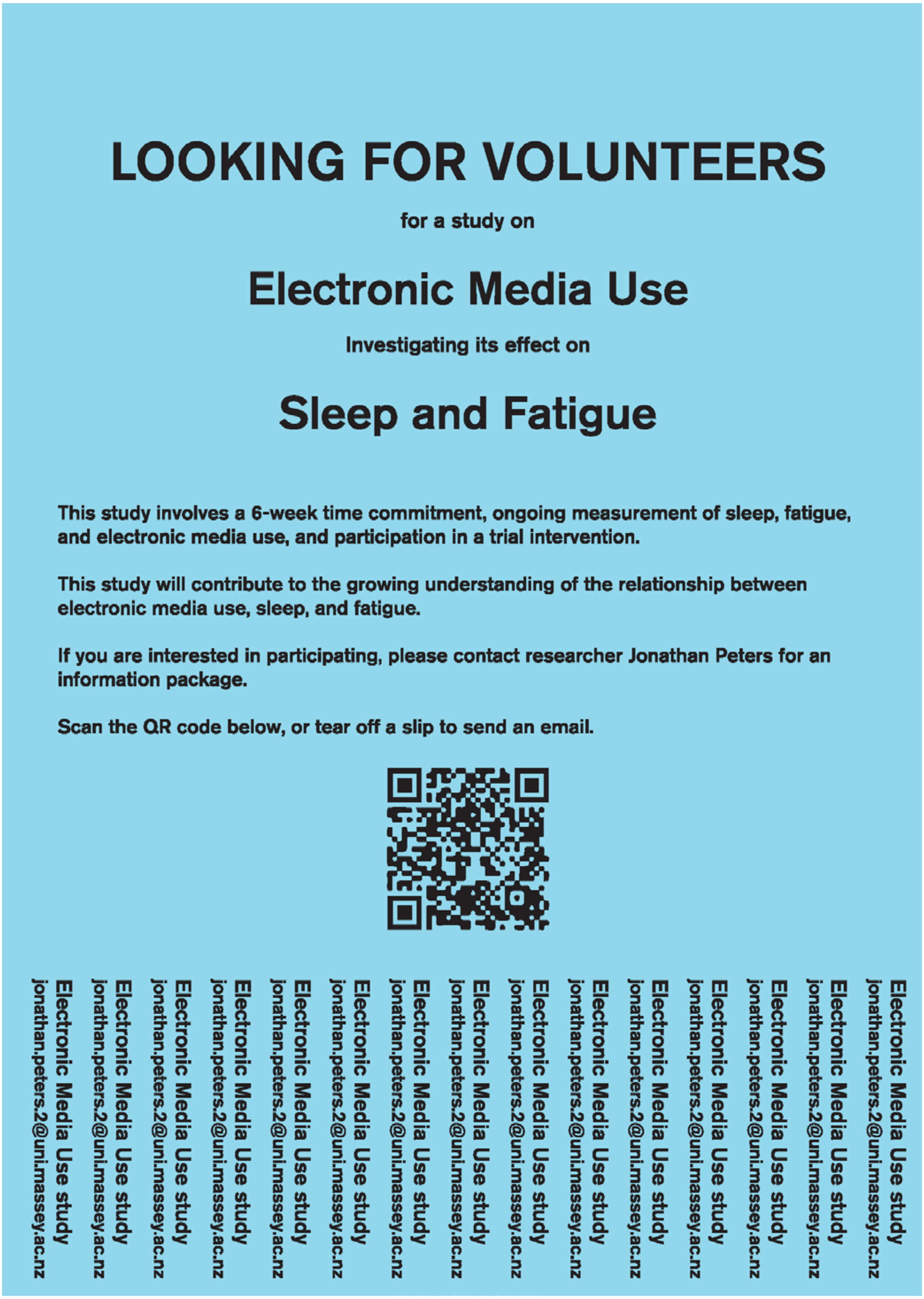
Appendix H

Advertising for the Single Case Research Design Study

This Appendix contains the study advertising that was onboard and alongside HMNZS Wellington



LOOKING FOR VOLUNTEERS

for a study on

Electronic Media Use

Investigating its effect on

Sleep and Fatigue

This study involves a 6-week time commitment, ongoing measurement of sleep, fatigue, and electronic media use, and participation in a trial intervention.

This study will contribute to the growing understanding of the relationship between electronic media use, sleep, and fatigue.

If you are interested in participating, please contact researcher Jonathan Peters for an information package.

Scan the QR code below, or tear off a slip to send an email.

Electronic Media Use study
jonathan.peters.2@uni.massey.ac.nz

Electronic Media Use study
jonathan.peters.2@uni.massey.ac.nz

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jonathan.peters.2@uni.massey.ac.nz

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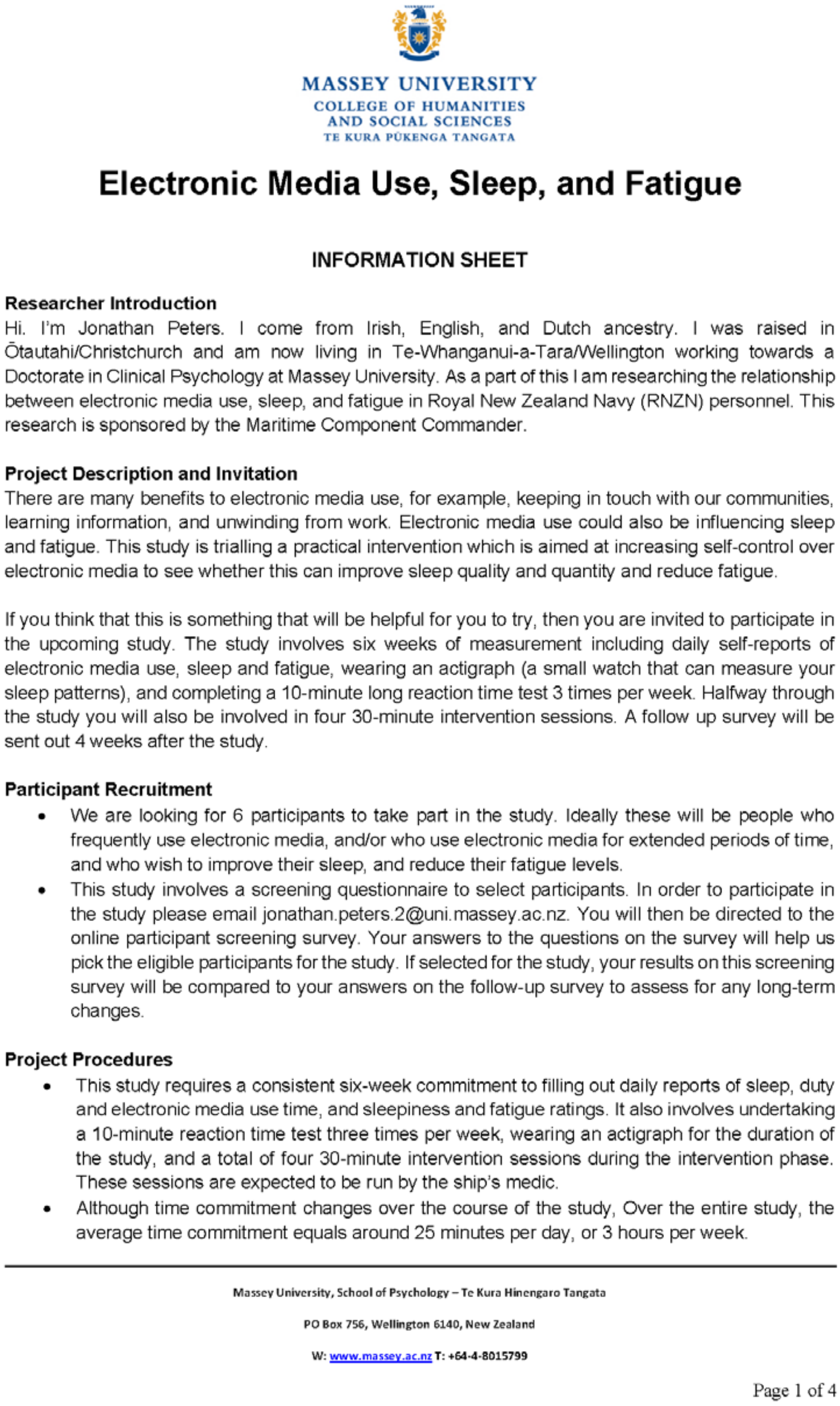
jonathan.peters.2@uni.massey.ac.nz

Appendix I

Study Information Sheet

This Appendix contains the information sheet for the single case research design study that was provided to interested participants.



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COLLEGE OF HUMANITIES
AND SOCIAL SCIENCES
TE KURA PŪKENGA TANGATA

Electronic Media Use, Sleep, and Fatigue

INFORMATION SHEET

Researcher Introduction

Hi. I'm Jonathan Peters. I come from Irish, English, and Dutch ancestry. I was raised in Ōtautahi/Christchurch and am now living in Te-Whanganui-a-Tara/Wellington working towards a Doctorate in Clinical Psychology at Massey University. As a part of this I am researching the relationship between electronic media use, sleep, and fatigue in Royal New Zealand Navy (RNZN) personnel. This research is sponsored by the Maritime Component Commander.

Project Description and Invitation

There are many benefits to electronic media use, for example, keeping in touch with our communities, learning information, and unwinding from work. Electronic media use could also be influencing sleep and fatigue. This study is trialling a practical intervention which is aimed at increasing self-control over electronic media to see whether this can improve sleep quality and quantity and reduce fatigue.

If you think that this is something that will be helpful for you to try, then you are invited to participate in the upcoming study. The study involves six weeks of measurement including daily self-reports of electronic media use, sleep and fatigue, wearing an actigraph (a small watch that can measure your sleep patterns), and completing a 10-minute long reaction time test 3 times per week. Halfway through the study you will also be involved in four 30-minute intervention sessions. A follow up survey will be sent out 4 weeks after the study.

Participant Recruitment

- We are looking for 6 participants to take part in the study. Ideally these will be people who frequently use electronic media, and/or who use electronic media for extended periods of time, and who wish to improve their sleep, and reduce their fatigue levels.
- This study involves a screening questionnaire to select participants. In order to participate in the study please email jonathan.peters.2@uni.massey.ac.nz. You will then be directed to the online participant screening survey. Your answers to the questions on the survey will help us pick the eligible participants for the study. If selected for the study, your results on this screening survey will be compared to your answers on the follow-up survey to assess for any long-term changes.

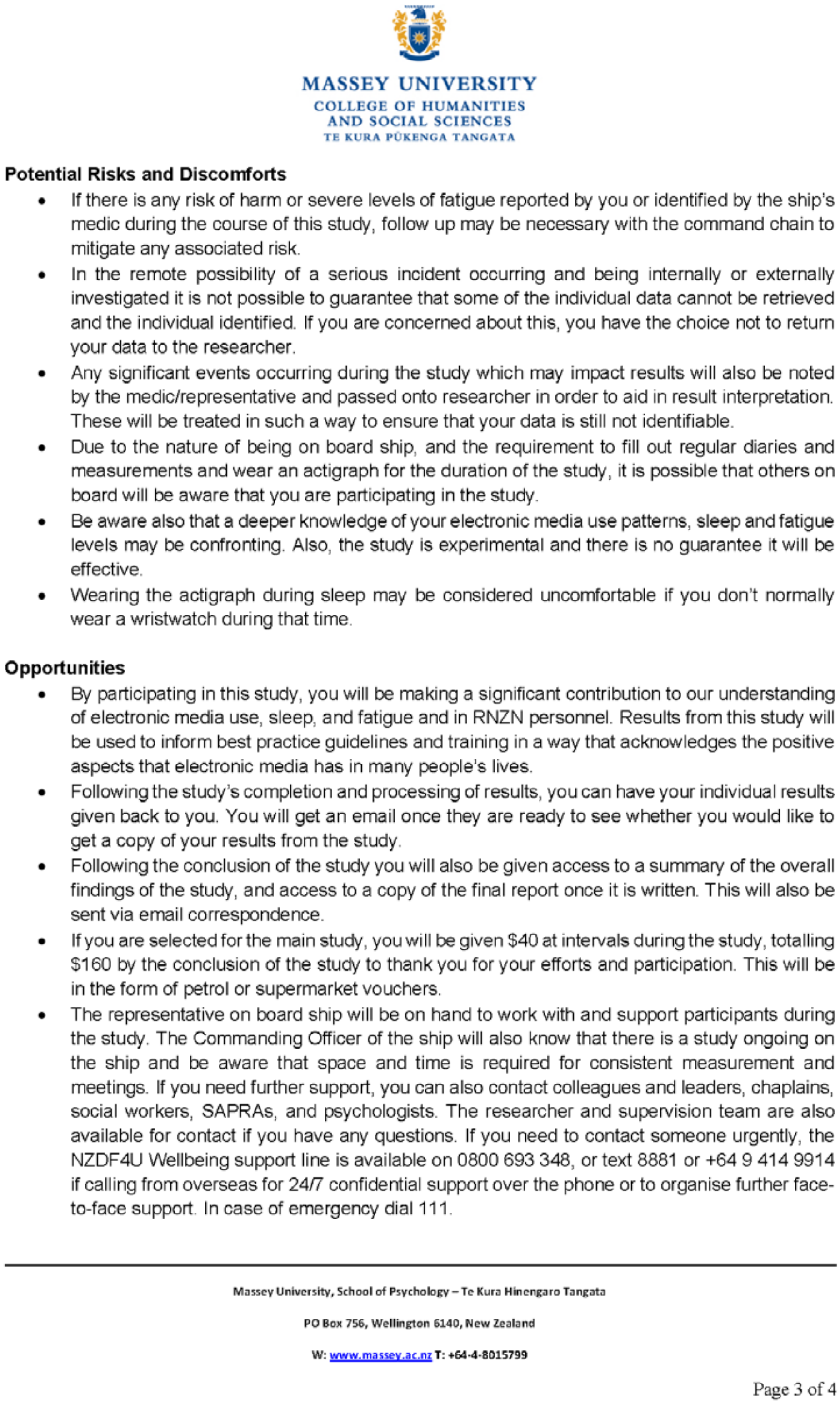
Project Procedures

- This study requires a consistent six-week commitment to filling out daily reports of sleep, duty and electronic media use time, and sleepiness and fatigue ratings. It also involves undertaking a 10-minute reaction time test three times per week, wearing an actigraph for the duration of the study, and a total of four 30-minute intervention sessions during the intervention phase. These sessions are expected to be run by the ship's medic.
- Although time commitment changes over the course of the study, Over the entire study, the average time commitment equals around 25 minutes per day, or 3 hours per week.

- You will be provided with measures books which need to be filled in each day. Some measures are to be completed in the morning, some in the afternoon, and some in the evening just before going to sleep. These measures are all brief It is expected that overall, these take less than 10 minutes per day to complete.
- If you have a screen-timing application on your main electronic media device (e.g. your smartphone) it would be ideal if you were able to activate this (these applications are already installed and active on most Apple and Android devices). You will be requested to, if possible, write down screen-time and unlocks/pickups data from these applications every day.
- The four 30-minute meetings with the ship's medic will involve an assessment of patterns of electronic media use, and education around electronic media use and sleep. They will also involve reflections on bedtime routines, and activities to help take control of electronic media use. This part of the study also involves a more detailed electronic media use diary which is to be filled in throughout the day whenever you use electronic media.
- A follow up questionnaire will be administered 4 weeks following the end of the 6-week study. This contains questions about sleep, fatigue, and electronic media use similar to the intake questionnaire, as well as any feedback you may have on the study for the researcher. The follow up questionnaire is expected to take less than 30-minutes.

Data Management

- Information that goes back to the researcher comprises: the intake and follow-up survey answers, measures and log books, the electronic media use diaries, actigraphy and psychomotor vigilance task data, information about any significant events which may impact results (reported by you or the ship's medic), and any feedback you may have on the study which you choose to share with the ship's medic or researcher. Neither you nor the medic are responsible for analysis of the data during the study: data analysis will be conducted by the research team following the study's conclusion.
- Information you collect during this study will be compared to your own information to assess individual changes over time.
- All participant data will be anonymised for interpretation. All participant data will be made unidentifiable in any resulting publications to protect your privacy.
- Data will be stored securely by the ship's medic while on board the ship. Following the end of the study, your data will be transferred to the researcher. It will be stored digitally on a secure database on Massey University servers. Following interpretation of results, this data will be archived securely at Massey University Wellington, for 5 years and then securely destroyed.
- To maintain anonymity of outcome data, while still being able to link data together, you will create a Self-Generated Identification Code (SGIC) at the end of the screening survey to use throughout the study on any forms and measurements that go back to the researcher. The SGIC is to aid in data management and will not be published. On the intake survey SGICs will need to be linked to your contact details. These links will be stored separately from the rest of the data for analysis and only accessed for contact/recruitment, and feedback of individual results. Identities will not be reported either in the report to the RNZN or in any academic reporting from the study.



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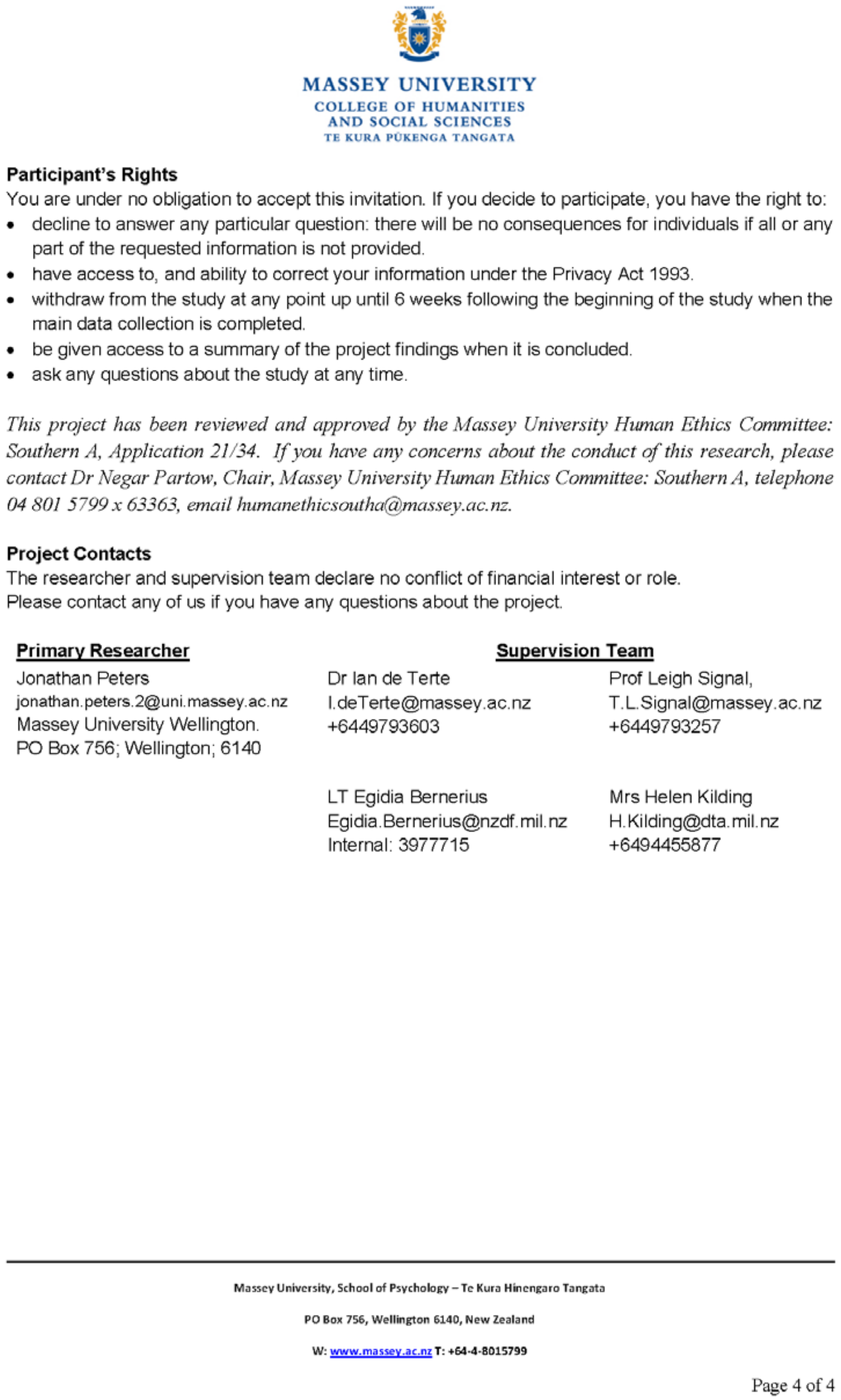
Potential Risks and Discomforts

- If there is any risk of harm or severe levels of fatigue reported by you or identified by the ship's medic during the course of this study, follow up may be necessary with the command chain to mitigate any associated risk.
- In the remote possibility of a serious incident occurring and being internally or externally investigated it is not possible to guarantee that some of the individual data cannot be retrieved and the individual identified. If you are concerned about this, you have the choice not to return your data to the researcher.
- Any significant events occurring during the study which may impact results will also be noted by the medic/representative and passed onto researcher in order to aid in result interpretation. These will be treated in such a way to ensure that your data is still not identifiable.
- Due to the nature of being on board ship, and the requirement to fill out regular diaries and measurements and wear an actigraph for the duration of the study, it is possible that others on board will be aware that you are participating in the study.
- Be aware also that a deeper knowledge of your electronic media use patterns, sleep and fatigue levels may be confronting. Also, the study is experimental and there is no guarantee it will be effective.
- Wearing the actigraph during sleep may be considered uncomfortable if you don't normally wear a wristwatch during that time.

Opportunities

- By participating in this study, you will be making a significant contribution to our understanding of electronic media use, sleep, and fatigue and in RNZN personnel. Results from this study will be used to inform best practice guidelines and training in a way that acknowledges the positive aspects that electronic media has in many people's lives.
- Following the study's completion and processing of results, you can have your individual results given back to you. You will get an email once they are ready to see whether you would like to get a copy of your results from the study.
- Following the conclusion of the study you will also be given access to a summary of the overall findings of the study, and access to a copy of the final report once it is written. This will also be sent via email correspondence.
- If you are selected for the main study, you will be given $40 at intervals during the study, totalling $160 by the conclusion of the study to thank you for your efforts and participation. This will be in the form of petrol or supermarket vouchers.
- The representative on board ship will be on hand to work with and support participants during the study. The Commanding Officer of the ship will also know that there is a study ongoing on the ship and be aware that space and time is required for consistent measurement and meetings. If you need further support, you can also contact colleagues and leaders, chaplains, social workers, SAPRAs, and psychologists. The researcher and supervision team are also available for contact if you have any questions. If you need to contact someone urgently, the NZDF4U Wellbeing support line is available on 0800 693 348, or text 8881 or +64 9 414 9914 if calling from overseas for 24/7 confidential support over the phone or to organise further face-to-face support. In case of emergency dial 111.



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Participant's Rights

You are under no obligation to accept this invitation. If you decide to participate, you have the right to:

- decline to answer any particular question: there will be no consequences for individuals if all or any part of the requested information is not provided.
- have access to, and ability to correct your information under the Privacy Act 1993.
- withdraw from the study at any point up until 6 weeks following the beginning of the study when the main data collection is completed.
- be given access to a summary of the project findings when it is concluded.
- ask any questions about the study at any time.

This project has been reviewed and approved by the Massey University Human Ethics Committee: Southern A, Application 21/34. If you have any concerns about the conduct of this research, please contact Dr Negar Partow, Chair, Massey University Human Ethics Committee: Southern A, telephone 04 801 5799 x 63363, email humanethicsoutha@massey.ac.nz.

Project Contacts

The researcher and supervision team declare no conflict of financial interest or role.
Please contact any of us if you have any questions about the project.

Primary Researcher	**Supervision Team**	
Jonathan Peters jonathan.peters.2@uni.massey.ac.nz Massey University Wellington. PO Box 756; Wellington; 6140	Dr Ian de Terte I.deTerte@massey.ac.nz +6449793603	Prof Leigh Signal, T.L.Signal@massey.ac.nz +6449793257
	LT Egidia Bernerius Egidia.Bernerius@nzdf.mil.nz Internal: 3977715	Mrs Helen Kilding H.Kilding@dta.mil.nz +6494455877

Massey University, School of Psychology – Te Kura Hinengaro Tangata

PO Box 756, Wellington 6140, New Zealand

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Appendix J

Participant Consent Form

This Appendix contains the consent forms that participants in the single case research design study each completed.

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Electronic Media Use, Sleep, and Fatigue

PARTICIPANT CONSENT FORM - INDIVIDUAL

I have read and I understand the Information sheet for the Electronic Media Use, Sleep and Fatigue study. I have had the details of the study explained to me, any questions I had have been answered to my satisfaction, and I understand that I may ask further questions at any time. I have been given sufficient time to consider whether to participate in this study. I understand participation is voluntary and that I may withdraw from the study at any time.

I agree to participate in this study under the conditions set out in the Information Sheet.

Declaration by Participant:

I [print full name] ___________ ____________ hereby consent to take part in this study.

Signature: ________________________ Date: ________________

Massey University, School of Psychology – Te Kura Hinengaro Tangata
PO Box 756, Wellington 6140, New Zealand
W: www.massey.ac.nz T: +64-4-8015799

Appendix K

Intake Survey

This Appendix contains the paper and pencil version of the intake survey given to participants as a pre assessment and screening for the single case research design study. This survey was also provided on the online Qualtrics software.

Electronic Media Use, Sleep, and Fatigue

Participant Screening Survey

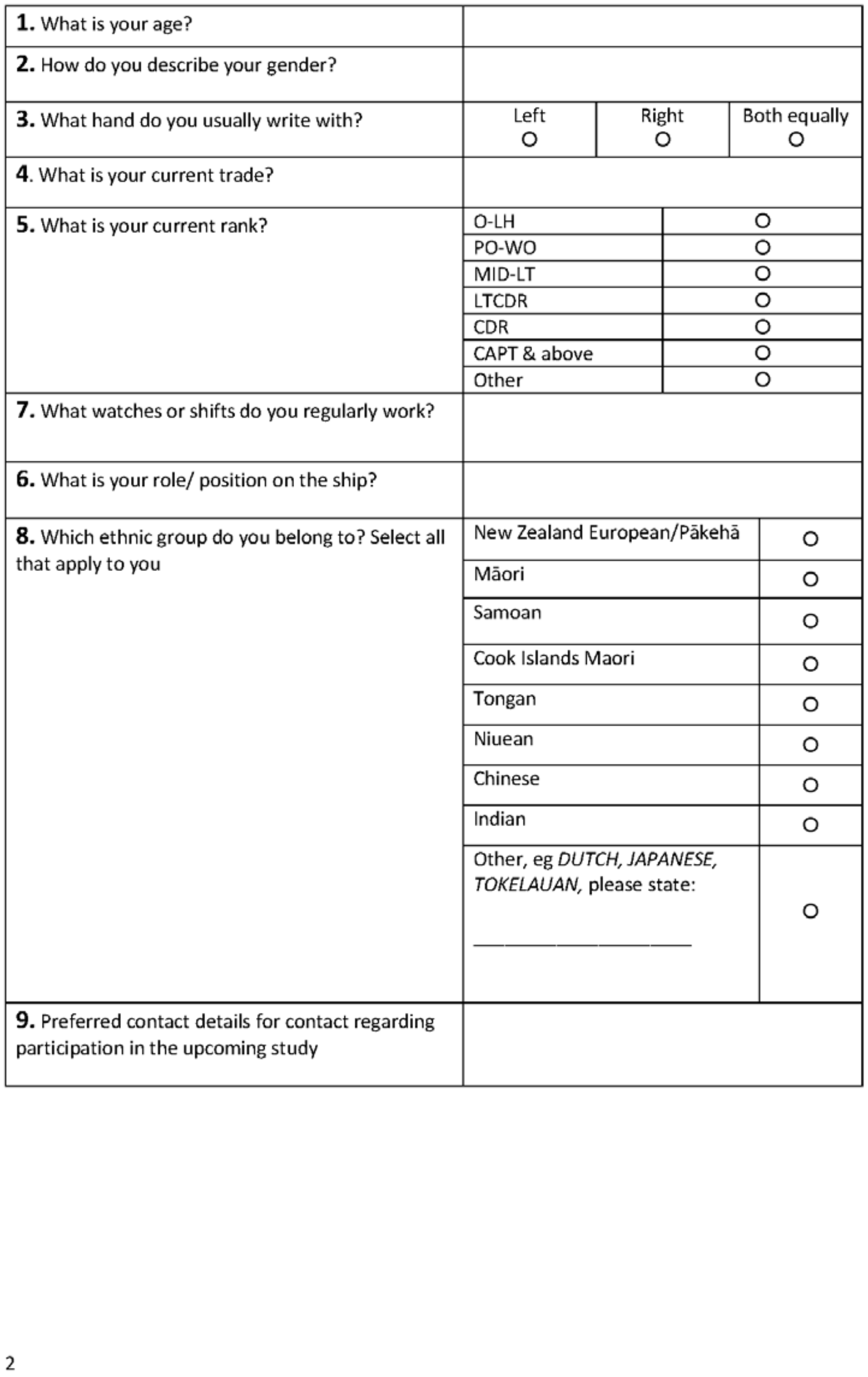
Welcome to the intake/screening survey for the Electronic Media Use, Sleep, and Fatigue study. Thank you for your interest in the study so far. This questionnaire should take 10 to 15 minutes to complete. Demographic information will not be used to decide who takes part in the intervention study. To preserve anonymity of research data, we will not be reporting individual participant demographics either. Instead, a grouped summary of the research sample's demographics will be reported. If you are not selected for the study, then, after the study, by request, we will send out a digital workbook containing activities and resources for electronic media use and sleep. In the current survey, feel free to skip questions that you are not comfortable answering or that you believe may compromise your anonymity. The question about handedness is so that we can prepare the psychomotor vigilance tasks for the individuals selected for the study.

In completing this survey, you hereby provide consent for your answers to be shared with the researchers listed below in order to select participants for the electronic media, sleep, and fatigue study. Your participation is voluntary. Your data will not be published or reported in any way unless you are selected for the study.

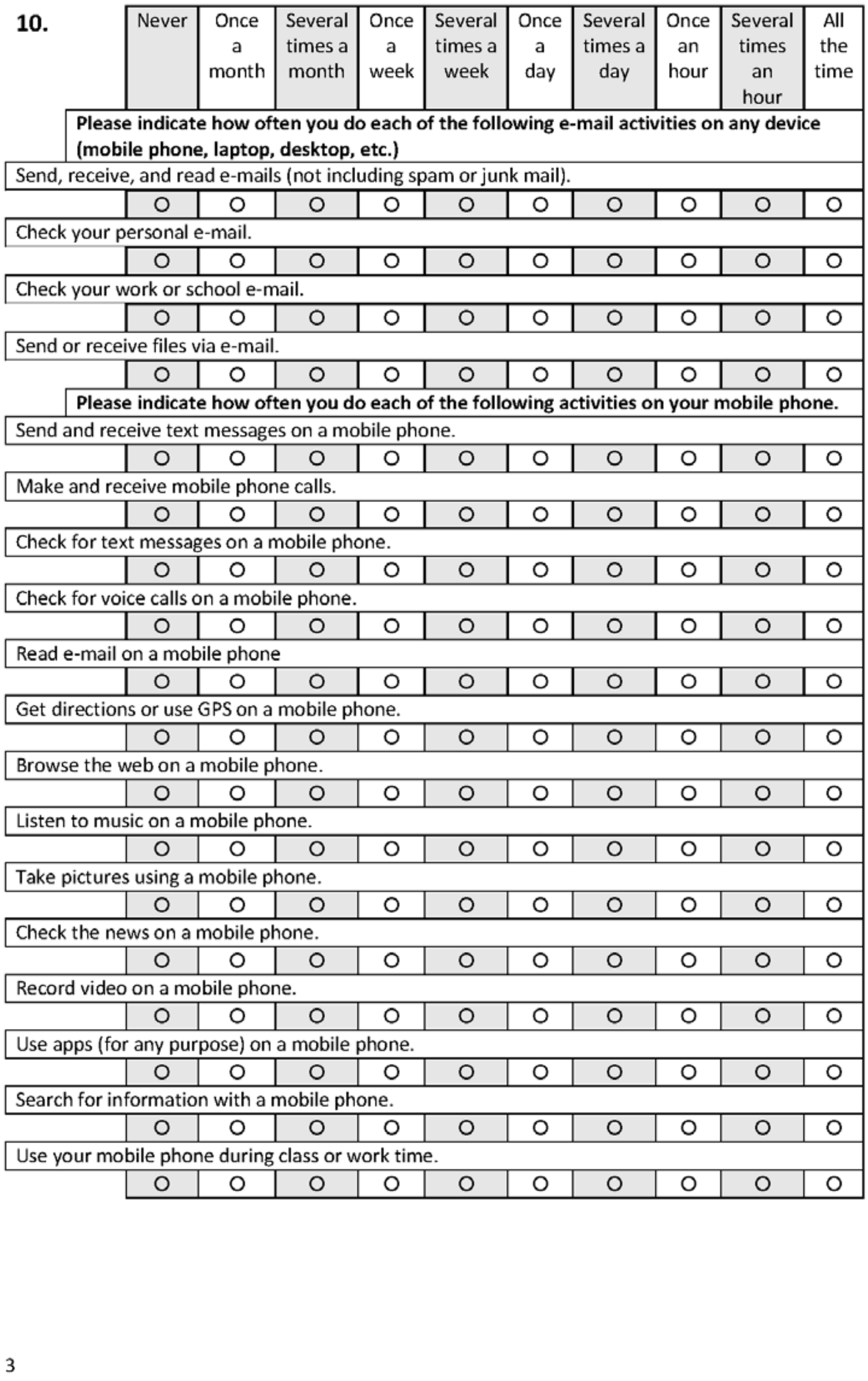
Researchers' contact details:

Primary Researcher	**Supervision Team**	
Jonathan Peters jonathan.peters.2@uni.massey.ac.nz Massey University Wellington. PO Box 756; Wellington; 6140	Dr Ian de Terte I.deTerte@massey.ac.nz +6449793603	Prof Leigh Signal, T.L.Signal@massey.ac.nz +6449793257
	LT Egidia Bernerius Egidia.Bernerius@nzdf.mil.nz Internal: 3977715	Mrs Helen Kilding H.Kilding@dta.mil.nz +6494455877

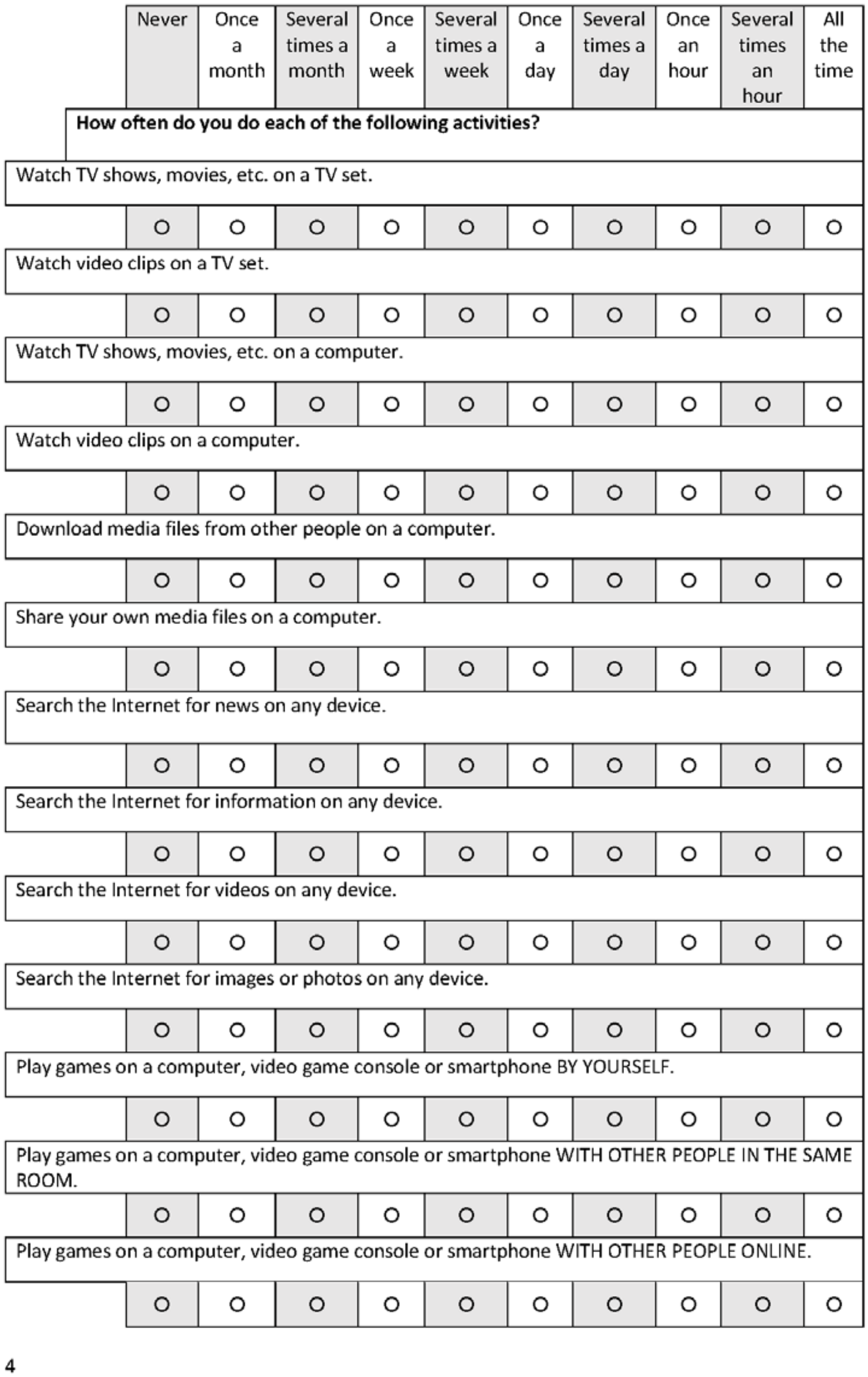
If you need support following the survey, please contact the Medic or Navy Psychologist or the NZDF4U Wellbeing support line on 0800 693 348 for support.



1. What is your age?			
2. How do you describe your gender?			
3. What hand do you usually write with?	Left ○	Right ○	Both equally ○
4. What is your current trade?			
5. What is your current rank?	O-LH	○	
	PO-WO	○	
	MID-LT	○	
	LTCDR	○	
	CDR	○	
	CAPT & above	○	
	Other	○	
7. What watches or shifts do you regularly work?			
6. What is your role/ position on the ship?			
8. Which ethnic group do you belong to? Select all that apply to you	New Zealand European/Pākehā	○	
	Māori	○	
	Samoan	○	
	Cook Islands Maori	○	
	Tongan	○	
	Niuean	○	
	Chinese	○	
	Indian	○	
	Other, eg *DUTCH, JAPANESE, TOKELAUAN,* please state: ____________________	○	
9. Preferred contact details for contact regarding participation in the upcoming study			



10.	Never	Once a month	Several times a month	Once a week	Several times a week	Once a day	Several times a day	Once an hour	Several times an hour	All the time
Please indicate how often you do each of the following e-mail activities on any device (mobile phone, laptop, desktop, etc.)										
Send, receive, and read e-mails (not including spam or junk mail).	○	○	○	○	○	○	○	○	○	○
Check your personal e-mail.	○	○	○	○	○	○	○	○	○	○
Check your work or school e-mail.	○	○	○	○	○	○	○	○	○	○
Send or receive files via e-mail.	○	○	○	○	○	○	○	○	○	○
Please indicate how often you do each of the following activities on your mobile phone.										
Send and receive text messages on a mobile phone.	○	○	○	○	○	○	○	○	○	○
Make and receive mobile phone calls.	○	○	○	○	○	○	○	○	○	○
Check for text messages on a mobile phone.	○	○	○	○	○	○	○	○	○	○
Check for voice calls on a mobile phone.	○	○	○	○	○	○	○	○	○	○
Read e-mail on a mobile phone	○	○	○	○	○	○	○	○	○	○
Get directions or use GPS on a mobile phone.	○	○	○	○	○	○	○	○	○	○
Browse the web on a mobile phone.	○	○	○	○	○	○	○	○	○	○
Listen to music on a mobile phone.	○	○	○	○	○	○	○	○	○	○
Take pictures using a mobile phone.	○	○	○	○	○	○	○	○	○	○
Check the news on a mobile phone.	○	○	○	○	○	○	○	○	○	○
Record video on a mobile phone.	○	○	○	○	○	○	○	○	○	○
Use apps (for any purpose) on a mobile phone.	○	○	○	○	○	○	○	○	○	○
Search for information with a mobile phone.	○	○	○	○	○	○	○	○	○	○
Use your mobile phone during class or work time.	○	○	○	○	○	○	○	○	○	○



How often do you do each of the following activities?	Never	Once a month	Several times a month	Once a week	Several times a week	Once a day	Several times a day	Once an hour	Several times an hour	All the time
Watch TV shows, movies, etc. on a TV set.	○	○	○	○	○	○	○	○	○	○
Watch video clips on a TV set.	○	○	○	○	○	○	○	○	○	○
Watch TV shows, movies, etc. on a computer.	○	○	○	○	○	○	○	○	○	○
Watch video clips on a computer.	○	○	○	○	○	○	○	○	○	○
Download media files from other people on a computer.	○	○	○	○	○	○	○	○	○	○
Share your own media files on a computer.	○	○	○	○	○	○	○	○	○	○
Search the Internet for news on any device.	○	○	○	○	○	○	○	○	○	○
Search the Internet for information on any device.	○	○	○	○	○	○	○	○	○	○
Search the Internet for videos on any device.	○	○	○	○	○	○	○	○	○	○
Search the Internet for images or photos on any device.	○	○	○	○	○	○	○	○	○	○
Play games on a computer, video game console or smartphone BY YOURSELF.	○	○	○	○	○	○	○	○	○	○
Play games on a computer, video game console or smartphone WITH OTHER PEOPLE IN THE SAME ROOM.	○	○	○	○	○	○	○	○	○	○
Play games on a computer, video game console or smartphone WITH OTHER PEOPLE ONLINE.	○	○	○	○	○	○	○	○	○	○

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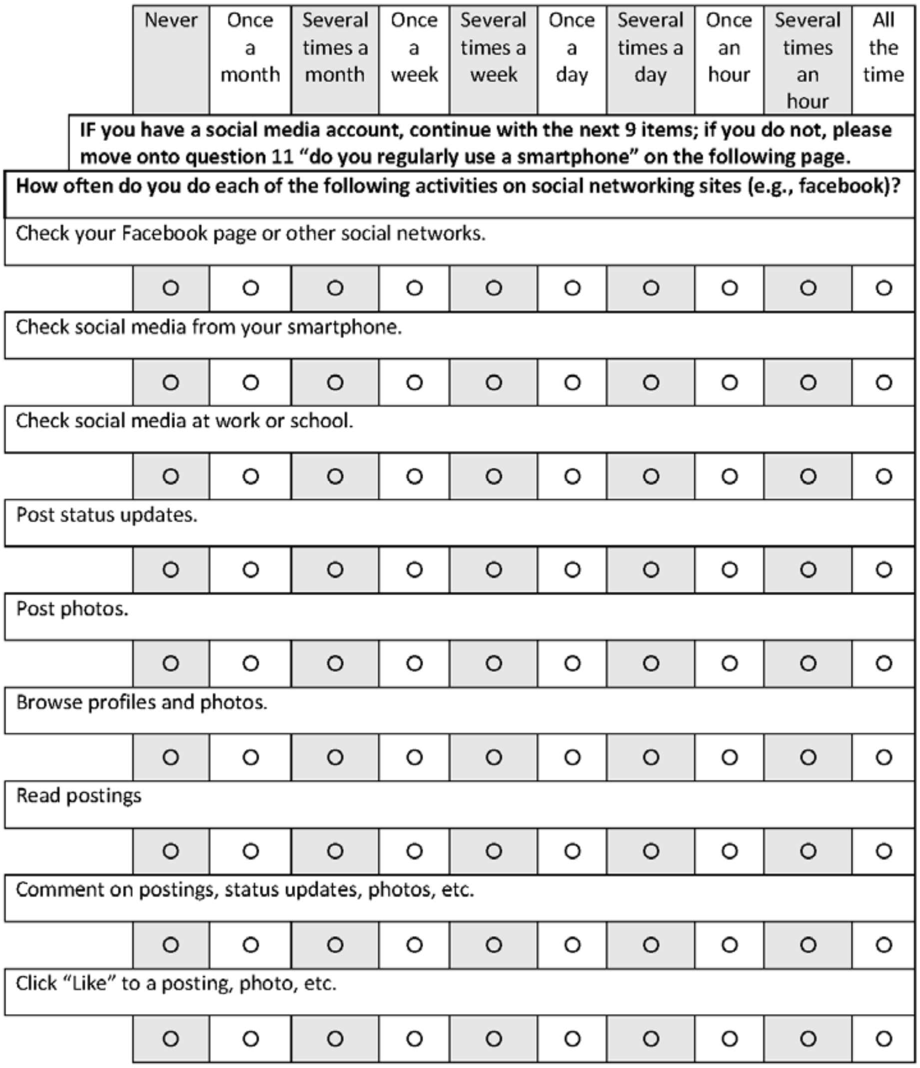

	Never	Once a month	Several times a month	Once a week	Several times a week	Once a day	Several times a day	Once an hour	Several times an hour	All the time
IF you have a social media account, continue with the next 9 items; if you do not, please move onto question 11 “do you regularly use a smartphone” on the following page.										
How often do you do each of the following activities on social networking sites (e.g., facebook)?										
Check your Facebook page or other social networks.	○	○	○	○	○	○	○	○	○	○
Check social media from your smartphone.	○	○	○	○	○	○	○	○	○	○
Check social media at work or school.	○	○	○	○	○	○	○	○	○	○
Post status updates.	○	○	○	○	○	○	○	○	○	○
Post photos.	○	○	○	○	○	○	○	○	○	○
Browse profiles and photos.	○	○	○	○	○	○	○	○	○	○
Read postings	○	○	○	○	○	○	○	○	○	○
Comment on postings, status updates, photos, etc.	○	○	○	○	○	○	○	○	○	○
Click “Like” to a posting, photo, etc.	○	○	○	○	○	○	○	○	○	○

11. Do you regularly use a smartphone? (please circle)

Yes / No

12. Please estimate the amount of time that you think you spent on your smartphone yesterday.

_____________ Hours _________ Minutes

To answer the following two questions, you are required to have an active screen timing application on your smartphone.

For apple devices this is called "Screen time". It is accessed through Settings\Screen Time. This will come up with a daily average from the past week. Tap on "See all activity" and then on the bar in the graph that corresponds to yesterday, you will be able to see the amount of screen time from yesterday and, when you scroll down the page, the number of times you picked up your phone – under the "Pick-Ups" heading.

For android users this is called "Digital Wellbeing". If you open your phone's Settings application and tap on "Digital Wellbeing and parental controls", then under "Your digital wellbeing tools" tap "Show your data". Click on "Dashboard" (in more recent versions of Android just tap on the current reading for today). This will bring up a chart of your recent use. Then click on the bar in the chart corresponding with yesterday's use. You will be able to see the total amount of screen time and, when you scroll down, the number of device "unlocks" that your phone had yesterday.

13. Are you able to access this screen time data on your smartphone? (Screen time on Apple devices, or digital wellbeing on Android devices.) Please Circle:

Yes / No

14. If you answered yes to the above question, what was your actual screen time recorded from yesterday?

___________Hours __________ Minutes

15. How many pick-ups / unlocks were recorded from yesterday?

_______________ Pickups (apple) / unlocks (android)

16.

The following questions relate to your usual sleep habits during the past month only. Your answers should indicate the most accurate reply for the majority of days and nights in the past month. Please answer all questions.

1. During the past month, what time have you usually gone to bed at night?

USUAL BED TIME ___________

2. During the past month, how long (in minutes) has it usually taken you to fall asleep each night?

NUMBER OF MINUTES ___________

3. During the past month, what time have you usually gotten up in the morning?

GETTING UP TIME ___________

4. During the past month, how many hours of actual sleep did you get at night? (This may be different than the number of hours you spent in bed.)

HOURS OF SLEEP PER NIGHT ___________

For each of the remaining questions, check the one best response. Please answer all questions.

	Not during the past month	**Less than once a week**	**Once or twice a week**	**Three or more times a week**
5. During the past month, how often have you had trouble sleeping because you . . .				
a) Cannot get to sleep within 30 minutes	○	○	○	○
b) Wake up in the middle of the night or early morning	○	○	○	○
c) Have to get up to use the bathroom	○	○	○	○
d) Cannot breathe comfortably	○	○	○	○
e) Cough or snore loudly	○	○	○	○
f) Feel too cold	○	○	○	○
g) Feel too hot	○	○	○	○
h) Had bad dreams	○	○	○	○
i) Have pain	○	○	○	○
j) Other reason(s), please describe ______________________________	○	○	○	○

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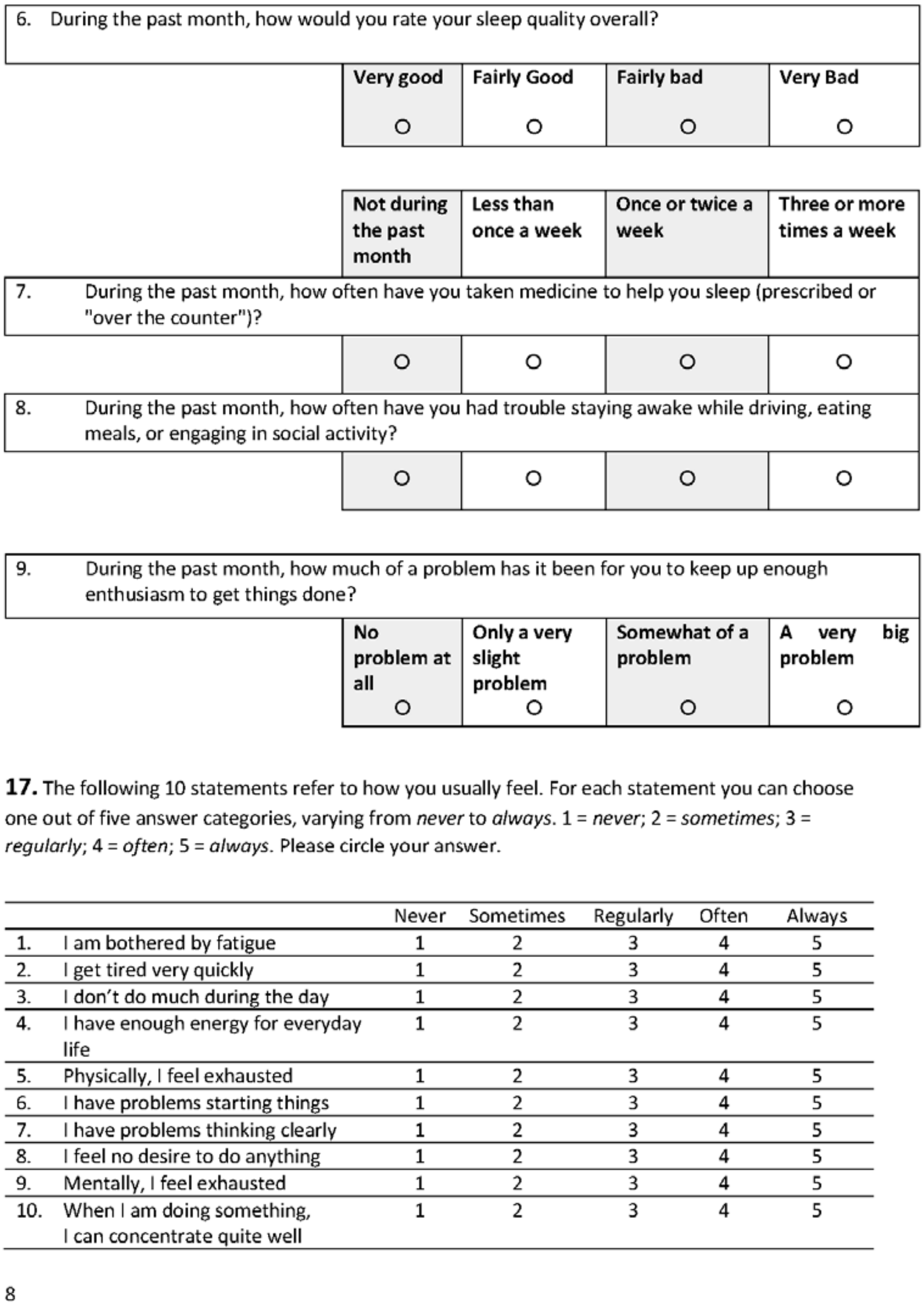

6. During the past month, how would you rate your sleep quality overall?

Very good	Fairly Good	Fairly bad	Very Bad
○	○	○	○

	Not during the past month	Less than once a week	Once or twice a week	Three or more times a week
7. During the past month, how often have you taken medicine to help you sleep (prescribed or "over the counter")?	○	○	○	○
8. During the past month, how often have you had trouble staying awake while driving, eating meals, or engaging in social activity?	○	○	○	○

9. During the past month, how much of a problem has it been for you to keep up enough enthusiasm to get things done?

No problem at all	Only a very slight problem	Somewhat of a problem	A very big problem
○	○	○	○

17. The following 10 statements refer to how you usually feel. For each statement you can choose one out of five answer categories, varying from *never* to *always*. 1 = *never*; 2 = *sometimes*; 3 = *regularly*; 4 = *often*; 5 = *always*. Please circle your answer.

		Never	Sometimes	Regularly	Often	Always
1.	I am bothered by fatigue	1	2	3	4	5
2.	I get tired very quickly	1	2	3	4	5
3.	I don't do much during the day	1	2	3	4	5
4.	I have enough energy for everyday life	1	2	3	4	5
5.	Physically, I feel exhausted	1	2	3	4	5
6.	I have problems starting things	1	2	3	4	5
7.	I have problems thinking clearly	1	2	3	4	5
8.	I feel no desire to do anything	1	2	3	4	5
9.	Mentally, I feel exhausted	1	2	3	4	5
10.	When I am doing something, I can concentrate quite well	1	2	3	4	5

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18.

Self-Generated Identification Code (SGIC)

A Self-Generated Identification Code (SGIC) protects your identity and ensures that your data remains anonymous. The SGIC will be used throughout the study so that your responses can be matched together whilst protecting your anonymity.

In order to create your SGIC for the current study, think of answers to the following.

Spaces 1 & 2: **Your birth month** (e.g. For April, you would write 0/4)
Spaces 3 & 4: The first two letters of your **first middle name** (e.g. for Maria, you would write M/A. If you don't have a middle name write X/X).
Space 5: The **first letter** of City/Town you were born in (e.g. for Tauranga, you would write /T/)
The example above would create an SGIC as follows 0 / 4 / M / A / T
Note. If any of the questions aren't applicable to you, fill in the blank spaces with "X"

Enter your SGIC

___ /___ /___ /___ /___
1 2 3 4 5

If you are selected for the study, you will be required to write this SGIC on all study documents that are returned to the research team. There will be reminders for how to complete your SGIC on each of the documents.

This concludes the intake survey for the electronic media, sleep, and fatigue study. Thank you for your interest in the study. The research team will be in contact with you via email or via your preferred contact details to advise you on whether you are selected for the study and, if you are selected, provide instructions for the next steps.

Appendix L

Follow-up Survey

This Appendix contains the follow-up survey given to participants approximately six months after their participation in the single case research design study. This survey was only provided on the online Qualtrics software.

Electronic Media Use, Sleep, and Fatigue

Follow-up survey

Welcome to the follow-up survey for the Electronic Media Use, Sleep, and Fatigue study. Thank you for your participation in the study so far. This is the final step in the study. This questionnaire should take 10 to 15 minutes to complete. Please feel free to skip questions that you are not comfortable answering or that you believe may compromise your anonymity.

Researchers' contact details:

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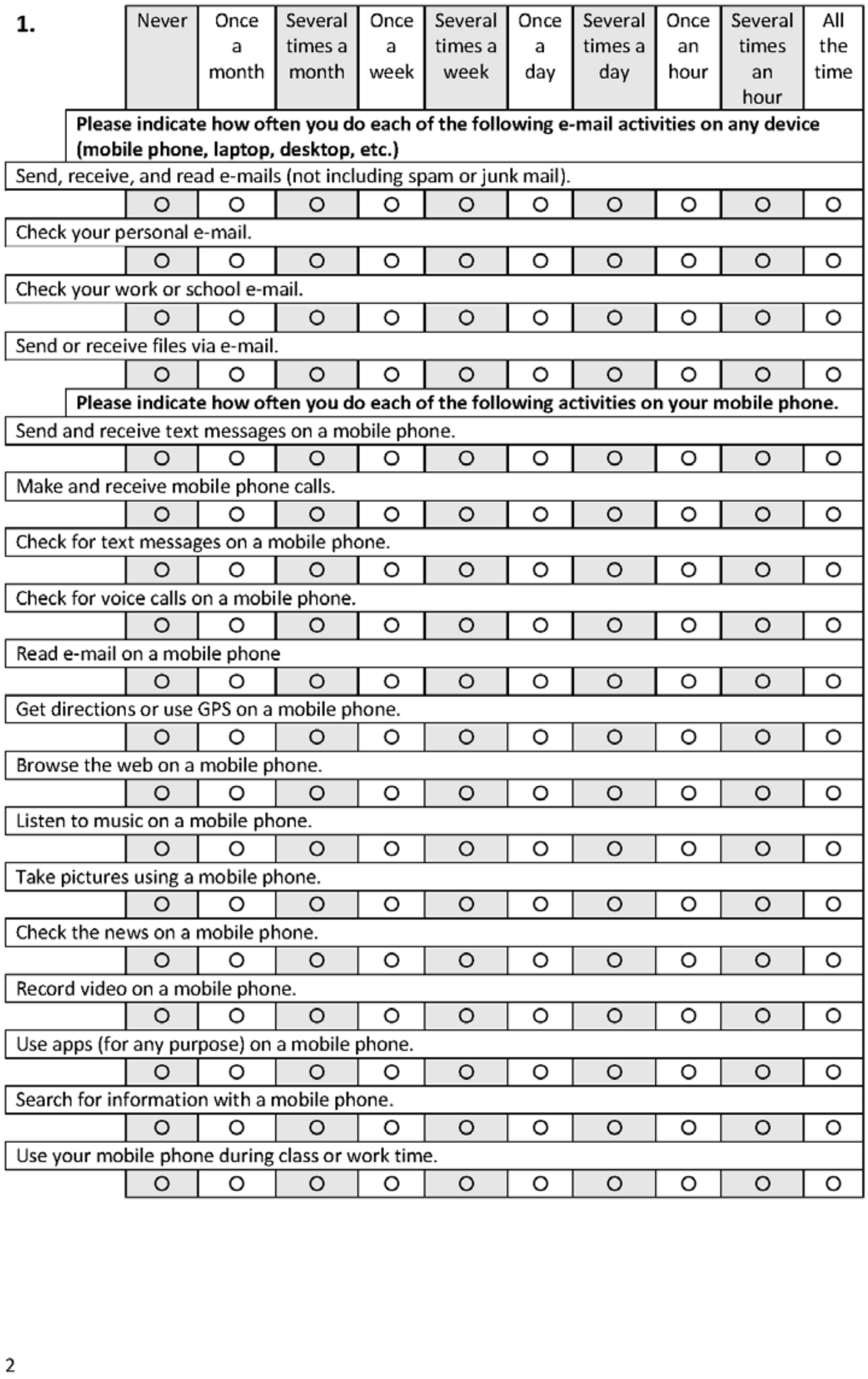

1.	Never	Once a month	Several times a month	Once a week	Several times a week	Once a day	Several times a day	Once an hour	Several times an hour	All the time
Please indicate how often you do each of the following e-mail activities on any device (mobile phone, laptop, desktop, etc.)										
Send, receive, and read e-mails (not including spam or junk mail).	○	○	○	○	○	○	○	○	○	○
Check your personal e-mail.	○	○	○	○	○	○	○	○	○	○
Check your work or school e-mail.	○	○	○	○	○	○	○	○	○	○
Send or receive files via e-mail.	○	○	○	○	○	○	○	○	○	○
Please indicate how often you do each of the following activities on your mobile phone.										
Send and receive text messages on a mobile phone.	○	○	○	○	○	○	○	○	○	○
Make and receive mobile phone calls.	○	○	○	○	○	○	○	○	○	○
Check for text messages on a mobile phone.	○	○	○	○	○	○	○	○	○	○
Check for voice calls on a mobile phone.	○	○	○	○	○	○	○	○	○	○
Read e-mail on a mobile phone	○	○	○	○	○	○	○	○	○	○
Get directions or use GPS on a mobile phone.	○	○	○	○	○	○	○	○	○	○
Browse the web on a mobile phone.	○	○	○	○	○	○	○	○	○	○
Listen to music on a mobile phone.	○	○	○	○	○	○	○	○	○	○
Take pictures using a mobile phone.	○	○	○	○	○	○	○	○	○	○
Check the news on a mobile phone.	○	○	○	○	○	○	○	○	○	○
Record video on a mobile phone.	○	○	○	○	○	○	○	○	○	○
Use apps (for any purpose) on a mobile phone.	○	○	○	○	○	○	○	○	○	○
Search for information with a mobile phone.	○	○	○	○	○	○	○	○	○	○
Use your mobile phone during class or work time.	○	○	○	○	○	○	○	○	○	○

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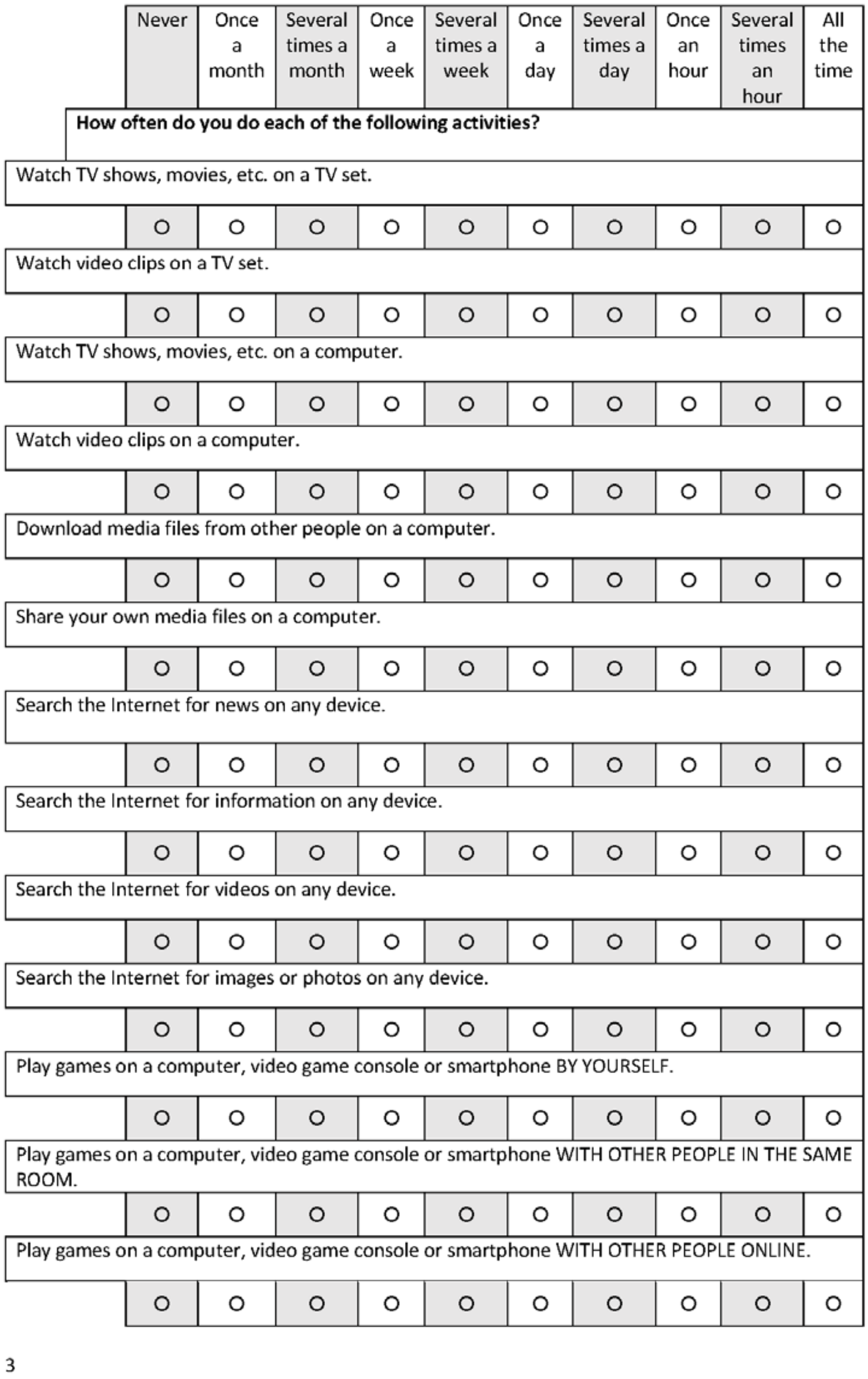


How often do you do each of the following activities?	Never	Once a month	Several times a month	Once a week	Several times a week	Once a day	Several times a day	Once an hour	Several times an hour	All the time
Watch TV shows, movies, etc. on a TV set.	○	○	○	○	○	○	○	○	○	○
Watch video clips on a TV set.	○	○	○	○	○	○	○	○	○	○
Watch TV shows, movies, etc. on a computer.	○	○	○	○	○	○	○	○	○	○
Watch video clips on a computer.	○	○	○	○	○	○	○	○	○	○
Download media files from other people on a computer.	○	○	○	○	○	○	○	○	○	○
Share your own media files on a computer.	○	○	○	○	○	○	○	○	○	○
Search the Internet for news on any device.	○	○	○	○	○	○	○	○	○	○
Search the Internet for information on any device.	○	○	○	○	○	○	○	○	○	○
Search the Internet for videos on any device.	○	○	○	○	○	○	○	○	○	○
Search the Internet for images or photos on any device.	○	○	○	○	○	○	○	○	○	○
Play games on a computer, video game console or smartphone BY YOURSELF.	○	○	○	○	○	○	○	○	○	○
Play games on a computer, video game console or smartphone WITH OTHER PEOPLE IN THE SAME ROOM.	○	○	○	○	○	○	○	○	○	○
Play games on a computer, video game console or smartphone WITH OTHER PEOPLE ONLINE.	○	○	○	○	○	○	○	○	○	○

3

	Never	Once a month	Several times a month	Once a week	Several times a week	Once a day	Several times a day	Once an hour	Several times an hour	All the time
If you have a social media account, continue with the next 9 items; if you do not, please move onto question 11 “do you regularly use a smartphone” on the following page.										
How often do you do each of the following activities on social networking sites (e.g., facebook)?										
Check your Facebook page or other social networks.	○	○	○	○	○	○	○	○	○	○
Check social media from your smartphone.	○	○	○	○	○	○	○	○	○	○
Check social media at work or school.	○	○	○	○	○	○	○	○	○	○
Post status updates.	○	○	○	○	○	○	○	○	○	○
Post photos.	○	○	○	○	○	○	○	○	○	○
Browse profiles and photos.	○	○	○	○	○	○	○	○	○	○
Read postings	○	○	○	○	○	○	○	○	○	○
Comment on postings, status updates, photos, etc.	○	○	○	○	○	○	○	○	○	○
Click “Like” to a posting, photo, etc.	○	○	○	○	○	○	○	○	○	○

2. Do you regularly use a smartphone? (please circle)

Yes / No

3. Please estimate the amount of time that you think you spent on your smartphone yesterday.

_____________ Hours _________ Minutes

To answer the following two questions, you are required to have an active screen timing application on your smartphone.

For apple devices this is called "Screen time". It is accessed through Settings\Screen Time. This will come up with a daily average from the past week. Tap on "See all activity" and then on the bar in the graph that corresponds to yesterday, you will be able to see the amount of screen time from yesterday and, when you scroll down the page, the number of times you picked up your phone – under the "Pick-Ups" heading.

For android users this is called "Digital Wellbeing". If you open your phone's Settings application and tap on "Digital Wellbeing and parental controls", then under "Your digital wellbeing tools" tap "Show your data". Click on "Dashboard" (in more recent versions of Android just tap on the current reading for today). This will bring up a chart of your recent use. Then click on the bar in the chart corresponding with yesterday's use. You will be able to see the total amount of screen time and, when you scroll down, the number of device "unlocks" that your phone had yesterday.

4. Are you able to access this screen time data on your smartphone? (Screen time on Apple devices, or digital wellbeing on Android devices.) Please Circle:

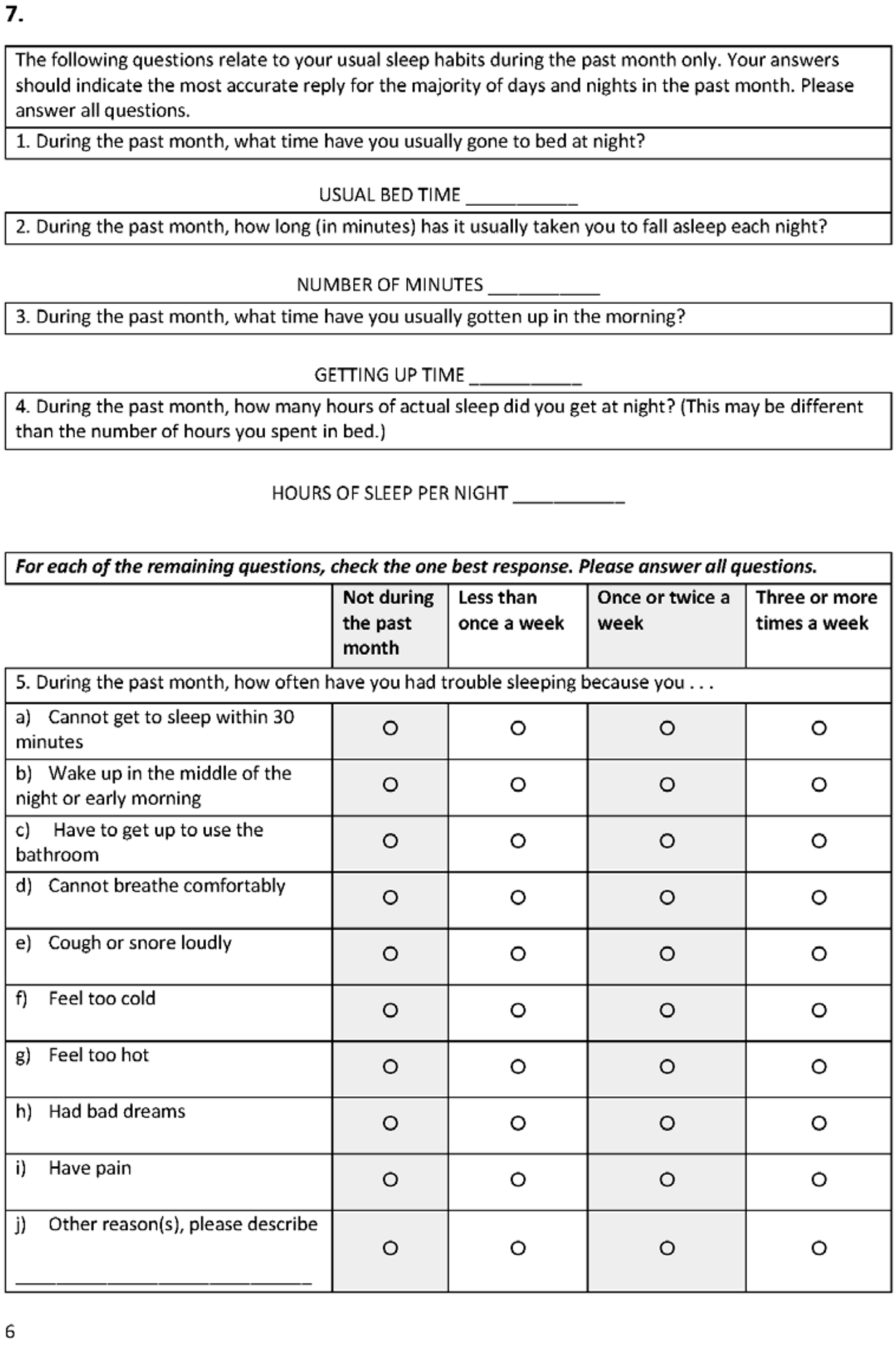
Yes / No

5. If you answered yes to the above question, what was your actual screen time recorded from yesterday?

___________Hours __________ Minutes

6. How many pick-ups / unlocks were recorded from yesterday?

_______________ Pickups (apple) / unlocks (android)



7.

The following questions relate to your usual sleep habits during the past month only. Your answers should indicate the most accurate reply for the majority of days and nights in the past month. Please answer all questions.

1. During the past month, what time have you usually gone to bed at night?

USUAL BED TIME ___________

2. During the past month, how long (in minutes) has it usually taken you to fall asleep each night?

NUMBER OF MINUTES ___________

3. During the past month, what time have you usually gotten up in the morning?

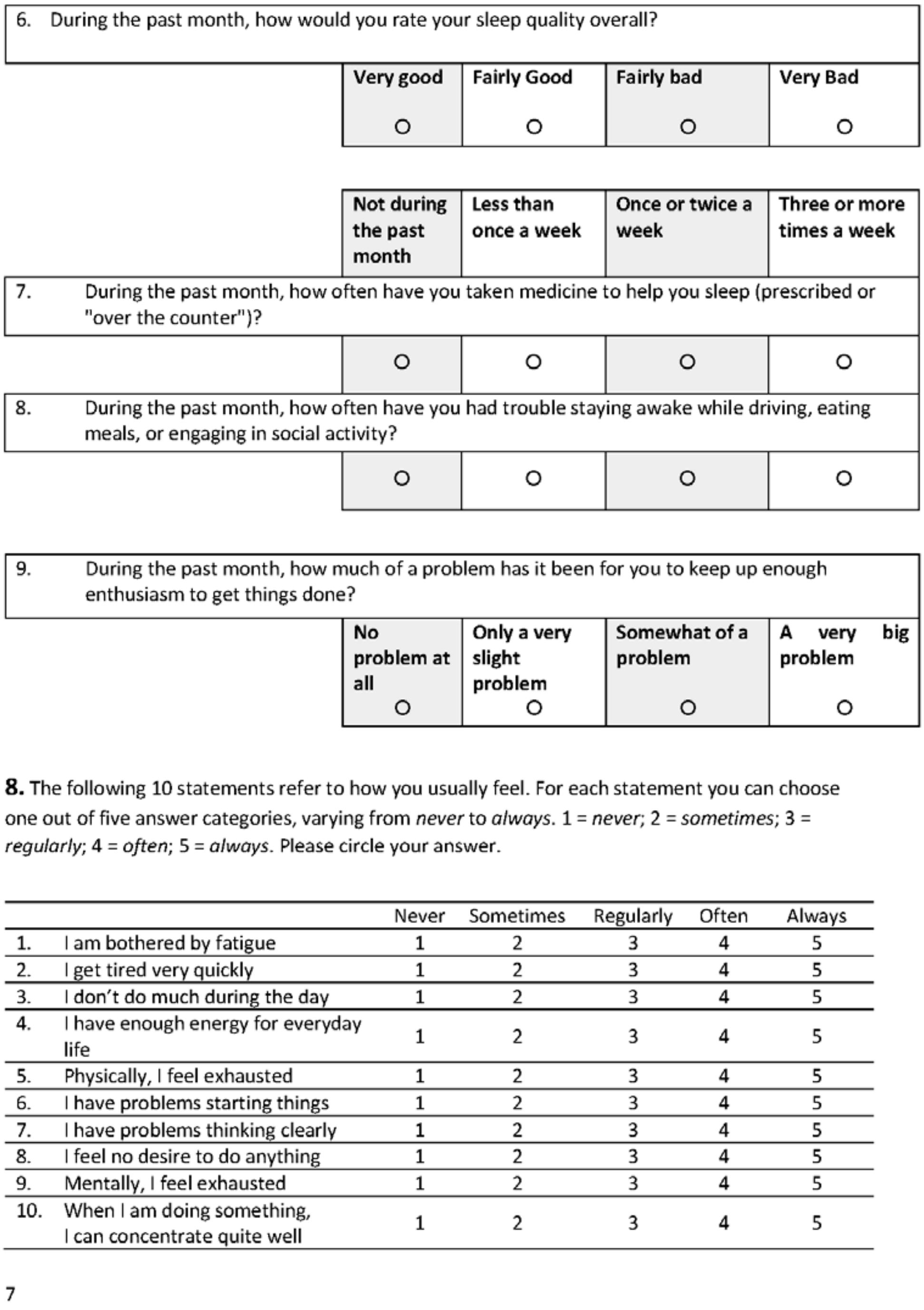
GETTING UP TIME ___________

4. During the past month, how many hours of actual sleep did you get at night? (This may be different than the number of hours you spent in bed.)

HOURS OF SLEEP PER NIGHT ___________

For each of the remaining questions, check the one best response. Please answer all questions.

	Not during the past month	**Less than once a week**	**Once or twice a week**	**Three or more times a week**
5. During the past month, how often have you had trouble sleeping because you . . .				
a) Cannot get to sleep within 30 minutes	○	○	○	○
b) Wake up in the middle of the night or early morning	○	○	○	○
c) Have to get up to use the bathroom	○	○	○	○
d) Cannot breathe comfortably	○	○	○	○
e) Cough or snore loudly	○	○	○	○
f) Feel too cold	○	○	○	○
g) Feel too hot	○	○	○	○
h) Had bad dreams	○	○	○	○
i) Have pain	○	○	○	○
j) Other reason(s), please describe ______________________________	○	○	○	○



6. During the past month, how would you rate your sleep quality overall?

Very good	Fairly Good	Fairly bad	Very Bad
○	○	○	○

	Not during the past month	Less than once a week	Once or twice a week	Three or more times a week
7. During the past month, how often have you taken medicine to help you sleep (prescribed or "over the counter")?	○	○	○	○
8. During the past month, how often have you had trouble staying awake while driving, eating meals, or engaging in social activity?	○	○	○	○

9. During the past month, how much of a problem has it been for you to keep up enough enthusiasm to get things done?

No problem at all	Only a very slight problem	Somewhat of a problem	A very big problem
○	○	○	○

8. The following 10 statements refer to how you usually feel. For each statement you can choose one out of five answer categories, varying from *never* to *always*. 1 = *never*; 2 = *sometimes*; 3 = *regularly*; 4 = *often*; 5 = *always*. Please circle your answer.

		Never	Sometimes	Regularly	Often	Always
1.	I am bothered by fatigue	1	2	3	4	5
2.	I get tired very quickly	1	2	3	4	5
3.	I don't do much during the day	1	2	3	4	5
4.	I have enough energy for everyday life	1	2	3	4	5
5.	Physically, I feel exhausted	1	2	3	4	5
6.	I have problems starting things	1	2	3	4	5
7.	I have problems thinking clearly	1	2	3	4	5
8.	I feel no desire to do anything	1	2	3	4	5
9.	Mentally, I feel exhausted	1	2	3	4	5
10.	When I am doing something, I can concentrate quite well	1	2	3	4	5

9. Have you continued to use the EMU diaries since completing the study?

Yes / No

10. Please briefly outline what you found the most helpful about the intervention/study.

11. Please briefly outline what was least helpful about the intervention/study.

12. If there are any improvements that you think could be made to the intervention/study, please list below.

13. Do you have any further feedback that would be helpful for the researchers to know? Please detail.

14.

Self-Generated Identification Code (SGIC)

A Self-Generated Identification Code (SGIC) protects your identity and ensures that your data remains anonymous. The SGIC will be used throughout the study so that your responses can be matched together whilst protecting your anonymity.

In order to create your SGIC for the current study, think of answers to the following.

Spaces 1 & 2: **Your birth month** (e.g. For April, you would write 0/4)
Spaces 3 & 4: The first two letters of your **first middle name** (e.g. for Maria, you would write M/A. If you don't have a middle name write X/X).
Space 5: The **first letter** of City/Town you were born in (e.g. for Tauranga, you would write /T/)
The example above would create an SGIC as follows 0 / 4 / M / A / T
Note. If any of the questions aren't applicable to you, fill in the blank spaces with "X"

Enter your SGIC

____ /____ /____ /____ /____
1 2 3 4 5

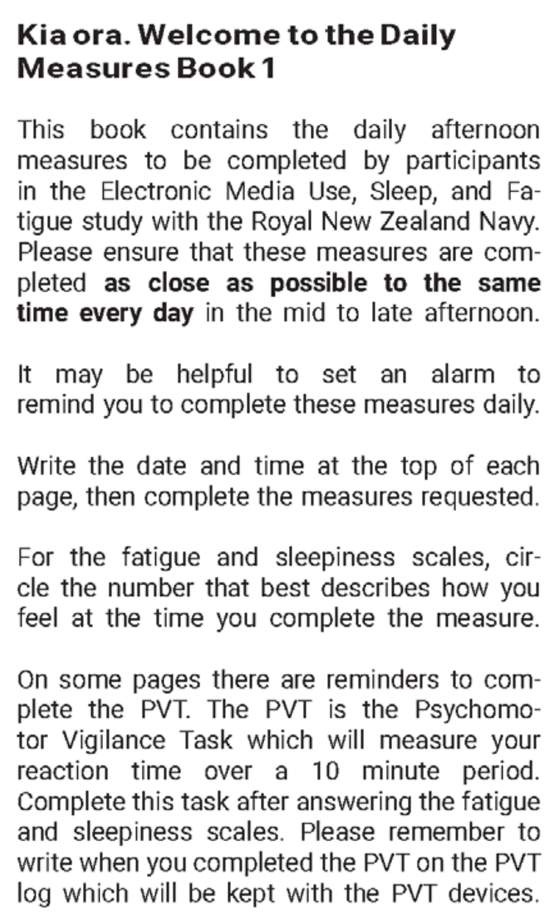
This concludes the follow-up survey for the electronic media, sleep, and fatigue study. Thank you for your participation in the study. The results of this study will be used to inform the best current practice for the RNZN and contribute to ongoing research into the relationship between electronic media, sleep, and fatigue.

The research team will be in contact with you via email or via your preferred contact details, once the analysis of data is complete, to see whether you would like access to a summary of your individual results.

Appendix M

Daily Measures Books Excerpt

This Appendix contains an excerpt from the daily measures books that participants carried with them during the single case experimental design study for assessing fatigue and sleepiness daily throughout the six weeks of their participation in the MBD component. Three books were given to each participant; one per phase. The content of the daily measures were equivalent, though covers were different for each phase to quickly differentiate them.



Kia ora. Welcome to the Daily Measures Book 1

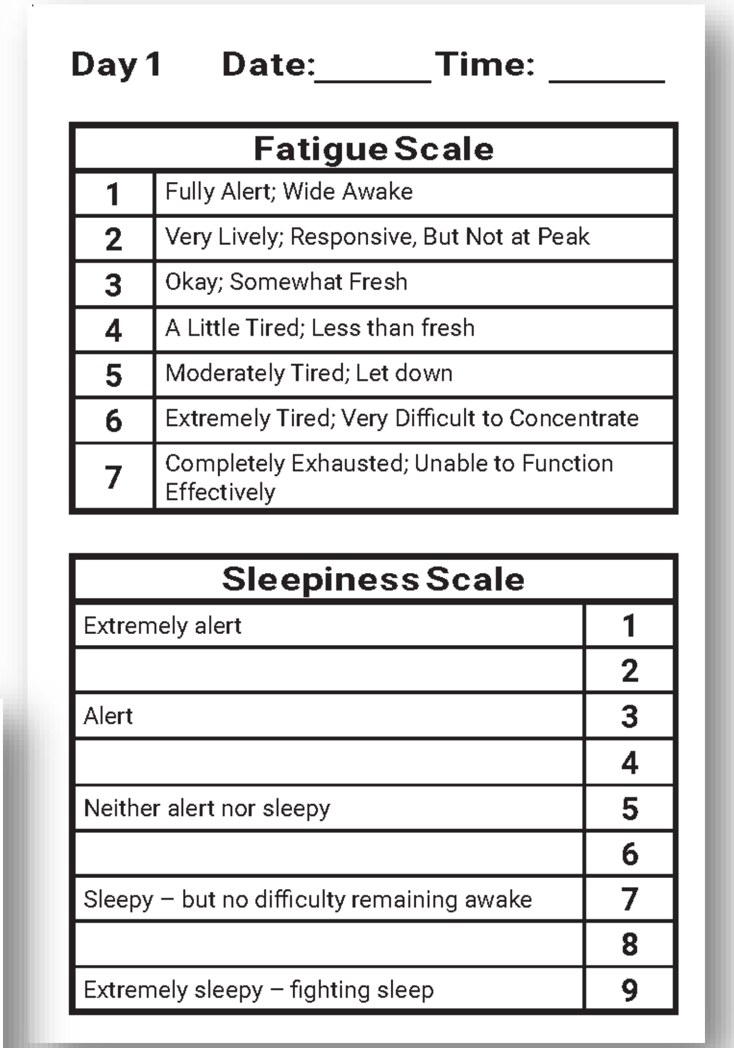
This book contains the daily afternoon measures to be completed by participants in the Electronic Media Use, Sleep, and Fatigue study with the Royal New Zealand Navy. Please ensure that these measures are completed **as close as possible to the same time every day** in the mid to late afternoon.

It may be helpful to set an alarm to remind you to complete these measures daily.

Write the date and time at the top of each page, then complete the measures requested.

For the fatigue and sleepiness scales, circle the number that best describes how you feel at the time you complete the measure.

On some pages there are reminders to complete the PVT. The PVT is the Psychomotor Vigilance Task which will measure your reaction time over a 10 minute period. Complete this task after answering the fatigue and sleepiness scales. Please remember to write when you completed the PVT on the PVT log which will be kept with the PVT devices.



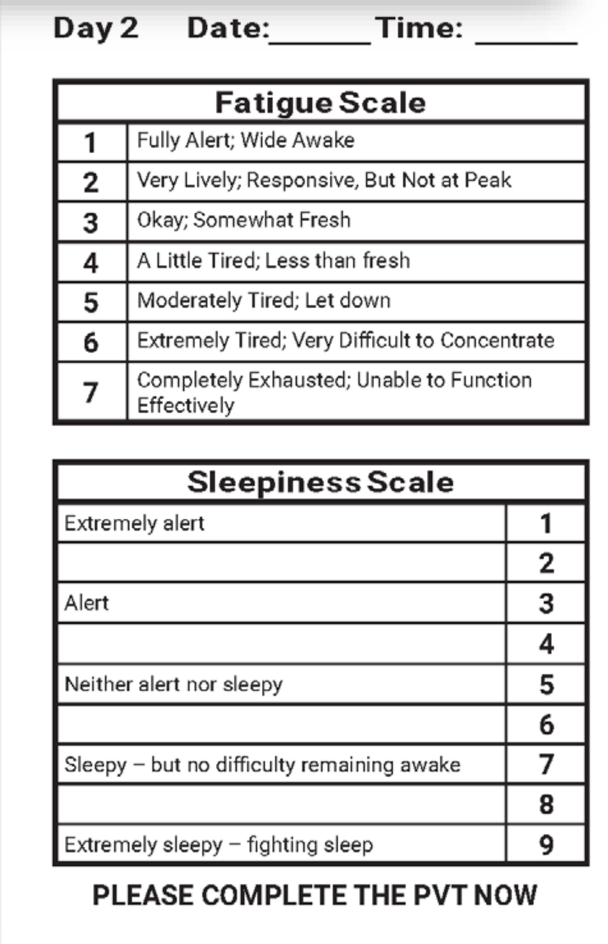
Day 1 Date:______Time: ______

Fatigue Scale

1	Fully Alert; Wide Awake
2	Very Lively; Responsive, But Not at Peak
3	Okay; Somewhat Fresh
4	A Little Tired; Less than fresh
5	Moderately Tired; Let down
6	Extremely Tired; Very Difficult to Concentrate
7	Completely Exhausted; Unable to Function Effectively

Sleepiness Scale

Extremely alert	1
	2
Alert	3
	4
Neither alert nor sleepy	5
	6
Sleepy – but no difficulty remaining awake	7
	8
Extremely sleepy – fighting sleep	9



Day 2 Date:______Time: ______

Fatigue Scale

1	Fully Alert; Wide Awake
2	Very Lively; Responsive, But Not at Peak
3	Okay; Somewhat Fresh
4	A Little Tired; Less than fresh
5	Moderately Tired; Let down
6	Extremely Tired; Very Difficult to Concentrate
7	Completely Exhausted; Unable to Function Effectively

Sleepiness Scale

Extremely alert	1
	2
Alert	3
	4
Neither alert nor sleepy	5
	6
Sleepy – but no difficulty remaining awake	7
	8
Extremely sleepy – fighting sleep	9

PLEASE COMPLETE THE PVT NOW

Appendix N

Sleep Duty Electronic Media Use Logbook

EMU

Sleep / Duty / Electronic Media

LOGBOOK

This Appendix contains an excerpt of the Sleep / Duty / Electronic Media Use Logbook that participants were instructed to keep in their quarters for documenting time spent on each activity during each day. It also contained the morning measurement and a place to document any inbuilt screen timing application data. Each page was essentially equivalent apart from the introduction page. Time logs were designed for 1 hour per cm. Transposition into this appendix has likely distorted this proportion

Please label this book with your SGIC. This should be the same as the one you entered at the end of the screening survey.

SGIC Instructions

Spaces 1 & 2: Your birth month (e.g. For April, you would write 0 4)

Spaces 3 & 4: The first two letters of your first middle name
(e.g. for Maria, you would write M A. If you don't have a middle name write X X).

Space 5: The first letter of City/Town you were born in (e.g. for Tauranga, you would write T)

Please write your SGIC here

_____ _____ _____ _____ _____

This book contains Sleep/Duty/Electronic media logs for the entirety of the study. This book is to be kept close to sleeping area/bed and filled out every morning upon waking and evening when going to sleep. Please remember the times that you start and finish work and fill out the duty log with this information. If you have trouble remembering your exact working schedule, then take notes in the margins of your Daily Measures Book and copy these into the daily sleep and duty diary at the end of the day. It isn't expected that you are able to remember every single time you use electronic media for the purposes of this book. Just use your best estimate.

Instructions

The Morning Questionnaire

Give yourself a few minutes after waking up before completing these ratings. Your feelings immediately after the alarm goes off may be a little skewed. Give yourself time to fully wake up, then complete the ratings. Circle the answer that best describes how you feel you slept last night, and estimate the total number of hours that you slept. Don't forget to mark your wake-up time on the visual log, and signal your wake up time using the event marker on the actigraph too.

To answer the next two questions, you need to have your Screen-Time / Digital Wellbeing application running on your phone. This can be usually accessed through the settings menu. Often this gives you a weekly average by default. Each morning, record the screen time and pickups/ unlocks that your phone recorded on the previous day. The instructions for finding this are different for each phone. Try and work it out with the research representative during orientation if possible so that you will know where to go to find this information. Every morning, write down the number of hours and minutes that the screen Time / Digital Wellbeing app recorded for yesterday. Write down the number of pickups and unlocks recorded also.

The Sleep/Duty/Electronic Media Use Logs

These are provided in the form of timelines. There is a 24H clock going from Midnight to Midnight along the top of these timelines.

On the sleep timeline, indicate the start of any sleep period longer than 10 minutes with a line labelled B (for Begin) and the end of these sleep periods with an arrow labelled F (for Finish). Use a horizontal line to signal any time that the actigraph was not worn.

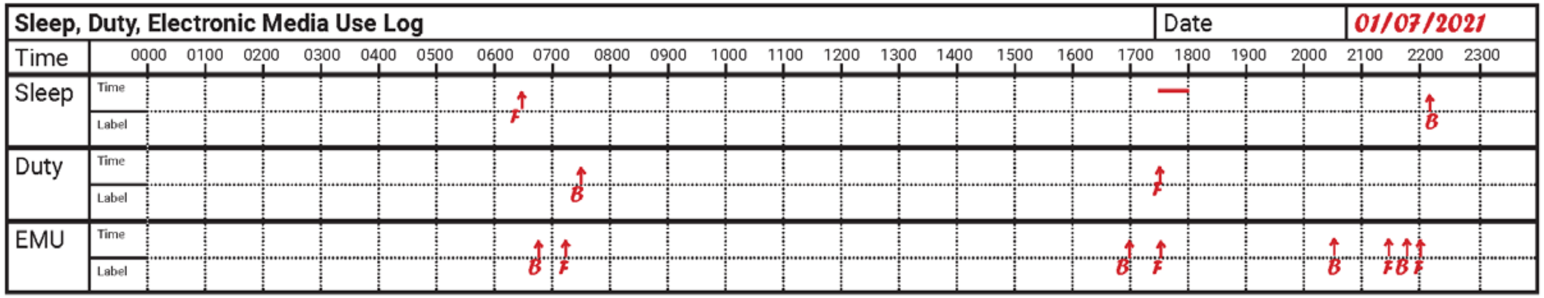
On the duty timeline. indicate the beginning of any periods of work with an arrow labelled B, and the end of this period of work with an arrow labelled F on the duty diaries.

On the EMU timeline, similarly to the others, Indicate the start of any electronic media use times longer than 10 minutes with an arrow labelled B, and the finish time of any electronic media use with an arrow labelled F.

On the next page is an example of how to complete these pages. You can see that the person who made this example woke up after a fairly good sleep at 0630, they had slept for 6 hours and 30 minutes. They used their phone for 2 hours 20 minutes the day before and had 42 unlocks. They decided to go to sleep at 2215. They took their actigraph watch off between 1730 and 1800. They began their work duty at 0730 and finished their work duty at 1700. They were using electronic media between 0645 and 0715, then again between 1700 and 1730, and between 2030 and 2130, then briefly from 2145 to 2200.

DEMO

Morning Questionniare				Date	01/07/2021	Time	0640
How would you rate the quality of your previous night's sleep? (Please circle)				Estimate how many hours/minutes of sleep you got last night? (This may be different than the amount of time you spent in bed)			
Very good	[✓ Fairly good]	Fairly bad	Very bad	6	Hours	30	Minutes
Open your Screen-Time / Digital Wellbeing app, how many hours / minutes did you use your phone for yesterday?				How many pickups / unlocks were recorded?			
2	Hours	20	Minutes	42		Pickups / Unlocks	



Sleep, Duty, Electronic Media Use Log Date 01/07/2021

Instructions

Complete the Morning Questionnaire every morning soon after waking. Mark your wake up time on the log also. Remember to use the event marker on the actigraph to signal wake time too.

Before going to bed mark in the log all periods of Sleep, Duty, or Electronic Media Use (EMU) of more than 10 minutes duration from the day by placing a line in the time rows for Sleep, Duty, and EMU. In the "label" row below each time mark write either "B" for begin or "F" for finish.

Just before going to sleep, mark the time when you start trying to go to sleep in the log as a "begin" time in the sleep row. Remember to use the event marker on your actigraph to signal this time too.

If you had removed your actigraph during the day, draw a horizontal line on the sleep log "time" row to cover approximately the time that the actigraph was not being worn.

Day 1

Morning Questionniare				Date		Time	
How would you rate the quality of your previous night's sleep? (Please circle)				Estimate how many hours/minutes of sleep you got last night? (This may be different than the amount of time you spent in bed)			
Very good	Fairly good	Fairly bad	Very bad		Hours		Minutes
Open your Screen-Time / Digital Wellbeing app, how many hours / minutes did you use your phone for yesterday?				How many pickups / unlocks were recorded?			
	Hours		Minutes			Pickups / Unlocks	

Sleep, Duty, Electronic Media Use Log																				Date					
Time		0000	0100	0200	0300	0400	0500	0600	0700	0800	0900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300
Sleep	Time																								
	Label																								
Duty	Time																								
	Label																								
EMU	Time																								
	Label																								

Instructions

Complete the Morning Questionnaire every morning soon after waking. Mark your wake up time on the log also. Remember to use the event marker on the actigraph to signal wake time too.

Before going to bed mark in the log all periods of Sleep, Duty, or Electronic Media Use (EMU) of more than 10 minutes duration from the day by placing a line in the time rows for Sleep, Duty, and EMU. In the "label" row below each time mark write either "B" for begin or "F" for finish.

Just before going to sleep, mark the time when you start trying to go to sleep in the log as a "begin" time in the sleep row. Remember to use the event marker on your actigraph to signal this time too.

If you had removed your actigraph during the day, draw a horizontal line on the sleep log "time" row to cover approximately the time that the actigraph was not being worn.

Appendix O

Psychomotor Vigilance Task Log

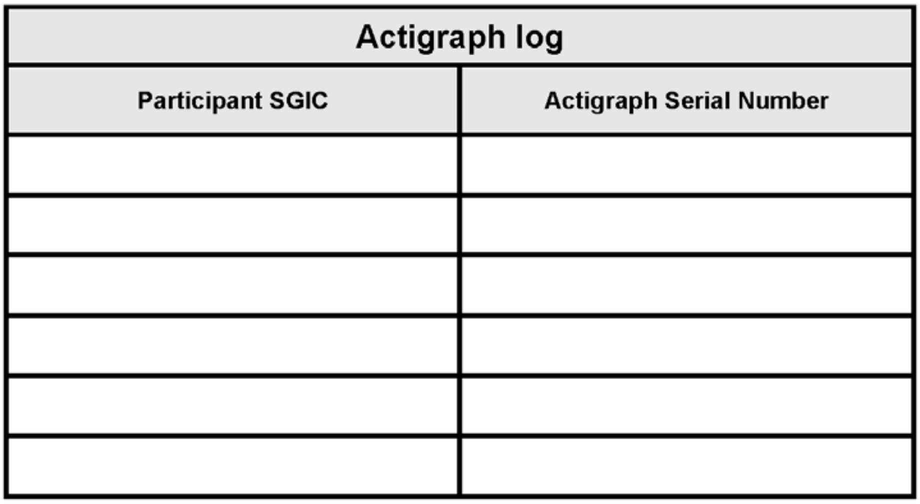
This Appendix contains an excerpt of the log for identifying the participant's self-generated identification code to the date and time of PVT administration for data parsing.

PVT log			
Date	Start Time	PVT device number (1 or 2)	Participant SGIC

Appendix P

Actigraph Assignment Log

This Appendix contains the log given to the research representative for identifying the participant's research code to their actigraph watch.

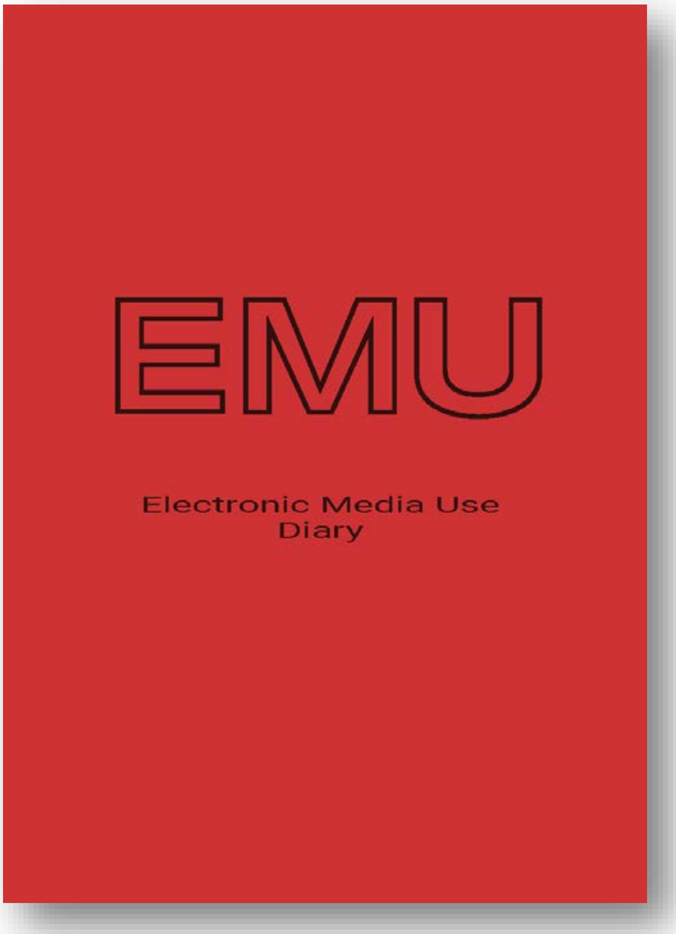


Actigraph log

Participant SGIC	Actigraph Serial Number

Appendix Q

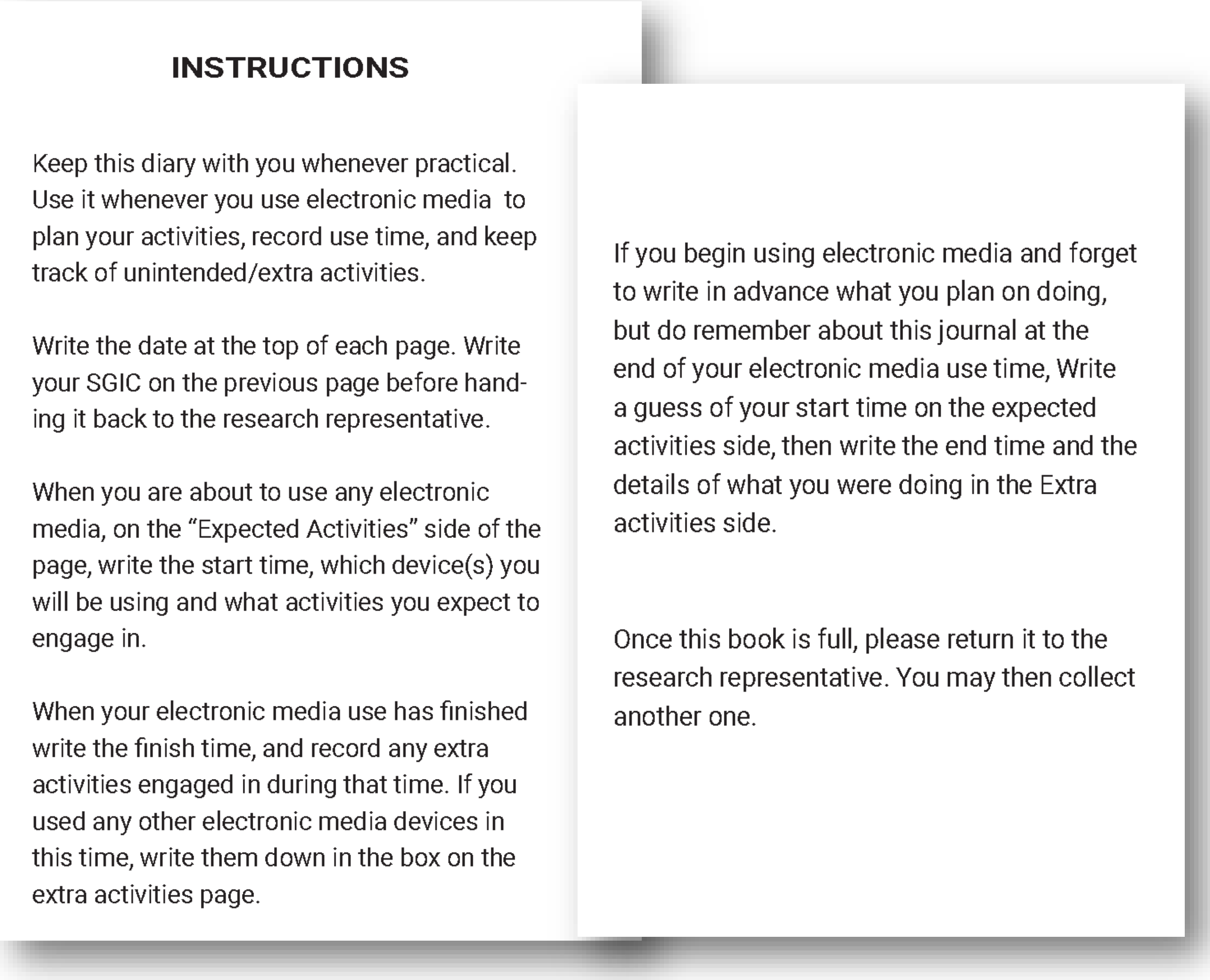
Electronic Media Use Diaries Excerpt



EMU

Electronic Media Use
Diary

This Appendix contains an excerpt of the EMU diaries that were introduced to participants at the beginning of the EMU-SRI.



INSTRUCTIONS

Keep this diary with you whenever practical. Use it whenever you use electronic media to plan your activities, record use time, and keep track of unintended/extra activities.

Write the date at the top of each page. Write your SGIC on the previous page before handing it back to the research representative.

When you are about to use any electronic media, on the “Expected Activities” side of the page, write the start time, which device(s) you will be using and what activities you expect to engage in.

When your electronic media use has finished write the finish time, and record any extra activities engaged in during that time. If you used any other electronic media devices in this time, write them down in the box on the extra activities page.

If you begin using electronic media and forget to write in advance what you plan on doing, but do remember about this journal at the end of your electronic media use time, Write a guess of your start time on the expected activities side, then write the end time and the details of what you were doing in the Extra activities side.

Once this book is full, please return it to the research representative. You may then collect another one.

Date:		**Expected Activities**
Start time		
Device(s)		
Start time		
Device(s)		
Start time		
Device(s)		
Start time		
Device(s)		
Start time		
Device(s)		
Start time		
Device(s)		
Start time		
Device(s)		
Start time		
Device(s)		
Start time		
Device(s)		

		Extra Activities
End time		
Device(s)		
End time		
Device(s)		
End time		
Device(s)		
End time		
Device(s)		
End time		
Device(s)		
End time		
Device(s)		
End time		
Device(s)		
End time		
Device(s)		
End time		
Device(s)		

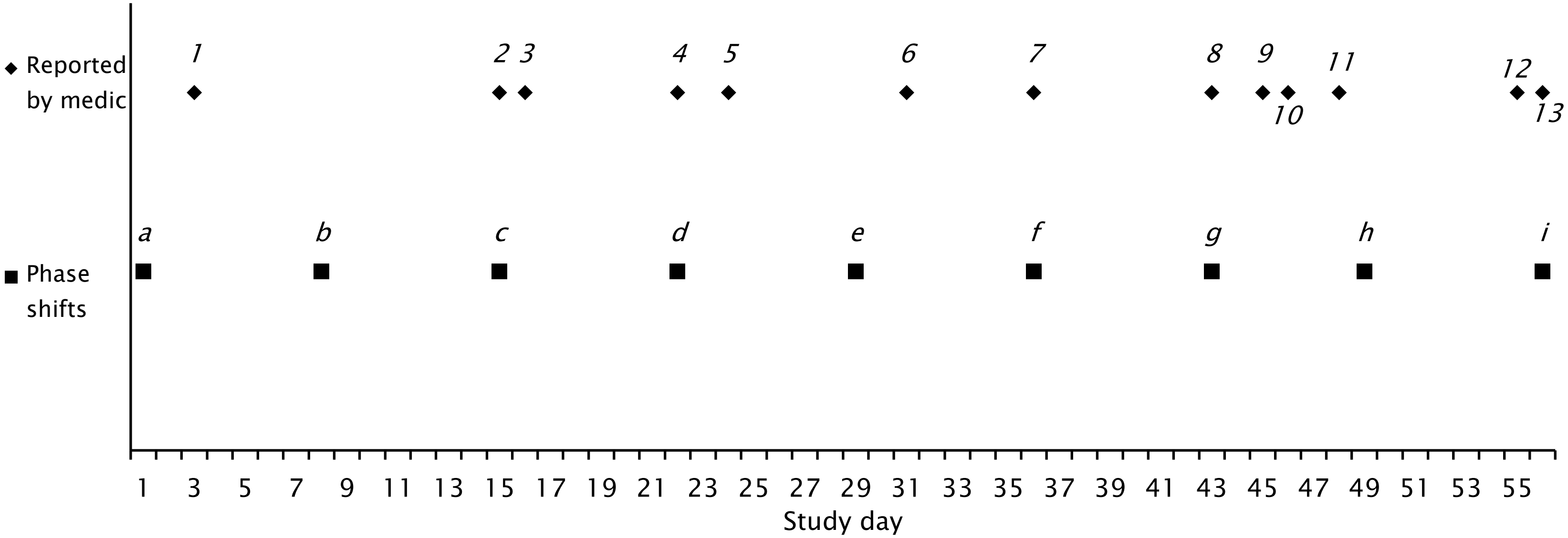
Appendix R

Study Events Reported by Research Representative and Study Phase Shifts

This Appendix contains Figure R1, a chart that documents the major events that occurred during the study with the RNZN. It also documents the phases of the study for each of the participants. It has been scaled to align with the timeseries charts presented in ***Appendices T through Y****. It was used to maintain awareness of events that occurred during the timeseries data analysis. It can be torn off from the publication for use in analysing timeseries charts.*

Figure R1

Major Study Events Reported by RR and Study Phase Shifts



Note. Events reported by RR: (1) Returned to land; (2) New sailing departed; (3) Left cell reception; (4) Arrived at new destination, sim cards issued; (5) Left cell reception; (6) "Cabin fever creeping in", Intervention session 4 for P3 and P4 postponed by one day; (7) Reached NZ cell reception; (8) Departed NZ, left cell reception; (9) Personal hardware recalled and returned later that day, clocks moved back one hour; (10) Clocks moved back one hour; (11) Personal hardware use restricted by location; (12) Personal hardware restrictions lifted, clocks moved forward 1 hour; (13) Clocks moved forward 1 hour. Study phase shifts: (a) P1&2 phase 1 began; (b) P3&4 phase 1 began; (c) P1&2 phase 2 began, P5&6 phase 1 began; (d) P3&4 phase 2 began; (e) P5&6 phase 2 began, P1&2 phase 3 began; (f) P3&4 phase 3 began; (g) P5&6 phase 3 began, P1&2 end of phase 3; (h) P3&4 end of phase 3; (i) P5&6 end of phase 3.

Participants 1 and 2. Participants 1 and 2 began the timeseries component on study day 1, 25 October 2021. They collected baseline measurement until they began phase two on study day 15, 8 November 2021. On this same day the ship left for a new sailing, and they had their first intervention session. Session 2 was on study day 17, Wednesday 10 November 2021; session 3 on study day 22, 15 November 2021; and finally, session 4 on study day 24, 17 November 2021.

Participants 3 and 4. Participants 3 and 4 began the timeseries component on study day 8, 1 November 2021. They collected baseline measurement until they began phase two. Halfway through baseline measurement the ship departed for the new sailing. They began phase 2 on study day 22, 15 November 2021. On this same day the ship arrived at the new destination, and they had their first intervention session. Session 2 was on study day 24, Wednesday 17 November 2021; session 3 on study day 29, 22 November 2021; and finally, session 4 was postponed by a day to study day 32, 25 November 2021.

Participants 5 and 6. Participants 5 and 6 began the timeseries component on study day 15, 8 November 2021, as the ship left for its new sailing. Halfway through baseline measurement the ship arrived at the new destination. They collected baseline measurement until they began phase two. They began phase 2 on study day 29, 22 November 2021. On this same day they had their first intervention session. Session 2 was on study day 31, Wednesday 24 November 2021; session 3 was on study day 36, 29 November 2021, this same day the ship returned to cellphone reception in Aotearoa. Session 4 was on study day 38, 1 December 2021.

Appendix S

Assessing Time of Day Influence on Time Sensitive Measures

This appendix considers the influence of time of day on the self-reported fatigue and sleepiness scores, and PVT RRT/minute slopes of participants in the Single Case Research Design study (Chapter 4)

Assessing Time of Day Influence on Time Sensitive Measures

Circadian phase influences subjective fatigue and sleepiness ratings, as well as PVT-assessed vigilance and fatigue (Gander et al., 2015, Balkin & Wesensten, 2011). Participants in Single Case Research Design study (Chapter 4 of this thesis) were instructed to record SPFS and KSS scores at as close to the same time every day for 6 weeks to test the influence of an intervention targeting EMU on subjective fatigue and sleepiness. They were also instructed to complete 10 minute PVTs as close to the same time of day thrice weekly. Some participants completed their measures at differing times from day to day. Therefore it was important to account for the hypothesised effect of time-of-day on sleepiness and fatigue which could be influencing both self-report fatigue and sleepiness scores and PVT performance. In particular, the decrement in performance observed from minute to minute over the course of a 10 minute PVT, which documents a measure of cognitive fatigue shows a marked effect of time of day (Balkin & Wesensten, 2011). This appendix documents the processes of assessing for the impact of time of day of these assessments on their scores, and also documents the process of correcting for time of day of PVT assessment on RRT vs minute slope scores.

Method

Full context of this study is documented in Chapter 4. Of relevance here; participants carried self-report measures books containing SPFS and KSS assessments for scoring subjective fatigue and sleepiness as close as possible to the same time every day for 6 weeks. Ten-minute PVTs were also completed thrice weekly during the study. PVT files were parsed and analysed through REACT software which analysed RRT vs minute slopes as a measure of the fatiguing effect of time on task on the PVTs. All scores were transcribed into an MS Excel workbook. Scatterplots were drawn up to map respective scores of each measure by time of day of measurement. Timeseries charts mapping time of day by study day were also drawn up to assess for any systemic changes in time of day that measures were reported over the course of the study for each participant. Charts were primarily explored visually (Tukey, 1977). For the PVTs, RRT vs minute slope scores showed in some cases clear curvilinear relationship, therefore binomial regression functions were calculated in MS Excel for each participant. This regression function captured an estimate of the variation in fatigue propensity based on time of day of PVT administration. These functions were then subtracted from each of the raw RRT vs minute slope scores based on the time of day of assessment to create a final chart for each participant: RRT vs minute slope corrected for time of day of assessment.

Results

Self Report Daily Measures

Figure S1 shows the scatterplots for the five participants graphing time of day against SPFS scores. Figure S2 shows scatterplots for the five participants graphing time of day against KSS scores. Figure S3 shows basic timeseries charts assessing whether there were any trends or any systemic changes over study days in variation in time of day that the self-report (daily) measures were taken.

The self-report scores obtained by participant P2 were the only ones that showed a small trend based on time of day: subjective sleepiness and fatigue scores increased as the time became later. In the linear model employed by MS Excel Time of day explained 37% of the variance in fatigue scores and 34% of changes in sleepiness scores for that participant. In all the others less than 10% of variance was explained by time of day. P5 completed all measures at the same time.

The charts in Figure S3 show that the only participant who had significant systematic changes to daily measures book measurement time was P3 who assessed their daily measures two hours later after day 18.

Figure S1

SPFS scores as a function of time of day for five participants

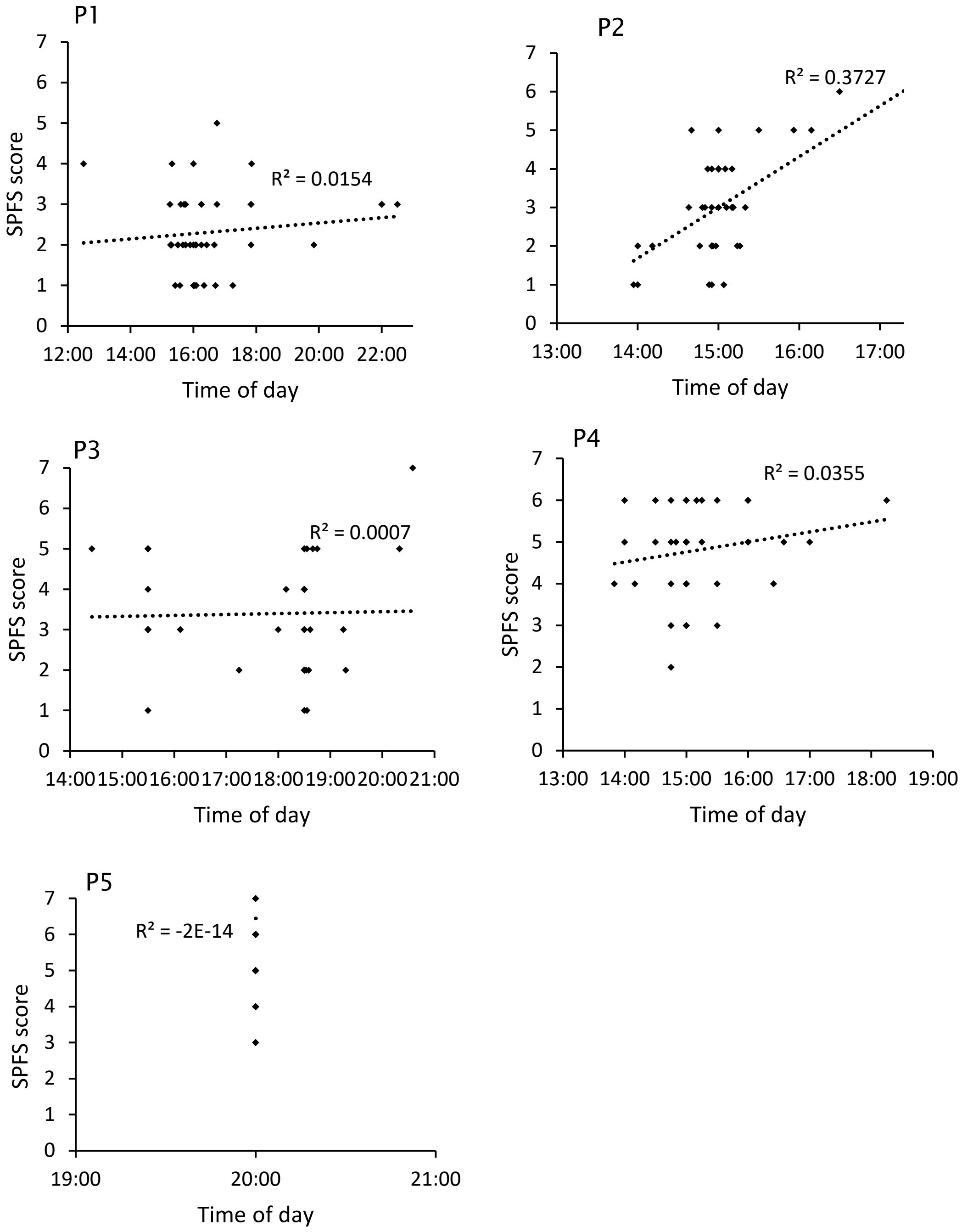


Figure S2

KSS scores as a function of time of day for five participants

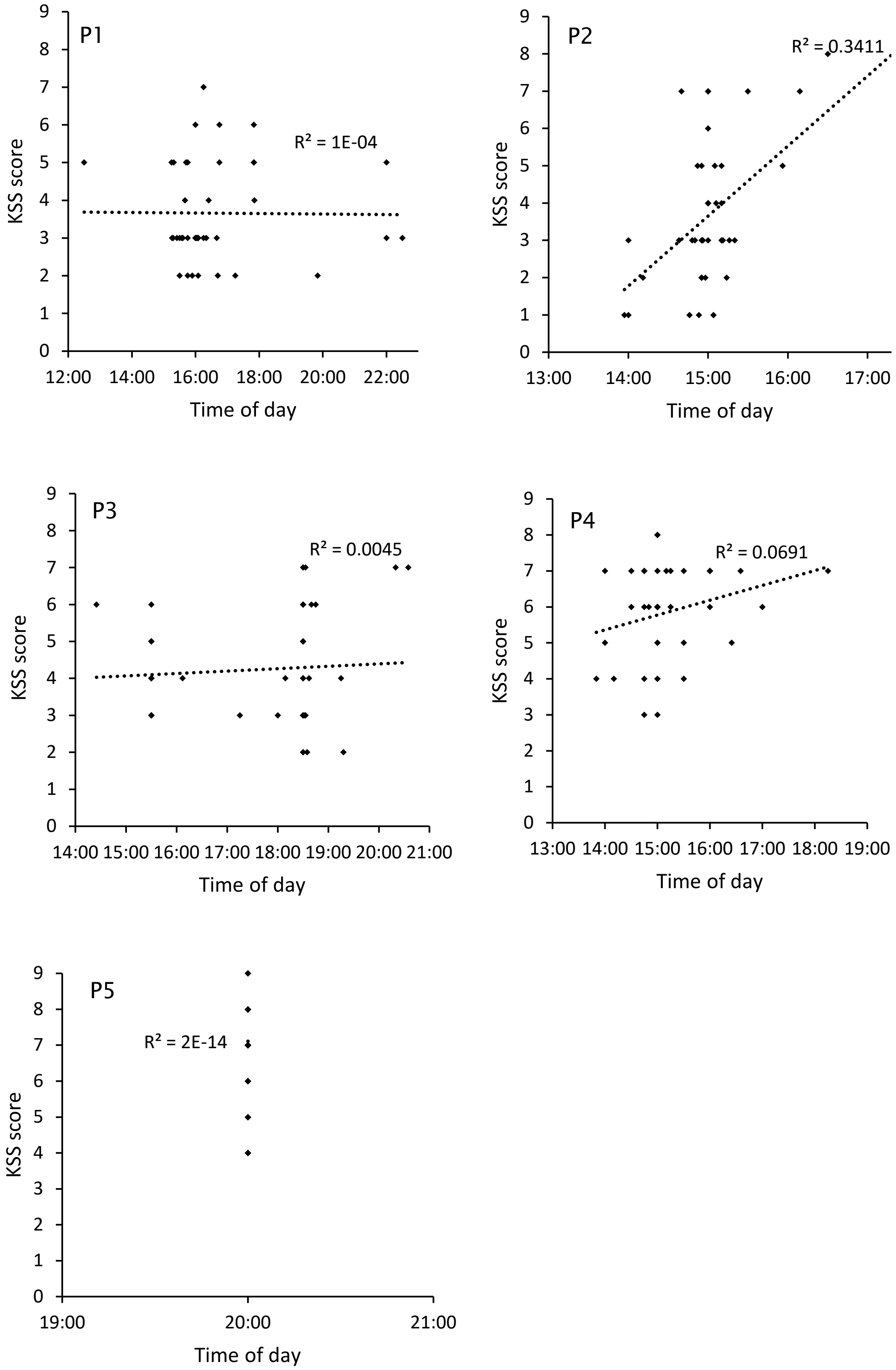
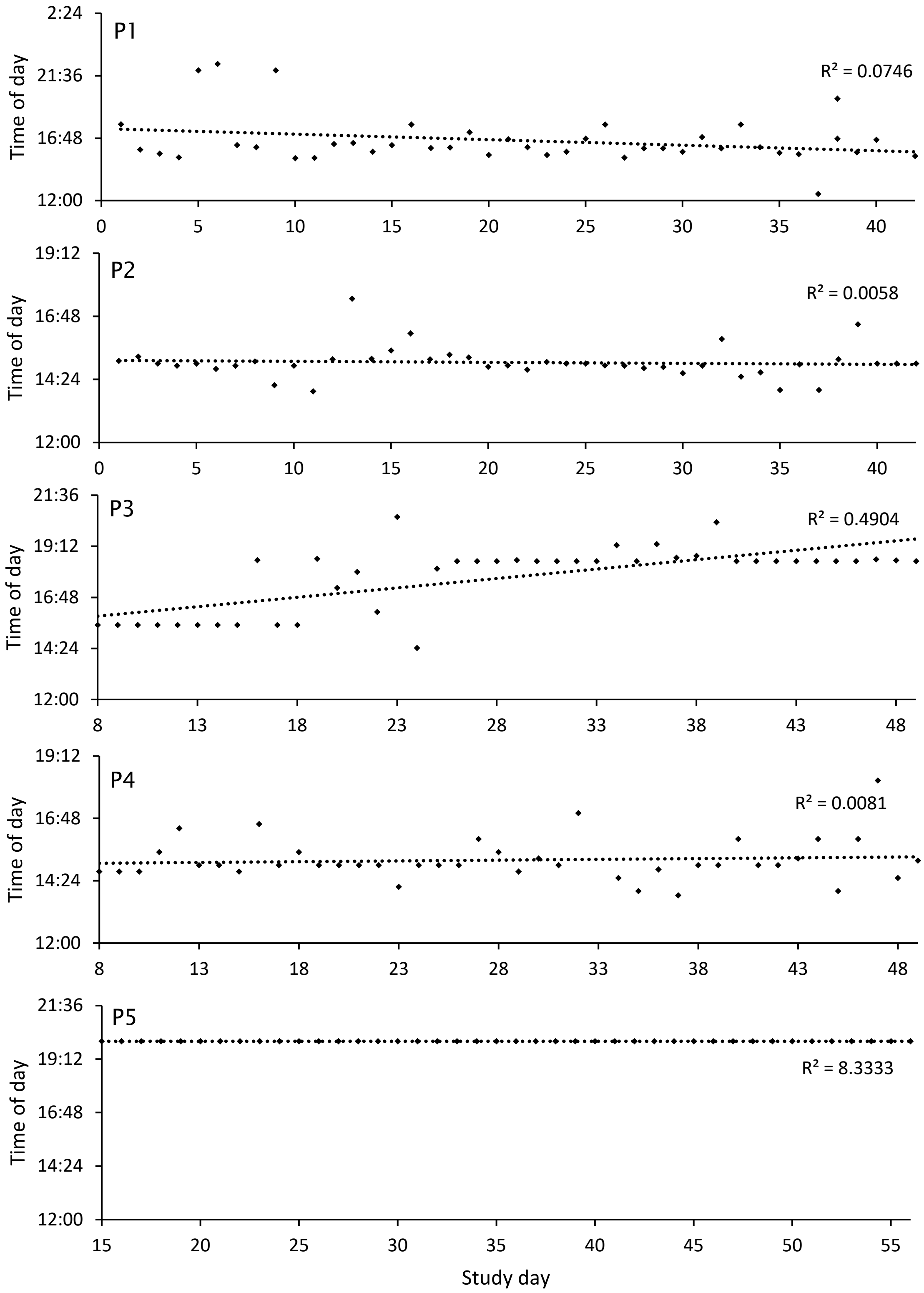


Figure S3

Time of day for SPFS and KSS measures as a function of study day



PVTs

Figure S4

PVT fatigue slopes (RRT vs minute slopes) as a function of time of day for 5 participants

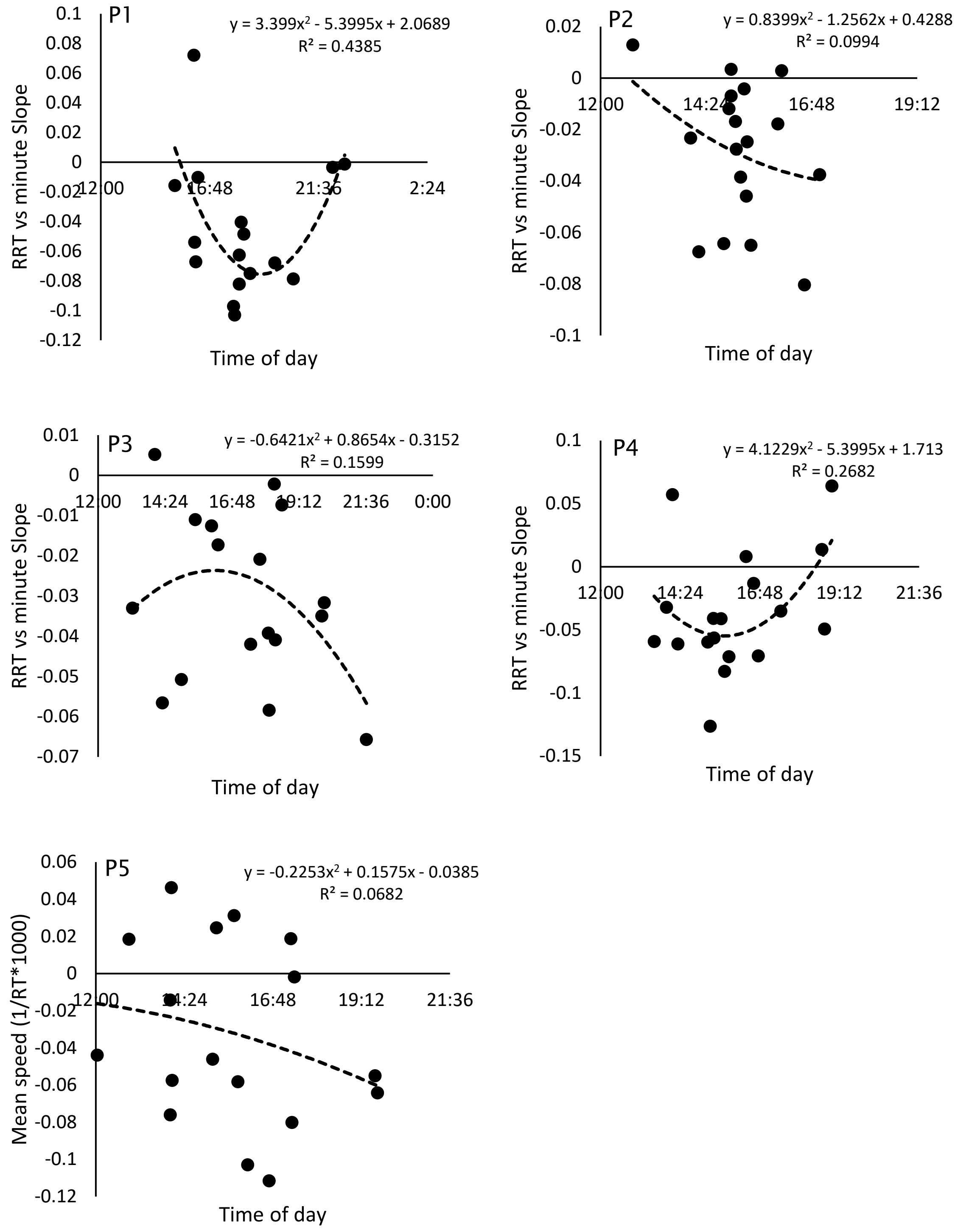
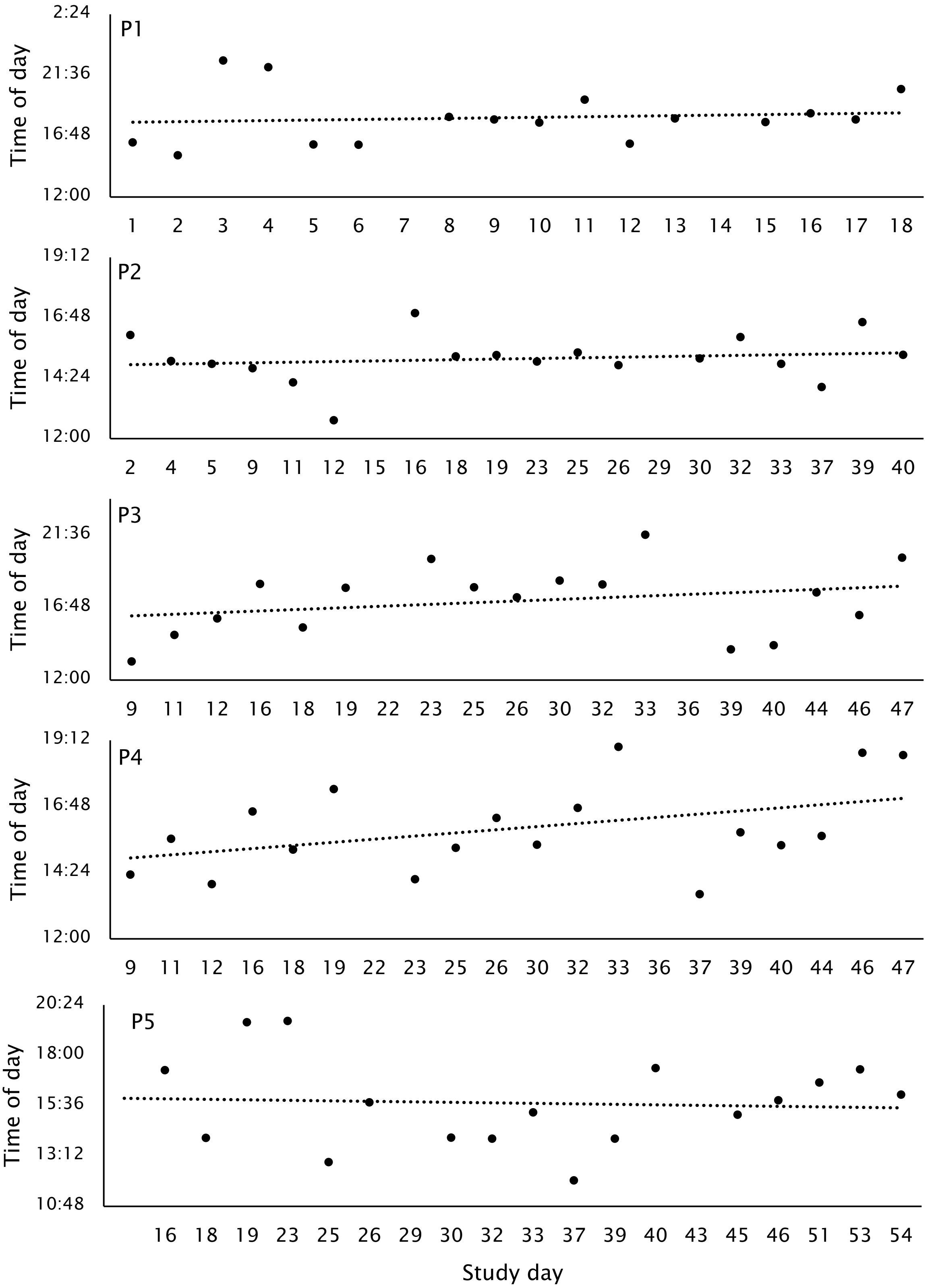


Figure S5

Time of Day of PVT Assessment vs. Study Day for P1–P5



Illustrative Instance: P1

To outline the rationale for the creation of the RRT vs minute slopes corrected for time of day, let us take the illustrative instance of participant 1's RRT vs minute slope scores. Figure S6 duplicates Figure T15 (See appendix T). We can see an increase in fatigue propensity evidenced by flat slopes in baseline and generally negative slopes in phases 2 and 3 of the study.

Figure S6

RRT vs Minute Slope as a Function of Study Day for P1

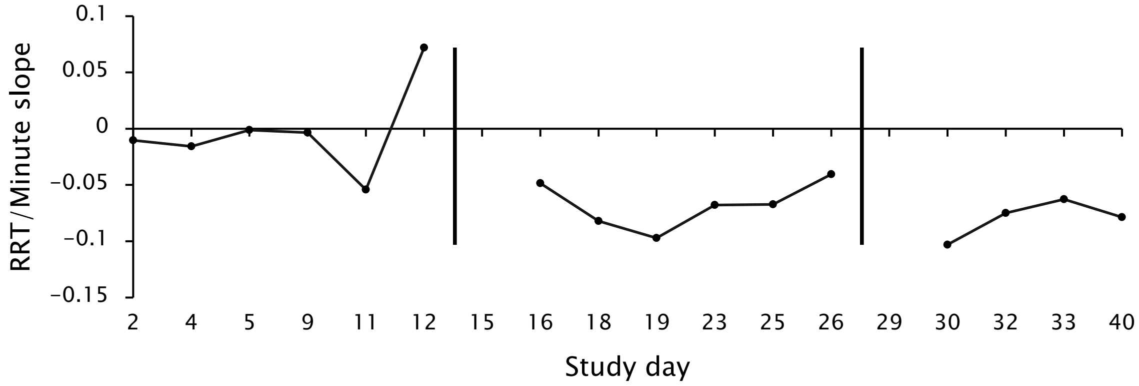


Figure S7 (opposite) duplicates Figure S5 (P1, see previous page) with timeseries lines added to more clearly see how time of day of PVT assessment changed from baseline phase to phases 2 and 3.

Figure S7

Time of Day of PVT Assessment vs. Study Day for P1

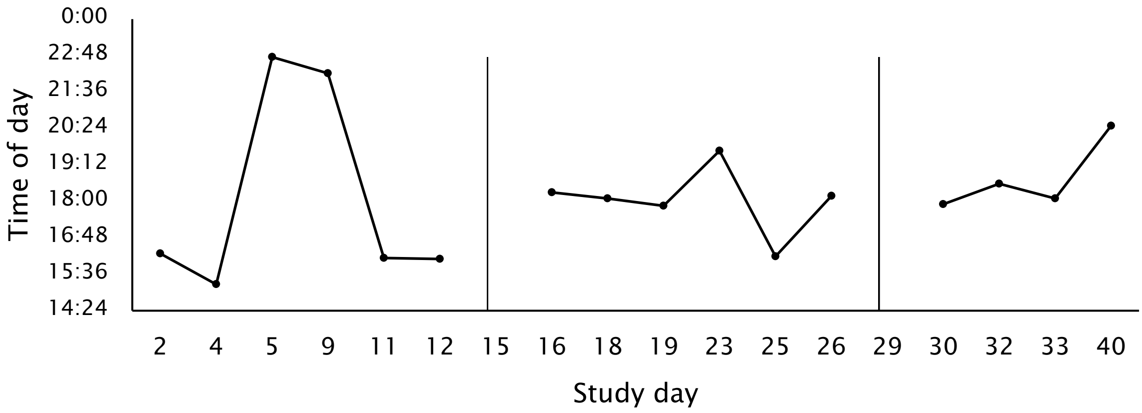
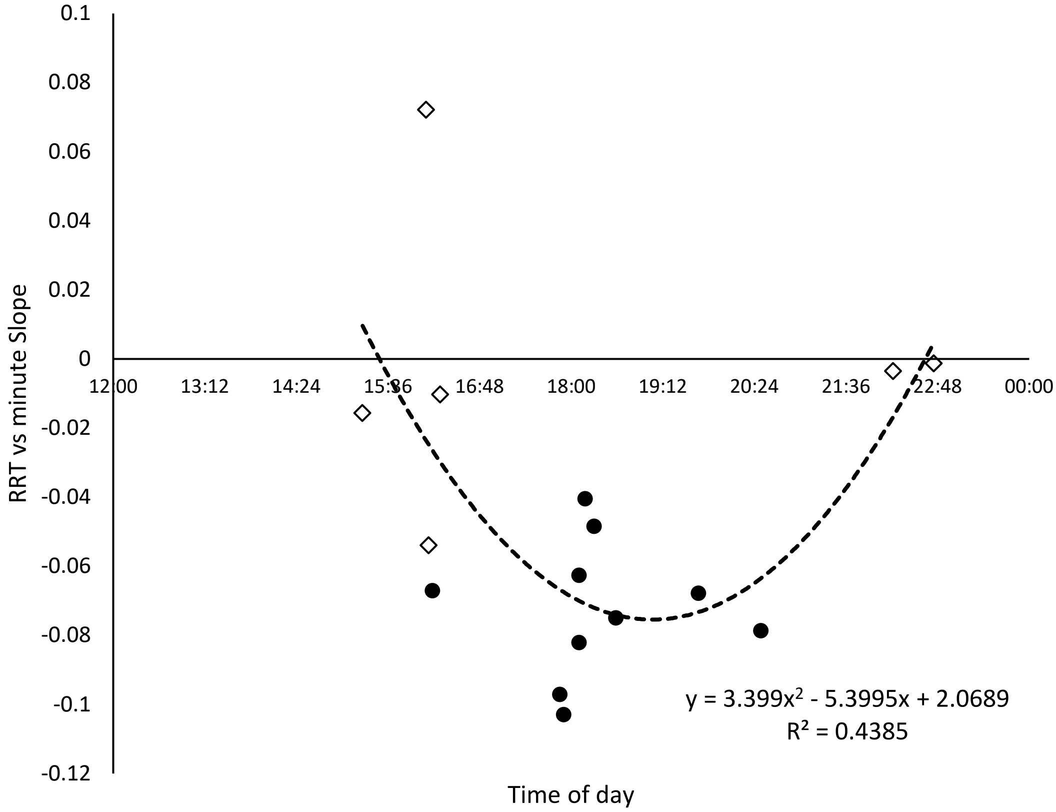


Figure S7 shows that during baseline, P1 completed measures earlier afternoon, or later evening, whereas in phases 2 and 3, measures tended to be in later afternoon or early evening. This pattern of performance is shown more clearly below in Figure S8 (overleaf) wherein performance fatigue as shown by RRT vs minute slopes is mapped vs time of day of assessment for participant 1.

Figure S8

Fatigue Slope vs Time of Day for P1



Note. ◊ Indicate baseline measures, whereas • indicate measures from phases 2 and 3. Equation is best fitting binomial regression curve calculated in MS Excel.

PVT RRT vs minute slopes showed a curvilinear relationship to time of day in this case. The binomial function fit by MS Excel could account for 43.85% variance in this score for this participant. In the fatigue slope graph. When compared with Baseline measurement, PVTs occurred more during an obvious trough of performance in time of day in phases 2 and 3, indicated by the solid black circular markers. The variation in time of day documented here could account for some of the apparent fatigue propensity exacerbation of P1 from baseline to intervention and follow-up phases in the MBD study.

The function for P1's RRT vs. Minute slope score vs. time of day of measurement calculated by MS Excel (see Figure S8) = y = $3.399x^2 - 5.3995x + 2.0689$ where y = RRT vs minute slope, and x = time of day. This function was subtracted from each score for P1 to correct for assessment of time of day. The transformed values were plotted against time of day, illustrated in figure S9.

Figure S9

Transformed RRT vs Minute Slopes VS Time of Day for P1

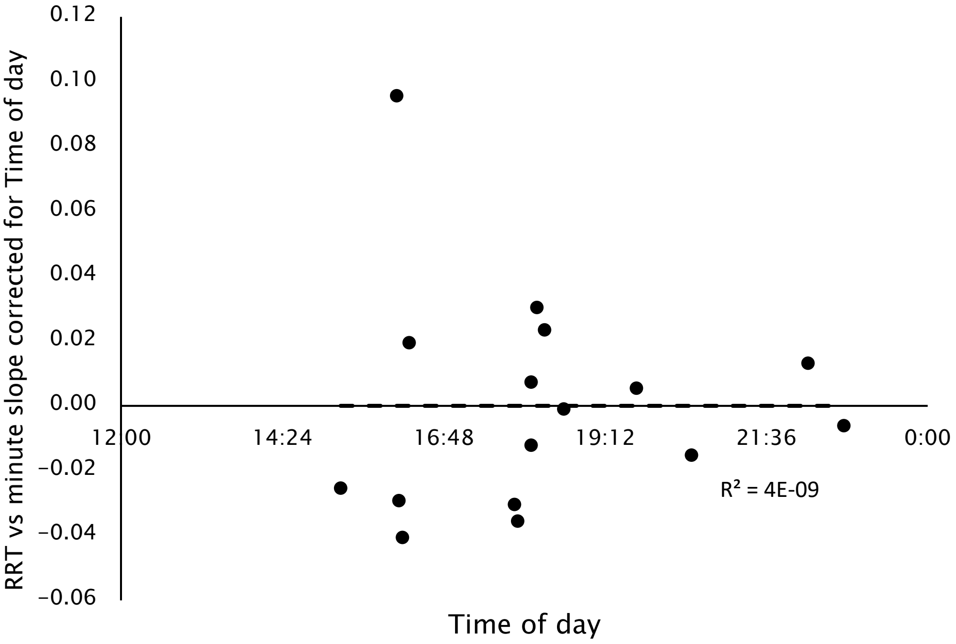
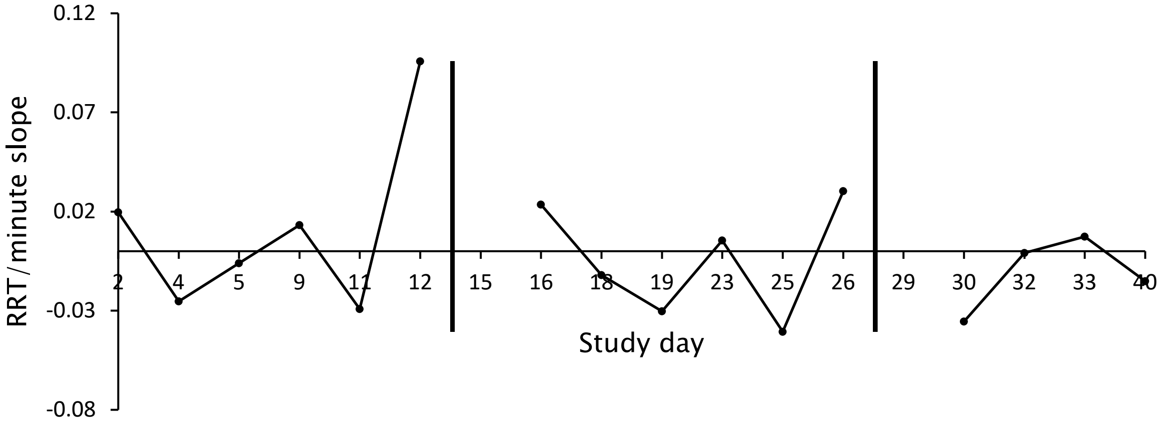


Figure S9 shows that the transformation of RRT per minute slopes was successful at removing the influence of time of day on scores. These corrected RRT vs minute slope values were then plotted against study day for P1. Figure S10 shows that the declining performance between baseline and phases 2 and 3 (in figure S6) disappears when correcting for time of day.

Figure S10

RRT vs Minute Slope Score Corrected for Time of Day as a Function of Study Day P1



The same process of transformation was completed with the other participants' RRT vs minute slope scores on the PVT. The results of these are presented for each timeseries chart in participants' respective appendices (see Appendices T-X) following their uncorrected timeseries charts to facilitate comparison.

Summary

Regarding self-report measures, the participant whose scores for subjective measures had a small observed correlation between time of day and scores on the daily subjective fatigue and sleepiness measures (P2) did not show any systemic changes in time of day that measures were reported and study day. Conversely, the participant that showed a systemic change in the time of day that self-report measures were completed (P3) did not show any systemic patterns in time of day impacting on scores. For PVT assessment of fatigue, the relationships in some cases showed a clear shifting performance based on time of day. Participants showed a great breadth in the time of day of their PVT testing. Correction for this was attempted through finding and subtracting the curvilinear regression function that most closely matched the influence of time of day on their RRT vs minute slopes in a best attempt to remove the influence of time of day on testing. An example was given of this process in this appendix: P1 initially showed a medium-strong relationship between RRT/Minute slope and time of day, when time of day of testing function was subtracted from the scores, the declining performance between baseline and phases 2 and 3 disappeared. Similar subtractions were done for all the PVT scores for interpretation in the main SCRD study and are presented in the following appendices T–X which plot individual's results.

References

Gander PH, Mulrine HM, van den Berg MJ, Smith AA, Signal TL, Wu LJ, Belenky G. Effects of sleep/wake history and circadian phase on proposed pilot fatigue safety performance indicators. J Sleep Res. 2015 Feb;24(1):110-9. doi: 10.1111/jsr.12197.

Manolov, R., Arnau, J., Solanas, A., & Bono, R. (2010). Regression-based techniques for statistical decision making in single-case designs. *Psicothema*, *22*(4), 1026–1032.

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Appendix T

Individual Results for P1

This appendix shows individual results for P1 from multiple baseline single case experimental design study described in Chapter 5 of this thesis. Timeseries charts for each of the outcome measures are included. As many of these charts are similar, a general note is provided here: while these charts are separated into the three study phases represented by vertical lines, Percentage of nonoverlapping data assessment concatenated phases 2 and 3, as these represented the time after the introduction of the intervention. Discontinuous lines within phases indicate missing data. Fine dotted horizontal lines represent within phase medians, dashed horizontal lines represent overall medians.

Appendix T: Individual Results for P1

EMU Overview

Table T1

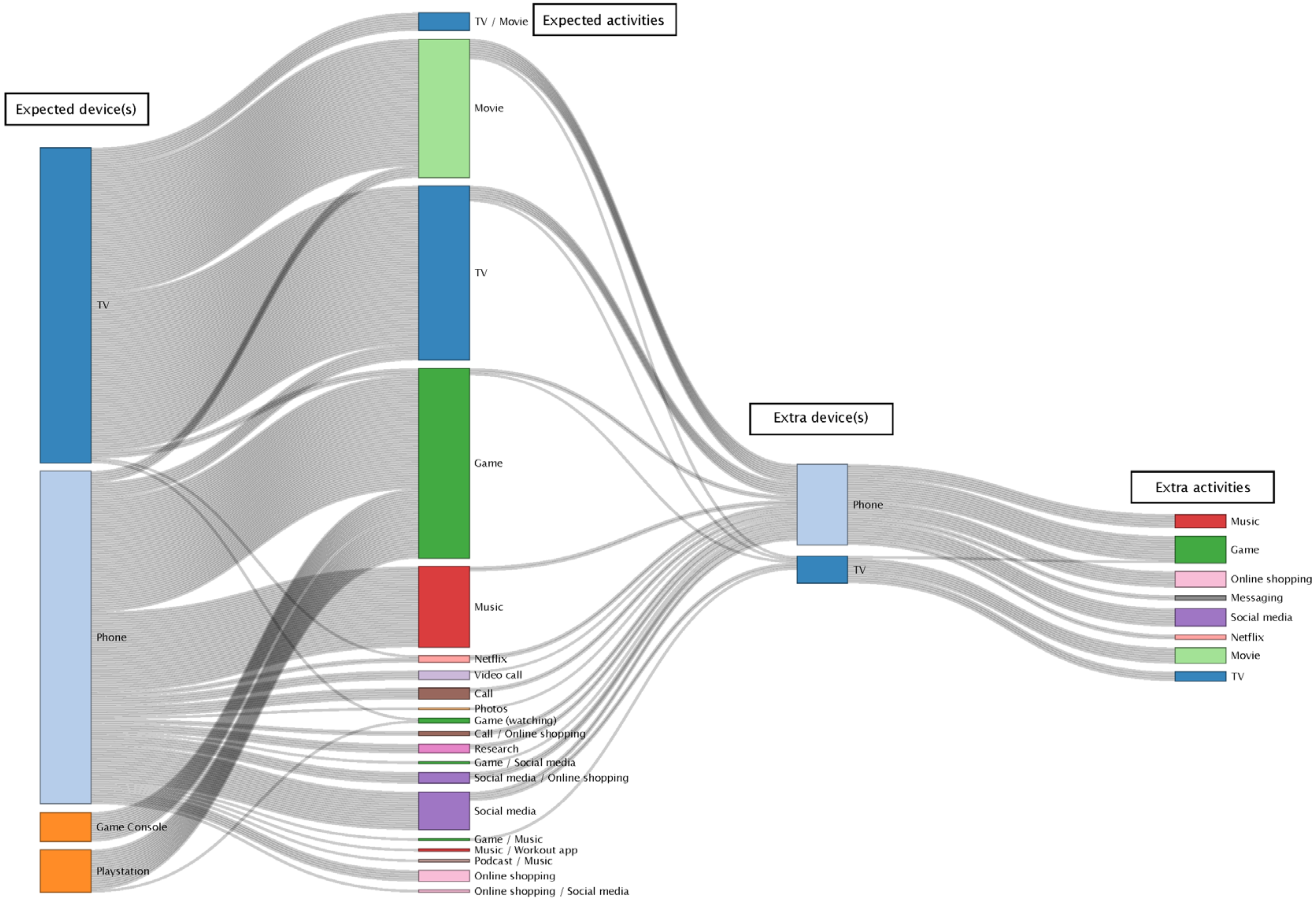
EMU Time Recorded by Device Organised by Intended Activities for P1

Device (Activities)	Sum of time recorded (Minutes)
Phone	**480**
Call	40
Call/ Trademe	85
Facebook	60
Facebook / Trademe	70
Games / Facebook	60
Games / Music	90
Google	45
Photos	30
Game Console	**270**
Game	270
TV	**670**
Movie	370
TV Series	300
Total	1420

Note. TV: Television.

Figure T1

Sankey Diagram Summarising the Entries of the EMU Diaries for P1



Note. This diagram was based on an aggregate of the 97 total entries made in EMU diaries by P1. Some reported activities and devices used were obfuscated and grouped to protect anonymity. When extra activity entries consisted of multiple activities, these were unfolded for simplifying the display. Expected activity entries that were multiple (denoted by “/”) were retained so that the nuance of links between expected activities and extra devices remained. 105 total links are documented here. Created in R using the NetworkD3 package.

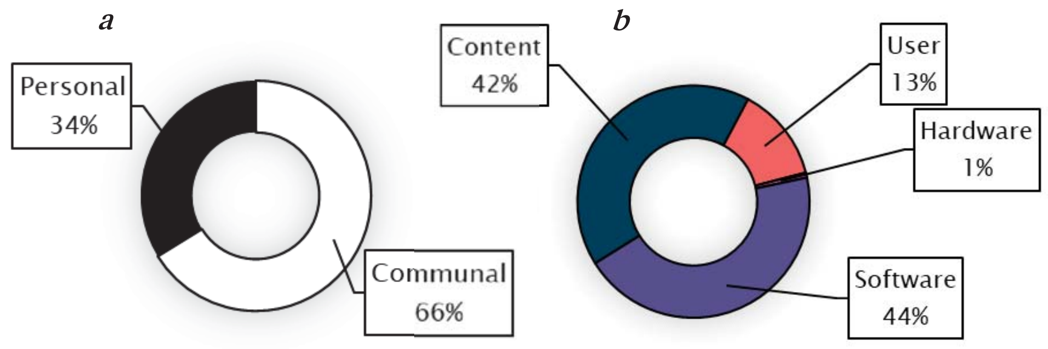
Figure T1

A Sankey Diagram Summarising the Entries of the EMU diaries for P1

(unfold)

Figure T2

Categorising EMU Descriptions and Communal Use for P1



Note. a. Personal versus communal EMU was identified through the EMU audits based on identified hardware of use from *expected devices* fields in the EMU diaries. Proportions were calculated based on sums of time spent per hardware identified in the diaries from which time spent could be inferred. *b.* Entries were categorised based on aspects of EMU identified in both *expected-* and *extra activities* fields and based on number of entries.

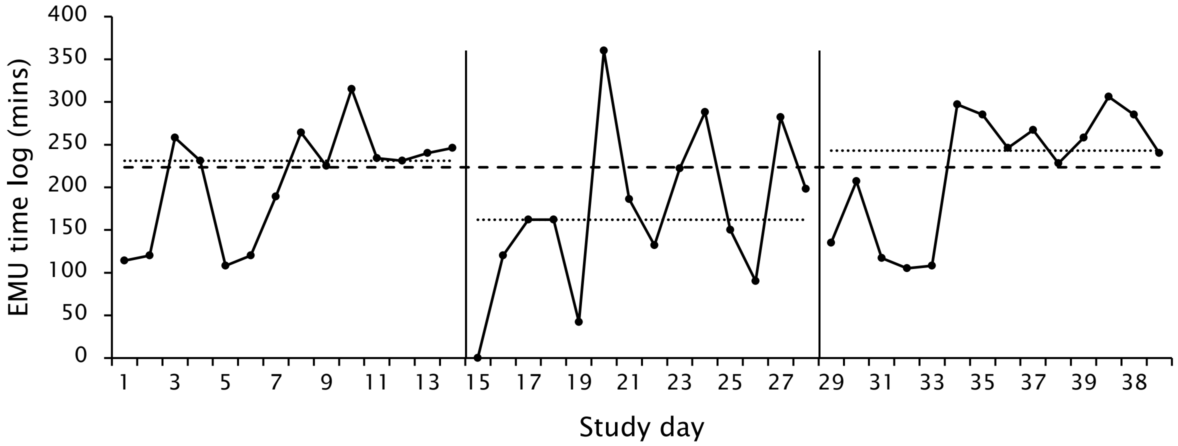
Timeseries Charts

The following timeseries charts (Figures T3 through T16) were plotted to determine the effectiveness of the intervention on changing variables of EMU, sleep and daytime functioning measures. On each chart, dashed lines represent the overall median, and the finer dotted lines represent the median for the individual phases to aid in visual analysis. Percentage of nonoverlapping data (PND) is presented in the notes of each chart. To calculate percentage of nonoverlapping data, phases 2 and 3 were concatenated for a measure of change after the introduction of the intervention. A general guideline for PND: scores below 50% are indicate less than effective; scores from 50% to 70% indicate questionable, from 70% to 90% are indicate effective, and above 90% indicate highly effective interventions (Scruggs & Mastropieri, 1998). Note also that duty times were also recorded and charted to aid in analysis of the timeseries data, however in the interest of anonymity these are not reported.

EMU

Figure T3

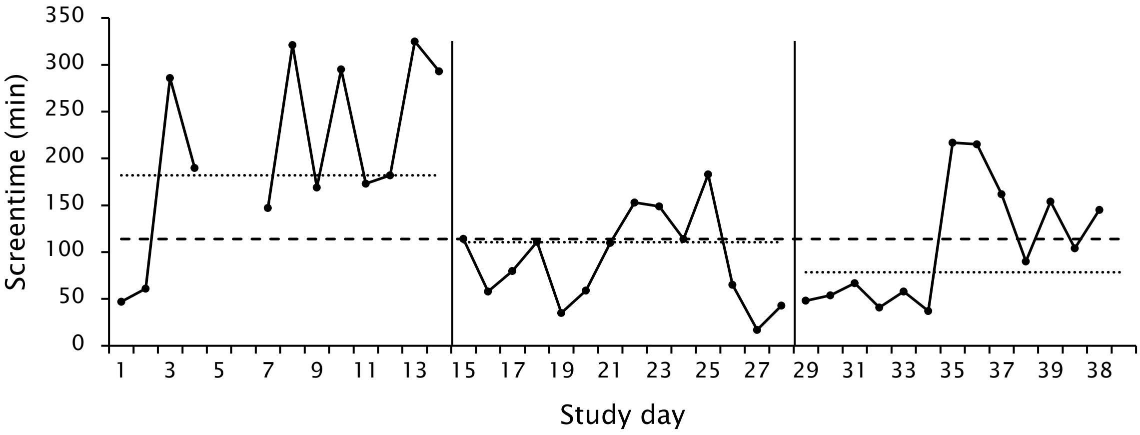
Logged EMU Time as a Function of Study Day for P1



Note. Unstable baseline; PND: 14.29% under minimum of baseline; (3.57% exceeding maximum of baseline).

Figure T4

Phone Screentime as a Function of Study Day for P1

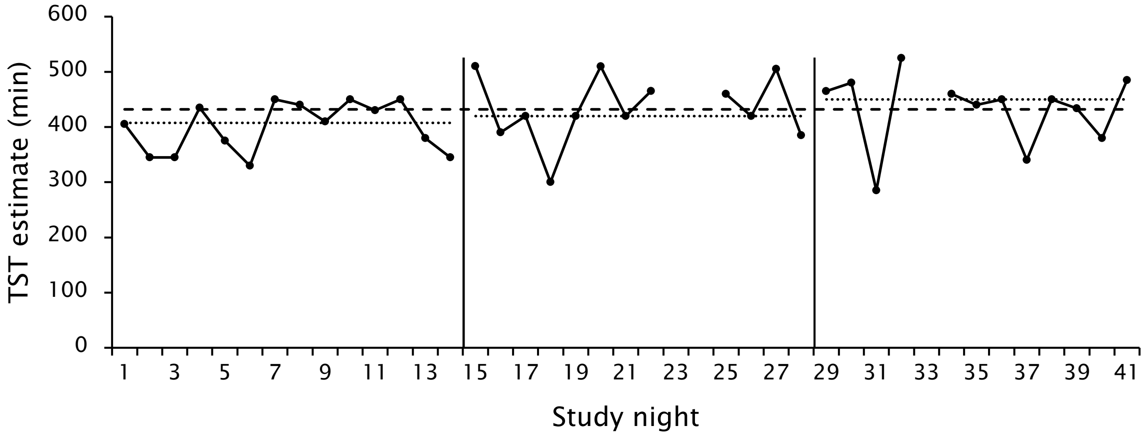


Note. Unstable baseline; PND: 18.52% under minimum of baseline; (0% exceeding maximum of baseline).

Subjective Sleep Measures

Figure T5

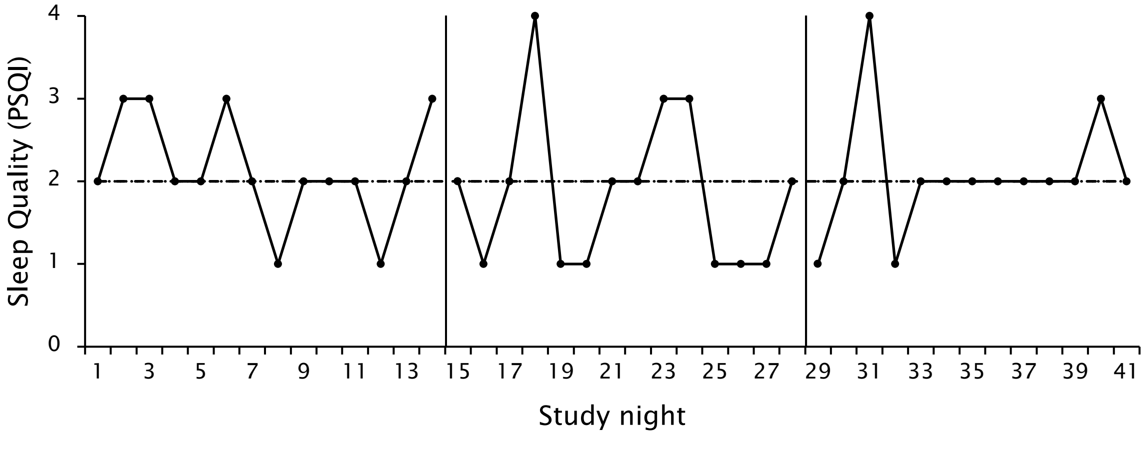
Estimated Sleep Duration as a Function of Study Night for P1



Note. Unstable baseline; PND: (8.33% under minimum of baseline); 41.67% exceeding maximum of baseline.

Figure T6

Sleep Quality as a Function of Study Night for P1

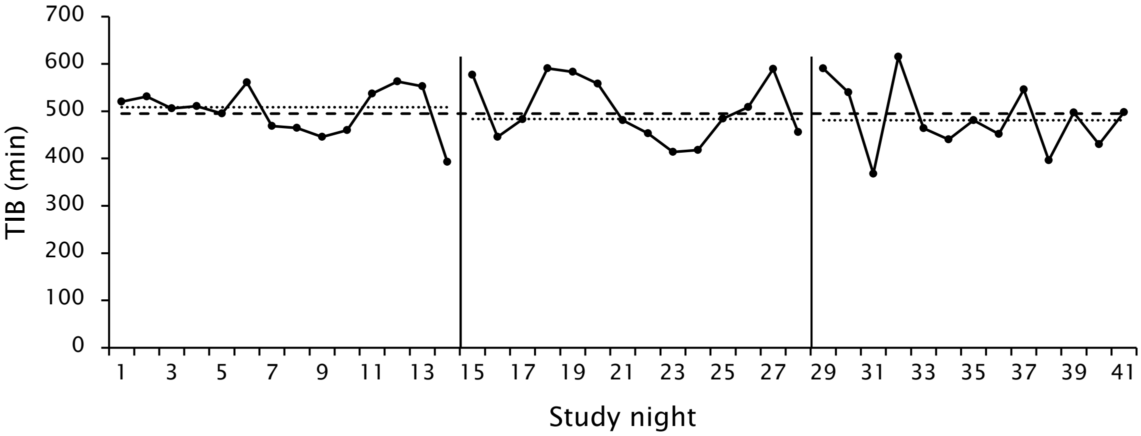


Note. Unstable baseline; PND: 0% under minimum of baseline; (7.41% exceeding maximum of baseline).

Actigraphy Sleep Measures

Figure T7

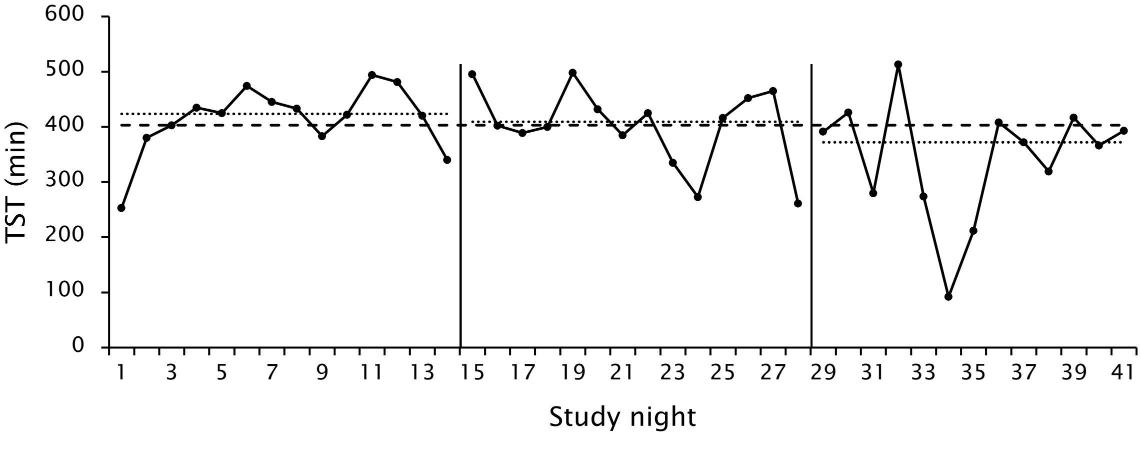
Time in Bed as a Function of Study Night for P1



Note. Stable Baseline; PND: (3.7% under minimum of baseline); 22.22% exceeding maximum of baseline.

Figure T8

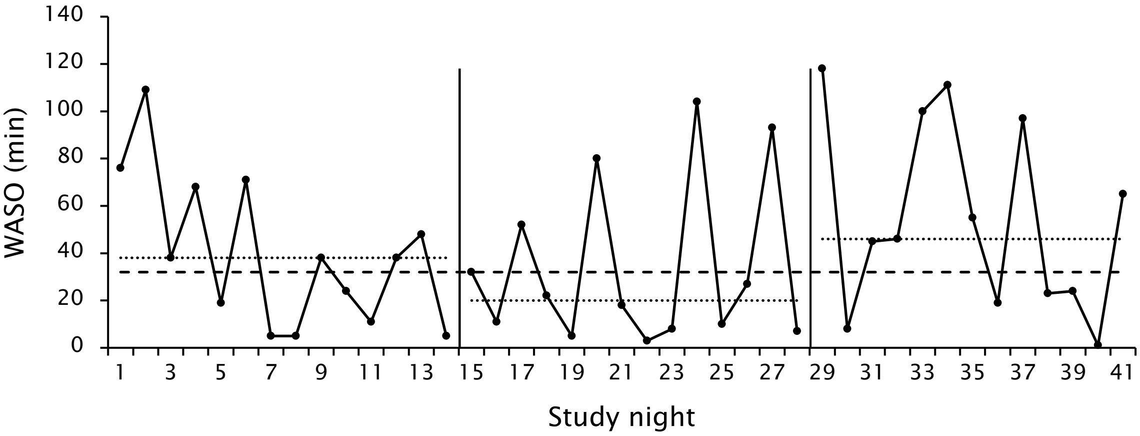
Total Sleep Time as a Function of Study Night for P1



Note. Unstable baseline; PND: (7.41% under minimum of baseline); 11.11% exceeding maximum of baseline.

Figure T9

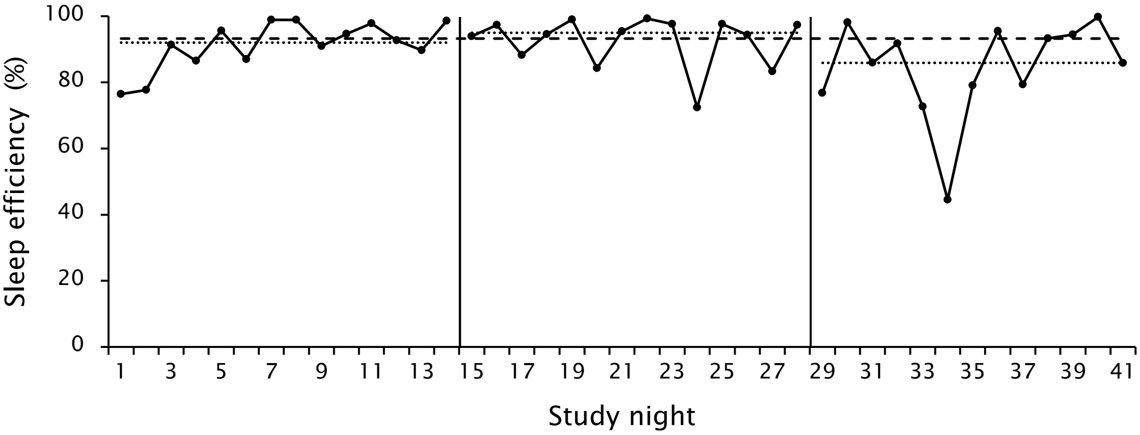
Wake After Sleep Onset as a Function of Study Night for P1



Note. Unstable baseline; PND: 7.41% under minimum of baseline; (7.41% exceeding maximum of baseline)

Figure T10

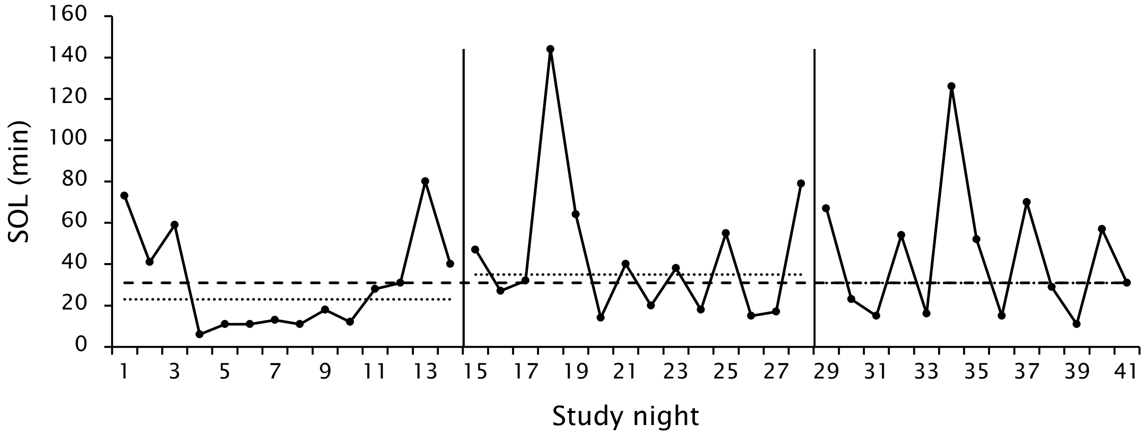
Sleep Efficiency as a Function of Study Night for P1



Note. Stable Baseline; PND: (11.11% under minimum of baseline); 11.11% exceeding maximum of baseline.

Figure T11

Sleep Efficiency as a Function of Study Night for P1

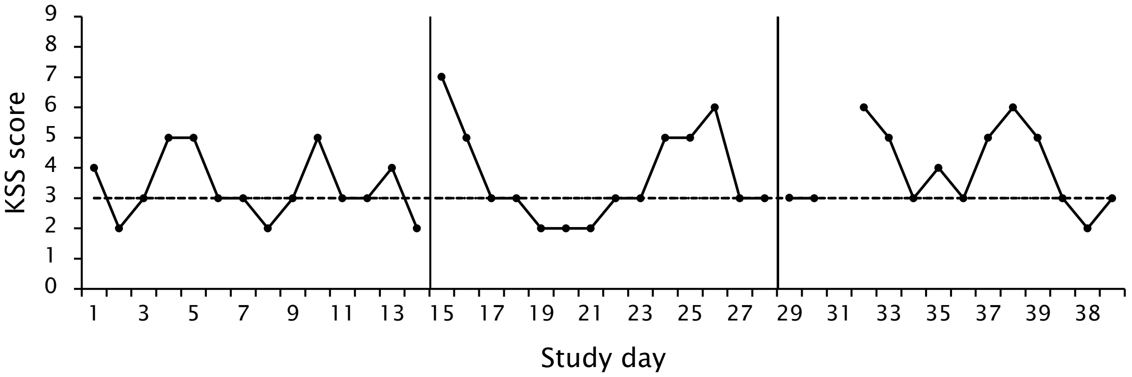


Note. Unstable baseline; PND: 0% under minimum of baseline; (7.41% exceeding maximum of baseline). SOL visually more consistent and lower when at home.

Vigilance/Sleepiness

Figure T12

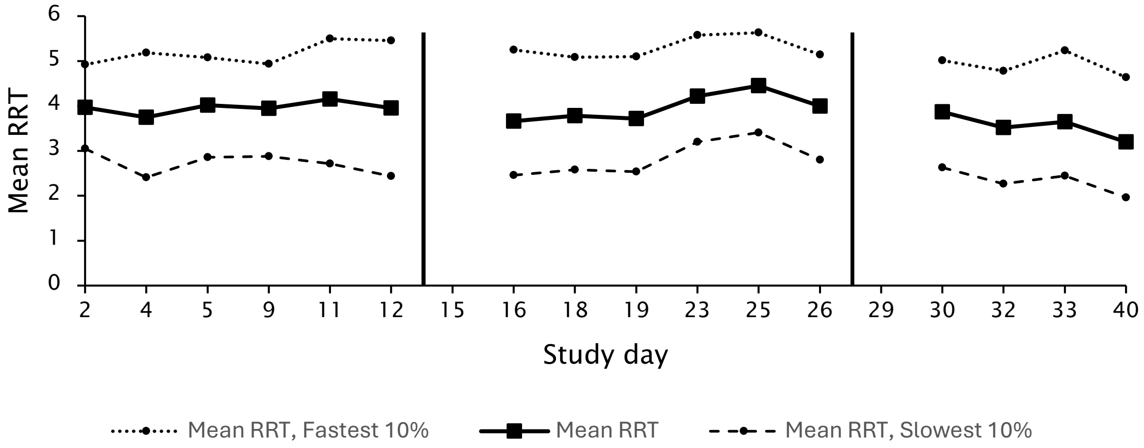
Subjective Sleepiness as a Function of Study Day for P1



Note. KSS: Karolinska Sleepiness Scale. Unstable baseline; PND: 0% under minimum of baseline; (14.81% exceeding maximum of baseline).

Figure T13

Psychomotor Vigilance Metrics as a Function of Study Day for P1

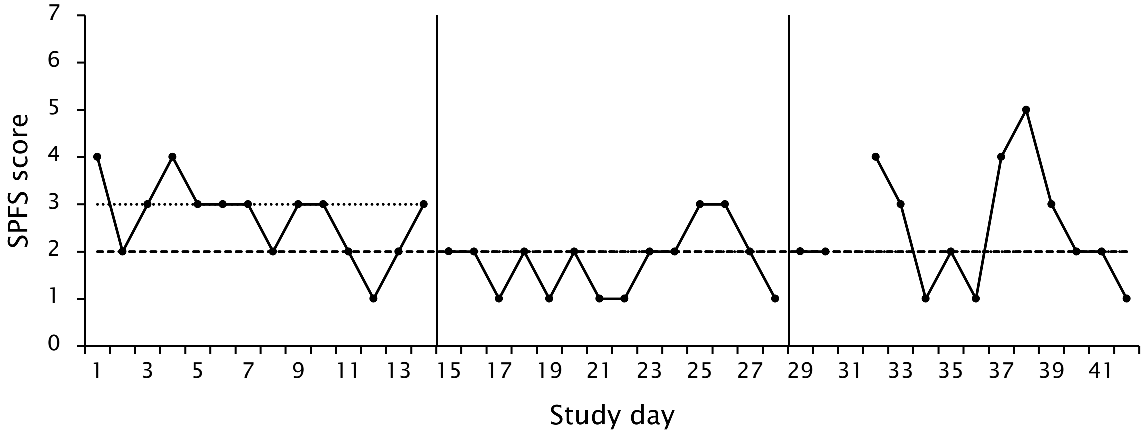


Note. All baselines were considered stable. For overall mean reciprocal reaction time (RRT): PND: 20% exceeding maximum of baseline, questionable decrease in mean overall speed of responses (50% under minimum of baseline) particularly evident after day 25. For mean of slowest 10% RRT: PND: 20% exceeding maximum of baseline (20% under minimum of baseline). For mean of fastest 10% RRT: PND: 20% exceeding maximum of baseline (20% under minimum of baseline). No notable changes due to intervention. Note also that these were plotted and analysed independently, however are reported together here in the interest of conciseness.

Fatigue

Figure T14

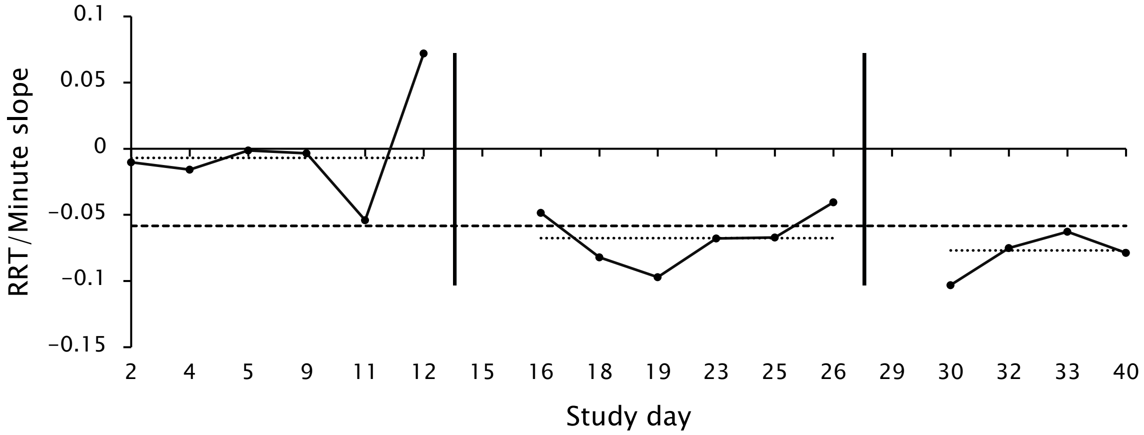
Subjective Fatigue Score as a Function of Study Day for P1



Note. SPFS: Samn Perelli Fatigue Scale. Unstable baseline; PND: 0% under minimum of baseline; (3.7% exceeding maximum of baseline).

Figure T15

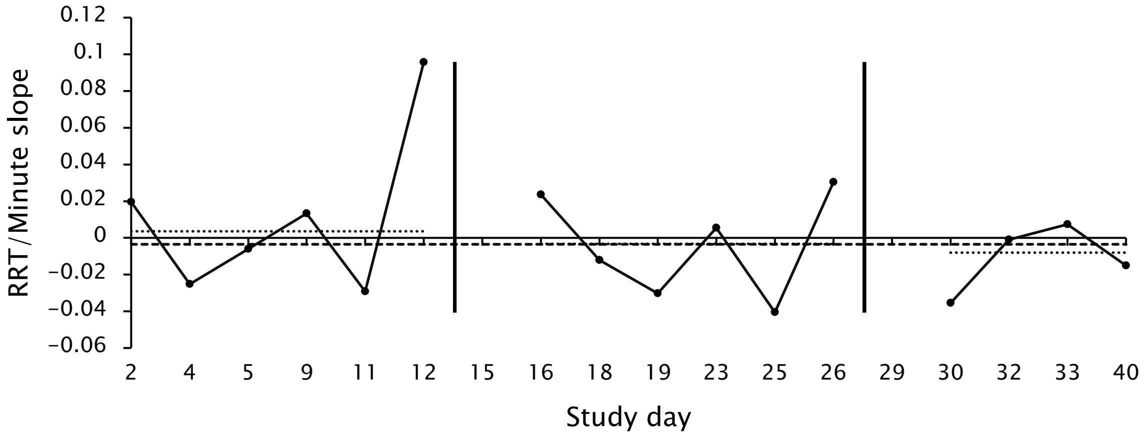
PVT RRT/Minute Slope as a Function of Study Day for P1



Note. Unstable baseline; PND: (80% under minimum of baseline); 0% exceeding maximum of baseline. Increase in fatigue propensity as measured by PVT.

Figure T16

PVT RRT/Minute Slope Corrected for Time of Day as a Function of Study Day for P1



Note. Unstable baseline; PND: 30% under minimum of baseline; 0% exceeding maximum of baseline. The increasing fatigue propensity plotted in the previous figure diminishes when the effect of time of day of testing is subtracted from scores (see Appendix S).

Summary

P1's most frequently intended hardware was phone or TV, with less frequent uses of PlayStation or other game consoles. Their most commonly intended activities were gaming, watching TV or movies, with less frequent music listening and social media. Their most used extra hardware was their phone, with less frequent unintended TV. All PlayStation use was intended at start. Most common extra activity was gaming, though social media, movie watching, music listening and online shopping were also common intended activities. P1 recorded 97 total entries in their EMU diary. EMU quantity showed a surprisingly sharp immediate drop in both subjectively reported and screentime application recordings for P1 between baseline and intervention phases. This may, however, be best explained through the ship leaving for a new sailing on Study Day 15, the first day of intervention phase. Subjectively estimated nightly sleep duration and sleep quality showed minimal change from baseline into the intervention phase for P1. Being highly variable, the objective sleep outcomes scores for P1 did not show any consistent systemic changes that could be attributed to the intervention's impact. Subjective fatigue scores for P1 were highly variable across the study, with no notable changes that could be attributed to the intervention. Subjective sleepiness scores were also highly variable within phases and showed no marked between phase changes. P1 did show slightly increased sleepiness scores at the very beginning of intervention phase, although this was likely due to increased duty at the beginnings of that phase. Average PVT response speed (RRT) for P1 showed a relatively stable baseline, an upwards trend in phase 2, and a downward trend in phase 3. This same pattern was more exaggerated in their mean RRT for their slowest 10% of responses, and subtler in their fastest 10% of responses. The impact of time on task on performance was evaluated through RRT vs minute slopes to capture a fatigue effect. P1 showed increased fatigue propensity from baseline to phases 2 and 3. When correcting P1's scores for time of day of assessment however, this declining performance disappeared, so it may have been due to a systemic change in measurement time between these phases.

Appendix U

Individual Results for P2

This appendix shows individual results for P2 from multiple baseline single case experimental design study described in Chapter 5 of this thesis. Timeseries charts for each of the outcome measures are included. As many of these charts are similar, a general note is provided here: while these charts are separated into the three study phases represented by vertical lines, Percentage of nonoverlapping data assessment concatenated phases 2 and 3, as these represented the time after the introduction of the intervention. Discontinuous lines within phases indicate missing data. Fine dotted horizontal lines represent within phase medians, dashed horizontal lines represent overall medians.

Appendix U: Individual Results for P2

EMU Overview

Table U1

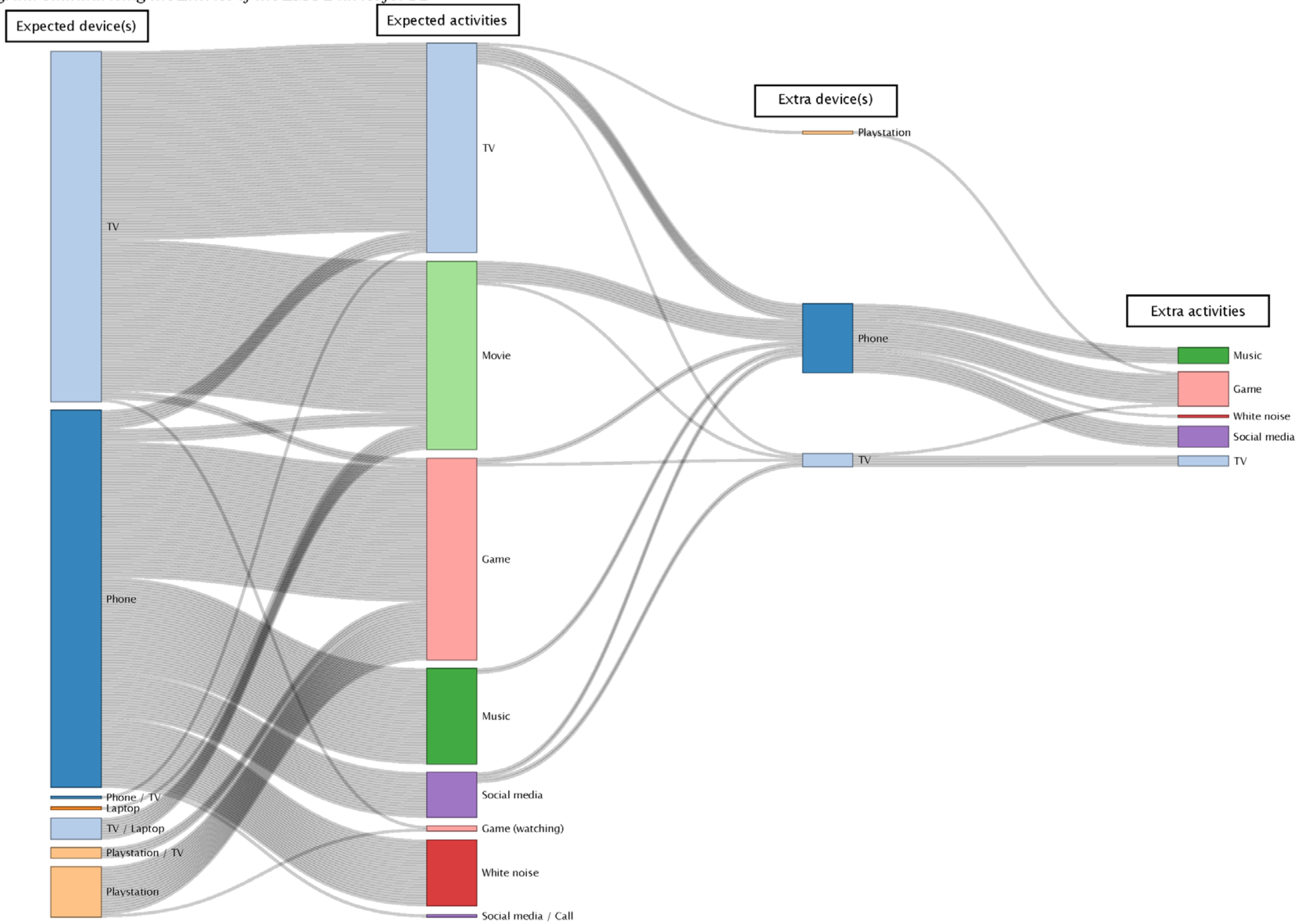
EMU Time Recorded by Device Organised by Intended Activities for P2

Device (Activities)	Sum of time recorded (Minutes)
Laptop	**180**
Movie through TV	180
Phone	**15,779**
Music	595
Music / PT	635
Music / White Noise	510
Music / Work	220
Social media	945
Social media / Call	46
TV Series	748
White Noise	12,080
Phone / TV	**65**
TV Series	65
PS4	**553**
Game	553
TV	**1,564**
Game	20
Movie	1280
TV Series	219
Watch Game Console	45
TV / Laptop	**861**
Movie	861
TV / PS4	**60**
Game	60
Total	19,062

Note. PT likely stands for personal training; TV: Television.

Figure U1

A Sankey Diagram Summarising the Entries of the EMU Diaries for P2



Note. This diagram was based on an aggregate of the 112 total entries made in EMU diaries by P2. Some reported activities and devices used were obfuscated and grouped to protect anonymity. All entries made by P2 in the "extra activities" column were single activities and required no unfolding. Expected activity entries that were multiple (denoted by "/") were retained so that the nuance of links between expected activities and extra devices remained. 112 total links are documented here. Created in R using the NetworkD3 package.

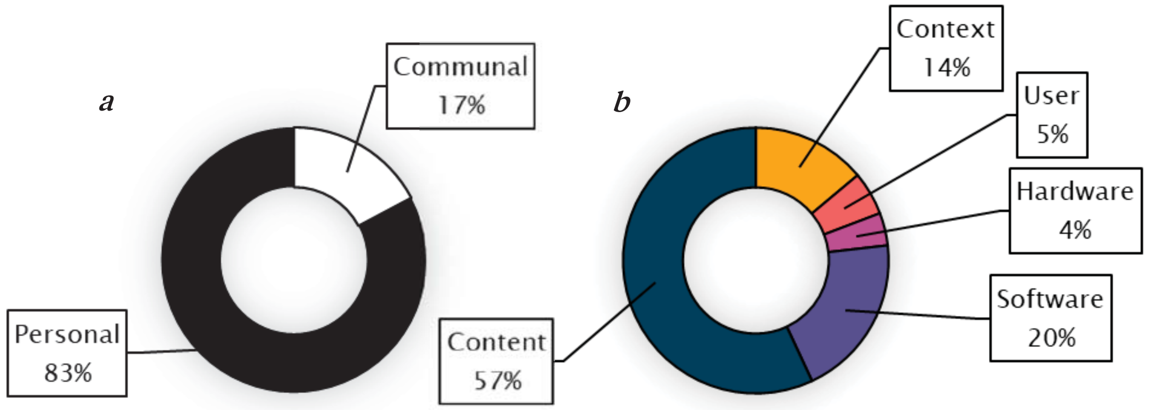
Figure U1

A Sankey Diagram Summarising the Entries of the EMU diaries for P2

(unfold)

Figure U2

Categorising EMU Descriptions and Communal Use for P2



Note. a. Personal versus communal EMU was identified through the EMU audits based on identified hardware of use from *expected devices* fields in the EMU diaries. Proportions were calculated based on sums of time spent per hardware identified in the diaries from which time spent could be inferred. *b*. Entries were categorised based on aspects of EMU identified in both *expected*- and *extra activities* fields and based on number of entries.

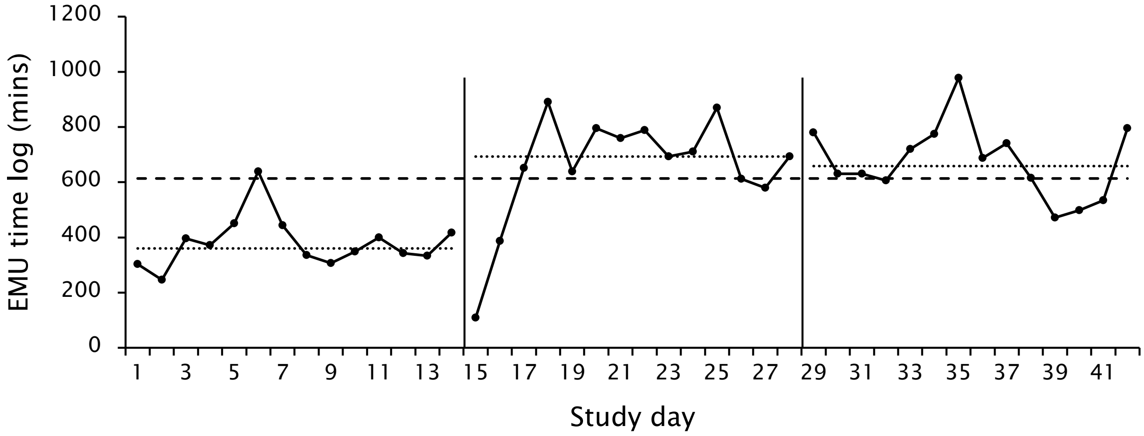
Timeseries Charts

The following timeseries charts (Figures U3 through U16) were plotted to determine the effectiveness of the intervention on changing variables of EMU, sleep and wake functioning measures. On each chart, dashed lines represent the overall median, and the finer dotted lines represent the median for the individual phases to aid in visual analysis. Percentage of nonoverlapping data (PND) is presented in the notes of each chart. To calculate percentage of nonoverlapping data, phases 2 and 3 were concatenated for a measure of change after the introduction of the intervention. A general guideline for PND: scores below 50% are indicate less than effective; scores from 50% to 70% indicate questionable, from 70% to 90% are indicate effective, and above 90% indicate highly effective interventions (Scruggs & Mastropieri, 1998). Note also that duty times were recorded and charted to aid in analysis of the timeseries data, however in the interest of anonymity these are not reported.

EMU

Figure U3

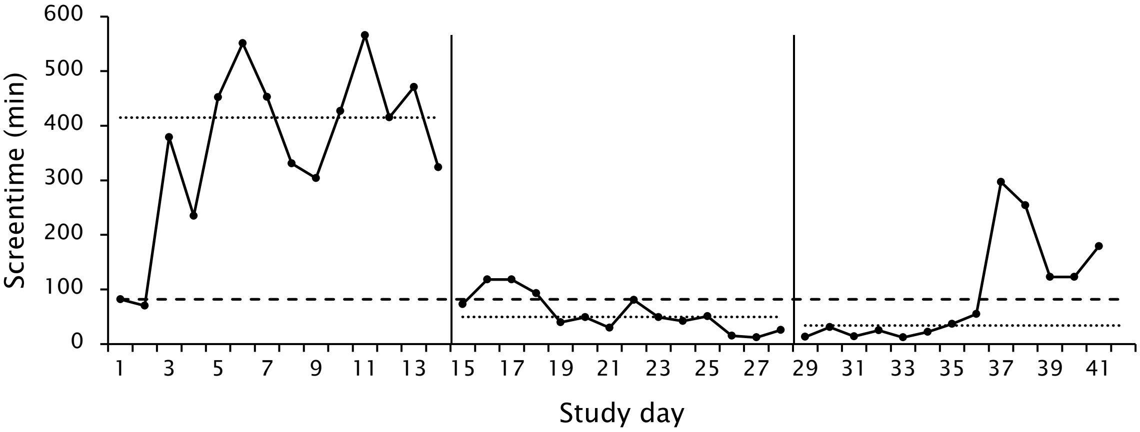
Logged EMU Time as a Function of Study Day for P2



Note. Unstable baseline; PND: 3.57% under minimum of baseline; (57.14% exceeding maximum of baseline). Questionable increase in reported EMU following intervention.

Figure U4

Phone Screentime as a Function of Study Day for P2

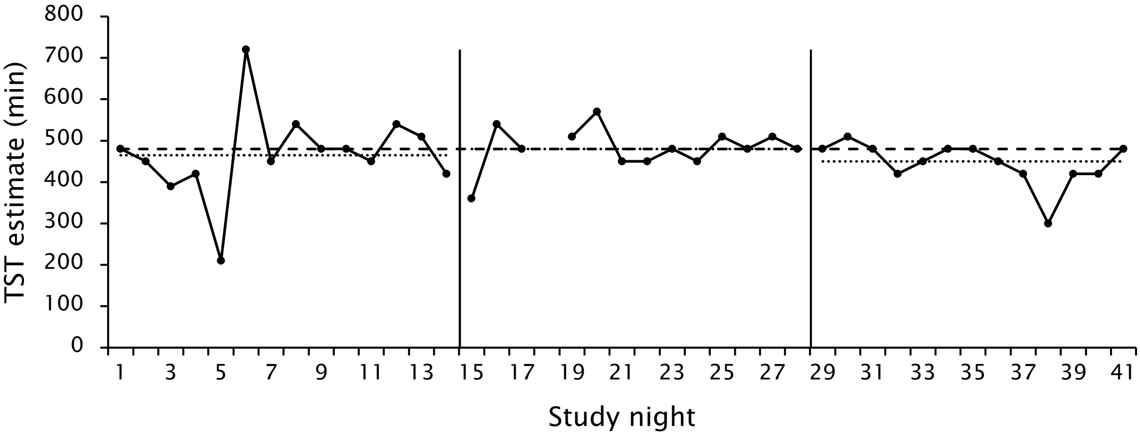


Note. Unstable baseline; PND: 62.96% under minimum of baseline; (0% exceeding maximum of baseline). Questionable decrease in EMU following intervention, possibly due to contextual changes (note that days 1 and 2 with <100 mins were during the conclusion of previous sailing, the ship left for new sailing as phase 2 began; and the peak at day 37 occurred as HMNZS Wellington returned to NZ cell phone reception.

Subjective Sleep Measures

Figure U5

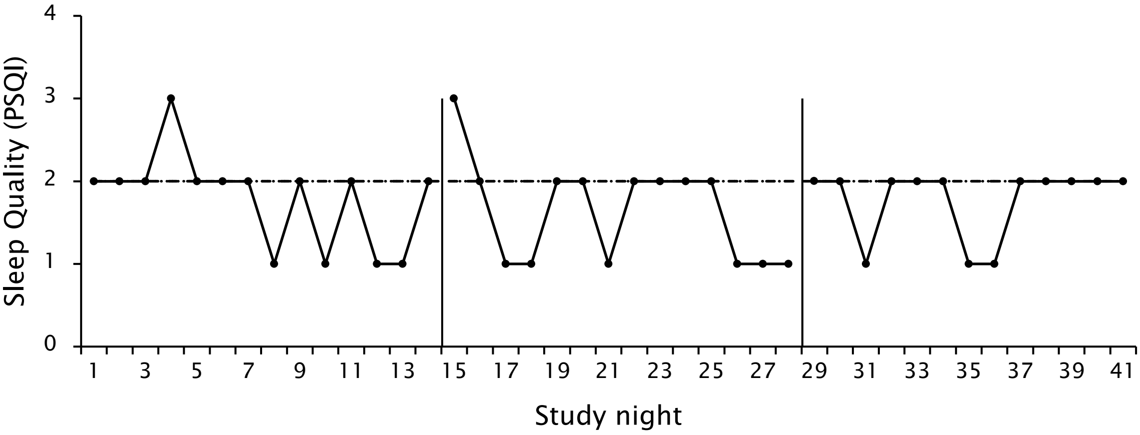
Estimated Sleep Duration as a Function of Study Night for P2



Note. Unstable baseline; PND: (0% under minimum of baseline); 0% exceeding maximum of baseline.

Figure U6

Sleep Quality as a Function of Study Night for P2

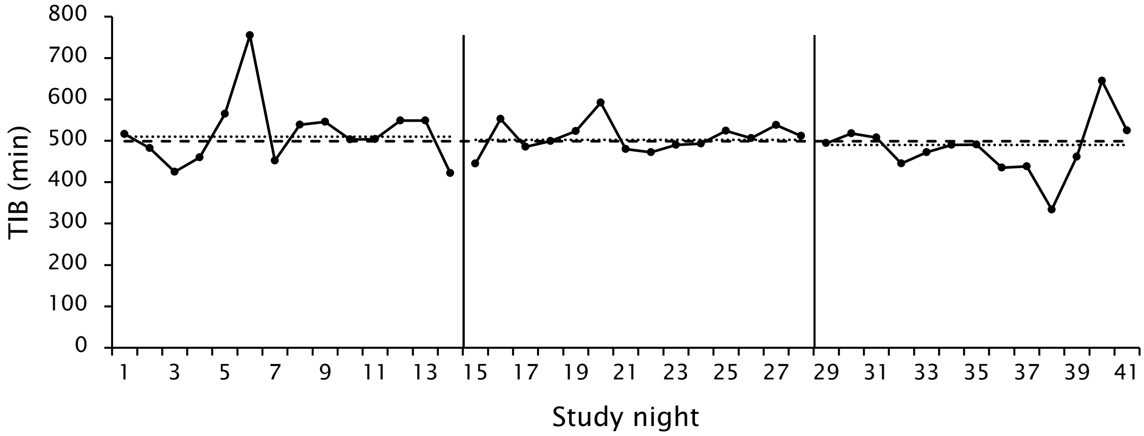


Note. Unstable baseline; PND: 0% under minimum of baseline; (0% exceeding maximum of baseline).

Actigraphy Sleep Measures

Figure U7

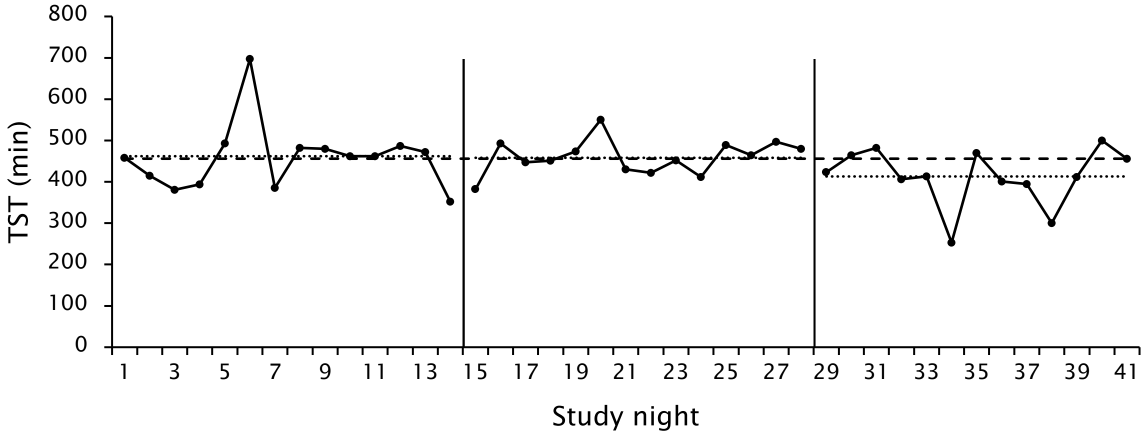
Time in Bed as a Function of Study Night for P2



Note. Unstable baseline; PND: (3.7% under minimum of baseline); 0% exceeding maximum of baseline.

Figure U8

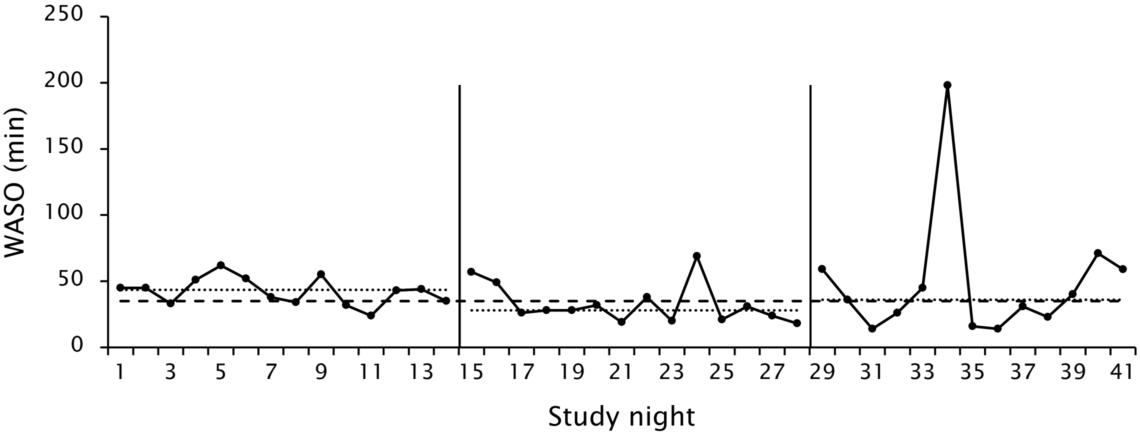
Total Sleep Time as a Function of Study Night for P2



Note. Unstable baseline; PND: (7.41% under minimum of baseline); 0% exceeding maximum of baseline.

Figure U9

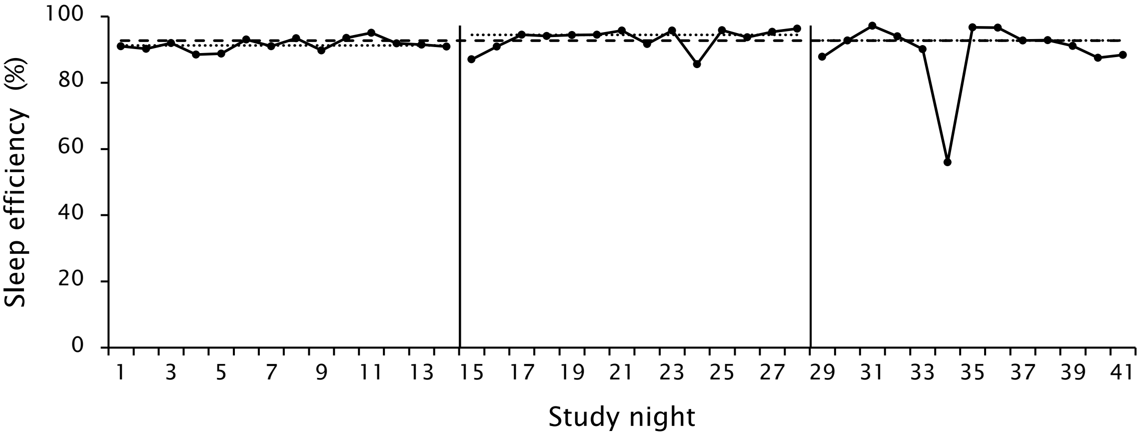
Wake After Sleep Onset as a Function of Study Night for P2



Note. Unstable baseline; PND: 29.63% under minimum of baseline; (11.11% exceeding maximum of baseline).

Figure U10

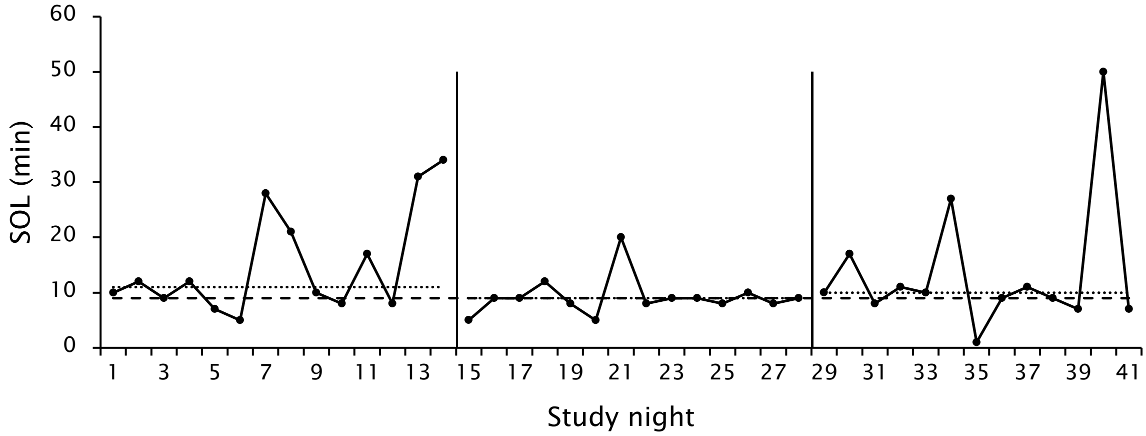
Sleep Efficiency as a Function of Study Night for P2



Note. Stable Baseline; PND: (22.22% under minimum of baseline); 29.63% exceeding maximum of baseline.

Figure U11

Sleep Onset Latency as a Function of Study Night for P2

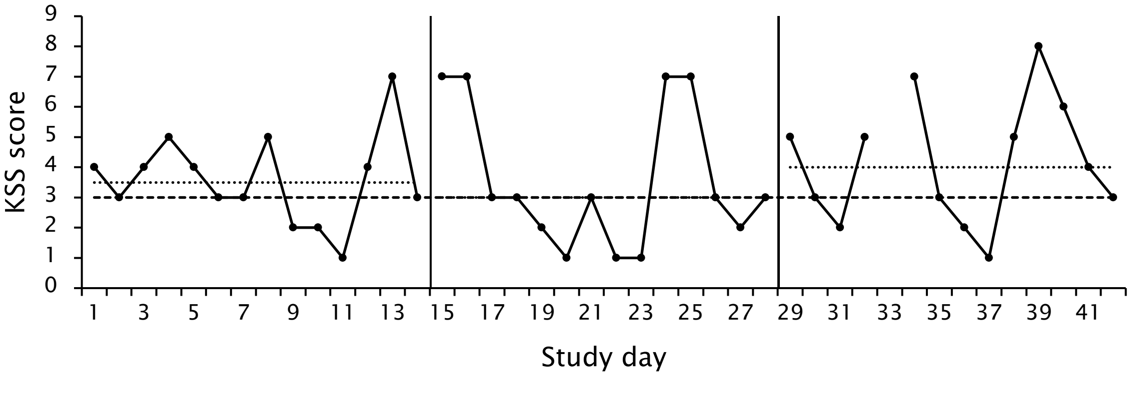


Note. Unstable baseline; PND: 3.7% under minimum of baseline; (3.7% exceeding maximum of baseline).

Vigilance/Sleepiness

Figure U12

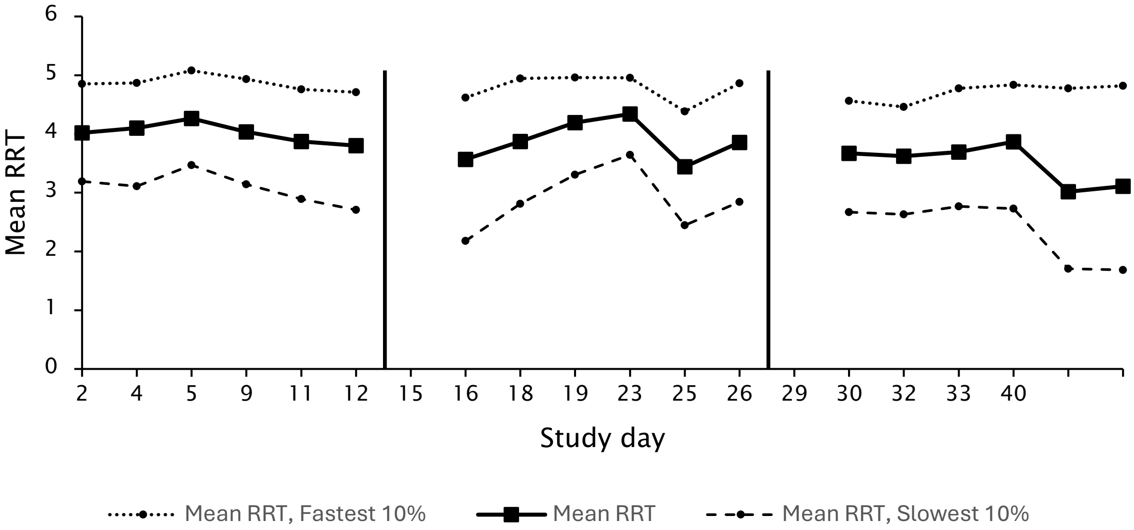
Subjective Sleepiness as a Function of Study Day for P2



Note. KSS: Karolinska Sleepiness Scale. Unstable baseline; PND: 0% under minimum of baseline; (3.7% exceeding maximum of baseline).

Figure U13

Overall Psychomotor Vigilance Metrics as a Function of Study Day for P2

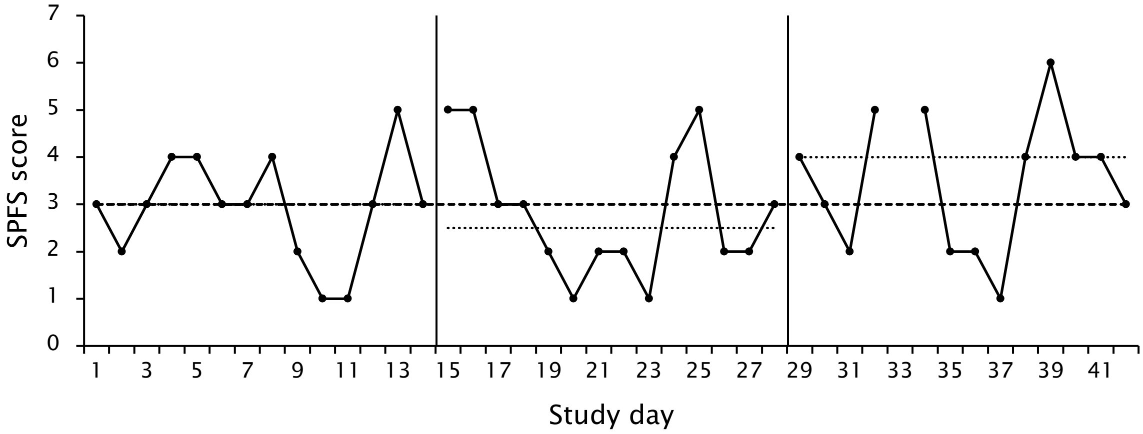


Note. P2: For overall mean reciprocal reaction time (RRT): Stable Baseline; PND: (58.33% under minimum of baseline); 8.33% exceeding maximum of baseline; For mean of slowest 10% RRT: Stable Baseline; PND: (50% under minimum of baseline); 8.33% exceeding maximum of baseline. For mean of fastest 10% RRT: Stable Baseline; PND: (33.33% under minimum of baseline); 0% exceeding maximum of baseline. Questionable decreases in mean RRT and mean RRT of slowest 10% of responses, fastest 10% of responses showed no notable effect. Note that these were plotted and analysed independently, however are reported in a single chart here in the interest of conciseness.

Fatigue

Figure U14

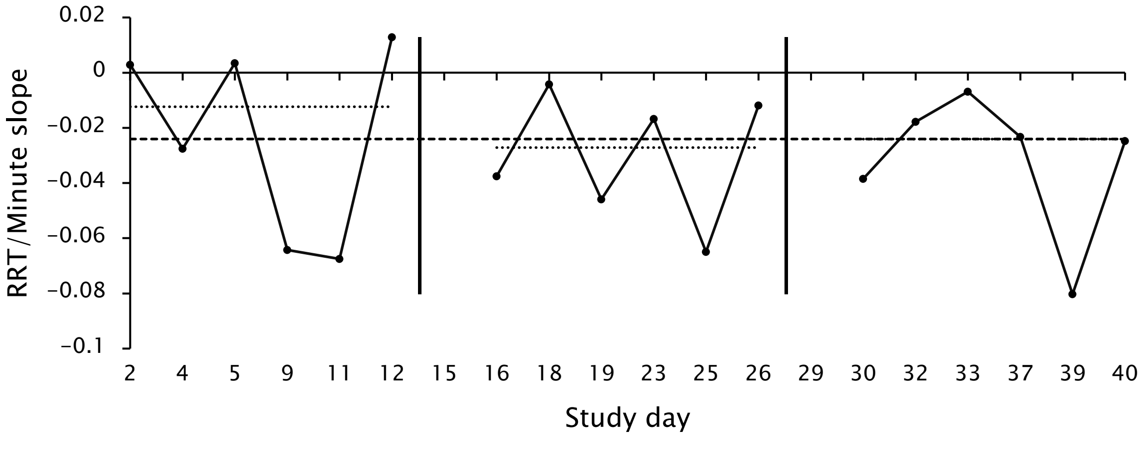
Subjective Fatigue Score as a Function of Study Day for P2



Note. SPFS: Samn Perelli Fatigue Scale. Unstable baseline; PND: 0% under minimum of baseline; (3.7% exceeding maximum of baseline).

Figure U15

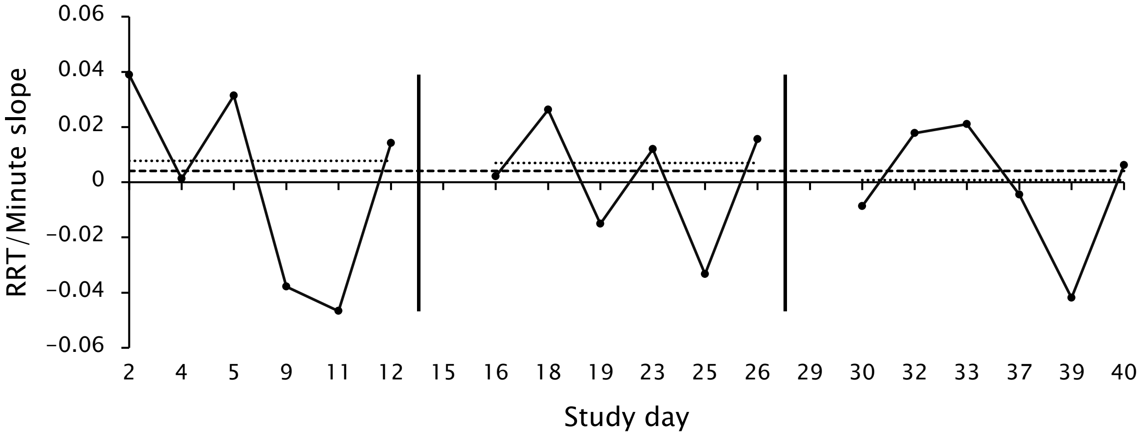
PVT RRT/Minute Slope as a Function of Study Day for P2



Note. Unstable baseline; PND: (8.33% under minimum of baseline); 0% exceeding maximum of baseline.

Figure U16

PVT RRT/Minute Slope Corrected for Time of Day as a Function of Study Day for P2

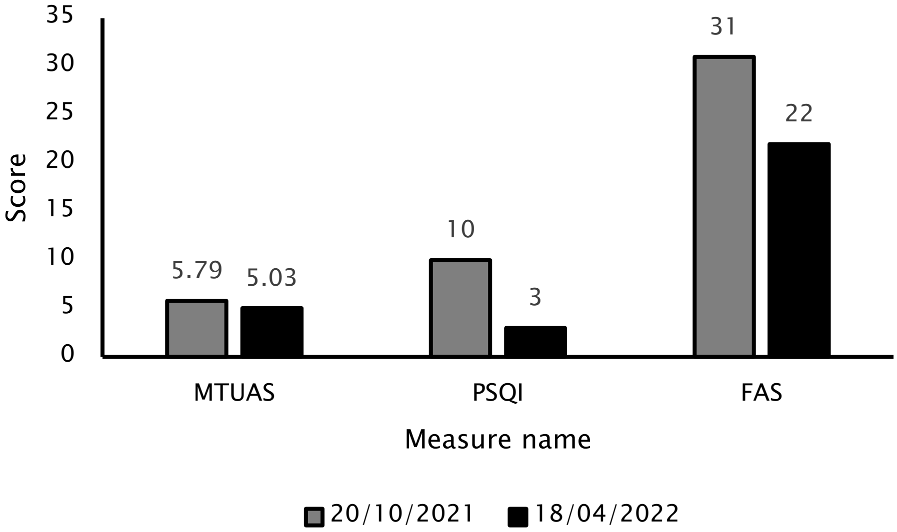


Note. Unstable baseline; PND: 0% under minimum of baseline; 0% exceeding maximum of baseline. No notable effect of intervention on fatigue propensity when correcting for time of day (see Appendix S).

Intake and Follow-up Assessment

Figure U17

Intake and 6-Month Follow-up Assessment for P2



Note. Numbers rounded to 2 decimal places for the MTUAS. MTUAS score dropped by 0.76 points, less than reliable change. PSQI scores improved to below generally accepted cutoff (<5) indicating no notable sleep problems at follow up, improving by 7 points indicating reliable change. FAS score improved by 9 points, indicating reliable change. Approximately 6 months between assessments.

Summary

For P2, the most frequently intended hardware was their TV or phone, with less frequent use of PlayStation, and combination of different hardware also occasionally intended. Their intended activities were approximately evenly split between watching TV, movies, and games, with less frequent, though still present intentions to listen to music, white noise, and using social media. Their most used extra hardware was their phone, with less commonly extra use of their TV or PlayStation. The most common extra activity was gaming. However, music, social media, and TV watching also occurred on several occasions as extra activities. In total, P2 noted 112 total entries in their EMU diaries. P2's EMU use time showed a surprisingly sharp immediate drop in both in subjectively reported and also measured through screentime applications use time between baseline and intervention phases. This was best explained through the ship leaving for a new sailing on study day 15, the beginning of their intervention phase. P2's estimated nightly sleep duration and sleep quality showed minimal change from baseline into the intervention phase. Although P2 showed a slight downward trend in estimated sleep duration over phase 3, this was not reflected in their actigraphy outcomes and overall trends appeared even. There was an apparently long WASO measured by actigraphy for P2 on study night 34, which interestingly did not reflect in their subjective estimates. Otherwise, while highly variable, the sleep outcomes scores for P2 did not show any consistent systemic changes that could be attributed to the intervention's impact. Subjective fatigue scores for P2 was highly variable across the study, with no notable changes that could be attributed to the intervention. Their subjective sleepiness scores were also highly variable within phases and showed no marked between phase changes. Their average response speed (RRT) in the PVTs also showed a relatively stable baseline, an even within-phase-2 trend, and a downward trend in phase 3. and while their overall mean RRT and mean RRT of slowest 10% of responses declined at the end of phase 3, their mean RRT for the fastest 10% of responses remained high and at level with baseline. The impact of time on task on performance was evaluated through RRT vs minute slopes to capture a fatigue effect. P2 showed high within-phase variability and a slight downward, although fluctuating trend within phases for this fatigue effect. Phases 2 and 3 for P2 were each similar to baseline indicating a fluctuating pattern though consistent fatigue propensity over the course of the study. Time of day correction did not substantially change P2's performance patterns. When comparing their intake and their 6-month follow-up questionnaire scores, P2 showed a reliable decrease in fatigue and a reliable improvement in sleep quality. Their measures of subjective longer-term EMU showed a decreasing trend, though this change was below the RCI threshold.

Appendix V

Individual Results for P3

This appendix shows individual results for P3 from multiple baseline single case experimental design study described in Chapter 5 of this thesis. Timeseries charts for each of the outcome measures are included. As many of these charts are similar, a general note is provided here: while these charts are separated into the three study phases represented by vertical lines, Percentage of nonoverlapping data assessment concatenated phases 2 and 3, as these represented the time after the introduction of the intervention. Discontinuous lines within phases indicate missing data. Fine dotted horizontal lines represent within phase medians, dashed horizontal lines represent overall medians.

Appendix V: Individual Results for P3

EMU Overview

Table V1

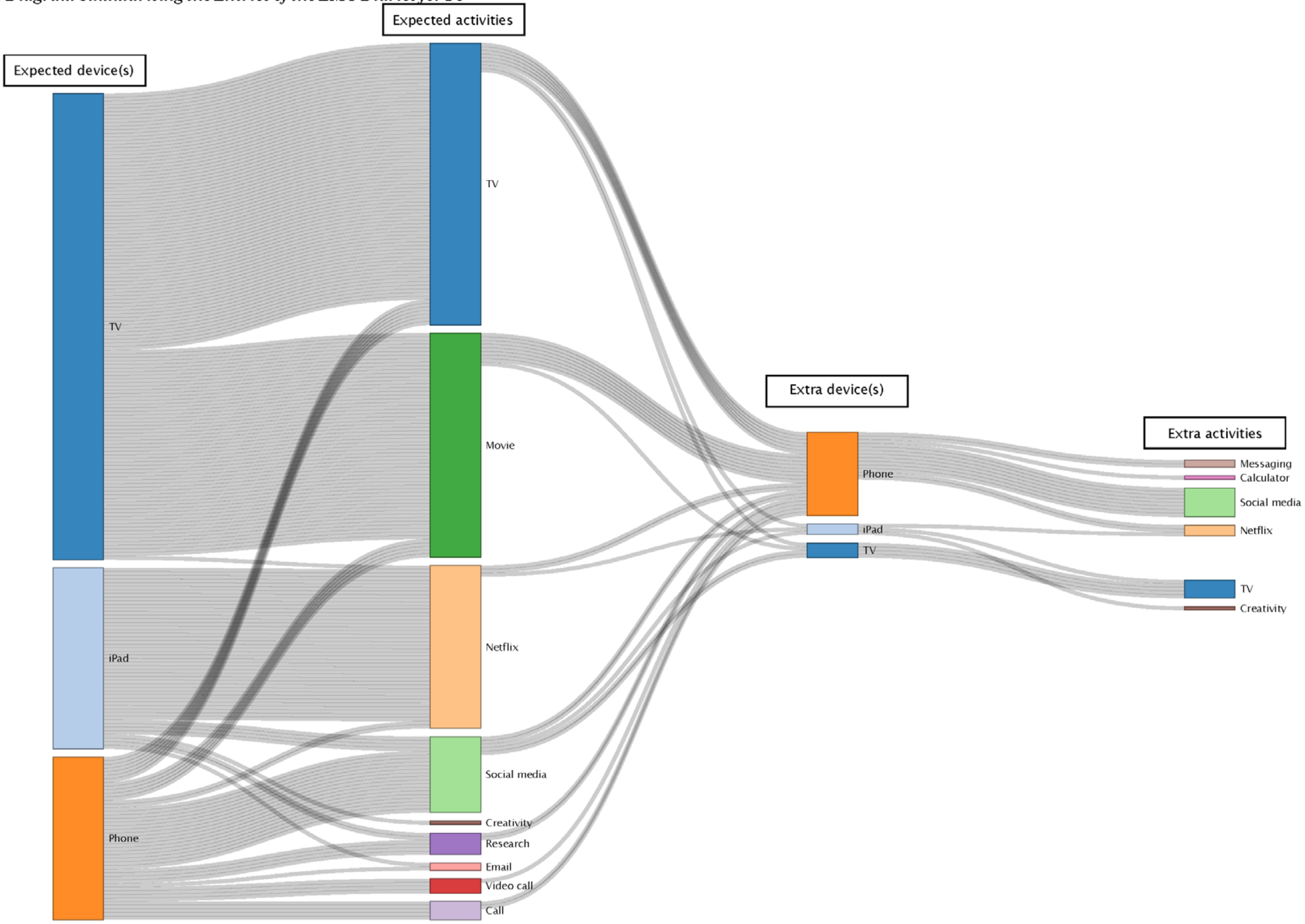
Time Spent on Intended Activities for P3

Device (Activities)	Sum of time recorded (Minutes)
iPad	**2103**
Creativity	25
Emails (reading)	30
Netflix	1658
researching	90
Social media	255
(blank)	45
Phone	**448**
Call	45
Facetime	163
Social media	240
TV	**1112**
Lounge TV	50
Mess TV	907
Mess TV (movie)	155
Total	3663

Note. TV: Television

Figure V1

A Sankey Diagram Summarising the Entries of the EMU Diaries for P3



Note. This diagram was based on an aggregate of the 106 total entries made in EMU diaries by P3. Some reported activities and devices used were obfuscated and grouped to protect anonymity. One extra activity entry consisted of multiple activities, this were unfolded for simplifying the display. All expected activity entries were singular. 107 total links are documented here. Created in R using the NetworkD3 package.

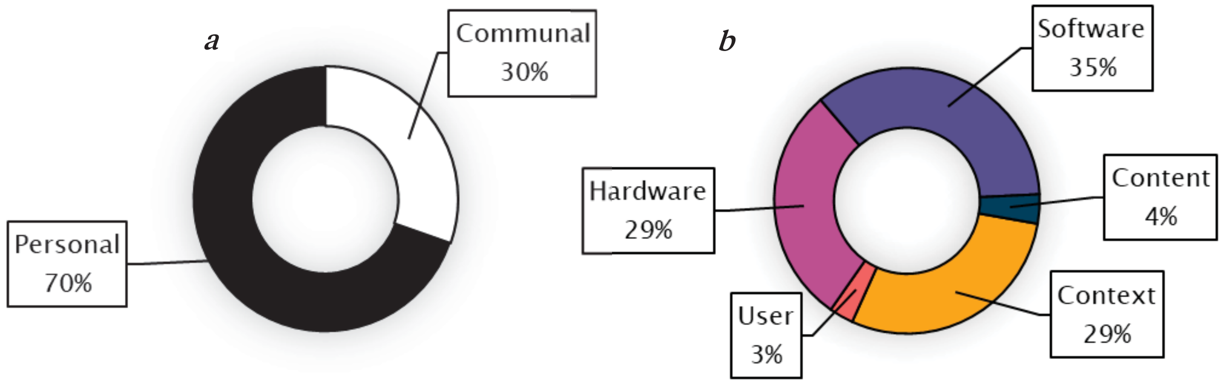
Figure V1

A Sankey Diagram Summarising the Entries of the EMU diaries for P3

(unfold)

Figure V2

Categorising EMU Descriptions and Communal Use for for P3



Note. a. Personal versus communal EMU was identified through the EMU audits based on identified hardware of use from *expected devices* fields in the EMU diaries. Proportions were calculated based on sums of time spent per hardware identified in the diaries from which time spent could be inferred. *b.* Entries were categorised based on aspects of EMU identified in both *expected*- and *extra activities* fields and based on number of entries.

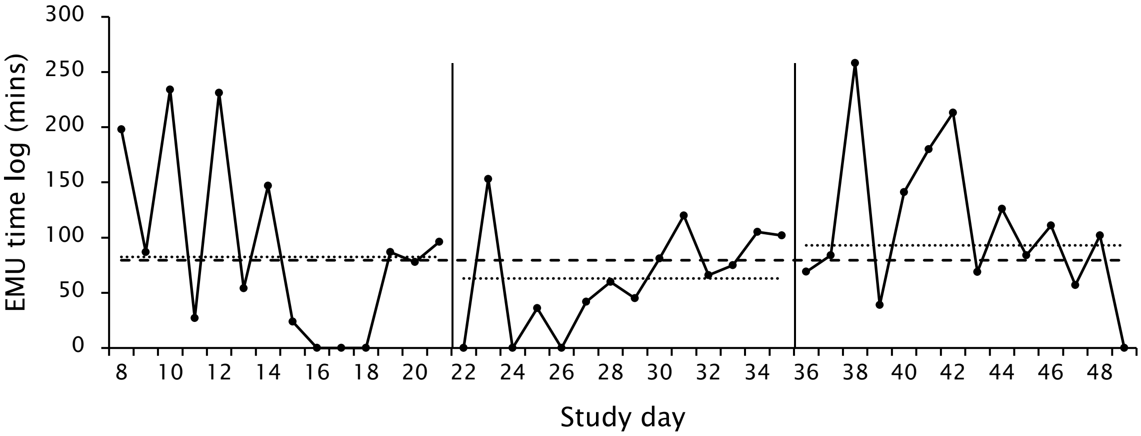
Timeseries Charts

The following timeseries charts (figures V3 through V16) were plotted to determine the effectiveness of the intervention on changing variables of EMU, sleep and wake functioning measures. On each chart, dashed lines represent the overall median, and the finer dotted lines represent the median for the individual phases to aid in visual analysis. Percentage of nonoverlapping data (PND) is presented in the notes of each chart. To calculate percentage of nonoverlapping data, phases 2 and 3 were concatenated for a measure of change after the introduction of the intervention. A general guideline for PND: scores below 50% are indicate less than effective; scores from 50% to 70% indicate questionable, from 70% to 90% are indicate effective, and above 90% indicate highly effective interventions (Scruggs & Mastropieri, 1998). Note also that duty times were recorded and charted to aid in analysis of the timeseries data, however in the interest of anonymity these are not reported.

EMU

Figure V3

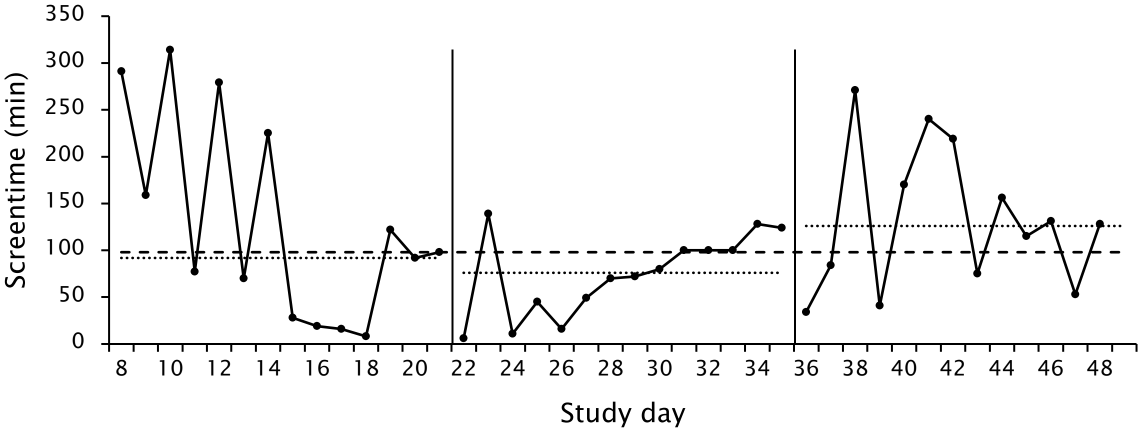
Logged EMU Time as a Function of Study Day for P3



Note. Unstable baseline; PND: 0% under minimum of baseline; (3.57% exceeding maximum of baseline).

Figure V4

Phone Screentime as a Function of Study Day for P3

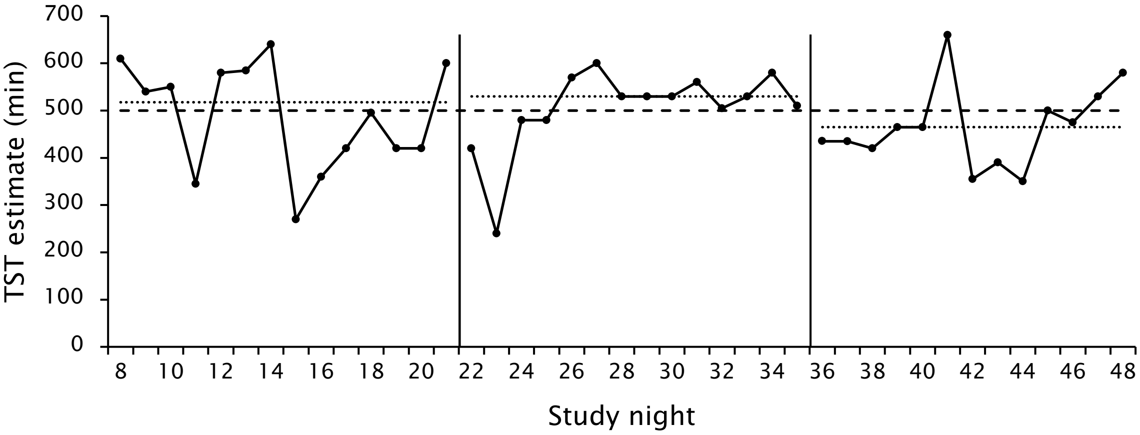


Note. Unstable baseline; PND: 3.7% under minimum of baseline; (0% exceeding maximum of baseline).

Subjective Sleep Measures

Figure V5

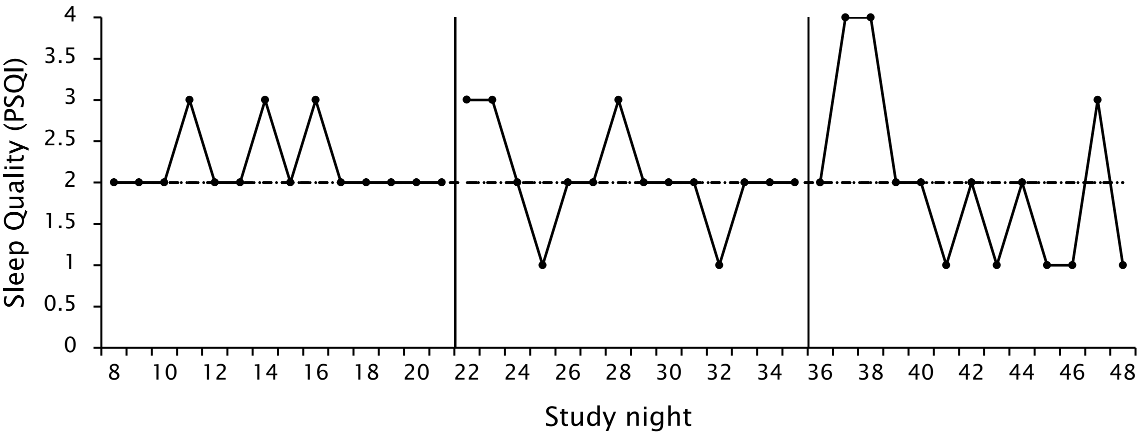
Estimated Sleep Duration as a Function of Study Night for P3



Note. Unstable baseline; PND: (3.7% under minimum of baseline); 3.7% exceeding maximum of baseline.

Figure V6

Sleep Quality as a Function of Study Night for P3

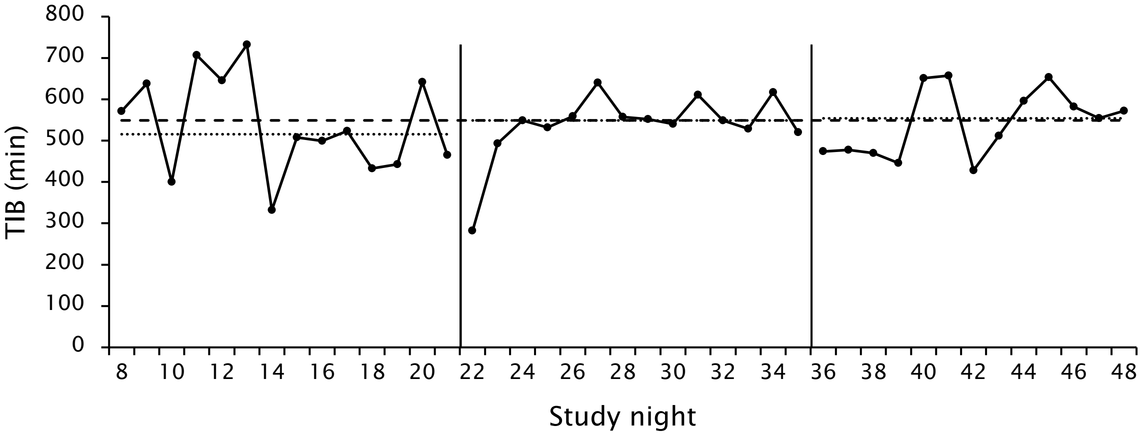


Note. Unstable baseline; PND: 25.93% under minimum of baseline; (7.41% exceeding maximum of baseline).

Actigraphy Sleep Measures

Figure V7

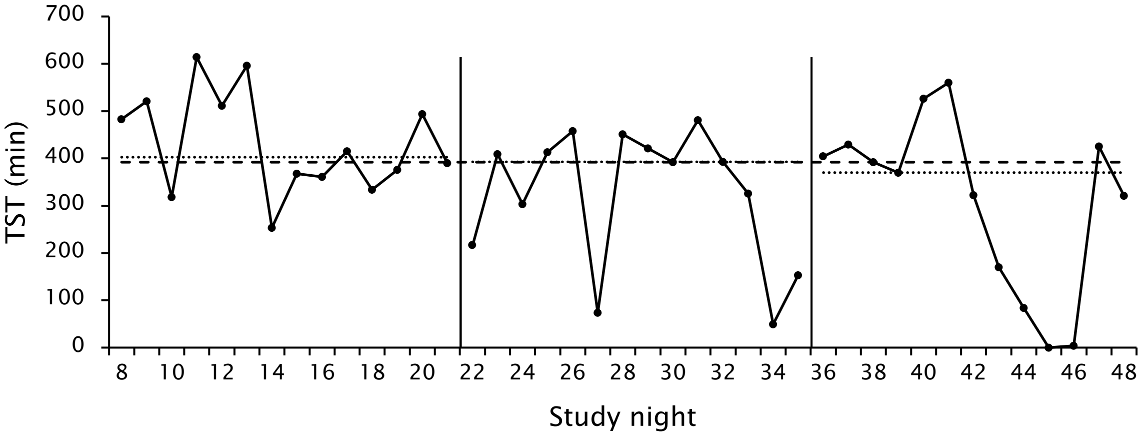
Time in Bed as a Function of Study Night for P3



Note. Unstable baseline; PND: (3.7% under minimum of baseline); 0% exceeding maximum of baseline.

Figure V8

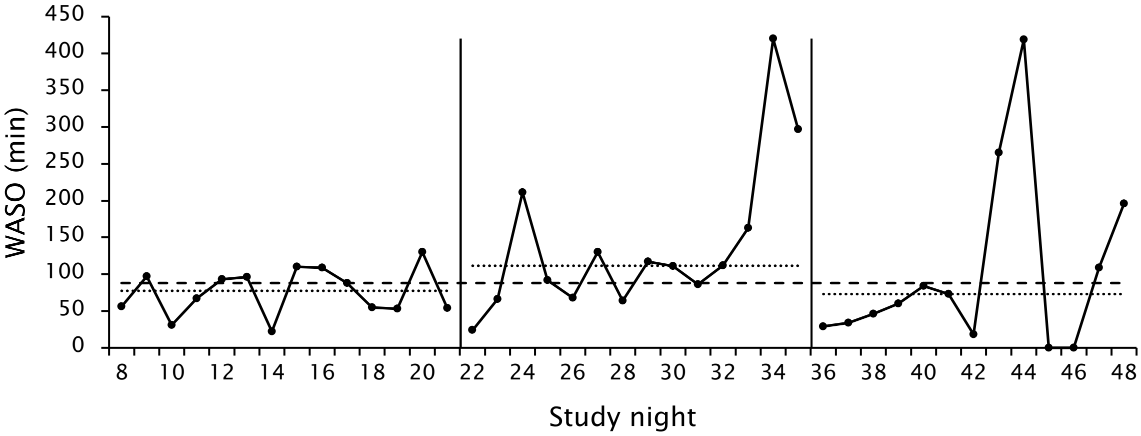
Total Sleep Time as a Function of Study Night for P3



Note. Unstable baseline; PND: (29.63% under minimum of baseline); 0% exceeding maximum of baseline.

Figure V9

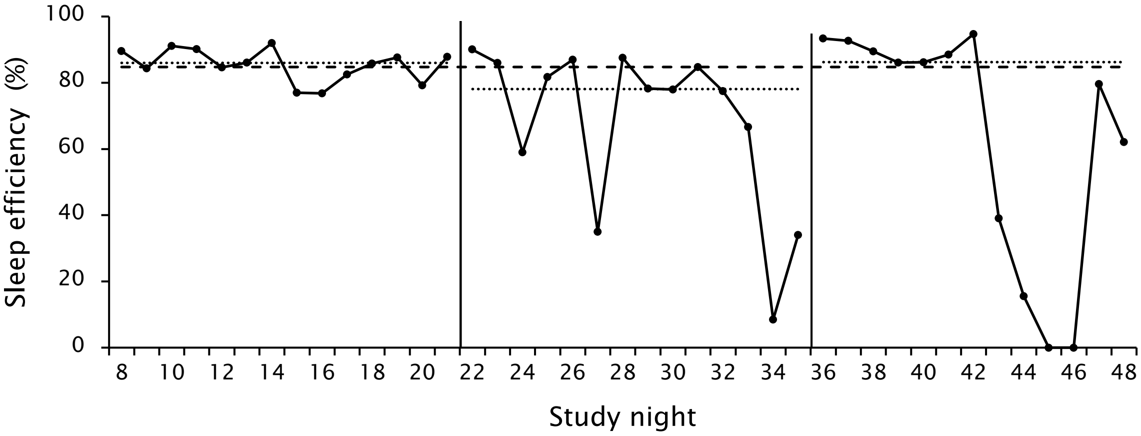
Wake After Sleep Onset as a Function of Study Night for P3



Note. Unstable baseline; PND: 4% under minimum of baseline; (28% exceeding maximum of baseline).

Figure V10

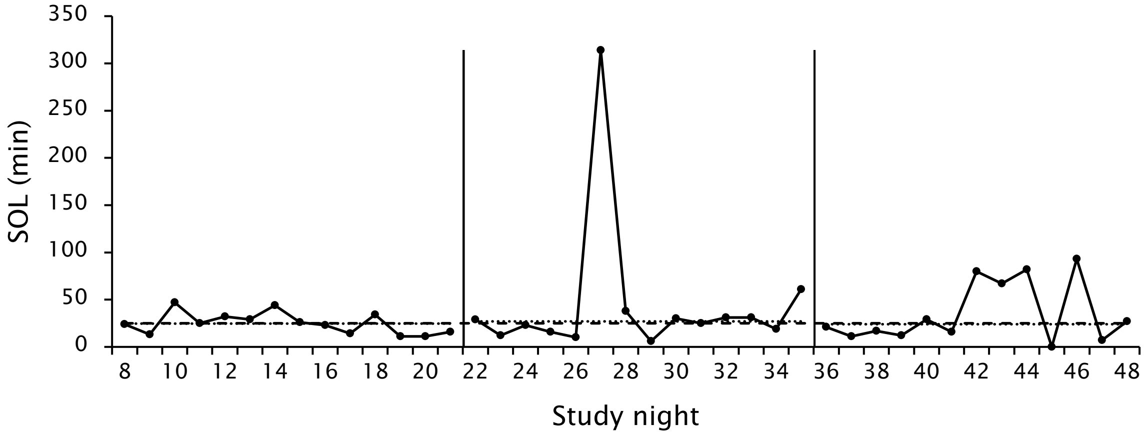
Sleep Efficiency as a Function of Study Night for P3



Note. Stable Baseline; PND: (32% under minimum of baseline); 12% exceeding maximum of baseline.

Figure V11

Sleep Onset Latency as a Function of Study Night for P3

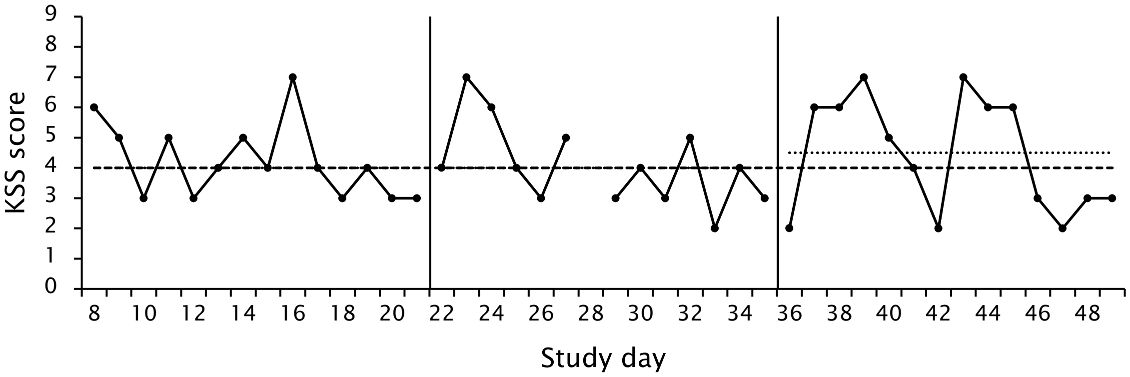


Note. Unstable baseline; PND: 11.54% under minimum of baseline; (23.08% exceeding maximum of baseline).

Vigilance/Sleepiness

Figure V12

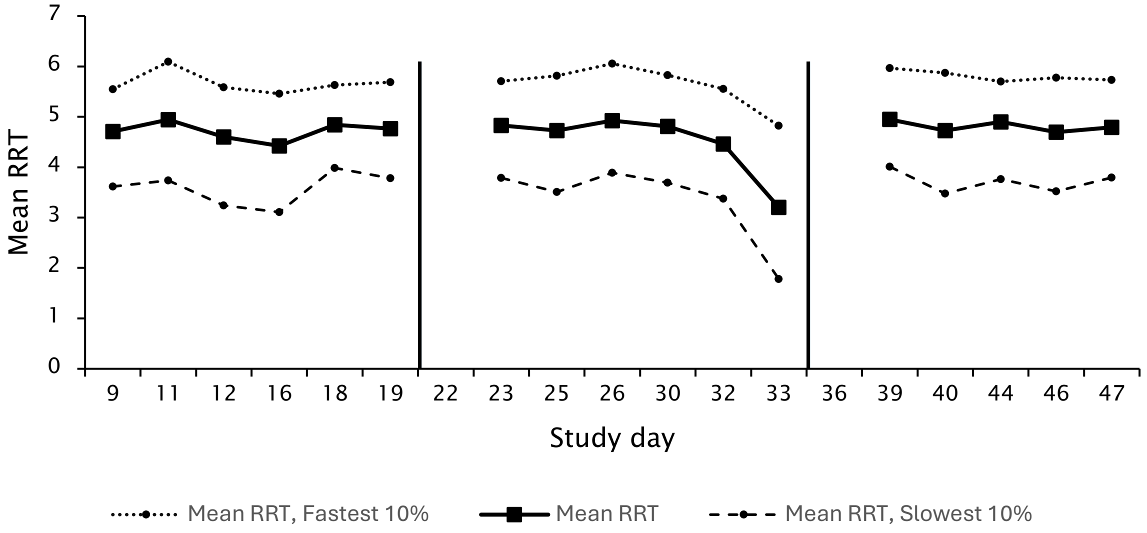
Subjective Sleepiness as a Function of Study Day for P3



Note. Unstable baseline; PND: 14.81% under minimum of baseline; (0% exceeding maximum of baseline).

Figure V13

Overall Psychomotor Vigilance Metrics as a Function of Study Day for P3

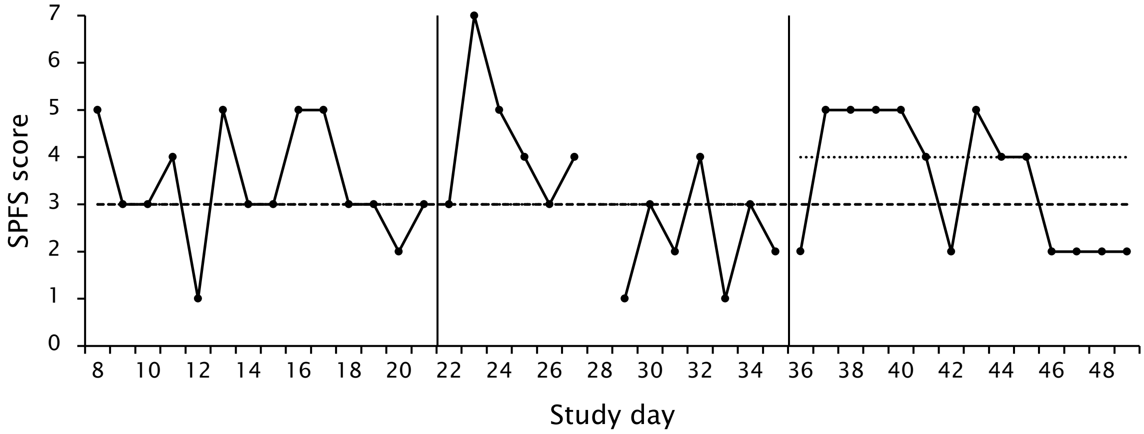


Note. P3: For overall mean reciprocal reaction time (RRT): Stable Baseline; PND: 9.09% under minimum of baseline; 9.09% exceeding maximum of baseline; For mean of slowest 10% RRT: Stable Baseline; PND: 9.09% under minimum of baseline; 9.09% exceeding maximum of baseline. For mean of fastest 10% RRT: Stable Baseline; PND: 9.09% under minimum of baseline; 0% exceeding maximum of baseline. Note that these were plotted and analysed independently, however are reported in a single chart here in the interest of conciseness.

Fatigue

Figure V14

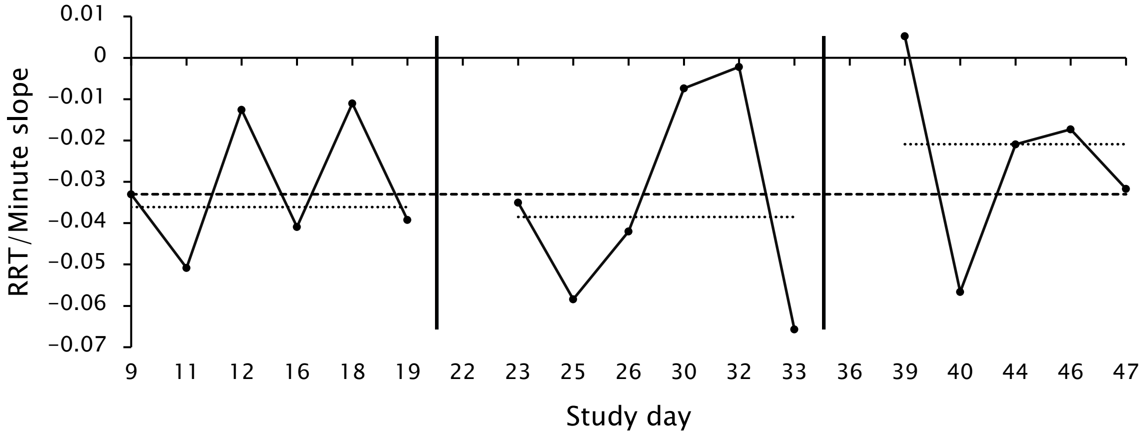
Subjective Fatigue Score as a Function of Study Day for P3



Note. Unstable baseline; PND: 0% under minimum of baseline; (3.7% exceeding maximum of baseline).

Figure V15

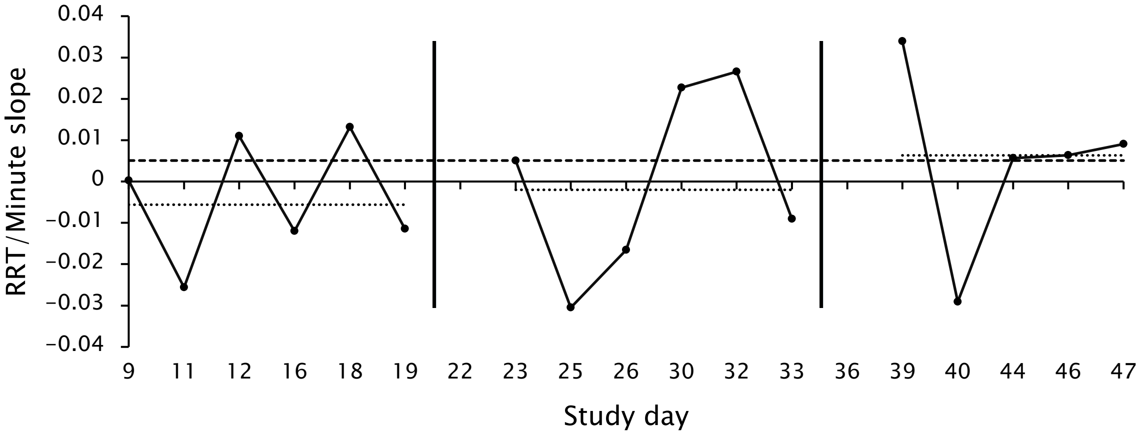
PVT RRT/Minute Slope as a Function of Study Day for P3



Note. Unstable baseline; PND: (27.27% under minimum of baseline); 27.27% exceeding maximum of baseline.

Figure V16

PVT RRT/Minute Slope Corrected for Time of Day as a Function of Study Day for P3

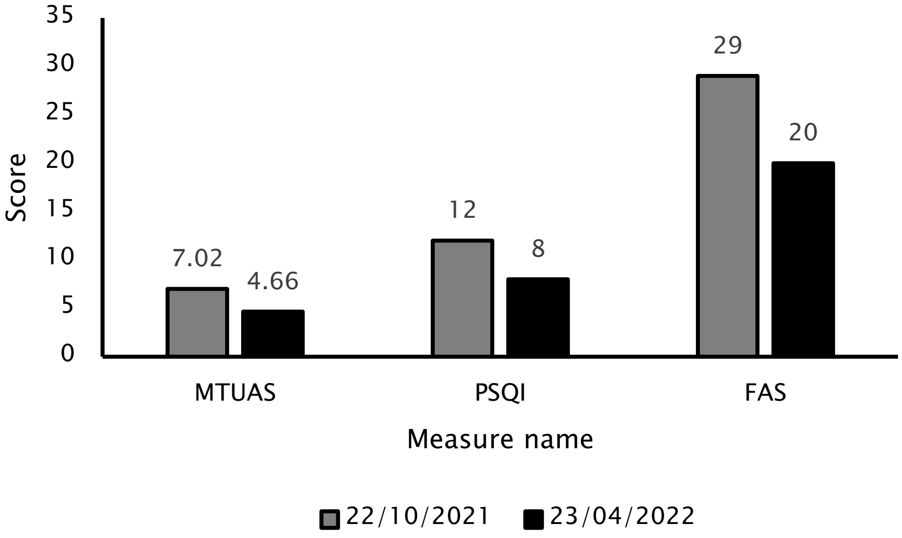


Note. Unstable baseline; PND: (18.18% under minimum of baseline); 27.27% exceeding maximum of baseline.

Intake and Follow-up Assessment

Figure V17

Intake and 6-Month Follow-up Assessment for P3



Note. MTUAS dropped by 2.36 points, indicating less than reliable change. PSQI dropped by 4 points, indicating less than reliable change. The FAS scores dropped 9 points, indicating reliable change. Approximately 6 months between assessments.

Summary

For P3, the most commonly used intended hardware was TV, with less frequent use of their iPad and phone. The most common activities that they intended for their EMU were TV, movie, and Netflix, though specific content was not documented. Social media was also often engaged in as expected activity on their phone, though this was less frequent than the others. For their extra activities, their most used extra was their phone, and thier most engaged in extra activity was social media. Overall, P3 documented 106 total entries in their EMU diary. P3's subjective EMU quantity showed a surprisingly sharp immediate drop in the middle of baseline EMU measurement. This was best explained through the ship leaving for a new sailing on study day 15, in the middle of their intervention phase. For P3, an even, although variable subjective estimate of sleep duration in baseline showed an upwards trend during phase 2, although this did not reach above their baseline measurement of sleep duration. This pattern was seemingly echoed in their time in bed measurements from actigraphy, although was not reflected in their actigraphically measured total sleep time. Consistent with this, their wake after sleep onset increased from baseline during phase 2 and their sleep efficiency showed a downward trend during both phases 2 and 3, jumping back to above baseline at the beginning of each phase. This pattern appeared to reflect a roughly fortnightly duty time pattern more so than any intervention effect. P3 reported being highly fatigued (SPFS score of 7) on the second day of intervention phase, this was a singular occurrence and balanced with a subsequent downward trend. Their subjective sleepiness score was highly variable within phases and showed no marked between phase changes. They showed stable within phase variability for mean RRT, with one PVT which showed marked lower speed at the end of phase 2 for both mean RRT and mean RRT of slowest 10% of responses; their fastest 10% speed was relatively robust to this performance drop. The impact of time on task on performance was evaluated through RRT vs minute slopes to capture a fatigue effect. P3 showed highly variable, although subtly increasing median within-phase fatigue scores, in line with an upwards trend observed in phase 1. Correcting for time of day did not substantially change this pattern. When comparing their intake and their 6-month follow-up questionnaire scores, P3 showed a reliable decrease in fatigue, with an unreliable based on RCI, though still notable increase in sleep quality (4 point improvement in PSQI). While their MTUAS measure of EMU decreased, this change was also below RCI threshold of reliability.

Appendix W

Individual Results for P4

This appendix shows individual results for P4 from multiple baseline single case experimental design study described in Chapter 5 of this thesis. Timeseries charts for each of the outcome measures are included. As many of these charts are similar, a general note is provided here: while these charts are separated into the three study phases represented by vertical lines, Percentage of nonoverlapping data assessment concatenated phases 2 and 3, as these represented the time after the introduction of the intervention. Discontinuous lines within phases indicate missing data. Fine dotted horizontal lines represent within phase medians, dashed horizontal lines represent overall medians.

Appendix W: Individual Results for P4

Electronic Media Use

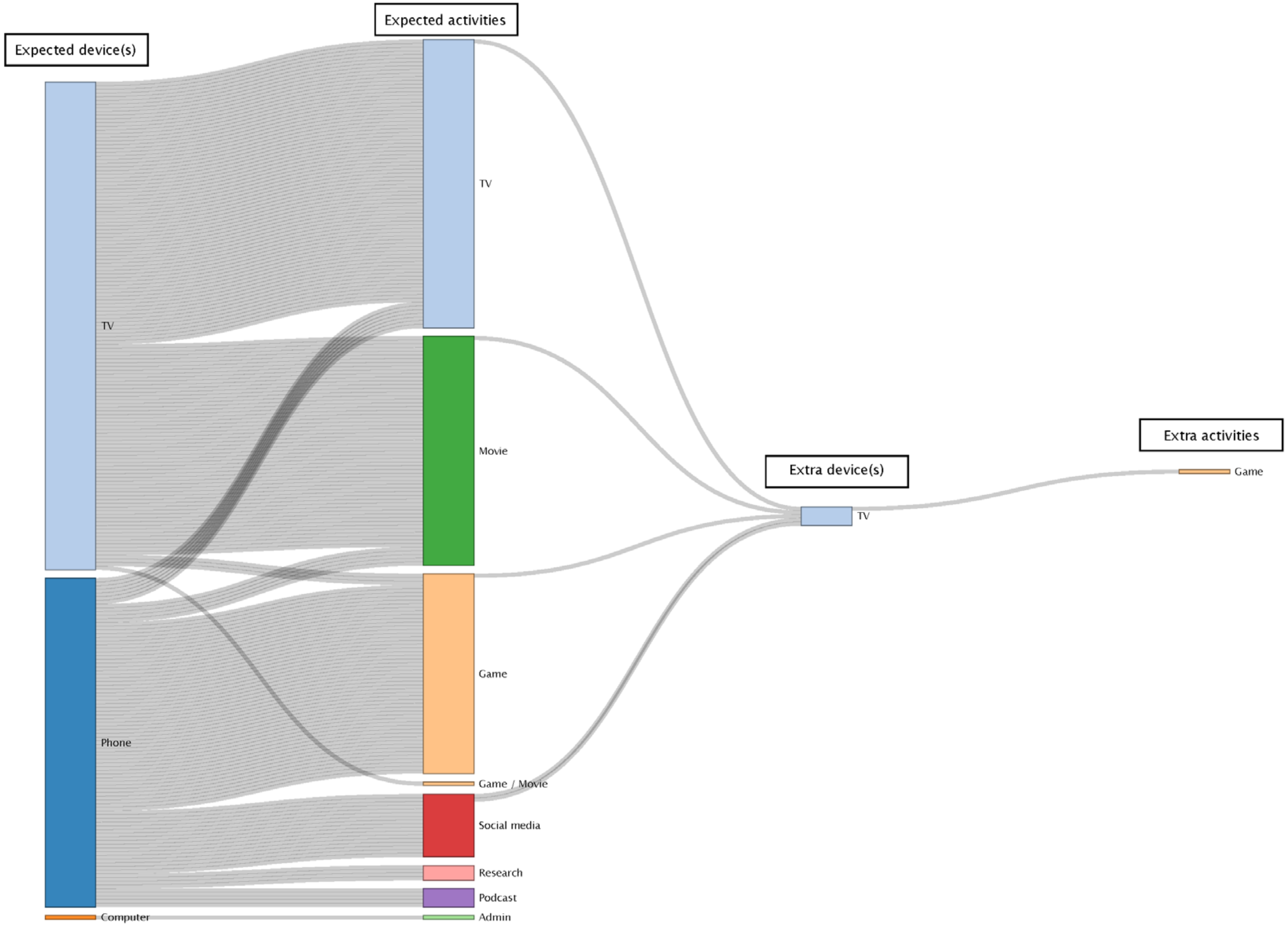
Table W1

Time Spent on Intended Activities for P4

Device (Activities)	Sum of time recorded (Minutes)
Computer	**120**
Admin	120
Phone	**2010**
Game	1215
Google Maps	15
Movie	450
Podcast	300
Social media	15
TV Series	15
TV	**2551**
Game / Movie	300
Movie	2051
Playstation	20
TV Series	180
Total	4681

Figure W1

A Sankey Diagram Summarising the Entries of the EMU Diaries for P4



Note. This diagram was based on an aggregate of the 79 total entries made in EMU diaries by P4. Some reported activities and devices used were obfuscated and grouped to protect anonymity. All entries made by P4 in the "extra activities" column were single activities and required no unfolding. 79 total links are documented here. Created in R using the NetworkD3 package.

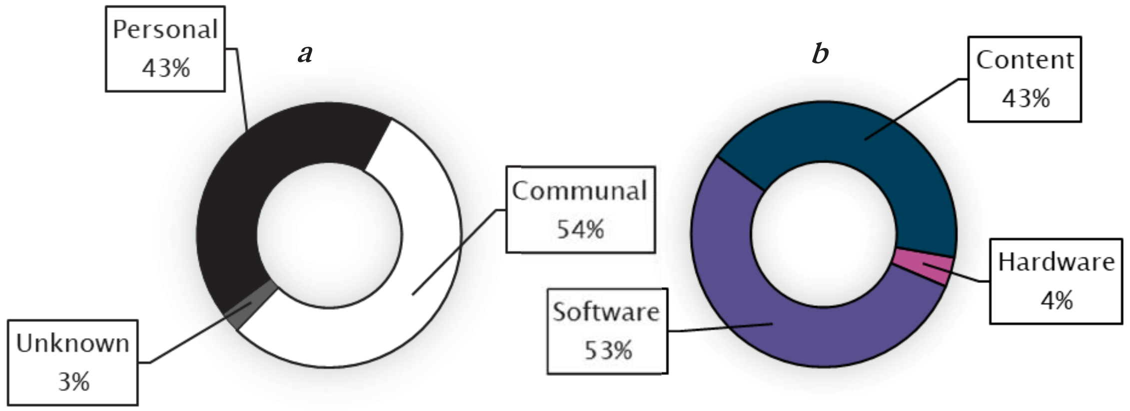
Figure W1

A Sankey Diagram Summarising the Entries of the EMU diaries for P4

(unfold)

Figure W2

Categorising EMU Descriptions and Communal Use for P4



Note. a. Personal versus communal EMU was identified through the EMU audits based on identified hardware of use from *expected devices* fields in the EMU diaries. Proportions were calculated based on sums of time spent per hardware identified in the diaries from which time spent could be inferred. *b*. Entries were categorised based on aspects of EMU identified in both *expected*- and *extra activities* fields and based on number of entries.

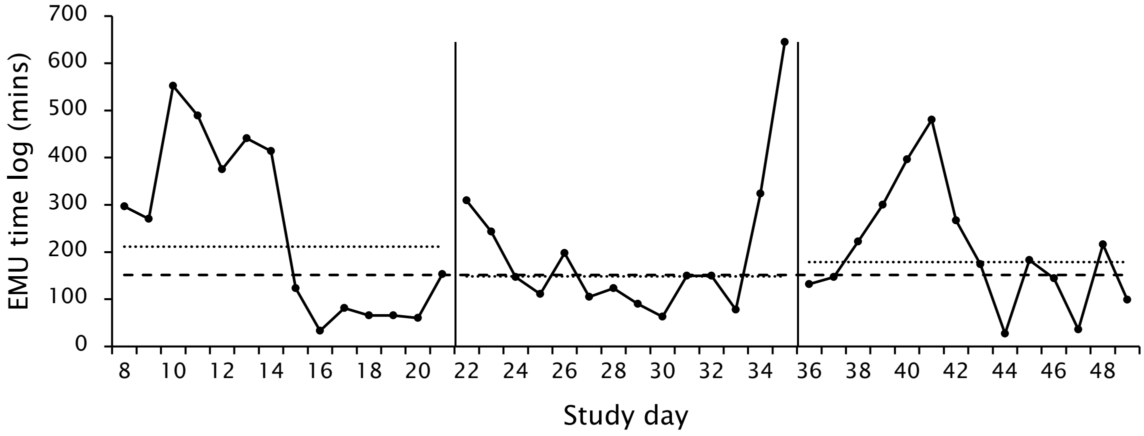
Timeseries Charts

The following timeseries charts (figures W3 through W16) were plotted to determine the effectiveness of the intervention on changing variables of EMU, sleep and wake functioning measures. On each chart, dashed lines represent the overall median, and the finer dotted lines represent the median for the individual phases to aid in visual analysis. Percentage of nonoverlapping data (PND) is presented in the notes of each chart. To calculate percentage of nonoverlapping data, phases 2 and 3 were concatenated for a measure of change after the introduction of the intervention. A general guideline for PND: scores below 50% are indicate less than effective; scores from 50% to 70% indicate questionable, from 70% to 90% are indicate effective, and above 90% indicate highly effective interventions (Scruggs & Mastropieri, 1998). Note also that duty times were recorded and charted to aid in analysis of the timeseries data, however in the interest of anonymity these are not reported.

EMU

Figure W3

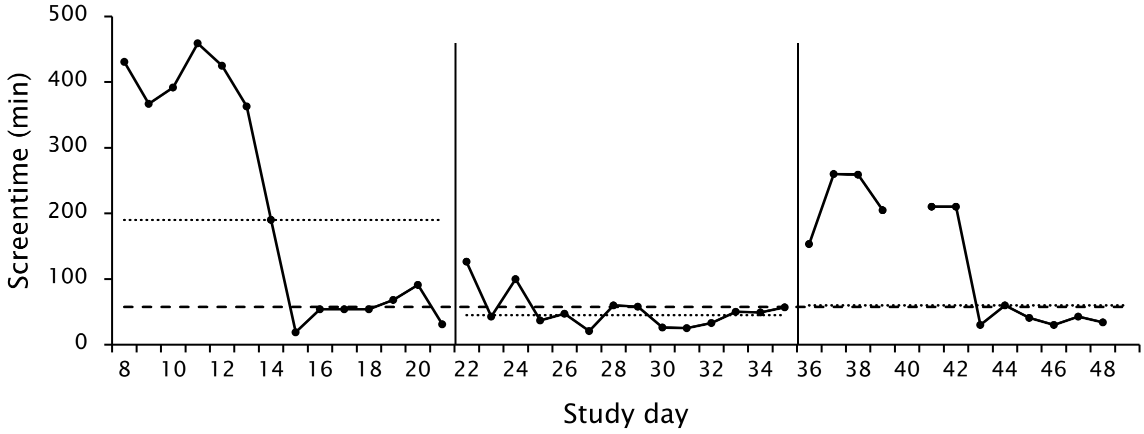
Logged EMU Time as a Function of Study Day for P4



Note. Unstable baseline; PND: 3.57% under minimum of baseline; (3.57% exceeding maximum of baseline).

Figure W4

Phone Screentime as a Function of Study Day for P4

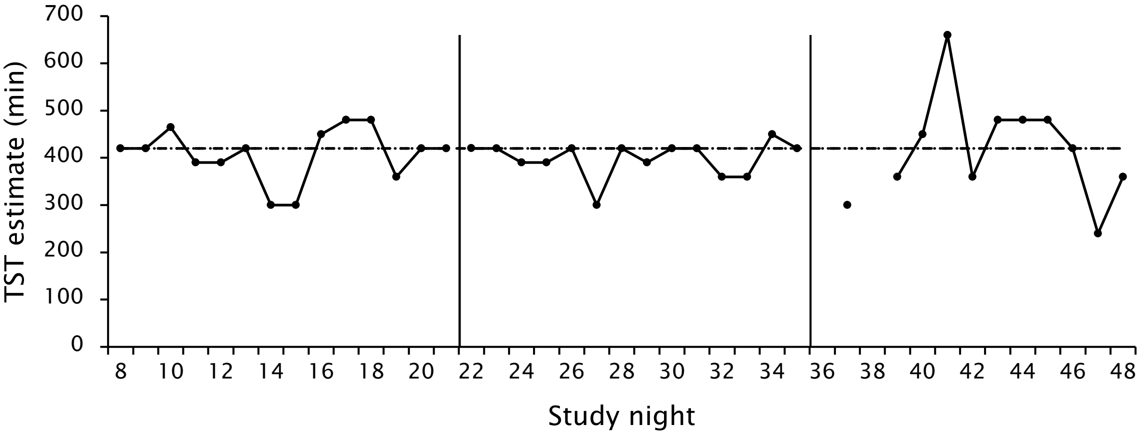


Note. Unstable baseline; PND: 0% under minimum of baseline; (0% exceeding maximum of baseline).

Subjective Sleep Measures

Figure W5

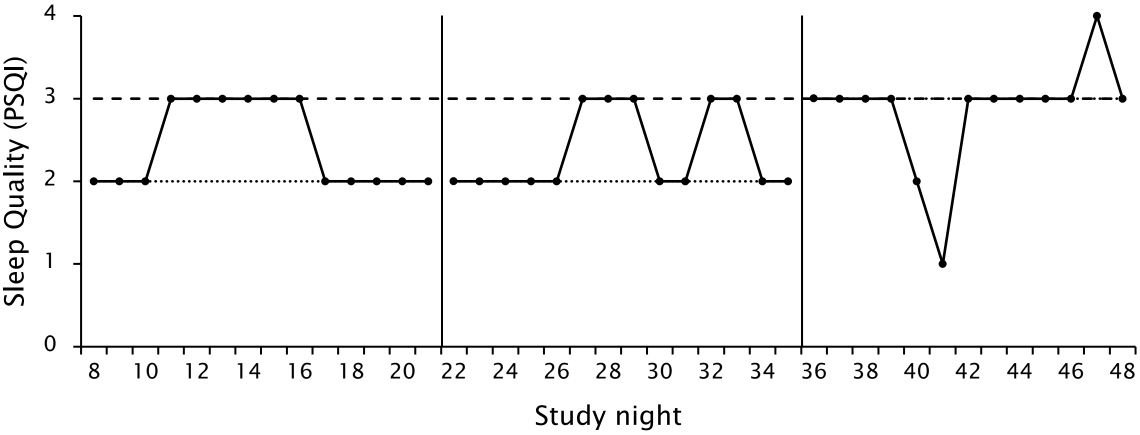
Estimated Sleep Duration as a Function of Study Night for P4



Note. Stable Baseline PND: (4% under minimum of baseline); 4% exceeding maximum of baseline.

Figure W6

Sleep Quality as a Function of Study Night for P4

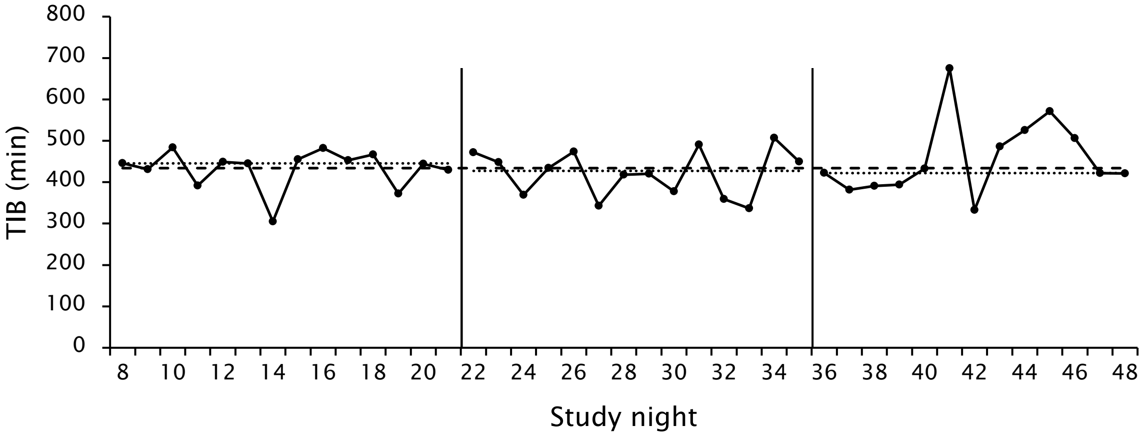


Note. Unstable baseline; PND: 3.7% under minimum of baseline; (3.7% exceeding maximum of baseline).

Actigraphy Sleep Measures

Figure W7

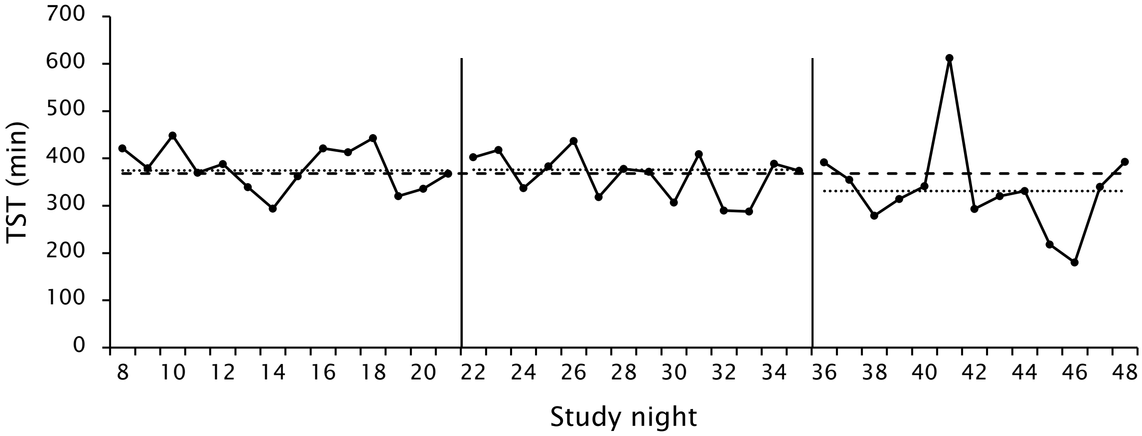
Time in Bed as a Function of Study Night for P4



Note. Stable Baseline; (PND: 0% under minimum of baseline); 25.93% exceeding maximum of baseline.

Figure W8

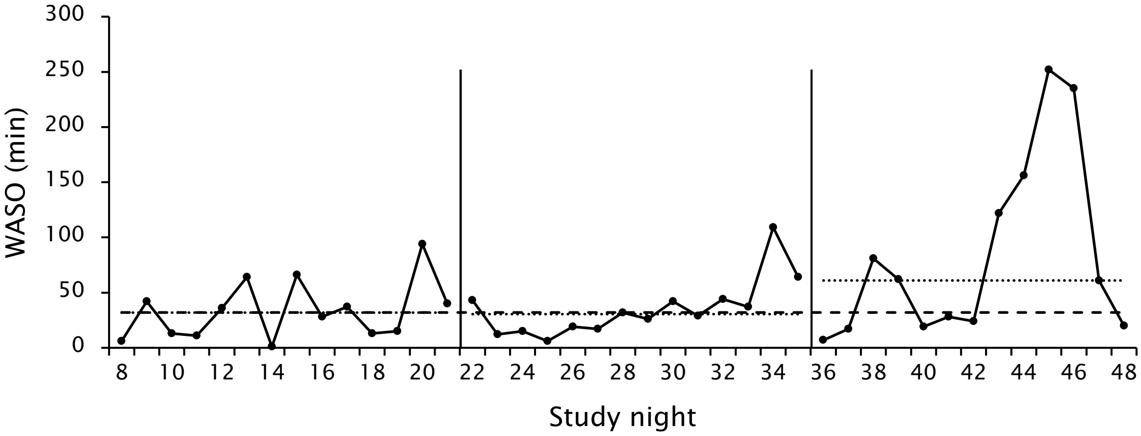
Total Sleep Time as a Function of Study Night for P4



Note. Unstable baseline; PND: (22.22% under minimum of baseline); 3.7% exceeding maximum of baseline.

Figure W9

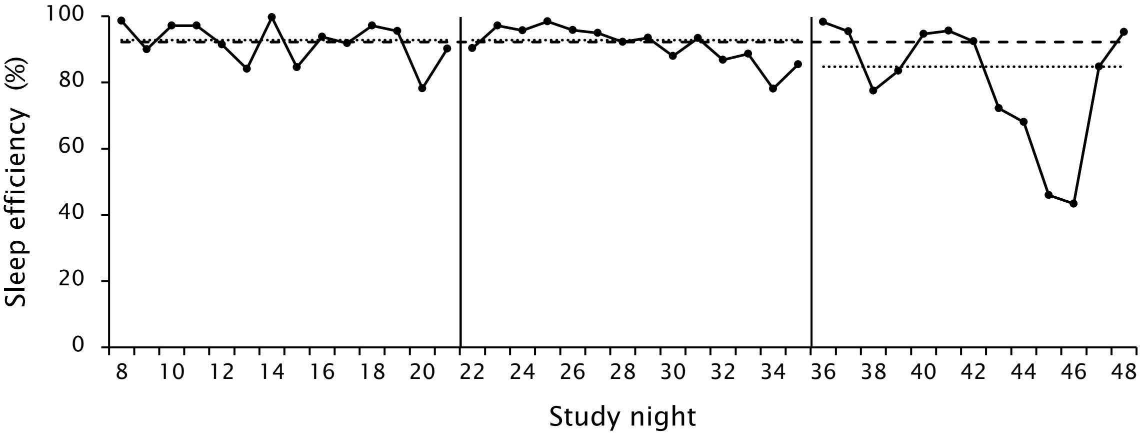
Wake After Sleep Onset as a Function of Study Night for P4



Note. Unstable baseline; PND: 0% under minimum of baseline; (18.52% exceeding maximum of baseline).

Figure W10

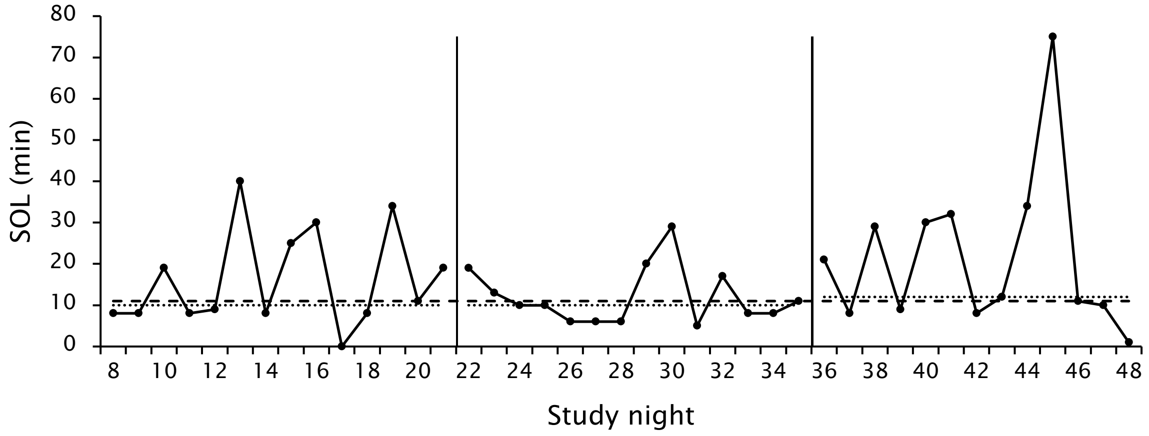
Sleep Efficiency as a Function of Study Night for P4



Note. Stable Baseline; PND: (22.22% under minimum of baseline); 0% exceeding maximum of baseline.

Figure W11

Sleep Onset Latency as a Function of Study Night for P4

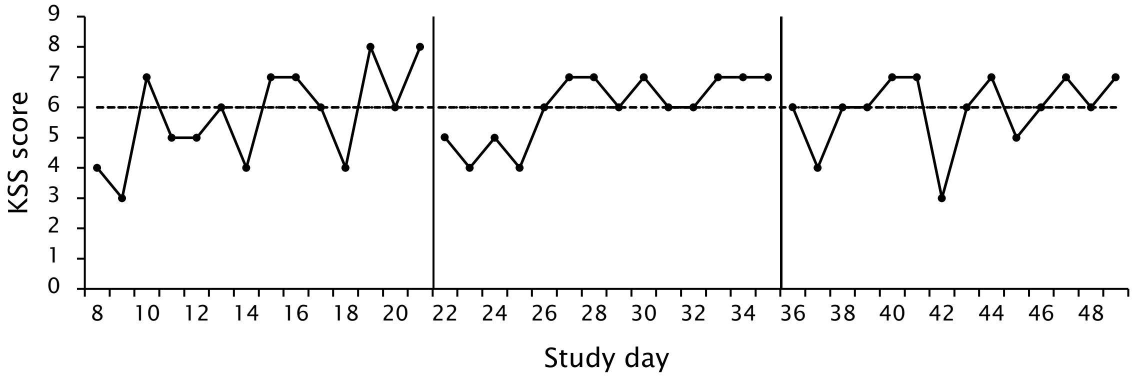


Note. Unstable baseline; PND: 0% under minimum of baseline; (3.7% exceeding maximum of baseline).

Vigilance/Sleepiness

Figure W12

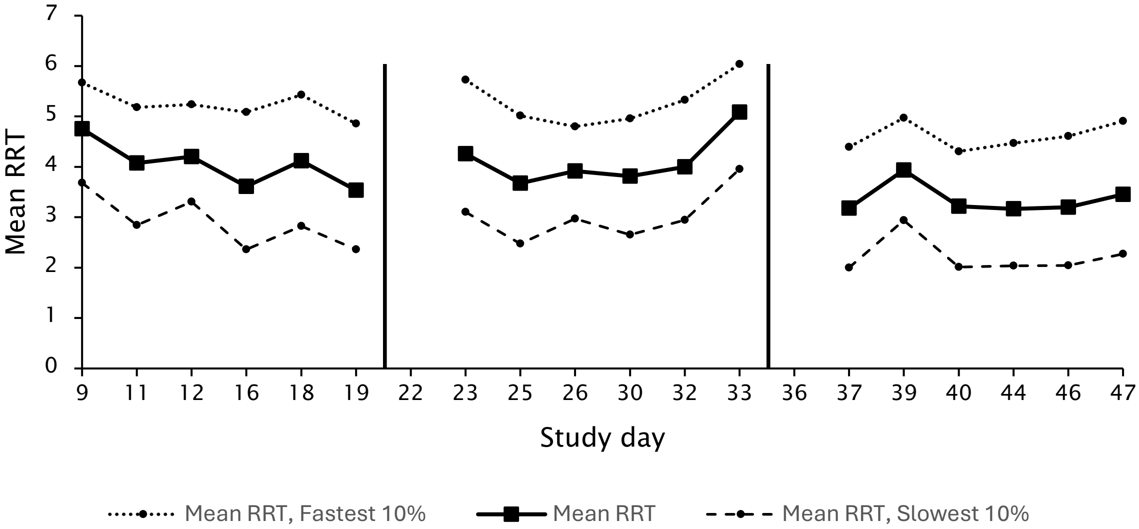
Subjective Sleepiness as a Function of Study Day for P4



Note. Unstable baseline; PND: 0% under minimum of baseline; (0% exceeding maximum of baseline).

Figure W13

Overall Psychomotor Vigilance Metrics as a Function of Study Day for P4

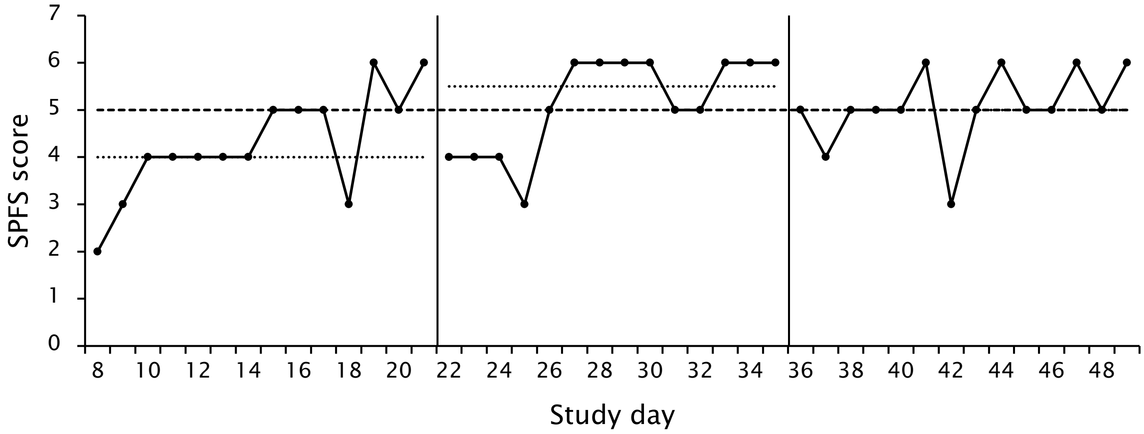


Note. P4: For overall mean reciprocal reaction time (RRT): Stable Baseline; PND: 41.67% under minimum of baseline; 8.33% exceeding maximum of baseline; For mean of slowest 10% RRT: Unstable baseline; PND: 41.67% under minimum of baseline; 8.33% exceeding maximum of baseline. For mean of fastest 10% RRT: Stable Baseline; PND: 41.67% under minimum of baseline; 16.67% exceeding maximum of baseline.

Fatigue

Figure W14

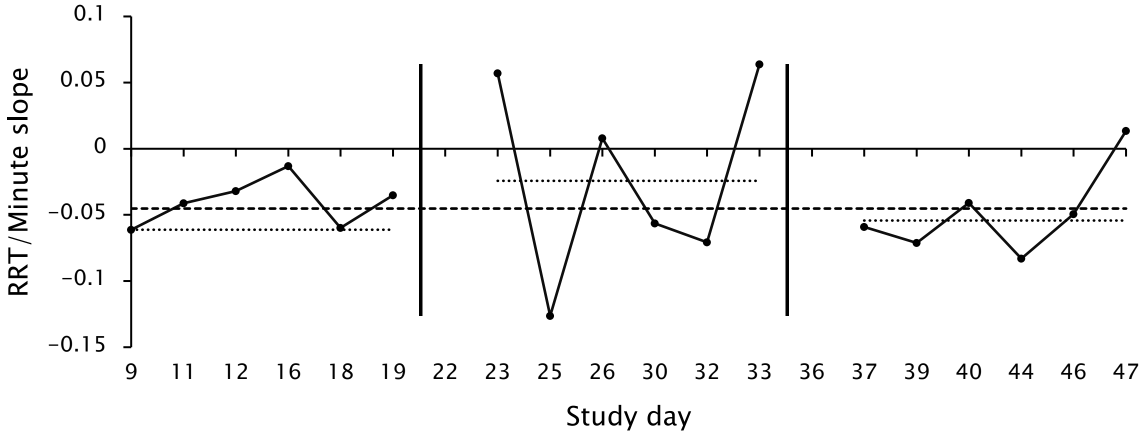
Subjective Fatigue Score as a Function of Study Day for P4



Note. Unstable baseline; PND: 0% under minimum of baseline;(0% exceeding maximum of baseline).

Figure W15

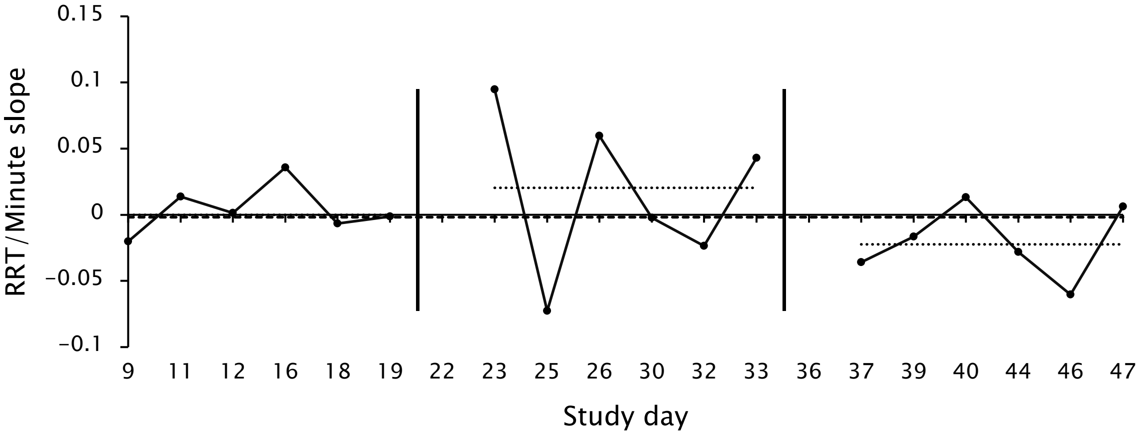
PVT RRT/Minute Slope as a Function of Study Day for P4



Note. Unstable baseline; PND: (33.33% under minimum of baseline); 33.33% exceeding maximum of baseline.

Figure W16

PVT RRT/Minute Slope Corrected for Time of Day as a Function of Study Day for P4



Note. Unstable baseline; PND: (41.67% under minimum of baseline); 25% exceeding maximum of baseline (see Appendix S).

Summary

P4's most engaged in intended hardware was TV, with less frequently documented phone use. Their most engaged in expected activities were watching TV or movies, with games also a prominent activity on their phone, and social media less frequent. Extra activities for P4 were rare indicating that much of their documented EMU was intentional, the only extra hardware that they documented was use of their TV and the only extra activity that they documented was gaming. P4 documented 79 total entries in their EMU diaries. EMU quantity showed a surprisingly sharp drop in the middle of baseline logged EMU time P4. This was best explained through the ship leaving for a new sailing on study day 15. They also showed a dramatic increase in logged EMU time around study day 35 which aligned with the ship reaching cellular reception. For P4, no substantial changes were noted in sleep quality following the introduction of the intervention, one marked outlying night with long SOL, WASO, and lowered sleep efficiency noted in actigraphy occurred following the ship leaving cellphone reception, and approximately when "clocks moved back one hour" twice in two days as reported by the research representative. Their EMU log time and phone screentime reporting were relatively low on these days, so the disrupted sleep was likely due to other factors. Interestingly, subjective reporting of sleep quality and quantity impressions for P4 did not reveal these anomalous nights. Overall, no consistent effect of the intervention on sleep metrics was able to be found. P4 showed an increasing trend of subjective fatigue over both baseline and phase 2. This trend stabilised during phase 3 with scores hovering around the overall median (SPFS score 5), phases 2 and 3 for P4 overlapped completely with the variable and upwards trending scores in baseline measurement. Their subjective sleepiness scores were highly variable within phases showed no marked between phase changes. Within PVT metrics P4 showed a declining trend in mean overall RRT over baseline measurement, which appeared to become an upward trend during phase 2, although stabilising at a lower level in phase 3. This pattern was consistent across mean, slowest 10% and fastest 10% mean RRTs in the PVT. The impact of time on task on performance was evaluated through RRT vs minute slopes to capture a fatigue effect. P4 showed an increase in variability of these fatigue slopes in phase 2, decreasing in phase 3, with a slight elevating trend in phase 2, though more consistent in baseline and phase 3. These patterns remained similar after correcting for time of day of testing.

Appendix X

Individual Results for P5

This appendix shows individual results for P5 from multiple baseline single case experimental design study described in Chapter 5 of this thesis. Timeseries charts for each of the outcome measures are included. As many of these charts are similar, a general note is provided here: while these charts are separated into the three study phases represented by vertical lines, Percentage of nonoverlapping data assessment concatenated phases 2 and 3, as these represented the time after the introduction of the intervention. Discontinuous lines within phases indicate missing data. Fine dotted horizontal lines represent within phase medians, dashed horizontal lines represent overall medians.

Appendix X: Individual Results for P5

EMU Overview

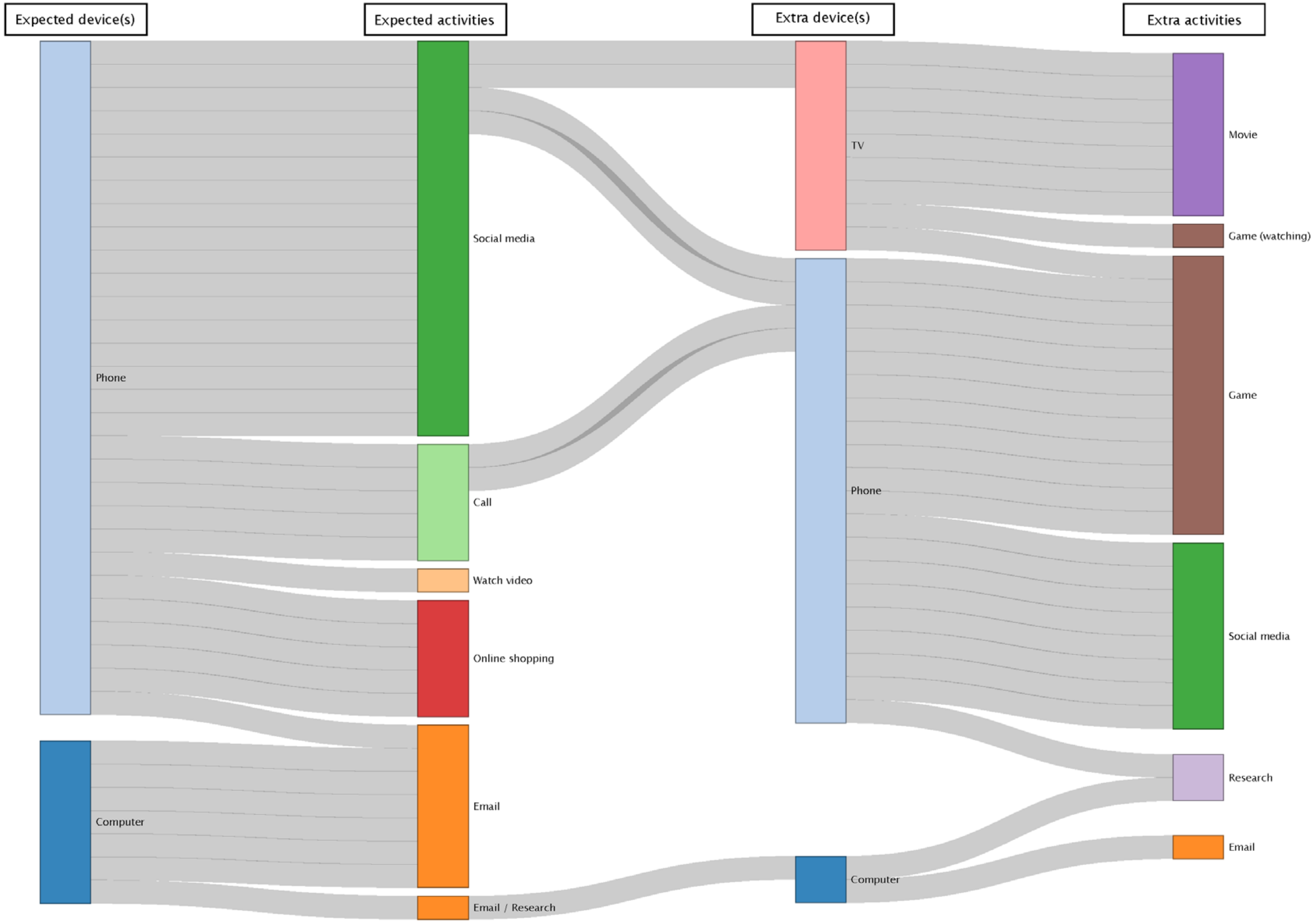
Table X1

Time Spent on Intended Activities for P5

Device (Activities)	Sum of time recorded (Minutes)
Computer	**188**
Email	103
Email / Admin	75
(blank)	10
Phone	**137**
Call	55
Trademe	30
Watch Video	32
(blank)	20
(blank)	**215**
Email	10
(blank)	205
Grand Total	540

Figure X1

A Sankey Diagram Summarising the Entries of the EMU Diaries for P5



Note. This diagram was based on an aggregate of the 21 total entries made in EMU diaries by P5. Some reported activities and devices used were obfuscated and grouped to protect anonymity. All entries made by P5 in the “extra activities” column were single activities and required no unfolding. 21 total links are documented here. Created in R using the NetworkD3 package.

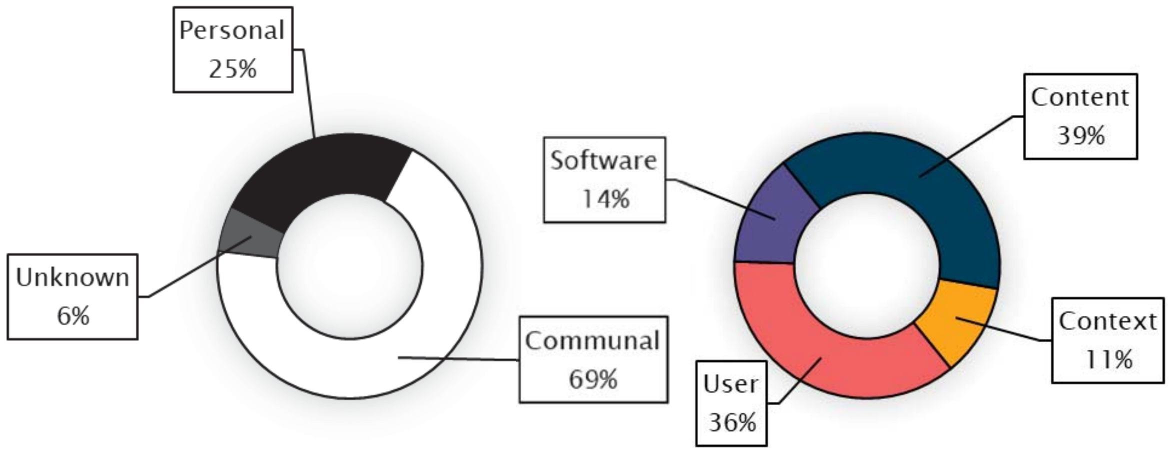
Figure X1

A Sankey Diagram Summarising the Entries of the EMU diaries for P5

(unfold)

Figure X2

Categorising EMU Descriptions and Communal Use for P5



Note. a. Personal versus communal EMU was identified through the EMU audits based on identified hardware of use from *expected devices* fields in the EMU diaries. Proportions were calculated based on sums of time spent per hardware identified in the diaries from which time spent could be inferred. *b*. Entries were categorised based on aspects of EMU identified in both *expected*- and *extra activities* fields and based on number of entries.

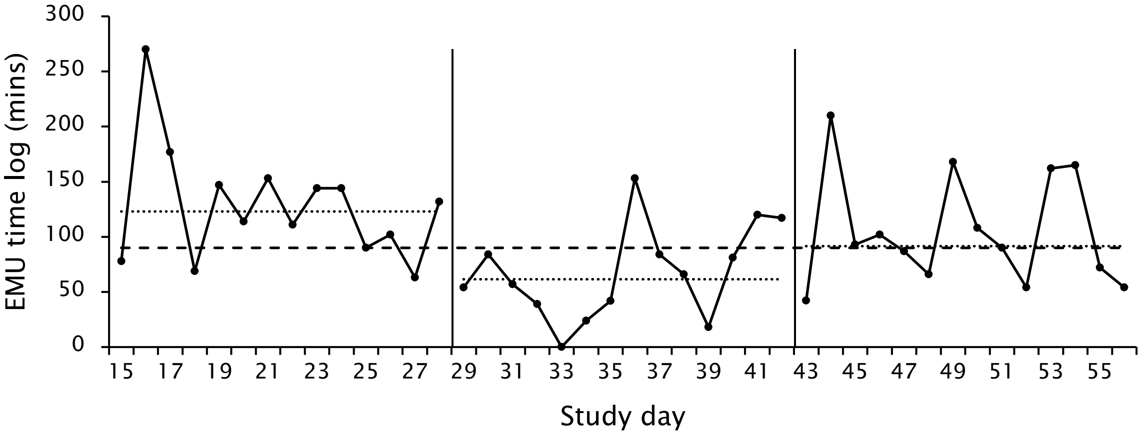
Timeseries Charts

The following timeseries charts (figures X3 through X16) were plotted to determine the effectiveness of the intervention on changing variables of EMU, sleep and daytime functioning measures. On each chart, dashed lines represent the overall median, and the finer dotted lines represent the median for the individual phases to aid in visual analysis. Percentage of nonoverlapping data (PND) is presented in the notes of each chart. To calculate percentage of nonoverlapping data, phases 2 and 3 were concatenated for a measure of change after the introduction of the intervention. A general guideline for PND: scores below 50% are indicate less than effective; scores from 50% to 70% indicate questionable, from 70% to 90% are indicate effective, and above 90% indicate highly effective interventions (Scruggs & Mastropieri, 1998). Note also that duty times were also recorded and charted to aid in analysis of the timeseries data, however in the interest of anonymity these are not reported.

EMU

Figure X3

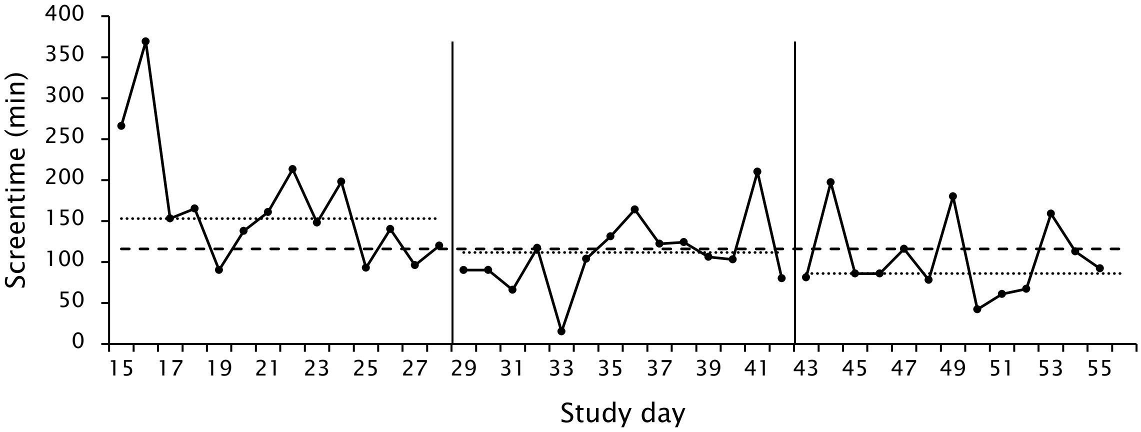
Logged EMU Time as a Function of Study Day for P5



Note. Unstable baseline; PND: 35.71% under minimum of baseline; (0% exceeding maximum of baseline).

Figure X4

Phone Screentime as a Function of Study Day for P5

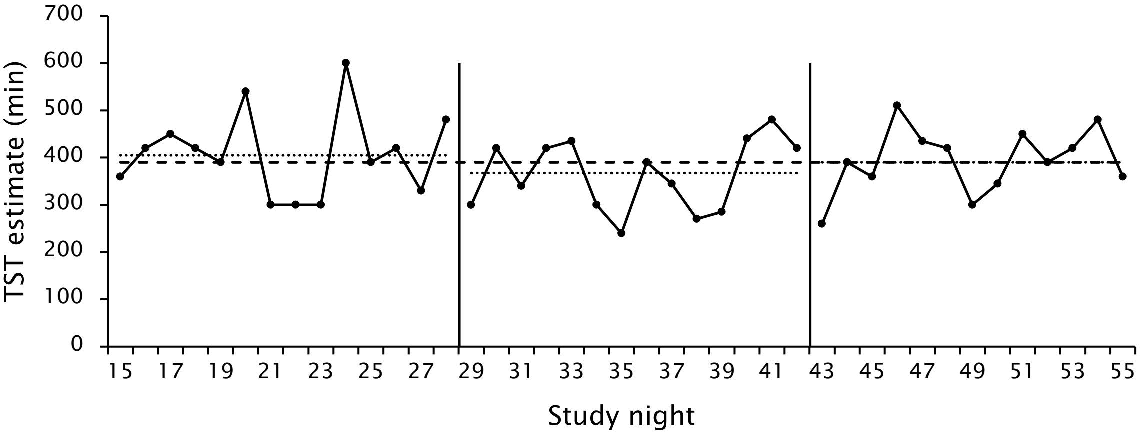


Note. Unstable baseline; PND: 37.04% under minimum of baseline; (0% exceeding maximum of baseline).

Subjective Sleep Measures

Figure X5

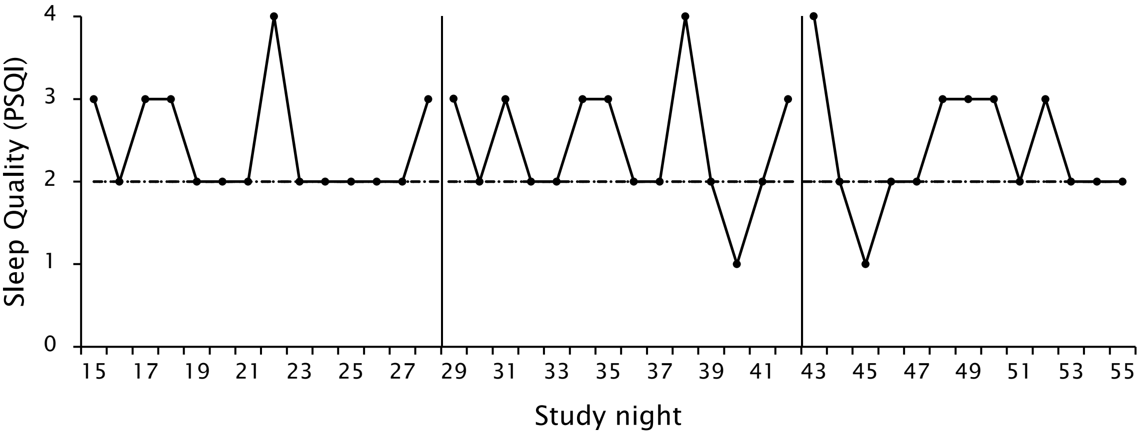
Estimated Sleep Duration as a Function of Study Night for P5



Note. Unstable baseline; PND: (14.81% under minimum of baseline); 0% exceeding maximum of baseline.

Figure X6

Sleep Quality as a Function of Study Night for P5

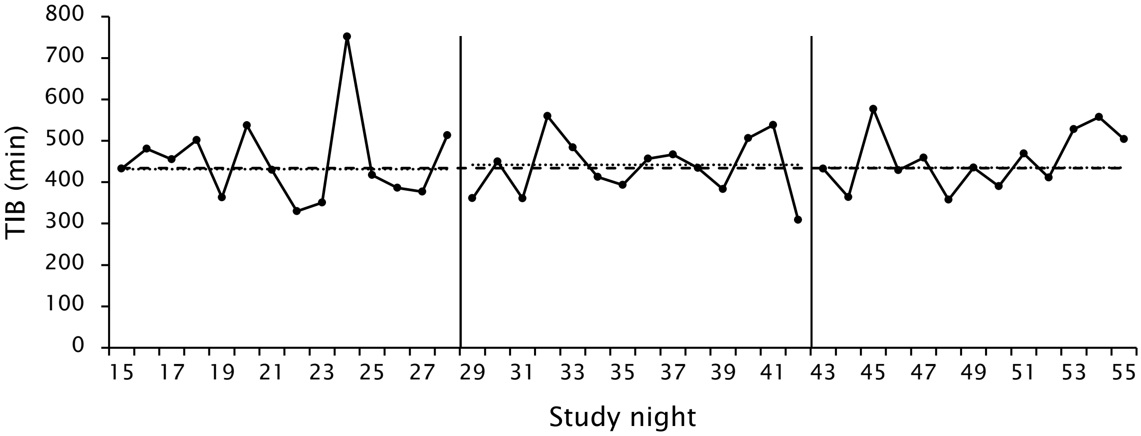


Note. Unstable baseline; PND: 7.41% under minimum of baseline; (0% exceeding maximum of baseline).

Actigraphy Sleep Measures

Figure X7

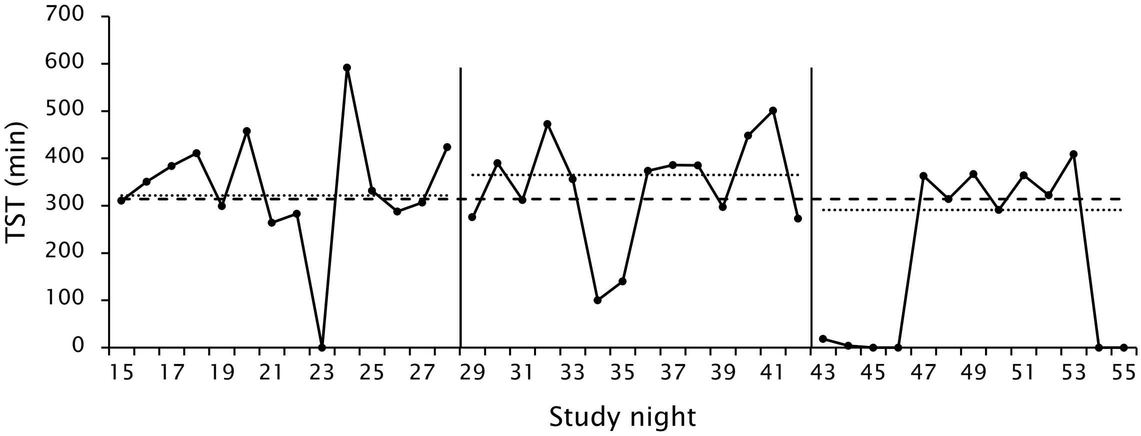
Time in Bed as a Function of Study Night for P5



Note. Unstable baseline; PND: (3.7% under minimum of baseline); 0% exceeding maximum of baseline.

Figure X8

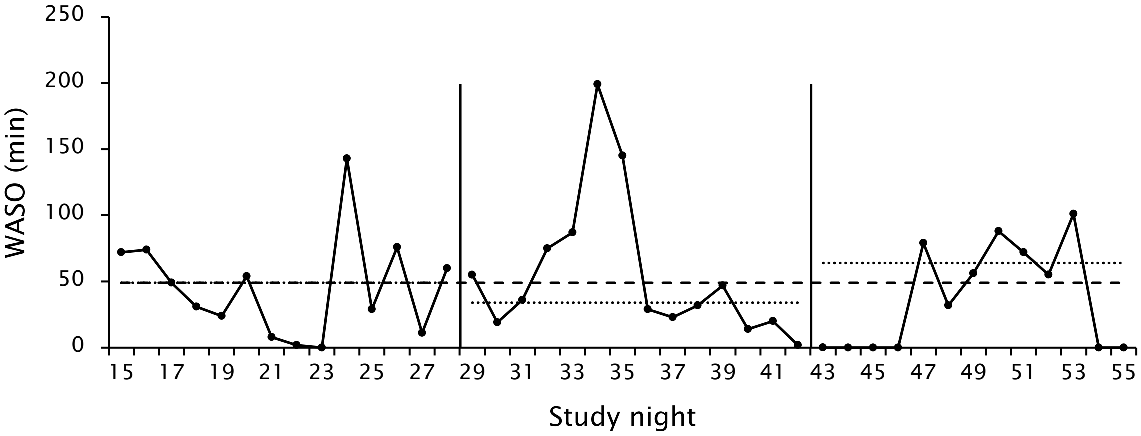
Total Sleep Time as a Function of Study Night for P5



Note. Unstable baseline; PND: (0% under minimum of baseline); 0% exceeding maximum of baseline.

Figure X9

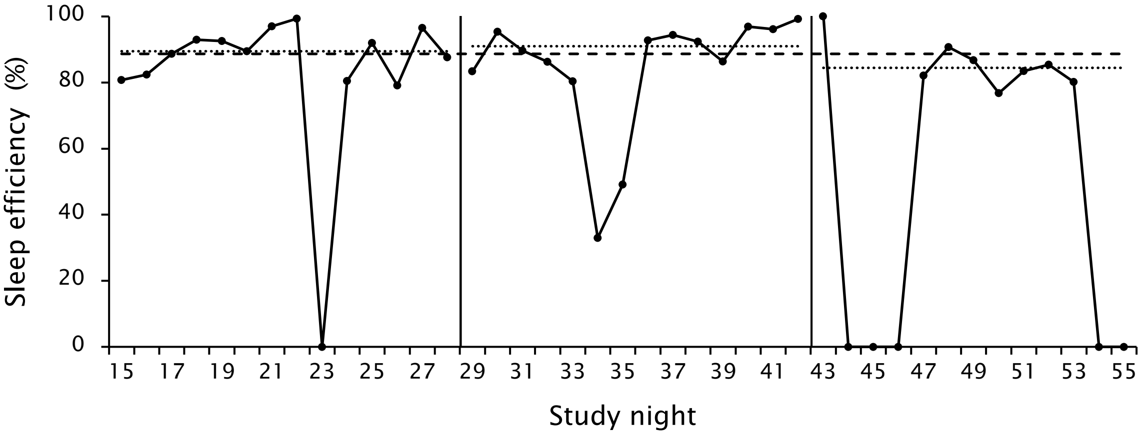
Wake After Sleep Onset as a Function of Study Night for P5



Unstable baseline; PND: 4.55% under minimum of baseline; (9.09% exceeding maximum of baseline).

Figure X10

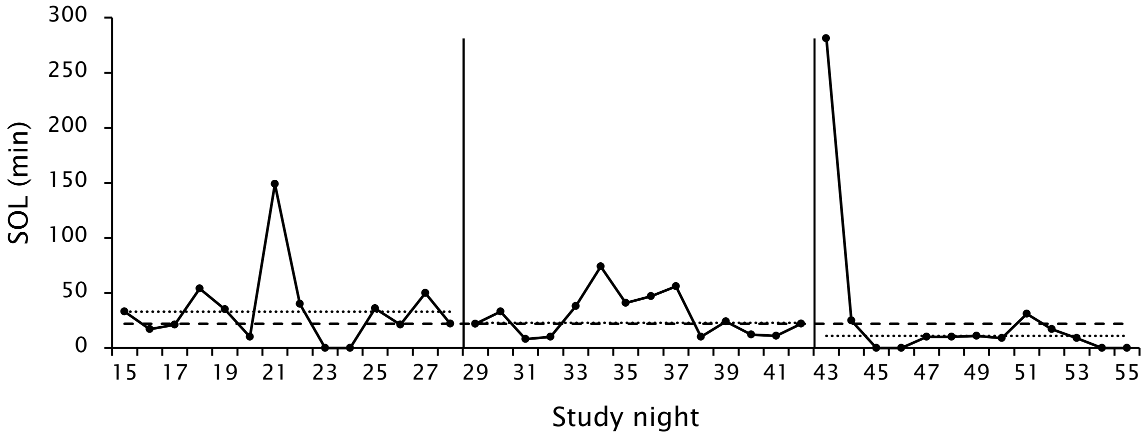
Sleep Efficiency as a Function of Study Night for P5



Note. Stable Baseline; PND: (13.64% under minimum of baseline); 4.55% exceeding maximum of baseline.

Figure X11

Sleep Onset Latency as a Function of Study Night for P5

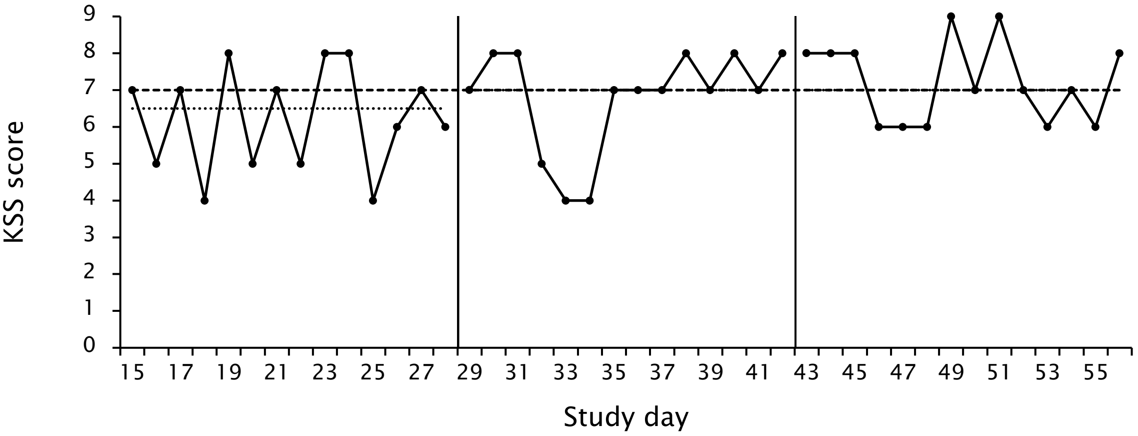


Note. Unstable baseline; PND: 0% under minimum of baseline; (4.35% exceeding maximum of baseline).

Vigilance/Sleepiness

Figure X12

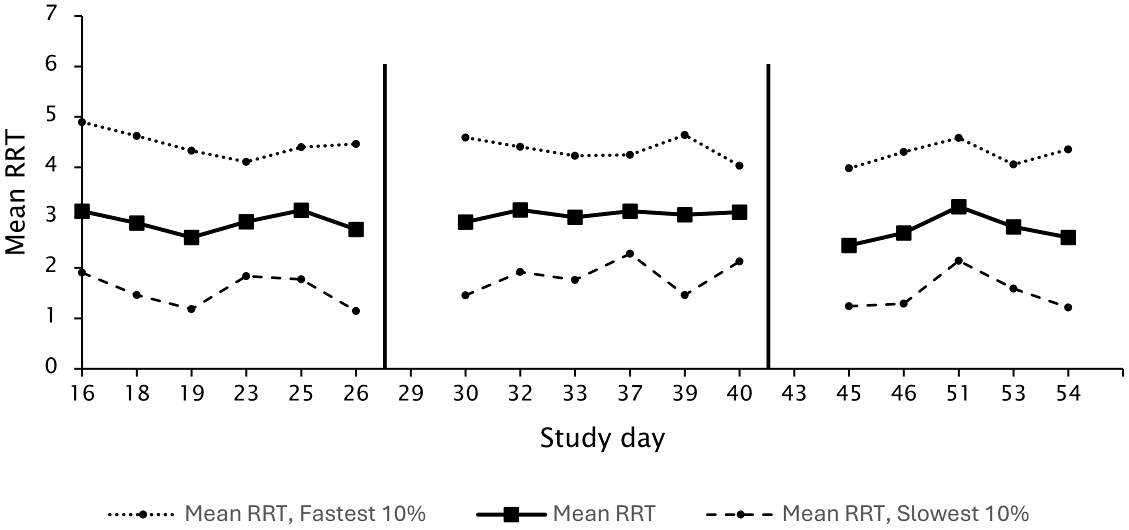
Subjective Sleepiness as a Function of Study Day for P5



Note. KSS: Karolinska Sleepiness Scale. Unstable baseline; PND: 0% under minimum of baseline; 7.14% exceeding maximum of baseline.

Figure X13

Overall Psychomotor Vigilance Metrics as a Function of Study Day for P5

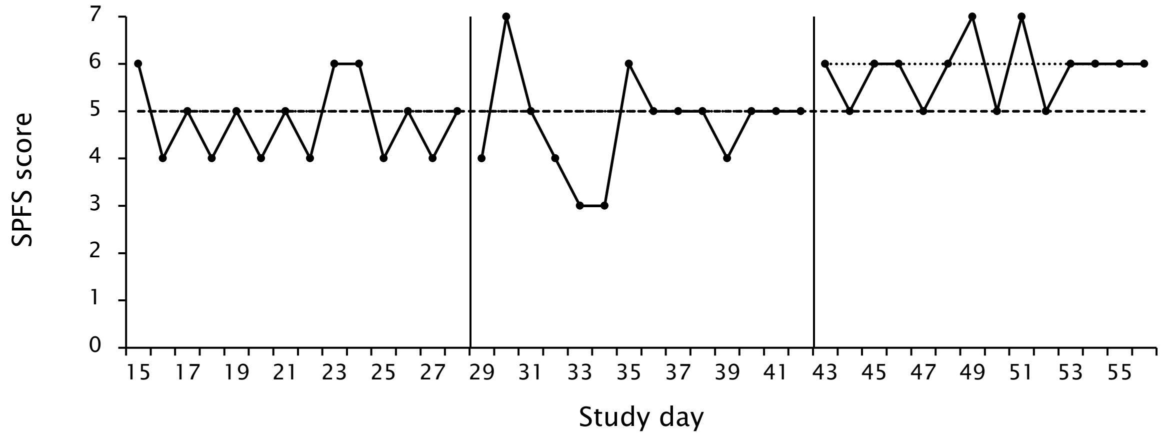


Note. P5: For overall mean reciprocal reaction time (RRT): Stable Baseline; PND: 18.18% under minimum of baseline; 18.18% exceeding maximum of baseline; For mean of slowest 10% RRT: Unstable baseline; PND: 0% under minimum of baseline; 36.36% exceeding maximum of baseline. For mean of fastest 10% RRT: Stable Baseline; PND: 27.27% under minimum of baseline; 0% exceeding maximum of baseline. Note also that these were plotted and analysed independently, however are reported together here in the interest of conciseness.

Fatigue

Figure X14

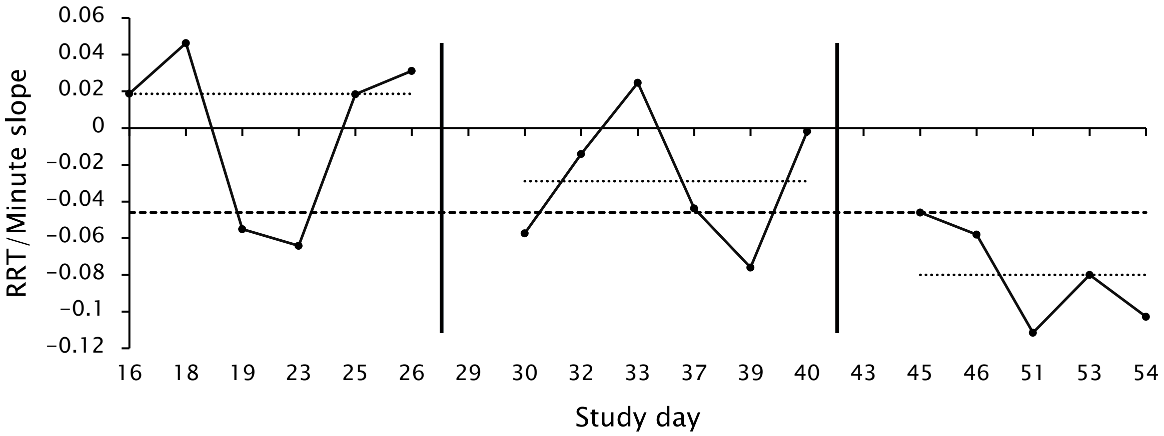
Subjective Fatigue Score as a Function of Study Day for P5



Note. Unstable baseline; PND: 7.14% under minimum of baseline; (10.71% exceeding maximum of baseline).

Figure X15

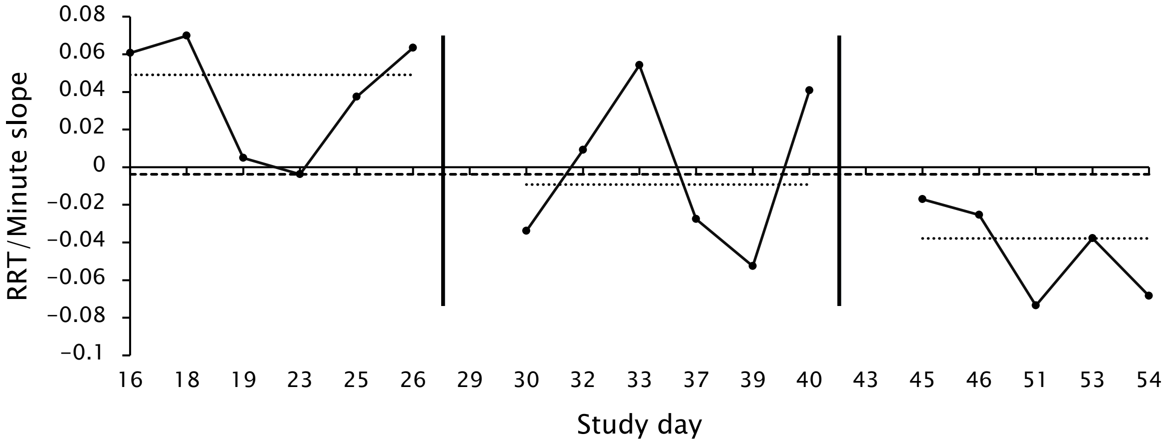
PVT RRT/Minute Slope as a Function of Study Day for P5



Note. Unstable baseline; PND: 36.36% under minimum of baseline; 0% exceeding maximum of baseline. No notable effect of intervention overall between baseline and phases 2 and 3 based on PND, although visually, an increasing fatigue propensity was noted, particularly in phase 3.

Figure X16

PVT RRT/Minute Slope Corrected for Time of Day as a Function of Study Day for P5



Note. Unstable baseline; PND: 72.73% under minimum of baseline; 0% exceeding maximum of baseline. When detrended from time of day of testing (see Appendix S), a notable increase in fatigue propensity was noted over the course of the study as measured by the PVT.

Summary

For P5, their most documented EMU hardware of use was their phone, with computer use less prominent and only documented for using email or research. Social media was their most common intended activity, with less frequent, though still common intention to engage in calls and online shopping on their phone. They often engaged in phone use, particularly for gaming and social media without documenting intended activities prior. TV use was also common as extra hardware, most often for watching a movie. P5 showed a slight decrease in subjectively reported and measured through screentime EMU following the introduction intervention session, however, this pattern was in line with a decreasing trend, and consistent with their highly variable baseline data. For P5, their subjective sleep duration and quality remained variable and relatively similar from baseline to phases 2 and 3. While in baseline, P5 did not note that their sleep quality was "very good" for any nights. However, there were single nights in each of phases 2 and 3 where they rated "very good" sleep. Actigraphy results reflected a relatively stable pattern, though with some disrupted sleep later in the study: In actigraphically assessed TST for P5, there was one sleepless night in baseline, and six relatively sleepless nights in phase 3, one of which had extended SOL, and short TST with high efficiency. Their final nights were marked with no sleep in actigraphy assessment. However, these sleepless nights were not echoed in their estimated sleep time, so may have been measurement error in the actigraphy. P5 showed no trend within phases in their subjective fatigue scores, with similar medians (SPFS score 5) in phases 1 and 2, and a higher median (SPFS score 6) in phase 3. Their subjective sleepiness scores were highly variable within phases and showed no marked between phase changes, save for a slightly increased sleepiness scores at the very beginning of phase 2, although this was likely due to a pattern of increased duty at the beginnings of each of the phases. Overall, a subtle trend of increasing subjective fatigue and sleepiness was observed over the study period. P5 showed an increased overall RRT when comparing phase 2 to baseline, and then slower and more variable metrics in phase 3 for mean RRT. Similar changes between phases were observed for each slowest and fastest 10% of responses, though these effects were subtle. The impact of time on task on performance was evaluated through RRT vs minute slopes to capture a fatigue effect. P5 showed similar patterns between baseline and phase 2, with flat trends in each phase, although a slightly lower mean in phase 2. Increased fatigue propensity was observed in phase 3 for P5. When correcting for time of day of assessment, this pattern was exaggerated.

Appendix Y

Individual Results for P6

This appendix shows individual results for P6 from the multiple baseline single case experimental design study described in Chapter5 of this thesis. P6 was included in the study due to a calculation error in participant selection. Timeseries outcomes were not analysed for P6. This appendix therefore contains only analysis of exploratory data from the EMU diaries, as well as thier intake and follow-up assessments.

Appendix Y: Individual Results for P6

Electronic Media Use Overview

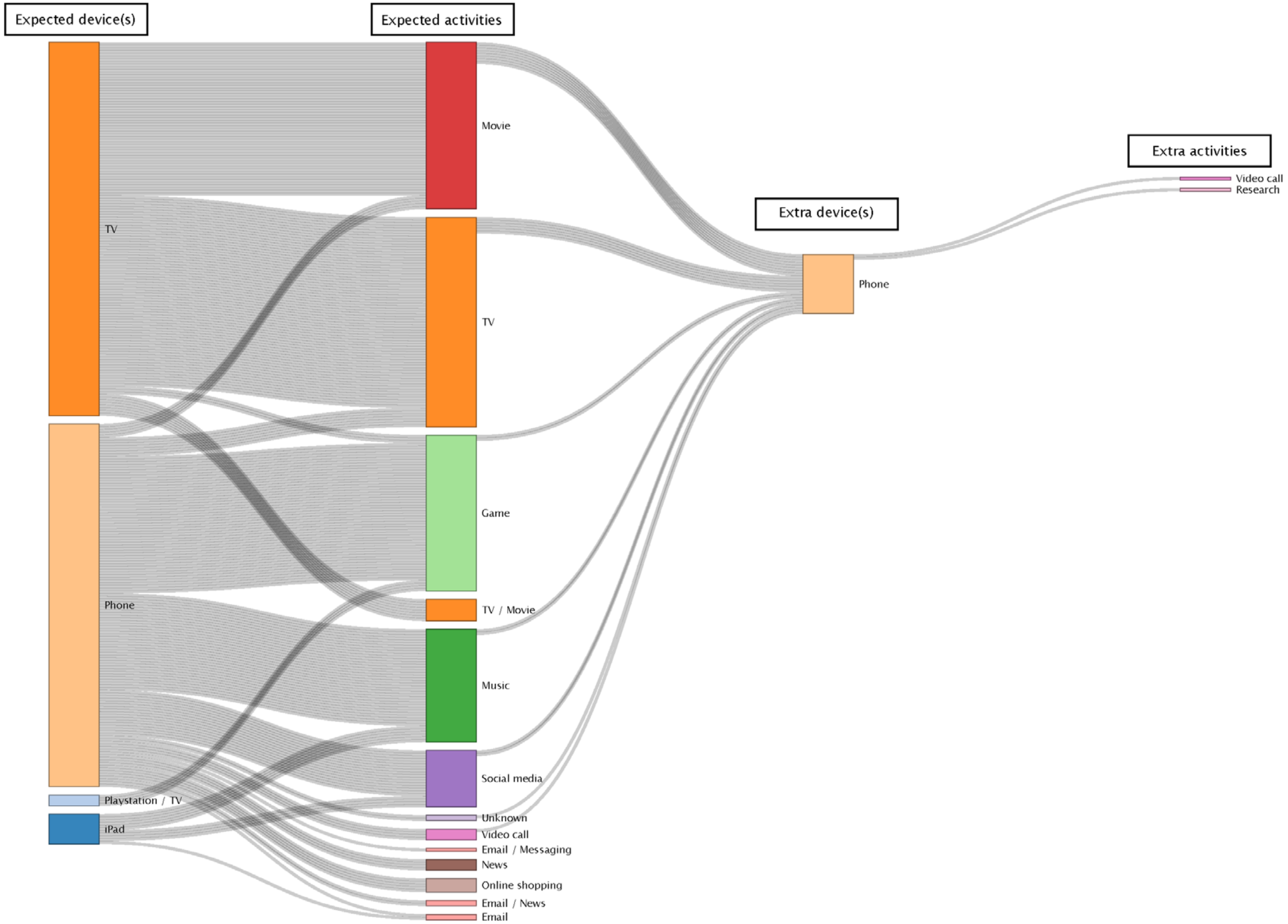
Table Y1

EMU Time Recorded by Device Organised by Intended Activities for P6

Device (Activities)	Sum of time recorded (Minutes)
iPad	743
Music	743
Phone	408
Check Emails & Message	20
Email	30
Email / News	70
Facetime	30
Instagram	6
Internet	20
News	110
Online	112
Trademe	10
TV	1363
Movie	590
TV	382
TV / Movie	231
TV on demand	50
TV Series	110
TV / PS4	45
Play Video Games	45
Total	2559

Figure Y1

A Sankey Diagram Summarising the Entries of the EMU Diaries for P6



Note. This diagram was based on an aggregate of the 36 total entries made in EMU diaries by Participant 6. Some reported activities and devices used were obfuscated and grouped to protect anonymity. All entries made by Participant 6 in the “extra activities” column were single activities and required no unfolding. Expected activity entries that were multiple (denoted by “/”) were retained so that the nuance of links between expected activities and extra devices remained. 36 total links are documented here. Created in R using the NetworkD3 package.

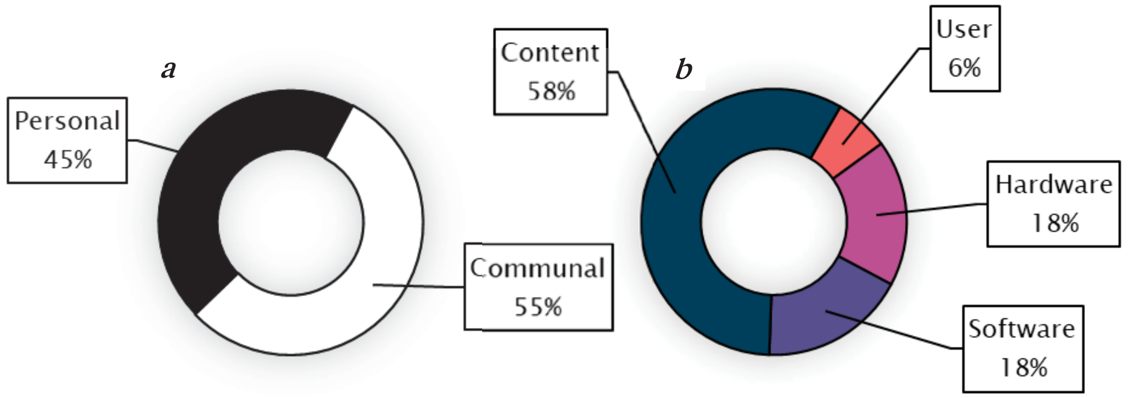
Figure Y1

A Sankey Diagram Summarising the Entries of the EMU diaries for P6

(unfold)

Figure Y2

Categorising EMU descriptions and communal use

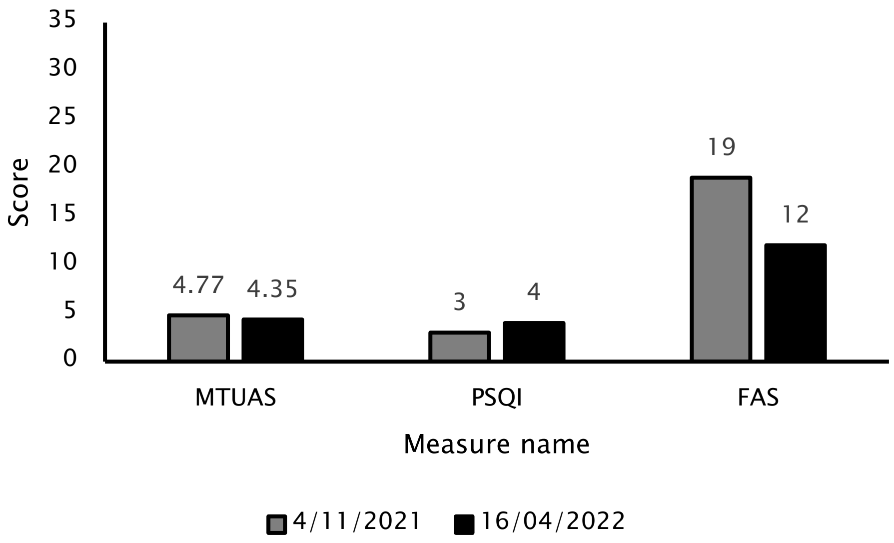


Note. a. Personal versus communal EMU was identified through the EMU audits based on identified hardware of use from *expected devices* fields in the EMU diaries. Proportions were calculated based on sums of time spent per hardware identified in the diaries from which time spent could be inferred. *b*. Entries were categorised based on aspects of EMU identified in both *expected*- and *extra activities* fields and based on number of entries.

Intake and Follow-up Assessment

Figure Y3

Intake and 6-Month Follow-up Assessment for P6



Note. Less than reliable change in MTUAS and PSQI global scores. Although trend towards lower FAS scores in follow-up assessment, still less than reliable change based on RCI.

Summary

For P6, the most often used expected devices were TV and phone. TV was often intended for watching a movie or TV, and phones often for gaming or music. P6 also used a PlayStation for gaming and an iPad, though less frequently for a variety of activities. The only documented extra device that they used was their phone and their only extra activities documented on their phone was video calling and research. In total they documented 36 entries in their EMU diary. Comparing P6's intake and follow up questionnaire showed trends towards decreased subjective fatigue as measured by the FAS, a one-point increase in PSQI, and a decrease in EMU as measured by the MTUAS. These changes fell below RCI thresholds.

ID:

Appendix Z

Research Case Study

Assessing Electronic Media Use and Sleep Alongside Suspected Chronic Fatigue Syndrome.

J. B. A. Peters

D Clin Psych Candidate

Massey University

Intern Psychologist

Te Whatu Ora Whanganui

To maintain client confidentiality in this thesis' case study, the presentation of the client's identifying information has been removed. The literature review that informed Jonathan's approach to the case during their internship in 2022 remains here, as do nonidentifiable aspects of the abstract and personal reflection. If the reader requires more information please contact the primary supervisor for this thesis, Associate Professor Ian de Terte. Contact: I.deTerte@massey.ac.nz

Candidate: J. B. A. Peters .... Date: 08/10/2025 ....

Research Supervisor: I. de Terte................................ Date: 10/10/2025 ....

Abstract

Chronic fatigue syndrome (CFS) is a complex and mysterious condition that can impact a person significantly. Post exertional malaise, a primary symptom of CFS, is an exacerbation of fatigue following physical or cognitive exertion. Emerging evidence suggests that active smartphone use might induce fatigue. This may, in some cases, lead to impacts on the recovery from post-exertional malaise for people who are suspected to have CFS.

Research Case Study: Assessing Electronic Media Use and Sleep Alongside Suspected Chronic Fatigue Syndrome.

Chronic Fatigue Syndrome

The diagnosis of Chronic Fatigue Syndrome (CFS) includes ruling out any acute medical conditions and investigating other biological aetiology to the fatigue. Such fatigue-similar conditions include hypothyroidism, fibromyalgia, Lyme disease, diabetes, multiple sclerosis, anaemia, vitamin and mineral deficiencies (see National Institute of Clinical Excellence; NICE, 2021, p. 95; and Young, 2020, pp. 32–40 for an overview). As the biological disease processes that need to be ruled out, listed above, are ones which a client may receive clinical tests to rule out, a difficulty arises in clinical practice and in research settings when possibly co-morbid or causal psychological conditions confound diagnosis. The confounding nature of psychological diagnosis appears to have originated from an early definition of CFS (Fukuda et al., 1994). In particular, Fukuda et al, (1994) listed diagnosis of major depressive disorder with psychotic or melancholic features as ruling out cases of unexplained chronic fatigue (Fukuda et al., 1994). The latest National Institute for Health and Care Excellence (NICE) guidelines for diagnostic assessment of CFS (NICE, 2021) recommend “an assessment of the impact of symptoms on psychological and social wellbeing” rather than an assessment of psychopathology as a confound (NICE, 2021, p. 12).

The current NICE guideline for CFS (NICE, 2021) include the following four diagnostic criteria for suspecting CFS, all of which must be present: (1) Debilitating fatigue, defined through feeling flu-like, restlessness or feeling “wired but tired”; low energy to start or finish activities and rapid loss of muscle strength or stamina after starting an activity or the experience of feeling physically drained or cognitive aspects of fatigue such as loss of concentration that is worsened by activity and is not caused by over-exertion and is not sufficiently relieved by rest; (2) Post exertional malaise, which refers to an often-delayed worsening of symptoms of fatigue that follows a period of activity which could previously be tolerated, lasting for several days to weeks; (3) unrefreshing sleep or sleep disturbance, either feeling exhausted upon waking, or broken or shallow sleep or hypersomnia; and (4) cognitive difficulties including problems with concentration, memory, task switching, slowed speech or verbal fluency, or slowed responsiveness (NICE, 2021).

Other diagnostic criteria for CFS from the American Institute of Medicine include impairment in ability to engage in activities that the person was able to engage in prior to their illness, post-exertional malaise, unrefreshing sleep, and either cognitive impairment or orthostatic intolerance (Committee on the Diagnostic Criteria for Myalgic Encephalomyelitis/Chronic Fatigue Syndrome et al., 2015). People who are suspected to have CFS, should be given the following recommendations; pacing and managing daily activity to not push through their symptoms, rest as needed, and maintain a balanced diet and stay hydrated (NICE, 2021). These guidelines for management of suspected CFS are similar to the more thorough recommendations for managing diagnosed CFS (NICE, 2021). The presence of these symptoms indicates that, in the absence of other medical diagnoses which may require more urgent attention and treatment, the treatment path that can be followed for someone with suspected CFS can follow a similar pathway as someone that has a confirmed diagnosis, while waiting for further clinical tests to be completed.

Fatigue and Depression

The diagnostic criteria for major depressive disorder (MDD) contain a subset of physical, or neurovegetative symptoms including sleep disruption, fatigue or loss of energy, psychomotor agitation or retardation, and diminished ability to think or concentrate (American Psychiatric Association, 2022). There is some overlap between CFS and MDD presentations, particularly if someone experiences MDD with melancholic features, which can lead these two conditions to become confused. A core differentiating criterion between these two presentations was found to be severity of reported self-reproach (Hawk et al., 2006). Natelson et al. (2019) argued that psychological and psychiatric conditions are still important to address as they impact on a person's quality of life; however, co-morbid psychiatric diagnoses should not rule out the presence of CFS.

Fatigue and Somatisation

Somatisation has been understood historically as psychological conflict or distress manifesting as physical symptoms either in absence of, or in the presence of conditions which may also manifest those symptoms (Lipowski, 1988). Lipowski (1988) noted a case example of what was then called *Postviral asthenia syndrome* which has similar presentation to CFS. Lipowski (1988) expressed concerns that these patients may be misdiagnosed as somatising, and also that they could develop somatisation as a result of having the symptoms being unexplained, which could increase focus on them, or lead to anxiety around having some associated physical illness.

The latest edition of the Diagnostic and Statistical Manual of Mental disorders (DSM-5-TR; American Psychiatric Association, 2022) includes Somatic Symptom

Disorder, which replaced the diagnosis of Somatisation Disorder from the fourth edition (American Psychiatric Association, 1994), in order to disentangle from the philosophical dilemmas of mind-body dualism (American Psychiatric Association, 2022). The redefinition no longer includes the need for the somatic symptoms to be unexplained medically, instead, the updated diagnostic classifications emphasised distress that these symptoms cause (or worry about what they might mean in the case of illness anxiety disorder) in a person's life and the level of preoccupation they may have with their symptoms. Ultimately, somatic symptom disorders became *rule in* (due to distress and impairment) rather than a *rule out* (due to possible unexplained nature) diagnoses (American Psychiatric Association, 2022). This update allows for individuals to be able to have both a somatic symptom and related disorder, as well as a diagnosed condition that could explain their symptoms; one no longer excludes the other. By validating a client's experience of their somatic symptoms, therapeutic alliance, the primary principle of treatment and management for people with somatic difficulties, may be achieved with less friction (Croicu et al., 2014).

Sleep and Fatigue

One of the main symptoms of CFS and its associated disorders is sleep disturbance, particularly nonrestorative sleep (Lim & Son, 2020). The relationships between sleep and fatigue, both physical and cognitive is vast. Fatigue is typically thought of as a complex physical and cognitive inability to carry out work due to the accrued effect of time-on-task (e.g., Balkin & Wesensten, 2011). People generally show increased vulnerability to this effect due to various biological and psychological factors, including circadian rhythm, sleep restriction and extended wakefulness (Balkin & Wesensten, 2011; Van Dongen et al., 2003). The biological underpinnings of

CFS are still unknown (Young, 2020), and despite sleep disturbance being prevalent in CFS, these disturbances have a heterogenous and complex presentation, so the role of sleep in the syndrome's maintenance is yet unclear (Gotts et al., 2014). Nevertheless, the NICE guidelines emphasise rest and sleep strategies as helpful in symptom management for CFS (NICE, 2021).

Sleep and Electronic Media Use

Electronic media use may impact sleep through a variety of mechanisms including time displacement, psychological arousal and physiological stimulation (Cain & Gradisar, 2010; Exelmans & Van den Bulck, 2017; Hale & Guan, 2015). Although causal mechanisms are yet to be fully understood, many have been hypothesised. Recently, Liu et al (2020) investigated the opposing effects on sleep health of bedtime procrastination and psychological detachment attained through electronic media use. They found that trait mindfulness may buffer the negative effect of electronic media use on sleep quality and quantity through bedtime procrastination(Liu et al., 2020). Mindfulness may also exacerbate the positive effect of electronic media use on sleep quality and quantity through fostering psychological detachment from stresses (Liu et al., 2020). They defined mindfulness as "a tendency to be attentive to and aware of what is taking place in the present" (Liu et al., 2020, p.4). By increasing awareness and mindfulness towards electronic media use, negative effects on sleep health may be reduced, and positive effects may be nurtured.

Fatigue and Electronic Media Use

There is emerging evidence that some kinds of electronic media use may have a direct impact on fatigue. Fortes et al. (2019) conducted a study on male soccer athletes and identified that performance is impaired after 30 minutes of active smartphone use when compared with passive watching of a documentary. Gantois et al., (2021) tested a similar protocol and found that participants that were engaged in active social media use on their smartphones for 30 minutes reported higher levels of subjective mental fatigue, and reduced overall physical performance (volume-load) in a resistance-training exercise. These findings from sport science indicate that there is some direct effect of electronic media use on fatigue. However the research is still nascent (see also Wilmer et al., 2017) and yet to be translated into clinical practice.

[CASE STUDY REMOVED TO PRESERVE CONFIDENTIALITY]

Reflection

Given my research topic of electronic media use and sleep and fatigue, I welcomed the opportunity to work with someone who was experiencing symptoms consistent with CFS in my placement at the physical health service. The hypothesis that emerged from a previous scoping review (manuscript in progress), based on the finding that electronic media use, sleep, and fatigue difficulties is mostly correlational, is that there may be some bidirectional causal impact that fatigue has on electronic media.

I found it difficult to figure out initially how to address a referral question pertaining to somatisation. In my reading, however, of the latest guidelines both by NICE and by the American Psychiatric Association, and literature surrounding engaging with clients with somatic difficulties, the importance of validating and expressing empathy for the client's experience was paramount for me. There has been a strong theme in my work for advocacy for the client to receive appropriate medical treatment and recognising that sessions with professionals be contained to avoid post-exertional malaise. However, given the number of professionals that the client has appointments for, and the need to travel for them, this post-exertional malaise seems often inevitable. This has led to us not having met in person over the past month and a half. We have discussed possibly running future sessions through teletherapy, so that, at least for the client's time with me, some fatigue of travel may be mitigated.

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