Curtin University
FUTURE OF WORK INSTITUTE

School of Management

Endurance in Extreme Work Environments

Belinda Cham

0000-0003-1543-4197

This thesis is presented for the degree of Doctor of Philosophy of Curtin University

May 2021

THESIS DECLARATION

To the best of my knowledge and belief this thesis contains no material previously published by any other person except where due acknowledgment has been made.

This thesis contains no material which has been accepted for the award of any other degree or diploma in any university.

The research presented and reported in this thesis was conducted in accordance with the National Health and Medical Research Council National Statement on Ethical Conduct in Human Research (2007) – updated March 2014. The proposed research studies received human research ethics approval from:

- The University of Western Australia Human Research Ethics Committee (RA/4/1/9059)
- The Curtin University Human Research Ethics Committee (HRE2018-0362 and HRE2020-0149),

The work described in this thesis was funded by an Australian Government Research Training Program (RTP) Scholarship and a Defence Science Technology Top-Up Scholarship.

This thesis contains published work and/or work prepared for publication, some of which has been co-authored. Please refer to the “Authorship Declaration” for further details.

Name: Belinda Cham

Signature:

Date: 03/05/2021

ABSTRACT

Extreme work environments are settings test the limits of human functioning and performance. The safety-critical and unpredictable nature of work in these settings requires workers to sustain optimal performance and operational readiness across a given duration – such as a mission, operation, expedition, or project. Moreover, workers in these settings face challenging working and living conditions, such as isolated, confined environments and/or dangerous environments (Brasher et al., 2010; Landon et al., 2019; Suedfeld & Steel, 2000). The overall aim of this thesis is to advance knowledge of how the demands and constraints within extreme work environments impact sustained human performance over time. Guided by this overarching aim, the goals of this thesis are to develop a theoretical framework of endurance that models how human performance is sustained over an intense long duration mission, and to provide a better understanding of how different types of work demands impact endurance in real-world extreme work environments. In Chapter 1, I provide a general introduction to the thesis and an overview of the studies in this thesis. In Chapter 2, I develop a theoretical framework that explains endurance in terms of sustainable energy management within an interconnected work-life system (work, non-work, and sleep). In Chapter 3, I focus on the work portion of the work-life system and conduct a cross-sectional investigation into how overload and underload impact endurance in the context of long-haul seafaring. The findings revealed that overload and underload showed differential relationships with fatigue-related outcomes, with underload being more detrimental to seafarer fatigue and wellbeing. In Chapter 4, I extend my investigation by taking a dynamic approach to exploring how overload and underload are linked to chronic and acute forms of fatigue in submarine operations. Results showed that the within-person relationships between overload and underload, and fatigue, looked qualitatively different over a working day. Moreover, there was evidence that overload and fatigue are reciprocally related, which poses risks of accumulation of fatigue over an operational activity. In Chapter 5, I consolidate these findings and discuss the theoretical contributions that this thesis makes to our understanding of how people function and perform over time in extreme work environments, as well as increasingly dynamic and complex conventional work environments. I conclude the thesis with a summary of practical implications, limitations, and directions for future research.

CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS AND ACRONYMS

AL	Allostatic Load Model
BFs	Bayes Factors
CoR	Conservation of Resources Theory
DV	Dependent variable
DSEM	Dynamic structural equation modelling
ER	Effort-recovery model
ESM	Experience sampling methodology
ILD	Intensive longitudinal data
JD-R	Job Demands-Resources Theory
PDR	Phenomenon-driven research

ACKNOWLEDGEMENTS

I am grateful to many for supporting me in so many different ways to ‘endure’ this PhD journey, which in some ways, has not been unlike an extreme work environment, involving a 3.5-year long mission featuring a high degree of uncertainty, dynamic task demands, high performance requirements, and unusual working/sleeping hours.

First, I am immensely grateful to my team of supervisors who have all made invaluable contributions with their time, knowledge, and experience. I have always considered myself lucky, for having scored the perfect “goldilocks” combination of supervisors with unique but complementary expertise across the board. Mark, thank you for supervising me across the trifecta (honours, masters, and PhD). It has been an absolute privilege to learn from you over the years, and I owe much of my growth to your wisdom and patience. Daniela, thank you for being the voice that grounds me. Your advice and feedback always help to clear the clutter and fog in my head, allowing me to focus on what needs to be done and how to achieve my goals. Michael, thank you for jumping on board this journey officially, even having already experienced as a colleague and friend how much I would pester you about a million and one things. You have been an invaluable mentor and friend, and I will fondly remember many of your various metaphors (babushka dolls) and lessons for years to come. Sam, without your support, this PhD would literally not have been possible. Thank you for giving me so many opportunities to stick my head into what is a complex and fascinating world under the surface of the ocean, and for always reminding me of the real-world impact that my research can have.

Karina. You have been a constant source of inspiration throughout the years, and you have shaped so much of my development, not only as a researcher, but also as a person attempting to navigate through the everyday complexities of life. Thank you for giving me so many opportunities to grow and learn, and for trusting in my ability before I trusted myself.

Alex. We have basically become the same human being over the last several years, sharing the same office, coming to work with unintentionally colour coordinated outfits, and eating (too many) croissants together in several different cities around the world. Thank you for keeping me sane through the PhD, project work, and life in general.

Dannielle, I would not be here today if you didn’t take me on as an RA back in 2014. So, thank you for giving me that opportunity and being one of my earliest supporters. From day one, you have always been a listening ear, a caring friend, and a sharer of life’s ups and downs.

To the rest of the Work Systems Design Team - Kat and Luke specifically, thank you for being such awesome team members. I couldn’t have asked for a better team to tackle the mission that was this PhD.

There are also many friends and colleagues from FoWI, wider Curtin, and UWA that I want to thank for supporting me and reminding me that “I got this”. Fellow PhD candidates, the Ops team (Sana, Diane, Abbe, thank you so much for making my PhD such an administrative breeze), my Chair Jane (and dog park gang member), and SO many others, you have made this journey so rewarding. I can’t express how much I appreciate all of you for providing friendly faces, moral support, career advice, administrative support and so much more. I count myself extremely lucky, to be able to undertake a PhD surrounded by such kind, wonderful, and supportive people.

I owe a great deal of thanks to my partner Quan, who has never doubted that I would find my way through all the obstacles (real and imagined) I’ve encountered throughout the PhD. On many occasions, your unwavering belief in me and my work has been the subtle push I needed to carry forward. You have supported me in all possible ways, remaining positive and upbeat when I felt less than resilient, taking on domestic duties when I was occupied with multiple deadlines, and celebrating my little wins when I neglected to do so.

I would like to thank my family for their support through my long education. To Mum, Uncle Ben, Dad, and Elain, thank you for your love and support, and for giving me the space and resources I needed over the last several years to focus on this PhD.

This thesis was supported by an Australian Government Research Training Program (RTP) and a top-up scholarship from the Maritime Division of Defence Science Technology Group, both of which I am very thankful for. Finally, thank you to all the volunteers who made my research possible.

RESEARCH OUTPUTS

Directly related to thesis

Manuscripts in Press

Cham, B. S., Andrei, D. M., Griffin, M. A., Grech, M., & Neal, A. (In Press). Investigating the Joint Effects of Overload and Underload on Chronic Fatigue and Wellbeing. *Work and Stress*

Cham, B. S., Boeing, A. A., Wilson, M. D., Griffin, M. A., & Jorritsma, K. (In Press). Endurance in Extreme Work Environments. *Organizational Psychology Review*.

Manuscripts in Preparation

Cham, B. S., Wilson, M. D., Andrei, D. M., & Griffin, M. A. (in preparation). Examining the dynamic relationship between workload and fatigue over multiple shifts of work. Target journal: *Journal of Organizational Behavior.*

Academic Presentations

Cham, B. S., Boeing, A. A., Wilson, M. D., Griffin, M. A., & Jorritsma, K. (2019). Submariner Endurance: A work-life system. *Society of Industrial and Organizational Psychology Annual Conference, Washington DC.*

Peripherally related to thesis

Manuscripts

Wilson. M. D., Ballard. T, Strickland. L., Boeing. A., **Cham. B**., Griffin. M., & Jorritsma. K. (2021). Understanding Fatigue in a Naval Submarine: Applying Biomathematical Models and Workload Measurement in an Intensive Longitudinal Design. *Applied Ergonomics, 94,* 103412.

Academic Presentations

Boeing. A., **Cham. B**., Jorritsma. K., & Griffin. M. (2018). Developing a measurement protocol for the submarine environment: A case study on exploring submariner endurance. *Defence Human Sciences Symposium. Curtin University.*

Boeing. A., **Cham. B**., Jorritsma. K., & Griffin. M. (2019). A sociotechnical systems approach to the design of underspecified future systems: A case study of a military submarine. *INCOSE Human Systems Integration Conference. Biarritz.*

AUTHORSHIP DECLARATION: CO-AUTHORED PUBLICATIONS

This thesis contains work that has been published and/or prepared for publication.

Details of the work: Cham, B. S., Boeing, A. A., Wilson, M. D., Griffin, M. A., & Jorritsma, K. (In Press). Endurance in Extreme Work Environments. *Organizational Psychology Review*.

Location in thesis: Chapter 2

Student contribution to work: The candidate led the development of this manuscript, from conceptualisation through to publication. The candidate did the majority of writing, with co-authors providing feedback through the review process.

The original concepts were developed as part of a research project funded by the Maritime Division of the Defence Science Technology Group (RES-61297) that the candidate worked on as a Research Officer.

Contributor	Conceptualis-ation & design	Data Source & Collection	Analysis & Statistical Method	Writing Original Draft	Review & Editing	Total % contribution
Belinda Cham	60	N/A	N/A	100	70	77
Co-author: Alexandra Boeing	10	N/A	N/A	0	10	6.5
I acknowledge that these represent my contribution to the above research output Signed:						
Co-author: Michael David Wilson	10	N/A	N/A	0	10	6.5
I acknowledge that these represent my contribution to the above research output Signed:						
Co-author: Mark Griffin	10	N/A	N/A	0	5	5
I acknowledge that these represent my contribution to the above research output Signed:						
Co-author: Karina Jorritsma	10	N/A	N/A	0	5	5
I acknowledge that these represent my contribution to the above research output Signed:						

Preamble: Authorship Declaration

Details of the work: Cham, B. S., Wilson, M. D., Andrei, D. M., & Griffin, M. A. (in preparation). Examining the dynamic relationship between workload and fatigue over multiple shifts of work.

Location in thesis: Chapter 4

Student contribution to work: The candidate led the development of this manuscript, from conceptualisation through to writing. The candidate collected the data and conducted the analysis, with co-authors providing feedback on later manuscript versions.

The data was collected as part of a research project funded by the Maritime Division of the Defence Science Technology Group (RES-61297) that the candidate worked on as a Research Officer.

Contributor	Conceptualis-ation & design	Data Source & Collection	Analysis & Statistical Method	Writing Original Draft	Review & Editing	Total % contribution
Belinda Cham	85	95	90	100	70	88
Co-author: Michael David Wilson	5	5	5	0	10	5
I acknowledge that these represent my contribution to the above research output Signed:						
Co-author: Daniela M Andrei	5	0	0	0	10	3
I acknowledge that these represent my contribution to the above research output Signed:						
Co-author: Mark Griffin	5	0	5	0	10	4
I acknowledge that these represent my contribution to the above research output Signed:						

Name: Belinda Cham

Signature: Date: 03/05/2021

I, **Professor Mark Griffin** certify that the student statements regarding their contribution to each of the works listed above are correct.

Signature: Date 03/05/2021

1 GENERAL INTRODUCTION

GENERAL INTRODUCTION

> *"The problem to be faced is the confinement of men in a sealed tube in complete isolation from the rest of the world and encompassed by sea. In this they must work, eat, sleep and play for a period of months, during which a high standard of health and morale has to be maintained."*
>
> *Miles, 1960*

The determinants of human functioning and performance in extreme work environments have been an ongoing topic of interest for many decades (Driskell et al., 2018; Harrison & Connors, 1984). Extreme work environments can be defined as (a) task contexts that are atypical in terms of the level of demands (e.g., time pressure) or the type of demands (e.g., confinement, danger), and (b) contexts in which ineffective performance has severe consequences (Bell et al., 2018). Extreme work environments typically studied include military operations (e.g., Brasher et al., 2010), long-duration spaceflight (e.g., Salas et al., 2015), nuclear plant control rooms (e.g., Stachowski et al., 2009) and Antarctic winter-over stations (e.g., Sandal et al., 2006).

Understanding the factors that drive performance in extreme environments is critical as ineffective performance has potentially serious consequences for individuals, teams, the organisation, and wider community. For example, time pressure was a key factor in the accidental collision that occurred between the USS Greeneville submarine and a Japanese trawler in 2001, which resulted in the deaths of 16 civilians (Drumheller & Benoit, 2004; Shattuck & Miller, 2006). However, it is important to note that understanding performance in these environments is a complex endeavour because the constraints and demands posed by extreme contexts mean conventional approaches towards work performance offer limited guidance.

For instance, in many extreme contexts, work, non-work, and sleep activities take place in the same confined environment and the boundaries between these life domains can be blurred (Brasher et al., 2010; Landon et al., 2019; Suedfeld & Steel, 2000). Although there is much research that explores the work, non-work, and sleep factors that impact human performance and functioning, this research exists in often disconnected bodies of literature (Crain et al., 2018). Moreover, previous research usually investigates contexts in which work and non-work domains of life are physically separated, such as office work (e.g., Kinnunen et al., 2017), teaching (e.g., Simbula, 2010) or hospitals (e.g., Hornung et al., 2013). As such, it is unclear how knowledge from these diverse areas should be integrated to fully understand how workers perform and function in situations where work, non-work, and sleep life domains overlap in terms of physical space and time. Additionally, workers in extreme work environments are typically required to sustain high performance over long duration missions. To understand the factors that predict fluctuations in performance over time, a within-persons research paradigm is most useful (McCormick et al., 2020). Despite this, previous research usually adopts a ‘static’ between-persons approach to investigating performance and its predictors (Navarro et al., 2015; Roe, 2018). That is, broad differences between individuals are compared, with little focus on change or variability over time.

The overall aim of this thesis was to advance knowledge of how the demands and constraints within extreme work environments impact sustained human performance over time. Guided by this overarching aim, the goals of this thesis are to develop a theoretical framework of endurance that models how human performance is sustained over an intense long duration mission, and to provide a better understanding of how different types of work demands impact endurance in real-world extreme work environments.

The remainder of this general introduction consists of three sections. First, I briefly recap on how performance in extreme environment has typically been studied, highlighting how current approaches do not provide a comprehensive understanding and thereby providing a rationale for why an endurance approach towards performance is a necessary and useful theoretical angle. Second, I describe the purpose, scope, and contributions of this thesis. Last, I provide an overview of the thesis chapters.

1.1 Background

Research on human performance in extreme environments gained initial momentum in the early 1960s (Harrison & Connors, 1984) and was spurred by several factors, including the advent of the space program (e.g., Grether, 1962), the commissioning of the first nuclear submarines (e.g., Weybrew, 1971), and the establishment of research bases in polar environments (e.g., Nelson, 1962). Across several extreme environments, early research highlighted the need to understand human performance and functioning in relation to the unique problems and challenges posed by these unique contexts (e.g., Nelson, 1962; Harrison & Connors, 1984). For example, compared to the diesel submarines operated in WWII which could only stay submerged up to three days, the first nuclear submarines commissioned in the 1950s could stay submerged for months (or, theoretically, until food and consumables ran out). As such, a major problem emerged in how submariners could maintain optimal performance and health, despite being required to work, rest, and sleep under psychologically and physically demanding conditions for several months (Miles, 1960).

These same challenges are still relevant to extreme work environments today (e.g., Landon et al., 2019), and there is perhaps an even greater need to address these problems, as technology is paving the way for humans to operate in even more remote and demanding environments. For example, NASA’s planned manned mission to Mars in the 2030s will involve a human crew undertaking a risky 3-year journey in a small and confined habitat; mission success and safety will depend on optimal performance and health being maintained on a daily basis (Drake, 2009). Despite the increasing rate at which technology is pushing humans into more intensive and challenging working situations, research in its current state is ill-equipped to inform the complexities inherent in how performance should be understood in extreme work environments. I consider two reasons for this below.

First, as stated earlier, extreme work environments require workers to sustain optimal performance each day, over a long duration mission. This means any understanding of performance in extreme work environments should account for the role of *time*, in order to capture how performance (and the factors that impact performance) might change or fluctuate over a mission (Roe, 2018). Previous research, however, has typically focused on more static conceptualisations of performance. For example, the individual attributes of grit and mental toughness have both been extensively studied as predictors of performance in stressful achievement contexts such as elite sports, military training, and medical surgery (Eskreis-Winkler et al., 2014; Mallett et al., 2014). While these individual attributes may be useful in predicting whether one individual is better suited for coping and performing within demanding situations, over another individual (i.e., a *between-person* research question), they do not inform why or how an individual’s performance fluctuates within a day or over several days in response to dynamic changes in their environment. A better understanding of sustained performance in extreme work environments requires an approach that incorporates the role of time and a focus on *within-person* variability (McCormick et al., 2020).

Second, a serious issue for many workers in extreme environments is that there is substantial blur between the life domains of work, non-work, and sleep. For instance, 24/7 operations mean work activities can disrupt non-work and sleep time, requiring workers to perform optimally in response to unpredictable events (Dawson et al., 2012; Krueger, 1989; Nicol & Botterill, 2004). Additionally, in some of the most extreme contexts, work, non-work, and sleep activities all take place in the same confined environment (Landon et al., 2019; Suedfeld & Steel, 2000). The implication of having work, non-work and sleep being closely linked is that experiences across all three life domains have more direct impacts on worker performance, compared to conventional environments where there is a greater degree of separation. Therefore, research seeking to unpack performance in extreme work environments would benefit from a comprehensive understanding of how factors across work, non-work, and sleep contribute to performance.

While a plethora of research on the work, non-work, and sleep drivers of performance exists as separate topics, there is little research that considers the associations amongst the three areas (Crain et al., 2018). For instance, research that examines fatigue and its effect on performance in 24-hour operations such as military environments, offshore oil and gas installations, and space exploration has generally focused on the role of inadequate sleep (e.g., Mallis & DeRoshia, 2005; Miller et al., 2008; Riethmeister et al., 2018), with very little consideration given to the impact of high workloads or cognitively demanding work tasks (cf. Parkes, 2017). Only recently have there been calls for more research to take a holistic approach to understanding performance in extreme work environments (e.g., Banks et al., 2019; Landon et al., 2019).

1.2 Purpose and Contributions of the Thesis

To address the challenges raised above, this thesis aims to advance knowledge of how the demands and constraints within extreme work environments impact sustained performance over time. This thesis will achieve this through two avenues. First, this thesis will establish a theoretical framework of endurance that models how human performance is sustained over time and impacted by work, non-work, and sleep factors over an intense long duration mission. Second, this thesis will conduct initial investigations into how different work demands impact endurance in real-world extreme work environments.

Developing an overarching theoretical framework of endurance is an important goal of this thesis because, as identified earlier, while there are many existing theories that inform performance, it is unclear how these various theories across different disciplines should be integrated to investigate performance in extreme work environments. The various characteristics of extreme work environments (e.g., long duration missions, blurring of work, non-work, and sleep elements) require a temporal and interdisciplinary approach towards understanding performance. An overarching framework of endurance that integrates diverse approaches to work stress, non-work recovery, and sleep science (among others), and adopts a within-person research paradigm, would be a significant contribution to advancing knowledge about how workers sustain ongoing high performance in extreme work environments.

Although a theoretical framework of endurance is inspired by the unique constraints posed by extreme environments, it can also be used to inform worker performance and wellbeing more generally. To illustrate, consider that many modern working environments share work features with extreme environments. Rapid technological advancements and an increasingly competitive environment mean that work features such as 24-hour operations, remote working, and work intensification are increasing (Kelliher & Anderson, 2010; Piasna, 2015). These features mean that modern work is characterised by a higher degree of blurring of work, non-work, and sleep life domains than ever before, with consequences such as a lack of psychological detachment and inadequate recovery becoming a widespread issue (Sonnentag et al., 2017; Sonnentag & Fritz, 2015). By offering a more comprehensive understanding of the interface between work, non-work, and sleep, developing an endurance framework would help to advance knowledge about how performance and recovery can be optimised in a range of modern working environments.

The second goal of this thesis is to provide evidence of how complex work factors impact endurance in extreme environments, as currently there is limited research on how work demands manifest and impact workers in these contexts. As mentioned earlier, most research to date conducted within extreme work environments has focused on the role of sleep on worker fatigue (e.g., Mallis & DeRoshia, 2005; Miller et al., 2008; Riethmeister et al., 2018). By contrast, there is little research that identifies the types of work demands that cause stress and fatigue in these environments, and the mechanisms through which they impact ongoing performance. This is despite work activities arguably being the most critical activity that is required of workers in these extreme contexts. Given mission safety and success depends on effective task performance, all other activities such as sleep and non-work recreational activities are typically only seen as necessary to the extent that they are required to support the ongoing capability to perform safety and effectively (e.g., Moffitt, 2008; Shay, 1998). Moreover, organisations have significant leverage points through work-related interventions to support individual and team performance in extreme environments (Driskell et al., 2018).

Therefore, to complement the development of a theoretical framework of endurance which specifies more broadly how work, non-work, and sleep activities affect sustained performance, I also begin an empirical investigation focusing on the critical work aspects that impact endurance. Specifically, I seek to shed light on how overload (i.e., work with too many demands) and underload (i.e., work with too few demands) are related to fatigue and performance in extreme work environments. It is well known across different extreme environments that the unpredictable yet safety critical nature of operations means workers face intense periods of time pressure that alternate with monotonous monitoring tasks to produce “hours of boredom and moments of terror” (Hancock & Krueger, 2010, p. 2; Salas & Oglesby, 2012). Although overload, and to a lesser extent underload, are both separately implicated as critical work factors that affect human fatigue and performance (Young et al., 2015), we currently understand very little about the combination of these demands in extreme work environments. For instance, there is little to no research that informs the relative unique (and collective) contributions of overload and underload on human fatigue in operational environments (Andrei et al., 2020; Bakker & Demerouti, 2017). There is also a gap in knowledge when it comes to understanding the day-to-day mechanisms by which these two demands cause changes in fatigue (Bakker & Demerouti, 2017). By studying the combination of overload and underload in more detail, I hope to provide a more comprehensive understanding of the complex work factors that drive endurance in real-world extreme work environments.

1.3 Overview of the Thesis

The body of this thesis is composed of three papers written in the style of manuscripts. An overview of Chapter 2 through to Chapter 5 is provided next.

Chapter 2 introduces the concept of endurance, defining it as an individual's capacity to sustain performance at high levels for safe and effective operations over the extended duration of a mission, operation, deployment, or expedition. This chapter acts as the primary literature review of this thesis and lays out the theoretical foundation by presenting a theoretical framework of endurance that informs and guides the subsequent two empirical studies (Chapter 3 and Chapter 4). Chapter 2 reviews and integrates diverse streams of literature from work stress (e.g., Ganster & Rosen, 2013), recovery (e.g., Demerouti et al., 2009), sleep (e.g., Dawson & McCulloch, 2005) to describe endurance in terms of a complex interaction between a worker and their 'work-life system' (i.e., work, non-work and sleep experiences and activities) over short- and long-term timeframes.

Chapter 3 begins my empirical investigation into endurance by focusing on the *work* component of the work-life system. Specifically, I investigate how overload and underload impact endurance in the extreme context of long-haul maritime shipping. As discussed, overload and underload are key work factors that have been implicated in several endurance related outcomes, such as fatigue, performance, and wellbeing (Driskell et al., 2018; Salas & Oglesby, 2012; Young et al., 2015). Long-haul shipping provides an ideal context for studying how the combination of overload and underload impacts endurance as seafarers experience overload during high time pressure port activities (e.g., frequent berthing, loading and unloading of ships), as well as underload during watchkeeping activities on the open ocean (e.g., monitoring the ocean horizon and/or engine room equipment) (Andrei et al., 2020). This cross-sectional study also integrates existing theoretical approaches from work psychology and cognitive psychology such as the Job Demands-Resources model (Bakker & Demerouti, 2014) and the Motivational Control Theory of Fatigue (Hockey, 2011) to specify how these work demands should impact endurance.

Chapter 4 extends my investigation into the work factors that impact endurance by explicitly considering the role of time. Specifically, I explore the dynamics underlying the within-person relationship between overload, underload, and fatigue in a different extreme work environment – submarine operations. The role of time is further unpacked by examining the effects of overload and underload across two different timeframes relevant to endurance: 1) the duration of a submarine operational activity, and 2) daily work shifts. Within Chapter 4, I also draw on theoretical models such as the Job Demands-Resources model (Bakker & Demerouti, 2014) and Hockey's (1993) model of compensatory control.

Chapter 5 summarises the findings of all the studies and discusses the overall theoretical, empirical, and practical contributions of this thesis. Limitations and related future directions are also presented.

2 ENDURANCE IN EXTREME WORK ENVIRONMENTS

2.1 Foreword

In this chapter, I develop a theoretical framework of endurance that specifies how workers sustain their performance and functioning over an intense mission in an extreme environment. To understand the many factors that impact and shape endurance, it is necessary to first develop a working definition of endurance and explain the processes that underlie endurance. In this chapter, I achieve this by building on and integrating existing theories and concepts of performance, recovery, stress, and human physiology to inform how endurance is shaped within constrained and demanding environments.

This chapter is presented as a journal article manuscript. A version of this manuscript was published in *Organizational Psychology Review*. See Appendix 2A for a copy of the copyright transfer agreement. Note that I use the term ‘we’ throughout this chapter to refer to the collective contributions of the manuscript co-authors.

Cham, B. S., Boeing, A. A., Wilson, M. D., Griffin, M. A., & Jorritsma, K. (In Press). Endurance in Extreme Work Environments. *Organizational Psychology Review*.

2.2 Abstract

Extreme work environments are inherently stressful and involve challenging working and living conditions. In contexts ranging from space exploration to disaster response, people must sustain performance under pressure, and function with limited resources. In this paper we develop the concept of endurance for extreme work environments, which we define as the capacity to sustain performance at high levels for safe and effective operations over extended durations (e.g., a mission, operation, deployment, or expedition). We integrate diverse streams of literature (e.g., work stress, recovery, and sleep) to describe endurance in terms of short – and long-term energy management processes as individuals interact with their work-life system (i.e., work, non-work, and sleep environment). We conclude with practical and theoretical implications for a better understanding of endurance, such as considering multiple time perspectives, and the role that researchers, practitioners, and organisations can play in optimising endurance in the field.

2.3 Introduction

Space shuttles, submarines, and polar stations are vastly different settings, but all share an emphasis on safety with a high cost of failure. Workers in these environments experience chronic exposure to high and sustained levels of stress, providing real-world opportunities to investigate the limits of human performance. A better understanding of human performance in extreme work environments is important from two perspectives. First, in extreme work environments, poor performance can have catastrophic consequences for the team, organisation, customers, and the broader community. Second, insights derived from extreme work environments are increasingly relevant to work features in modern work environments such as unpredictable patterns of activity and rest, intensification of work, and managing complexity and uncertainty. For example, automation, robots, and artificial intelligence are removing routine aspects of some roles, while increasing the complexity and uncertainty of the remaining work (Griffin et al., 2019; Parker & Grote, 2020). Moreover, technology is increasing around-the-clock activity in many industries, which places more emphasis on the human capacity to sustain performance over long periods (Krueger, 1989). Therefore, it is not surprising that there is growing interest in understanding how humans perform in extreme environments (Bell et al., 2018; Driskell et al., 2018).

Extreme work environments require workers to sustain optimal physical and psychological states such that they are ready to respond effectively to routine demands and unanticipated challenges across an extended duration. This duration can range from weeks and months (e.g., a submarine deployment) to years (e.g., the spaceflight to Mars) (Brasher et al., 2010; Flynn-evans). In this article, we extend our understanding of the factors that inform performance by developing the concept of endurance for extreme work environments. To date, endurance has typically been studied in the context of sports and refers to the capability to resist physical fatigue while engaging in exercise for a prolonged duration (Sjostrom et al., 1987).

We begin by providing an overview of extreme work environments and defining the concept of endurance. We then show how endurance provides additive explanatory value relative to extant constructs such as grit and resilience. Next, we integrate diverse bodies of literature to explain how endurance is shaped within constrained and demanding environments. We focus on processes of energy management across work, non-work, and sleep life domains (i.e., a work-life system) and consider how an interplay between short- and long-term dynamics impact endurance. We conclude by discussing implications for research and practice.

2.3.1 Defining Endurance

For extreme work environments, we define endurance as an individual's capacity to sustain performance at high levels for safe and effective operations over the extended duration of a mission, operation, deployment, or expedition. Our concept of endurance extends current approaches to work performance to capture the overall performance requirements of humans in extreme environments. In our paper we use the term 'mission' to encompass the various types of long-term goal-driven events such as expeditions (e.g., arctic expeditions), operations (e.g., counter terrorist operations), and deployments (e.g., combat deployments).

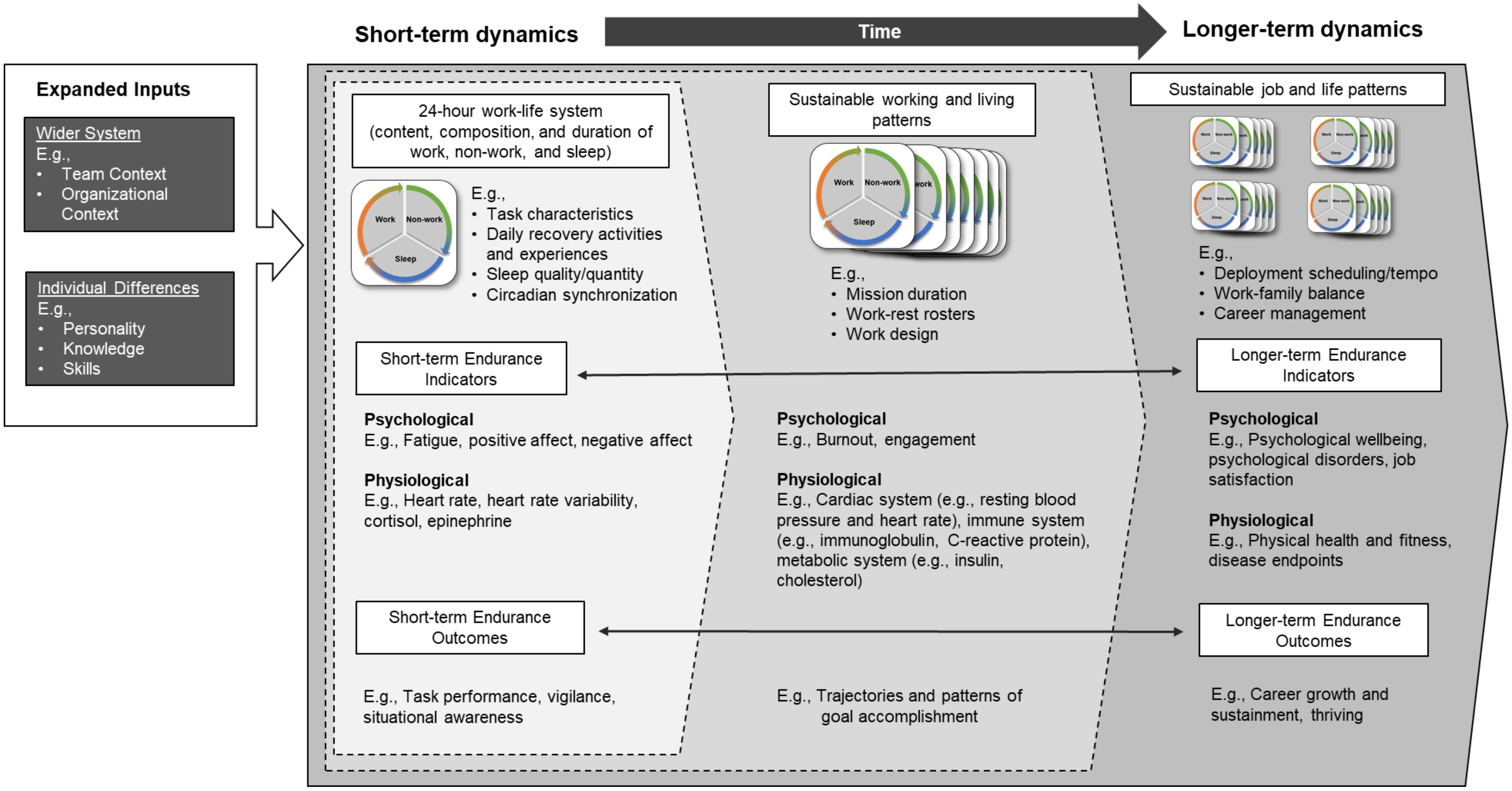
Endurance emphasises high performance because in extreme work environments such as spaceflight (Salas et al., 2015), high altitude mountaineering (Wickens et al., 2015), Special Forces operations (Urban, 2012), and polar workgroups (Leon et al., 2011), workers must perform safety critical tasks and activities over a long duration mission. Task demands evolve rapidly in these environments and failure to perform optimally—even for short periods—can result in mission risks and failure (Wickens & Huey, 1993). The exact standard of what constitutes 'high' or 'optimal' performance varies depending on the context. For example, the type of performance required during a high intensity combat situation will differ to the performance required during a prolonged and monotonous vigilance task.

Performance and safety are both important elements of endurance. In some contexts, high performance can come at costs to safety (Jiang & Probst, 2015). However, the need for individuals to maintain their own safety and the safety of others is imperative to mission success in many extreme work environments where threats to human lives can be immediate and significant. For example, submarine command teams must achieve mission objectives while also ensuring the safety of their own submarine and the safety of surrounding vessels (Stanton & Roberts, 2018).

An individual's underlying *capacity* for high performance is also central to our definition of endurance because extreme work environments require workers to maintain ongoing operational readiness to respond to unpredictable events. Operational readiness in a traditional military sense refers to a state of being able to react, respond, and carry out tasks at the required performance level (Cosenzo et al., 2007). It describes a latent potential for performance, as opposed to the observed actions, or 'doing' of performance (Roe, 2014).

We present a general model of endurance in Figure 2.1 depicting outcomes, indicators, and work-life patterns that constitute endurance. Temporal factors are inherently important in our model which differentiates short-term and long-term dynamics (Griffin & Clarke, 2011). A dynamic work-life system (i.e., work, non-work, and sleep experiences and activities) operates at multiple levels over time to affect psychological and physiological indicators of endurance. Outcomes related to endurance are also conceptualised at multiple levels, depending on the time frame of reference (e.g., task performance on a single day vs. a pattern of goal accomplishment over a several month-long mission). The dynamic process of energy management is central to our model and involves individuals adjusting their psychophysiological states in response to stressors and changes in their environment, for instance, expending energy to respond to demands and replenishing energy to reduce fatigue. The specifics of the processes are addressed in subsequent sections.

Figure 2.1. A temporal framework to understand the factors that impact and predict endurance.



2.4 Distinguishing Endurance from Related Constructs

Before presenting details of the endurance process, we consider how endurance is distinct from related constructs such as grit and resilience. First, grit is a personality trait defined as passion for and perseverance toward long-term goals (Duckworth et al., 2007). As such, the focus of grit is on the role of stable individual differences in how an individual approaches long-term challenges (i.e., between-persons approach). By contrast, endurance emphasises the dynamic interaction between an individual and their daily experiences (i.e., within-persons approach), although the extent to which individuals can endure in extreme work environments is likely driven by trait levels of grit. For instance, trait grit predicts retention and performance in military training programs (Maddi et al., 2017).

Resilience is another concept that is relevant to long-term functioning and performance in extreme work environments. Resilience is conceptualised as an emergent outcome and refers to the process of ‘bouncing back’ from adverse events (Hartwig et al., 2020). Defined in this way, resilience focuses on the specific temporal period *after* a triggering adverse event or chronic sequence of stressors that individuals and teams must respond to and recover from (Hartwig et al., 2020). Resilience plays an integral role in endurance, with individuals needing to be resilient and robust to the potentially significant adverse events they might face on long-duration missions. However, endurance focuses more broadly on complete trajectories of performance across an entire mission, which includes patterns leading up to and following potential acute and chronic stressors.

As summarised in Table 2.1, endurance is best viewed as an integrative concept that captures the dynamic processes through which humans not only survive but perform over the course of an inherently stressful and complex mission (Driskell et al., 2018). Endurance encompasses both short-term performance variability and long-term performance trajectories.

Table 2.1. Differentiating endurance from related constructs

Characteristic	Constructs		
	Endurance	Resilience	Grit
Explores high performance under adverse and stressful conditions	✓	✓	✓
Focus on person-environment interactions	✓	✓	✗
Described by short-term dynamics (e.g., processes that unfold daily)	✓	✓	✗
Described by long-term dynamics (e.g., processes that unfold over weeks - months)	✓	✓	✗
Focus on whole-of-mission trajectories of performance	✓	✗	✗

2.5 The Dynamics of Endurance

Performance, and the factors that impact performance, are dynamic and can fluctuate over time (Roe, 2014). For example, performance has been found to change in response to factors such as contextual workplace conditions and individual level factors (Alessandri et al., 2015). Recent research suggests that a within-person approach is most useful for understanding ongoing change in an individuals' states and behaviours as they interact with the environment across periods such as hours, days, and weeks (McCormick et al., 2020). This approach contrasts with conventional between-persons research that focuses on static questions regarding stable constructs, and highlights differences between people. In the following sections we detail the within-person processes and mechanisms underlying endurance over short and longer periods of time. To set the stage, we first explain processes of energy management, and how they support performance in demanding contexts.

2.5.1 Energy Management

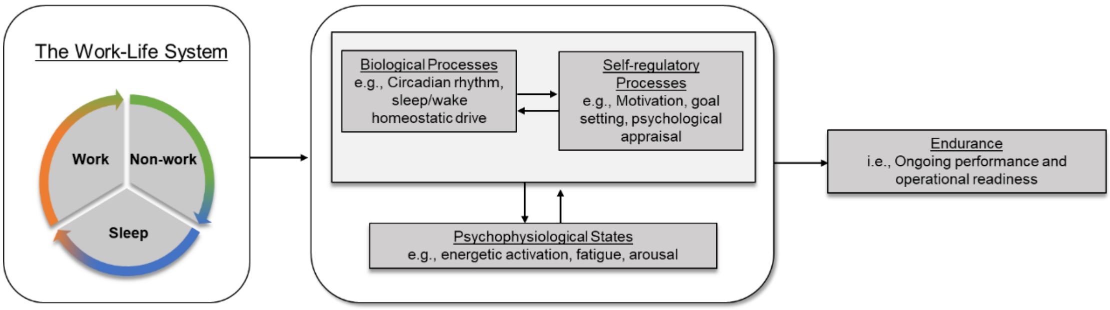
Energy management is the process of balancing energy expenditure in response to stressors and demands with recovery through processes of rest, sleep, and detachment (Meijman & Mulder, 1998). Over time, endurance is the successful management of these processes to maintain high levels of performance and safety.

Many studies concerned with human energy at work adopt the perspective of the Effort-Recovery (E-R) model (Meijman & Mulder, 1998) or its variations. The E-R model proposes that energy expenditure in response to work demands causes stress-related psychophysiological load reactions which are reversed by periods of recovery (Rau & Triemer, 2004). If adequate recovery does not occur, an individual may start the next working period in a suboptimal state, meaning compensatory effort is required to perform. This effort can lead to an accumulation of fatigue and negative health outcomes (Demerouti et al., 2009).

Recent research suggests the E-R model does not adequately explain the dynamics of energy expenditure and replenishment (Zijlstra et al., 2014). For instance, certain experiences during work (e.g., flow) can generate positive moods that help maintain short-term energy levels and overrule fatigue effects, and enjoyment of work tasks can have protective effects even if recovery is limited (Demerouti et al., 2012). Conversely, recovery outside of work can be hindered by work-related rumination (Querstret & Cropley, 2012). Therefore, it is not entirely clear when stress ends, and recovery starts. For extreme work environments where there is substantial blur between work and non-work domains, both in terms of physical space and time, it is critical to identify and understand the mechanisms underlying energy expenditure and energy restoration. A better understanding of these mechanisms will inform the specific factors that detract from or support an individual’s ongoing capacity to perform.

We propose that effective energy management facilitates endurance by enabling the psychophysiological states that sustain performance across the changing demands of the external environment. We depict the main elements and processes involved in energy management in Figure 2.2. Psychophysiological states (e.g., fatigue, arousal) are shaped by biological processes such as circadian rhythms and sleep/wake cycles; and self-regulatory processes such as motivation and goal setting (Zijlstra et al., 2014). Endurance involves successful short- and long-term energy management over a sustainable pattern of work, non-work, and sleep.

Figure 2.2. Model of energy management processes



2.5.1.1 The Role of Biological and Self-Regulatory Processes

Drawing on recent approaches toward energy regulation (Zijlstra et al., 2014), we propose that endurance involves the interaction of biological rhythms and goal-driven self-regulation processes through which people upregulate or downregulate their psychophysiological state to respond to demands and changes in the external environment. We describe these two aspects of endurance below.

First, humans have evolved several biological patterns and rhythms which support homeostasis through physiological regulation and modulate basic energetic activation. For instance, one of the most important of these internal biological processes is the circadian rhythm, otherwise known as the ‘biological clock’. Human energy levels and alertness fluctuate in a predictable pattern over the course of a 24-hour day, and a large part of this pattern is determined by the circadian rhythm (Dijk & Czeisler, 1995). This timekeeping system governs many physiological parameters such as core body temperature and metabolism (Buxton et al., 2012; Wright et al., 2002). These biological processes are modulated to varying extents by the external environmental (Wright et al., 2013). For example, circadian rhythms are disrupted due to the changes in light when travelling across multiple time zones.

Second, humans have the capacity to engage in more conscious goal-driven self-regulation to muster additional energy in line with psychological appraisal of the environment and the self (Neal et al., 2017). Self-regulation encompasses the various ways in which people modify their thoughts, feelings, and behaviours to reach a desired end state or goal (Gross, 2015). Situational demands can mean an individual’s current psychophysiological state deviates from the state required, for example, they need to be more energetic, vigilant, or relaxed, depending on what they perceive is required in that moment. When the required state is one of higher energetic activation, individuals can actively upregulate to a higher energetic state by mobilising compensatory effort to increase attention and focus (Hockey, 1997; Kahneman, 1973). For example, a night shift worker may be in a state of heightened sleepiness during their circadian low (03:00 am - 05:00 am) (Gander et al., 2011) and so must upregulate their energy and exert effort to compensate for their current state of fatigue. Similarly, there are times when the required state is one of lower energetic activation. For example, an individual ruminating after work about unsolved work problems may need to downregulate their psychophysiological state by engaging in activities (e.g., mindfulness exercises) to detach from work, which enables better sleep quality (Hülsheger et al., 2014; Querstet et al., 2017).

Goal-driven self-regulation can be viewed as a process of making choices that involve an interaction between a person and their environment (Neal et al., 2017). Although individuals choose how to spend their time, how much effort to exert, and what strategies to employ; constraints in the environment determine the goal-related choices that are available. Consider a sonar operator in a surface vessel or submarine who must remain vigilant for many hours to detect low-probability signals (Mackie et al., 1994). Although the requirement to focus attention and remain alert over a prolonged period has been found to be fatiguing (Warm et al., 2008), the high-risk environment means they must continue to invest as much effort and energy as required (or as possible) to meet the goal of keeping the vessel and crew safe. Workers in conventional environments have more flexibility to adopt self-regulatory strategies, which includes disengaging attention from the primary task and switching to a secondary task momentarily (Ariga & Lleras, 2011), or redirecting attention towards internal thoughts such as through mind-wandering (Thomson et al., 2015).

2.5.2 Energy Management within an Interconnected Work-Life System

We next consider how energy management processes evolve over time across the three life domains (work, non-work, and sleep), creating a ‘work-life system’. Past research indicates that activities and experiences that occur in one domain within a work-life system can have flow-on effects to other domains (Crain et al., 2018). In extreme work environments where work, non-work, and sleep are often tightly coupled, this can have important implications for endurance, as ineffective energy management in any single domain can have carry-over effects that impact ongoing performance.

Experiences across work, non-work, and sleep domains (see table 2.2 for a summary) have been shown to impact common psychological and physiological states (Crain et al., 2018). For instance, fatigue is a common outcome investigated across work ergonomics (e.g., Young et al., 2015), recovery research (e.g., Demerouti et al., 2009), and sleep science (e.g., Dawson & McCulloch, 2005). As such, research is increasingly recognising dependencies and interactions among work, non-work, and sleep, (Crain et al., 2018). For example, the amount and quality of sleep affects every day waking experiences at and away from work, with lack of sleep being associated with perceptions of stress (Minkel et al., 2012), and decreased cognitive functioning (Cohen et al., 2010). Similarly, work and non-work activities can impact the ability to obtain optimal sleep, such as work deadlines or social activity limiting the hours available for sleep (Basner et al., 2014).

Table 2.2. Illustrative experiences and activities across a work-life system

Key Life Domain	Illustrative experiences and activities
Work	• Task workload (e.g., cognitive and attentional load, Hancock & Matthews, 2019) • Job characteristics (e.g., job demands and resources, Bakker & Demerouti, 2014)
Non-work	• Type of recovery activity (e.g., leisure vs. obligated duties, Sonnentag, 2001) • Type of recovery experience (e.g., psychological detachment; relaxation; mastery; control, Sonnentag & Fritz, 2007)
Sleep	• Sleep quality/quantity (Barnes et al., 2016), sleep hygiene (Miller et al., 2011), circadian rhythms (Folkard, 1990)

An understanding of carry-over effects within the work-life system of an extreme environment is critical because work, non-work, and sleep are often highly interconnected in these contexts. Highly interconnected domains in a work-life system with little redundancy or flexibility mean disruptions can have an immediate and pervasive impact, with ripple effects throughout the entire system (Perrow, 1999). That is, extreme work environments have little redundancy because workers have less flexibility and choice with energy management strategies (e.g., they must perform optimally during work for safety reasons). The consequences and carry-over effects of ineffective energy management in one domain (e.g., insufficient sleep) have more direct and far-reaching implications, as workers continually compensate to maintain high performance. To illustrate, we can consider work, non-work, and sleep in space and undersea missions, where operations represent a tightly coupled work-life system with little flexibility (Landon et al., 2019). Each element of the work-life system (work, non-work, and sleep) is discussed sequentially below.

In space and undersea missions, the safety critical and unpredictable nature of work, means crew members must be ready to perform, and upregulate if necessary, not only during scheduled work hours, but also during non-work and sleep time (Evans-Flynn et al., 2016; Moffitt, 2008). Requirements include being ‘on-call’ to respond to critical events and incidents 24-hours a day, as well as undertaking obligatory tasks that occur outside of scheduled work hours, such as maintenance of systems, participation in drills, and meetings (Shattuck & Matsangas, 2017). Fatigue from extended periods of work present a serious risk, as a crew or team must be self-reliant for the duration of an undersea or space mission, given the difficult or impossible option of extracting existing personnel or inserting backup personnel once the mission has started (Brasher et al., 2010).

Non-work time is important for psychological detachment from stressful work periods but can be hard to obtain in space and undersea missions, meaning stress from work demands spills over to non-work time (Sonnentag & Fritz, 2015). Psychological detachment implies not only refraining from performing work-related tasks, but also mentally disconnecting from work (Sonnentag & Fritz, 2015). However, being constrained to work and live in close physical proximity to one’s workplace has been found to predict poorer psychological detachment and a reduced capacity for recovery (Searle, 2012). Moreover, psychological detachment is increased through engagement in enjoyable leisure activities such as exercise and joint activities with others (Feuerhahn et al., 2014; Hahn et al., 2012). With limited space, time, and choice of leisure activities impeding psychological detachment, workers are at risk of experiencing high levels of strain and negative affective states after a stressful workday (e.g., work-related rumination) that prevent effective recovery (Sonnentag, 2018).

Last, despite the critical role of adequate sleep for optimal human functioning, sleep is often the first domain to suffer in an extreme work environment (Miller et al., 2008). Sleep plays an important part in returning psychophysiological states to baseline, with humans requiring on average 8–8.5 hours of sleep per night (Watson et al., 2015). However, factors such as operational pressures, uncomfortable sleeping environments, and a ‘can (and will) do’ attitude towards meeting work goals mean sleep loss and/or deprivation is a common occurrence in extreme environments (e.g., Miller et al., 2011; Moffitt, 2008). For example, astronauts typically obtain less than 6 hours of sleep per day (Barger et al., 2014), with sleep being disrupted by suddenly shifted work operations, uncomfortable ambient temperatures, and an absence of circadian cues such as light cycles (Stuster, 2010).

As our examples illustrate, there is a high potential for carry-over effects within a constrained extreme environment. These effects highlight a need to consider how elements of the entire work-life system interact over time to affect energy management, and ultimately, the capability to endure.

2.6 Designing a Work-Life System to Optimise Endurance

We propose that organisations and individuals can optimise endurance by designing a work-life system that integrates across work, non-work, and sleep components. Designing a work-life system for optimised endurance requires individuals and organisations to actively shape and manage the content, composition, timing, and environment of work, non-work, and sleep components to reduce or prevent negative carry-over effects that would otherwise contribute to an accumulation of fatigue and strain.

A work-life system designed to consider the interconnected nature of work, non-work, and sleep allows for more sustainable patterns of energy management, and reflects a systemic approach to reducing the degree to which individuals need to compensate across the demands of a mission. Although compensation efforts are a critical component in energy management, repeated short-term compensation in response to environmental challenges leads to accumulation of strain and fatigue that impairs functioning and performance over longer periods (Ford et al., 2014;

McEwen, 2007). For example, although 24-hour sleep-deprived individuals may be able to maintain safety-critical task performance for a period using compensatory strategies (Hockey et al., 1998), chronic sleep loss has cumulative detrimental effects that are not easily reversed by short-term strategies, such as taking a single extended sleep (Cohen et al., 2010).

A systemic approach to mitigating a build-up of strain and fatigue is critical because the highly interconnected nature of extreme work-life systems means fatigue and strain can rapidly carry-over and accumulate from one working period to the next (Hockey, 1997). Additionally, there is less opportunity in extreme work environments to reverse any build-up of strain and fatigue. For instance, in the common working week pattern of five days of work and two days of rest, the weekend provides opportunity for respite to occur (Fritz et al., 2010). By contrast, extreme work environments often involve continuous work operations (i.e., 24/7), sometimes without weekends - for example, submarine crews are expected to work on a rotating shift schedule continuously for weeks to months before a dedicated rest period (Brasher et al., 2010; Moffitt, 2008).

Models of stress such as the allostatic load (AL) model (McEwen, 2007) specify that sustained exposure to stressors and/or sustained activation even when stressors are no longer present results in more permanent psychophysiological changes (e.g., elevated cortisol levels, hypertension) which impair functioning (e.g., increased sleep disturbances). Over time, as the body treats the stressful state as the new ‘set point’ (Selye, 1955), these changes decrease an individual’s capacity to cope with future stressors. By designing a work-life system to minimise negative carry-over effects from the onset of a mission, organisations and individuals can reduce or mitigate the risk of a vicious and unsustainable cycle of ongoing compensation, where extra effort has to be exerted at the beginning of every new working period to prevent performance breakdown (Hockey, 1997).

2.6.1 Organisational and Individual Strategies for Optimising Endurance

Organisations and individuals can leverage different strategies to design work-life systems for endurance and protect against the accumulation of strain and fatigue (Crain et al., 2018). In extreme work environments, organisations largely determine environmental constraints such as the physical working and living environment, the work design, and the degree of autonomy afforded to workers (Landon et al., 2019). A key strategy that organisations can implement is the design of work/rest schedules in line with criteria that support endurance across a whole work-life system. Work/rest schedule design is concerned with the daily structure and timing of work, non-work, and sleep elements across a mission. These schedules are critical in many extreme environments where work shifts need to support a platform (e.g., ship, submarine) to operate for 24-hours a day, while allowing individuals time for other duties, rest, and sleep (Colquhoun, 1985).

Although the design of work/rest schedules is not a new topic, an integrated work-life system approach is often missing. For example, while there is a large body of research on work/rest schedules in the offshore oil/gas industry, most research has focused on sleep-related issues (Riethmeister et al., 2019), with few studies accounting for work stressors or recovery opportunities (Parkes, 2017). Indeed, the offshore process industries still operate rosters that involve contracted 12-hour working shifts, and factors such as worker exposure to overtime are often not considered (Parkes, 2017).

Designing a work/rest schedule according to endurance criteria allows organisations to integrate human biological needs (e.g., sleep and recovery) with mission workload requirements as shaped by operational needs and constraints. For example, sleep criteria can include (a) allowing for an 8-hour block of uninterrupted sleep per 24-hour period (Watson et al., 2015) and (b) allowing for night-shift workers to have a circadian synchronised sleep period, which involves employing light-management techniques (Boivin & James, 2005). In terms of criteria for non-work, this may include allowing workers enough time to transition between work and sleep periods. For instance, an adequate amount of time should be factored into a schedule to allow for ‘winding down’ prior to sleep to maximise sleep quality/duration, as well as to mitigate the temporary effects of sleep inertia on work performance (i.e., grogginess and disorientation) after waking up (Tassi & Muzet, 2000). For work criteria, although these will be shaped by mission operational requirements, these criteria should aim to protect against excessive worker fatigue. For example, scheduled work periods should not exceed 8-hours of continuous work, as extended work shifts (e.g., 12-hour shifts) are associated with greater fatigue, and decrements in performance capacities and alertness, particularly where high workloads are concerned (Bendak, 2003; Macdonald & Bendak, 2000). We also note that work criteria such as those pertaining to working hours, will be related to and impacted by the number, skills, and experience levels of personnel an organisation deploys on a mission, as any additional/unexpected increase in demands must be absorbed by existing workers. Therefore, for a work/rest schedule to be operationally feasible, organisations are required to consider task allocations among team members and expected projections of workload to ensure teams set out from the beginning of a mission with sufficient levels of personnel to support around-the-clock work shifts.

Individual workers also shape the design of their work-life system when they interact with their environment on a day-to-day basis (Neal et al., 2017). Individuals optimise endurance and reduce negative carry-over effects by actively choosing what, when, and how they engage in activities and strategies that assist in regulating their energetic state effectively; whether this is a state of higher energetic activation to deal with high workloads, or a state of relaxedness and calmness for sleep and energy restoration. For example, how an individual integrates physical exercise as a non-work activity within their work-life system will have implications for endurance. Physical exercise is an important non-work activity that facilitates psychological detachment (Feuerhahn et al., 2014; Rook & Zijlstra, 2006). However, potential carry-over effects must be considered. For instance, engaging in high-intensity exercise ≤ 1 hour before bedtime can lead to sustained physiological activation (e.g., elevated heart rate) which can disrupt the onset of sleep (reducing total time slept) (Oda & Shirakawa, 2014). To optimise the benefits of physical activity for psychological detachment, workers would be best placed to engage in high-intensity exercise directly after work, or failing this, light exercise preceding a sleep period. This pattern creates the best opportunity for obtaining an adequate amount of sleep, which prepares the individual to deal with the demands of the next working period (Cohen et al., 2010).

2.7 Discussion

In this paper we have introduced ‘endurance’, a conceptualisation of performance that expands upon traditional approaches and is suited to understanding the unique demands of extreme work environments. We have explained, with focus on processes that unfold over a mission, how endurance is the capacity to sustain high performance over an extended duration. Drawing on diverse perspectives of work stress, performance, and physiology, we have argued that an endurance-approach to performance is needed to understand how an individual sustainably manages energy across daily work, non-work, and sleep experiences. In the face of long-term stress and limited opportunity for respite, endurance depends on avoiding accumulation of strain, as this leads to negative changes in mental and physical health, which affects future readiness to perform. Below, we discuss how this theoretical approach can be applied to support researchers and practitioners.

2.7.1 Research Implications

The concept of endurance has important implications for how researchers approach long-term performance in complex and uncertain work environments. We highlight two themes for future research.

2.7.1.1 Temporal Perspectives

The concept of endurance highlights the importance of understanding performance and functioning as it unfolds within individuals in their natural environment across short- and long-term timeframes (Klonek et al., 2019). In ideal circumstances, workers would be able to perform optimally daily, and also endure, however, these two situations are not synonymous. Factors that enable workers to perform in the short-term might have different implications for long-term endurance. For example, Grech et al. (2009) found that the relationship between workload and fatigue changed over consecutive days during a naval mission, such that at the beginning of the mission, low workload was associated with fatigue, however at the end, high workload was associated with fatigue. This is relevant to extreme work environments because demands such as workload are often variable and unpredictable across a mission. Additionally, there is currently limited understanding about how ongoing combinations of stressors (e.g., lack of sleep in combination with high workloads) impact workers over longer durations (i.e., over several months) in an operational environment. Future research would benefit from exploring relationships and implications over different timeframes, with attention paid to longer time windows (e.g., mission, deployment, assignment, or roster), as well as shorter-term fluctuations in dynamic states (Klonek et al., 2019).

One approach to advancing temporal research involves using intensive longitudinal data (ILD) to study within-person processes as they unfold over time (Hamaker & Wichers, 2017). New techniques to analysing ILD such as continuous-time dynamic modelling and dynamic structural equation modelling examine how a preceding state of the system (e.g., a person) gives rise to a subsequent state and interactions between variables (Driver & Voelkle, 2018; Hamaker et al., 2018). These techniques extend on conventional approaches (e.g., growth modelling) which typically focus on concurrent relationships between variables, rather than their dynamic interplay over time. For example, an interesting application of ILD is looking at inertia, or otherwise referred to as autoregressive effects. To date, inertia has typically been explored in the research of affect and is defined in this context as how much carry-over an emotion has from one moment to the next (Albers & Bringmann, 2020). This may be a valuable avenue for understanding endurance. Detecting a certain degree of inertia or change in inertia in indicators such as mood or fatigue, could provide insight into trajectories of endurance and how factors in a work-life system affect an individual’s ability to regulate their state.

A related future direction is to extend the temporal frame over a job/career, i.e., endurance across multiple missions (the right-hand portion of Figure 2.1). While a detailed discussion of endurance over a job/career is beyond the scope of this paper, we propose this perspective involves exploring how even longer-term processes and work/rest patterns over multiple years impacts outcomes such as retention, career development, and long-term health. For example, how much time does an individual require following a mission to recover sufficiently before the next mission? Relevant factors include how strenuous the previous mission was, how intense the upcoming mission is predicted to be, and what work-life looks like in-between missions (Castro & Adler, 1999). Additionally, work-related factors such as enriched work design (e.g., work that involves challenge, feedback and high-level skill use) and fulfilling career pathways (e.g., opportunities for personal and professional development) can facilitate overall job satisfaction and organisational commitment (Parker, 2014).

2.7.1.2 Adopting a Holistic Work-life System Approach

Endurance emphasises a whole work-life system approach towards exploring human performance and functioning. Modern work is characterised by significant blurring between work, non-work, and sleep due to factors like technological advances, work intensification, and the proliferation of a 24/7 society. Despite this, little research adopts an integrated approach towards work, non-work, and sleep (for an exception see Crain et al., 2018). Organisational research focuses on the work-nonwork interface, often neglecting sleep, despite its role in effective human functioning, worker safety, and performance (Crain et al., 2018). Future research could begin to adopt a more holistic approach by examining how work demands and respite activities affect functioning and performance throughout the whole work-life system.

For the purpose of brevity, we have focused on individual level endurance and the immediate work-life system in this paper, however, it is important to acknowledge that the individual sits within several systems, as depicted in the top left of Figure 2.1 (i.e., team and organisational context). Many factors across these systems have implications for endurance. For example, effective leadership in an extreme team may buffer stressors specific to work tasks and support a positive social climate that encourages effective teamwork under difficult circumstances (Zaccaro et al., 2009). Training is also another important element. Specialised stress training that focuses on contextual factors (e.g., organisational, environmental, and task demands) that are imposed upon the team may help counter the negative effects of extreme conditions on team performance (Driskell et al., 2008).

2.7.2 Applied Research to Inform Practical Interventions

In addition to theoretical directions, it is important to explore how endurance can be practically investigated and optimised in real-world settings, both for extreme contexts and conventional work environments. Following from our earlier discussion on endurance criteria in the design of work/rest schedules, we now concentrate on how researchers and practitioners can conduct applied research to inform these criteria and interventions.

Although some endurance criteria are straightforward to specify, for example, it is widely known that adults should obtain 8-hours of sleep for optimal performance, health, and wellbeing (Watson et al., 2015), this is not always the case. Often, organisations have limited insight into how individuals or teams work and live within an extreme environment, and/or there is limited existing research that provides actionable recommendations. This is where applied research conducted in real-world settings is important, as it allows for the capture of the complex factors that shape performance in extreme environments, which in turn generates context-specific recommendations to organisations (Bell et al., 2018). For example, even in a laboratory study where work tasks can be closely simulated, it is not practicable to replicate accumulative mission-level effects such as long-term sleep deprivation and isolation from loved ones due to ethical and logistical constraints (among others). In the following, we briefly discuss some challenges and opportunities associated with applied research and offer an example from our research.

Applied research that examines individuals and teams in extreme environments is not without challenges. First, access is a major obstacle. Even where access to is possible, it is often limited, as research goals cannot interfere with operations (Driskell et al., 2018). Additionally, it is not uncommon to rely on self-directed measurement protocols in settings where researchers cannot be present due to limited space and/or dangerous conditions (e.g., submarines, war zones). This raises questions as to how researchers can design measurement protocols that are robust, yet simple and flexible for minimal participant burden.

There are several ways researchers can tackle the challenges of field research. One promising avenue is wearable sensor technologies (Ganster et al., 2018). An increasing number of wearable devices are now equipped with sensors that allow for continuous measurement of the environmental context (e.g., audio/video streams) and physiological indicators (e.g., stress and health via heart rate variability). Second, where traditional experience sampling methodologies are too burdensome in a high-risk operational setting, researchers should consider using single-item measures (Fisher et al., 2016). Although multiple-item measures are traditionally preferred, single-item measures done systematically using validated items may increase response rates and minimise respondant burden (Fisher et al., 2016). This is pertinent if the intent is to capture dynamic fluctuations over time which requires high-frequency assessments (e.g., several times a day) (Kozlowski & Chao, 2018). Lastly, a useful complementary method is to draw on qualitatively rich sources of data such as case studies and focus groups studies. This can be a useful step in understanding the context, before diving into the often expensive and ‘one-shot’ opportunity to collect field data. For further discussions on conducting applied research in dynamic and complex contexts, we refer readers to Kerrissey et al. (2020) and Bell et al. (2018).

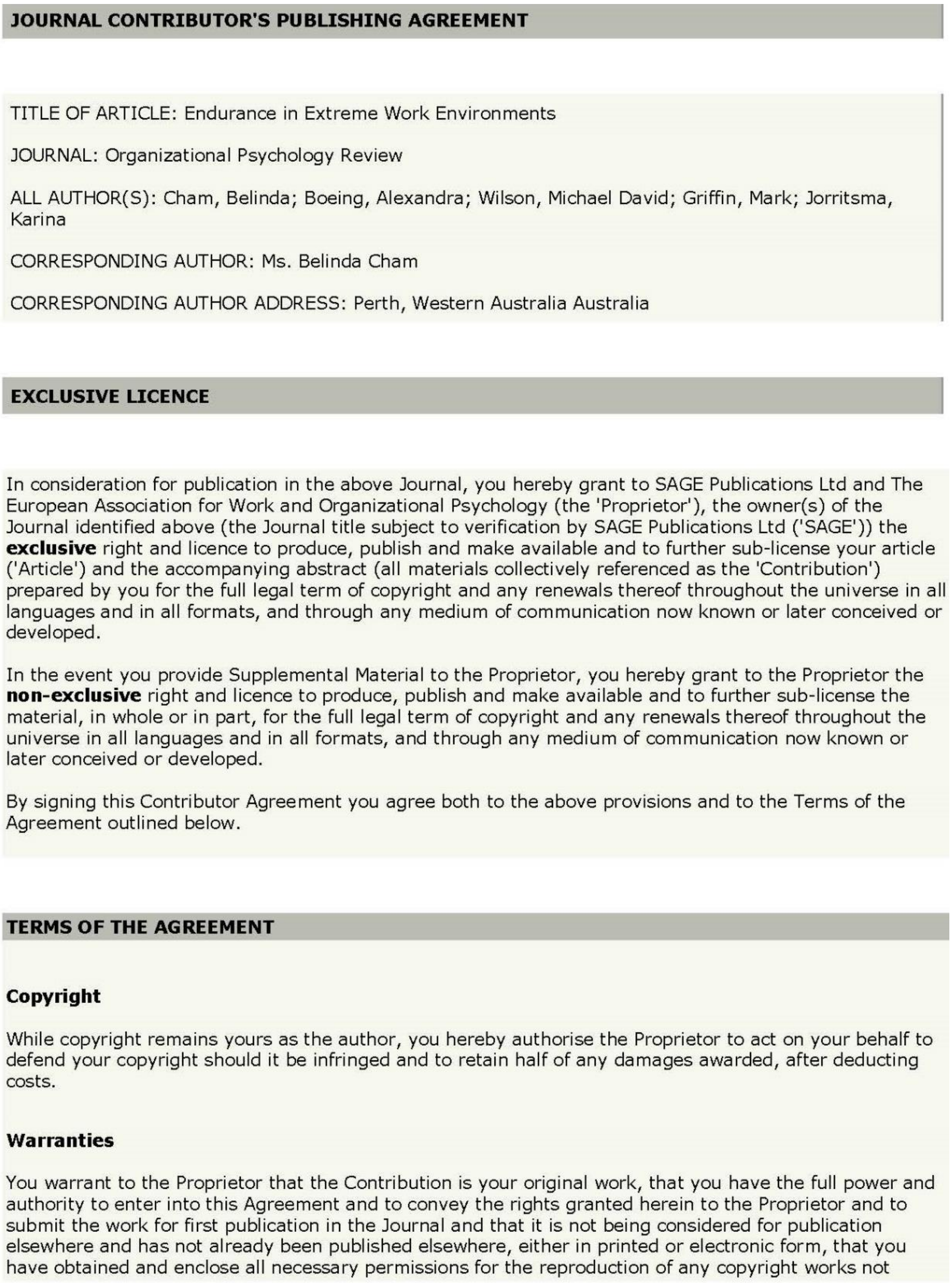
Our research team has utilised several of the above-mentioned methods (among others) as part of a large-scale research program which aims to inform and optimise submariner endurance within a future submarine platform design, intended to replace an existing fleet of submarines in the next several decades (See Boeing et al., 2020; Wilson et al., 2021). Existing literature offers limited guidance, with submariners facing several relatively unique operational constraints, such as tight limits on crew sizes, confined and isolated spaces (Brasher et al., 2010), and limited exposure to sunlight which has uncertain impacts on circadian processes (Bass & Lazar, 2016). Therefore, to develop appropriate endurance criteria to guide organisational interventions in a submarine context, it was critical to gather field data representative of the challenges inherent in a submarine work-life system.

As an initial step prior to collecting field data, the research team conducted qualitative research, which included desktop research (e.g., existing case studies/reports) and focus groups with submariners to understand the key features and constraints of the context. This data informed the development of a measurement protocol suited for ILD collection during live submarine operations, which consisted of wearable devices (i.e., actigraphy), daily diary surveys, and work/rest event logs, all of which enabled measurements at varying resolutions (e.g., minute-to-minute sleep/wake data to twice daily workload ratings) (see Wilson et al., 2021). A subset of the data including sleep/wake times, subjective fatigue and workload measurements was analysed with the Fatigue Impairment Predictions Suite (FIPS) (Wilson et al., 2020), which is an open-source framework that allows organisations, practitioners, and researchers to implement biomathematical models of fatigue (BMMs). BMMs are a family of dynamic phenomenological models that predict the neurobehavioural outcomes of fatigue (e.g., sleepiness, performance impairment) based on sleep/wake history (Dawson et al., 2017). Using this modelling tool, we compared hour-to-hour changes in submariner fatigue across different work/rest schedules. Drawing on these submarine-specific insights, as well as the multidisciplinary literature presented herein, we developed a comprehensive set of criteria for submariner endurance. These criteria have since been used to evaluate and inform staffing requirements for the future submarine platform, as well as develop recommendations for how technical components such as automation capability and platform habitability (e.g., bunking spaces, leisure spaces) should be designed to support endurance (see Boeing et al., 2020).

2.8 Conclusion

The concept of endurance provides insight on how individuals withstand variable and unpredictable stressors while sustaining performance and readiness over a long duration mission. Endurance focuses on dynamic changes in an individual's capacity to perform as they interact with their work-life system over short- and long-term timeframes. Given the changing nature of work, which is characterised by increased uncertainty and complexity due to advanced technology, we hope that the endurance concept will facilitate momentum in adopting an integrated approach towards understanding human performance and long-term wellbeing in not only extreme work environments, but also increasingly demanding conventional work environments.

2.9 Appendix 2A



JOURNAL CONTRIBUTOR'S PUBLISHING AGREEMENT

TITLE OF ARTICLE: Endurance in Extreme Work Environments

JOURNAL: Organizational Psychology Review

ALL AUTHOR(S): Cham, Belinda; Boeing, Alexandra; Wilson, Michael David; Griffin, Mark; Jorritsma, Karina

CORRESPONDING AUTHOR: Ms. Belinda Cham

CORRESPONDING AUTHOR ADDRESS: Perth, Western Australia Australia

EXCLUSIVE LICENCE

In consideration for publication in the above Journal, you hereby grant to SAGE Publications Ltd and The European Association for Work and Organizational Psychology (the 'Proprietor'), the owner(s) of the Journal identified above (the Journal title subject to verification by SAGE Publications Ltd ('SAGE')) the **exclusive** right and licence to produce, publish and make available and to further sub-license your article ('Article') and the accompanying abstract (all materials collectively referenced as the 'Contribution') prepared by you for the full legal term of copyright and any renewals thereof throughout the universe in all languages and in all formats, and through any medium of communication now known or later conceived or developed.

In the event you provide Supplemental Material to the Proprietor, you hereby grant to the Proprietor the **non-exclusive** right and licence to produce, publish and make available and to further sub-license the material, in whole or in part, for the full legal term of copyright and any renewals thereof throughout the universe in all languages and in all formats, and through any medium of communication now known or later conceived or developed.

By signing this Contributor Agreement you agree both to the above provisions and to the Terms of the Agreement outlined below.

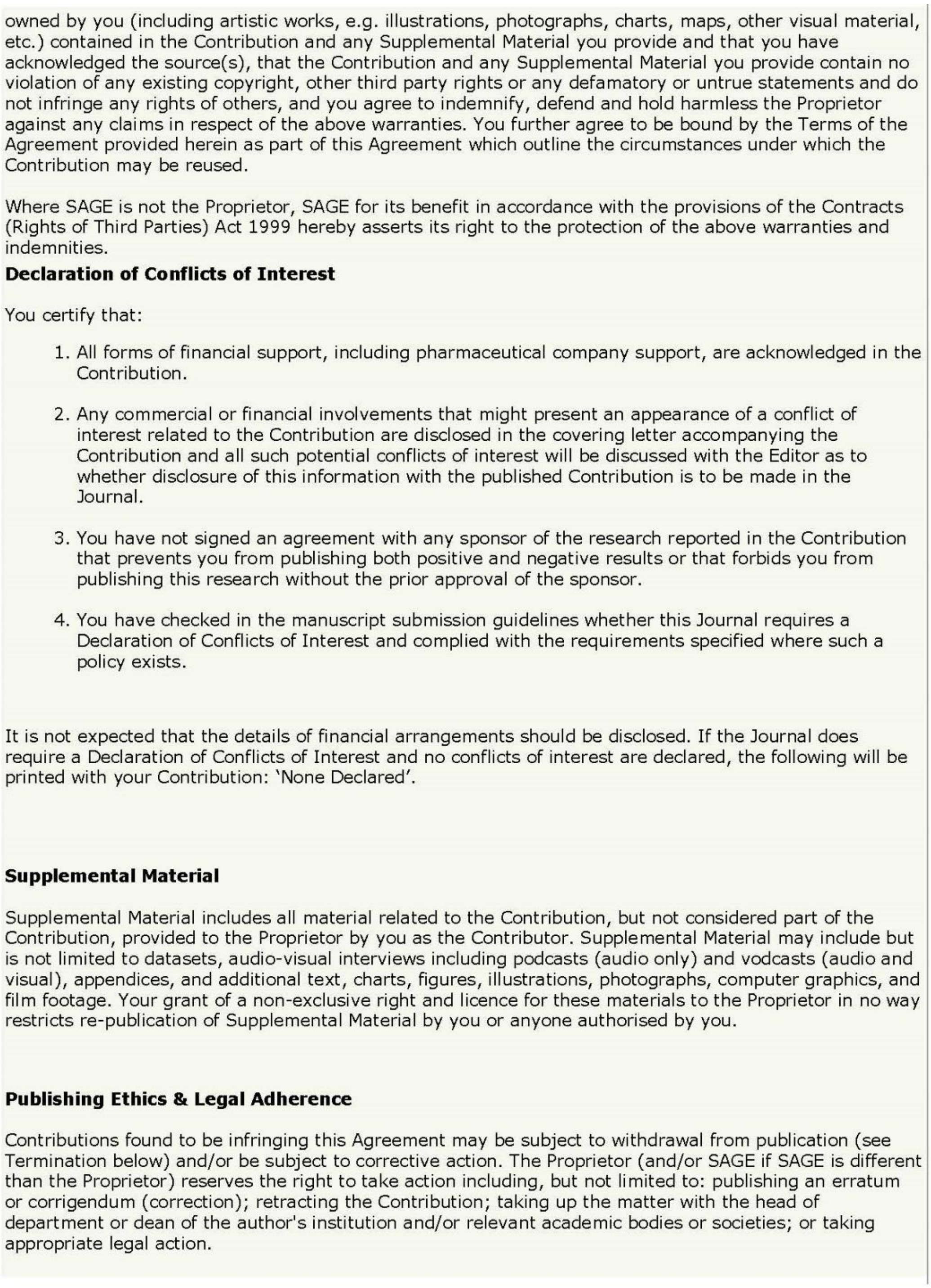
TERMS OF THE AGREEMENT

Copyright

While copyright remains yours as the author, you hereby authorise the Proprietor to act on your behalf to defend your copyright should it be infringed and to retain half of any damages awarded, after deducting costs.

Warranties

You warrant to the Proprietor that the Contribution is your original work, that you have the full power and authority to enter into this Agreement and to convey the rights granted herein to the Proprietor and to submit the work for first publication in the Journal and that it is not being considered for publication elsewhere and has not already been published elsewhere, either in printed or electronic form, that you have obtained and enclose all necessary permissions for the reproduction of any copyright works not



owned by you (including artistic works, e.g. illustrations, photographs, charts, maps, other visual material, etc.) contained in the Contribution and any Supplemental Material you provide and that you have acknowledged the source(s), that the Contribution and any Supplemental Material you provide contain no violation of any existing copyright, other third party rights or any defamatory or untrue statements and do not infringe any rights of others, and you agree to indemnify, defend and hold harmless the Proprietor against any claims in respect of the above warranties. You further agree to be bound by the Terms of the Agreement provided herein as part of this Agreement which outline the circumstances under which the Contribution may be reused.

Where SAGE is not the Proprietor, SAGE for its benefit in accordance with the provisions of the Contracts (Rights of Third Parties) Act 1999 hereby asserts its right to the protection of the above warranties and indemnities.

Declaration of Conflicts of Interest

You certify that:

1. All forms of financial support, including pharmaceutical company support, are acknowledged in the Contribution.
2. Any commercial or financial involvements that might present an appearance of a conflict of interest related to the Contribution are disclosed in the covering letter accompanying the Contribution and all such potential conflicts of interest will be discussed with the Editor as to whether disclosure of this information with the published Contribution is to be made in the Journal.
3. You have not signed an agreement with any sponsor of the research reported in the Contribution that prevents you from publishing both positive and negative results or that forbids you from publishing this research without the prior approval of the sponsor.
4. You have checked in the manuscript submission guidelines whether this Journal requires a Declaration of Conflicts of Interest and complied with the requirements specified where such a policy exists.

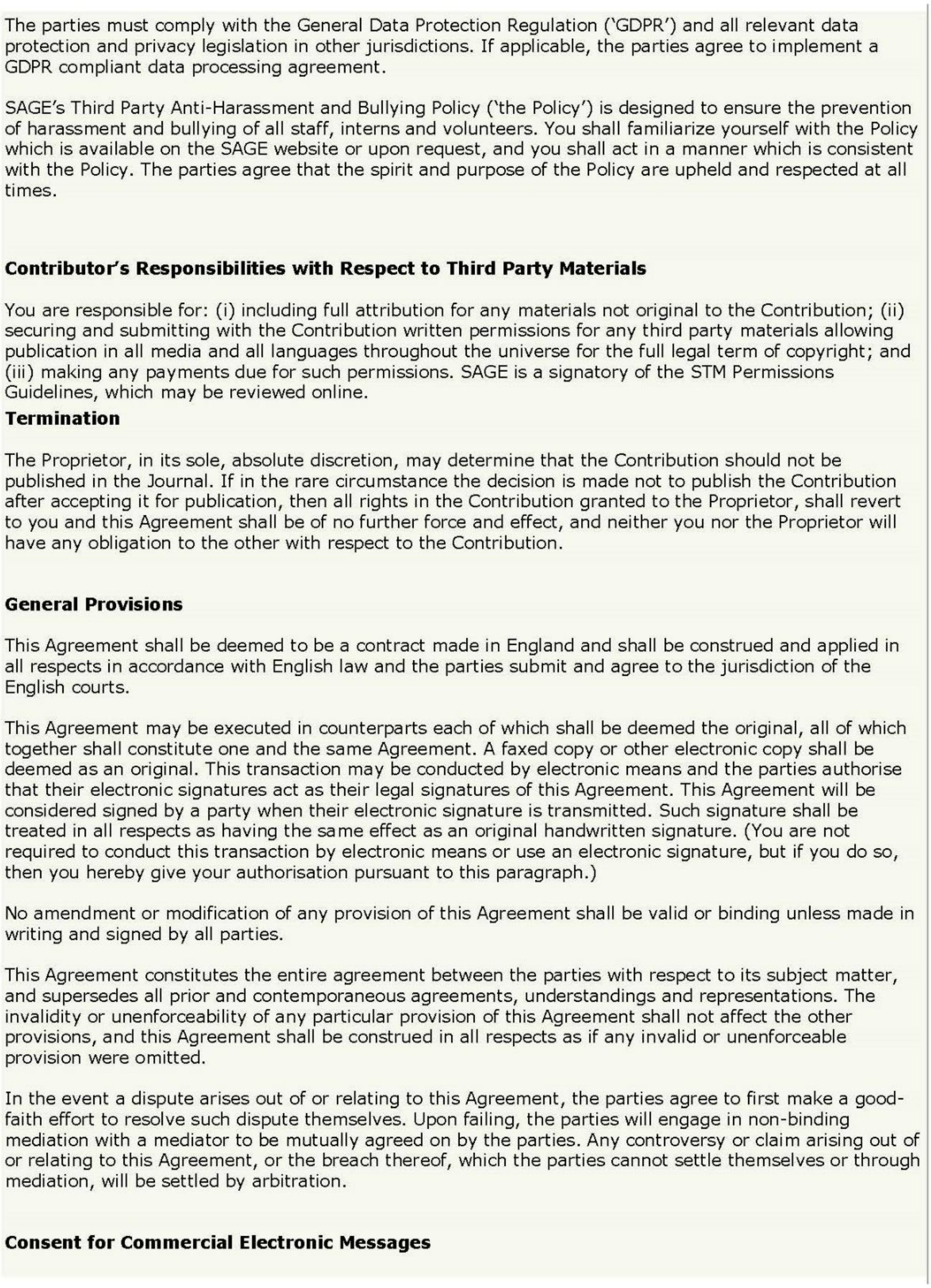
It is not expected that the details of financial arrangements should be disclosed. If the Journal does require a Declaration of Conflicts of Interest and no conflicts of interest are declared, the following will be printed with your Contribution: ‘None Declared’.

Supplemental Material

Supplemental Material includes all material related to the Contribution, but not considered part of the Contribution, provided to the Proprietor by you as the Contributor. Supplemental Material may include but is not limited to datasets, audio-visual interviews including podcasts (audio only) and vodcasts (audio and visual), appendices, and additional text, charts, figures, illustrations, photographs, computer graphics, and film footage. Your grant of a non-exclusive right and licence for these materials to the Proprietor in no way restricts re-publication of Supplemental Material by you or anyone authorised by you.

Publishing Ethics & Legal Adherence

Contributions found to be infringing this Agreement may be subject to withdrawal from publication (see Termination below) and/or be subject to corrective action. The Proprietor (and/or SAGE if SAGE is different than the Proprietor) reserves the right to take action including, but not limited to: publishing an erratum or corrigendum (correction); retracting the Contribution; taking up the matter with the head of department or dean of the author's institution and/or relevant academic bodies or societies; or taking appropriate legal action.



The parties must comply with the General Data Protection Regulation ('GDPR') and all relevant data protection and privacy legislation in other jurisdictions. If applicable, the parties agree to implement a GDPR compliant data processing agreement.

SAGE's Third Party Anti-Harassment and Bullying Policy ('the Policy') is designed to ensure the prevention of harassment and bullying of all staff, interns and volunteers. You shall familiarize yourself with the Policy which is available on the SAGE website or upon request, and you shall act in a manner which is consistent with the Policy. The parties agree that the spirit and purpose of the Policy are upheld and respected at all times.

Contributor's Responsibilities with Respect to Third Party Materials

You are responsible for: (i) including full attribution for any materials not original to the Contribution; (ii) securing and submitting with the Contribution written permissions for any third party materials allowing publication in all media and all languages throughout the universe for the full legal term of copyright; and (iii) making any payments due for such permissions. SAGE is a signatory of the STM Permissions Guidelines, which may be reviewed online.

Termination

The Proprietor, in its sole, absolute discretion, may determine that the Contribution should not be published in the Journal. If in the rare circumstance the decision is made not to publish the Contribution after accepting it for publication, then all rights in the Contribution granted to the Proprietor, shall revert to you and this Agreement shall be of no further force and effect, and neither you nor the Proprietor will have any obligation to the other with respect to the Contribution.

General Provisions

This Agreement shall be deemed to be a contract made in England and shall be construed and applied in all respects in accordance with English law and the parties submit and agree to the jurisdiction of the English courts.

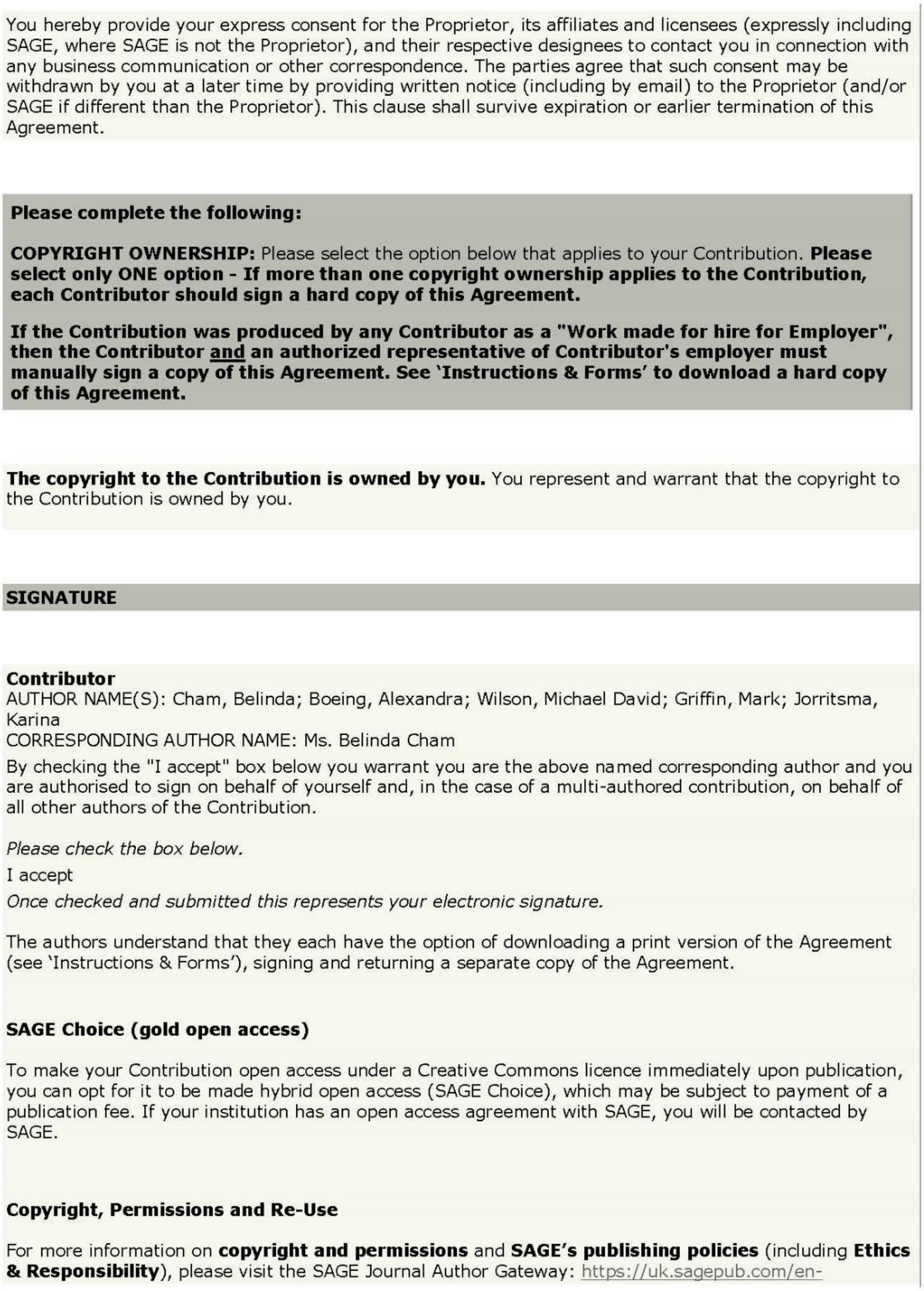
This Agreement may be executed in counterparts each of which shall be deemed the original, all of which together shall constitute one and the same Agreement. A faxed copy or other electronic copy shall be deemed as an original. This transaction may be conducted by electronic means and the parties authorise that their electronic signatures act as their legal signatures of this Agreement. This Agreement will be considered signed by a party when their electronic signature is transmitted. Such signature shall be treated in all respects as having the same effect as an original handwritten signature. (You are not required to conduct this transaction by electronic means or use an electronic signature, but if you do so, then you hereby give your authorisation pursuant to this paragraph.)

No amendment or modification of any provision of this Agreement shall be valid or binding unless made in writing and signed by all parties.

This Agreement constitutes the entire agreement between the parties with respect to its subject matter, and supersedes all prior and contemporaneous agreements, understandings and representations. The invalidity or unenforceability of any particular provision of this Agreement shall not affect the other provisions, and this Agreement shall be construed in all respects as if any invalid or unenforceable provision were omitted.

In the event a dispute arises out of or relating to this Agreement, the parties agree to first make a good-faith effort to resolve such dispute themselves. Upon failing, the parties will engage in non-binding mediation with a mediator to be mutually agreed on by the parties. Any controversy or claim arising out of or relating to this Agreement, or the breach thereof, which the parties cannot settle themselves or through mediation, will be settled by arbitration.

Consent for Commercial Electronic Messages



You hereby provide your express consent for the Proprietor, its affiliates and licensees (expressly including SAGE, where SAGE is not the Proprietor), and their respective designees to contact you in connection with any business communication or other correspondence. The parties agree that such consent may be withdrawn by you at a later time by providing written notice (including by email) to the Proprietor (and/or SAGE if different than the Proprietor). This clause shall survive expiration or earlier termination of this Agreement.

Please complete the following:

COPYRIGHT OWNERSHIP: Please select the option below that applies to your Contribution. **Please select only ONE option - If more than one copyright ownership applies to the Contribution, each Contributor should sign a hard copy of this Agreement.**

If the Contribution was produced by any Contributor as a "Work made for hire for Employer", then the Contributor and an authorized representative of Contributor's employer must manually sign a copy of this Agreement. See 'Instructions & Forms' to download a hard copy of this Agreement.

The copyright to the Contribution is owned by you. You represent and warrant that the copyright to the Contribution is owned by you.

SIGNATURE

Contributor
AUTHOR NAME(S): Cham, Belinda; Boeing, Alexandra; Wilson, Michael David; Griffin, Mark; Jorritsma, Karina
CORRESPONDING AUTHOR NAME: Ms. Belinda Cham

By checking the "I accept" box below you warrant you are the above named corresponding author and you are authorised to sign on behalf of yourself and, in the case of a multi-authored contribution, on behalf of all other authors of the Contribution.

Please check the box below.

I accept

Once checked and submitted this represents your electronic signature.

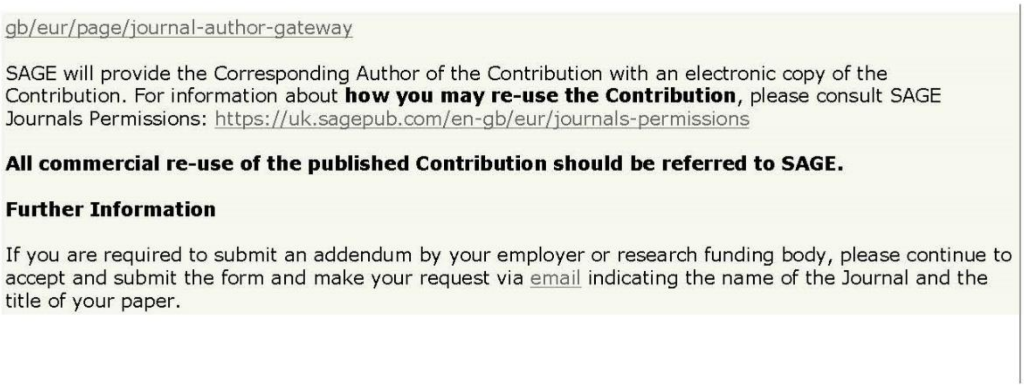
The authors understand that they each have the option of downloading a print version of the Agreement (see 'Instructions & Forms'), signing and returning a separate copy of the Agreement.

SAGE Choice (gold open access)

To make your Contribution open access under a Creative Commons licence immediately upon publication, you can opt for it to be made hybrid open access (SAGE Choice), which may be subject to payment of a publication fee. If your institution has an open access agreement with SAGE, you will be contacted by SAGE.

Copyright, Permissions and Re-Use

For more information on **copyright and permissions** and **SAGE's publishing policies** (including **Ethics & Responsibility**), please visit the SAGE Journal Author Gateway: https://uk.sagepub.com/en-



gb/eur/page/journal-author-gateway

SAGE will provide the Corresponding Author of the Contribution with an electronic copy of the Contribution. For information about **how you may re-use the Contribution**, please consult SAGE Journals Permissions: https://uk.sagepub.com/en-gb/eur/journals-permissions

All commercial re-use of the published Contribution should be referred to SAGE.

Further Information

If you are required to submit an addendum by your employer or research funding body, please continue to accept and submit the form and make your request via email indicating the name of the Journal and the title of your paper.

3 INVESTIGATING THE JOINT EFFECTS OF OVERLOAD AND UNDERLOAD ON CHRONIC FATIGUE AND WELLBEING

3.1 Foreword

In Chapter 2, I developed a theoretical framework of endurance, in which a key component was the work-life system (i.e., the work, non-work, and sleep elements a worker engages in daily). A first critical step in understanding the specific work-life system factors that impact endurance is to consider the work tasks that individuals must perform. I argue this is because optimal work performance is critical not only to mission goals, but also a fundamental requirement for safe living in extreme contexts (e.g., Flynn-Evans et al., 2016; Larson et al., 2019; Sandal et al., 2006). In Chapter 3, I aim to advance knowledge on the work factors that impact endurance by clarifying how work overload and underload relate to long-term endurance indicators (i.e., chronic fatigue and psychological wellbeing) in the real-world extreme setting of long-haul shipping. Long-haul seafarers, like most workers in safety critical and 24-hour operating environments, face sustained exposure to dynamic work demands that range from long periods of monotony and boredom to sudden periods of intense time pressure (Andrei et al., 2019). However, the combination of overload and underload, is not well understood, with one reason being that there is limited research on work situations involving underload in the first place (Bowling et al., 2005; Young et al., 2015). In this chapter, I present an empirical investigation into how overload and underload relate to seafarer chronic fatigue and psychological wellbeing when experienced separately, as well as in combination.

This chapter is presented as a journal article manuscript. A version of this manuscript was published in *Work and Stress*. See Appendix 3A for a copy of the copyright transfer agreement. Note that I use the term ‘we’ throughout this chapter to refer to the collective contributions of the manuscript co-authors.

> **Cham, B. S**., Andrei, D. M., Griffin, M. A., Grech, M., & Neal A. (In Press). Investigating the Joint Effects of Overload and Underload on Chronic Fatigue and Wellbeing. *Work and Stress*.

3.2 Abstract

Workers in safety critical and 24-hour operating environments face sustained exposure to many stressful situations, ranging from long periods of monotony and boredom, to sudden periods of intense time pressure. This study examines how the combination of overload and underload contributes to fatigue and wellbeing in 943 seafarers. Using latent moderated structural equation modelling, we found that underload showed a stronger association with chronic fatigue and impaired wellbeing, compared to overload. An interaction between overload and underload was also significantly related to psychological wellbeing, with increasing levels of overload weakening the negative relationship between underload and psychological wellbeing. Our research highlights that underload, despite previously not receiving much attention, is an important area of concern. Our findings also underscore the importance of unpacking the joint effects of concurrent job demands, and to consider how certain job demands may help to reduce the negative effects caused by other demands. Where current and future jobs may be subject to a reduction in demands (e.g., automation), it is important to consider how underload may impact worker fatigue and wellbeing.

3.3 Introduction

Fatigue is a serious issue in safety critical and high-performance industries that involve 24-hour operations, such as manufacturing, security, transport, health, and defence (Banks et al., 2019). In these settings, shift work and extended work hours over a sustained period of time can lead to chronic fatigue, which in turn, is associated with serious consequences such as impaired performance, physical and mental ill-health, and accidents (van Dijk & Swaen, 2003).

To mitigate or reduce chronic fatigue in increasingly complex and dynamic working environments, it is important to understand how the combination of overload (i.e., work with too many demands) and underload (i.e., work with too few demands) contributes to fatigue. For example, increasing use of automation in the mining industry will expose workers to both overload and underload (Rogers et al., 2019). Where a team of individuals once manually drove haul trucks at a mine site, now a single individual will monitor several autonomous haul trucks 1500 km away in a remote-control operation centre. In this scenario, underload is caused by passive work such as monitoring of digital screens and leads to consequences such as errors and lapses (Young & Stanton, 2002), and negative physical health (Melamed et al., 1995). However, workers facing underload are also likely to face overload, for instance, they will be passively monitoring the system until they are confronted by a critical event and demands rapidly increase.

Despite the likely increase in roles that involve both overload and underload, limited research examines how their combination is related to fatigue. Previous literature has tended to focus on overload (Bowling et al., 2015), while less attention has been given to underload (Andrei et al., 2020). This is surprising, as underload has been identified as a key risk for many jobs that involve monitoring tasks and automated activities (Young & Stanton, 2002). Although there is growing awareness of the importance of examining combinations of job demands (e.g., unique and joint effects) (Bakker & Demerouti, 2017), with very few exceptions (see Jimmieson et al., 2017; van Woerkom et al., 2016), this perspective remains overlooked in the literature.

The current study aims to disentangle the unique and interactive effects of overload and underload by extending the Job Demands-Resources (JD-R) model

(Bakker & Demerouti, 2014) and integrating the motivational control theory of fatigue (Hockey, 2011) to specify how overload and underload should operate in tandem. Motivational control theory assumes that fatigue is not caused by high demands per se, but rather the continued investment of high effort to meet demands that are unrewarding. We conduct our study in the maritime industry with seafarers, where both overload (e.g., frequent berthing, loading, and unloading of ships associated with hectic activity and high time pressure) and underload (e.g., watchkeeping activities involving monitoring the open ocean horizon and bridge and/or engine room equipment monitoring tasks) have been identified as important demands (Andrei et al., 2020). Next, we review past research on job demands, highlighting the existing literature’s focus on overload and relative neglect of underload. We then integrate motivational control theory to specify how overload and underload might operate together within a job and affect outcomes.

3.3.1 Theoretical Background

For this study, we build on the Job Demands-Resources (JD-R) model (Bakker & Demerouti, 2014) to generate a better understanding on how different types of demands such as overload and underload combine to impact on fatigue related outcomes. The JD-R model proposes that job characteristics can be classified either as job demands or job resources. Job demands (e.g., time pressure, emotional demands) refer to the physical, psychological, social, or organisational aspects of a job that require effort and are associated with costs such as burnout (a form of chronic fatigue), and ill-health (Alarcon, 2011). In contrast, job resources (e.g., autonomy, social support) are aspects of a job that mitigate the negative effect of job demands on exhaustion and support psychological needs.

To date, JD-R research has investigated combinations of job demands and resources, with many studies demonstrating interactions between the two constructs contributing to work outcomes (e.g., Bakker et al., 2005; Schaufeli & Bakker, 2004). In comparison, less attention has been paid to how combinations of demands affect outcomes (Bakker & Demerouti, 2017). This is surprising, given early arguments that in order for stress research to have external validity, it must deal with combinations of stressors, and distinguish between their effects as single stressors and in combinations, where those combinations are commonly encountered in work (Kahn & Byosiere, 1992). As the JD-R model is one of the leading models for investigating job stress (Schaufeli & Taris, 2014), and has been used to inform work design interventions and psychosocial risk policies on an organisational, regulator, and government level (e.g., Parker & Jorritsma, 2020), it is timely to expand on the model to consider the unique and combined effects of multiple demands. For this study, we focus on the demands of overload and underload.

3.3.1.1 Overload, Underload, and their Interaction

Overload is a function of high workload and/or high time pressure and describes a situation in which workers have too many demands (Perrewe & Ganster, 1989). The effects of overload are well documented, with meta-analyses demonstrating the negative implications that overload has for worker performance, and psychological and physical wellbeing (Bowling et al., 2015; Ganster & Schaubroeck, 1991). Overload has been linked with various forms of fatigue, including chronic fatigue and burnout (Leone et al., 2011) and has been identified as a primary work stressor across many occupations and countries (Glazer & Beehr, 2005).

In contrast to overload, underload has received little attention in the work psychology literature (Fisher, 1993), despite becoming more and more relevant to many current jobs in high risk and 24-hour operation industries, as well as jobs in which technology and automation can reduce demands. Underload is characterised by tasks that require ongoing attention yet provide little stimulation in return, such as inspection tasks and monitoring for infrequent events (Young et al., 2015). Early research by Karasek (1979) argued that these forms of 'passive work' combined the experience of low demands with low decision latitude. Contexts where underload has been raised as an issue include long-distance driving (Hancock & Parasuraman, 1992), airport baggage inspection (Hancock & Hart, 2002), and medical monitoring (Weinger, 1990).

Although less is known about underload compared to overload, evidence suggests that underload is associated with negative outcomes. For example, using driving simulators, researchers have found that performance in automated conditions is consistently inferior to manual conditions, and this was attributed to a reduction in external task demands and lowered task engagement (Saxby et al., 2013). From a longer-term perspective, underload may lead to a gradual unlearning and atrophy of skills (Karasek & Theorell, 1990), which presents risks for performance and safety in operational contexts. In terms of health, looking at jobs involving monitoring of automated technical processes, watchkeeping, sorting, and guarding tasks, Melamed et al. (1995) found that underload was associated with higher chronic heart disease risk factors. Lastly, recent evidence has found that vigilance demands, a construct closely related to underload, are more strongly related to chronic fatigue than overload (Andrei et al., 2020).

Research that systematically explores combinations of job demands is relatively limited (Bakker & Demerouti, 2017). Studies have either tended to group several demands into a composite index so that their independent effects cannot be isolated (e.g., Schaufeli & Bakker, 2004), or where independent effects are examined, possible interactions are not explored (e.g., Andrei et al., 2020). Noting this limitation in the JD-R literature, Bakker and Demerouti (2017) suggested that future research should consider the potential stress-exacerbating effects that certain combinations of demands might show. The present study responds to this call by investigating the independent and interactive effects of overload and underload.

When the outcomes of overload and underload are considered together, it becomes apparent that both demands are not readily explained by the assumptions that typically apply to job demands, as the JD-R model assumes that an increase in job demands requires additional compensatory effort, which drains a worker’s energetic resources, resulting in fatigue (Schaufeli & Taris, 2014). Such a mechanism does not readily explain the impact of underload, where workers experience fewer demands but still report negative consequences.

To provide a theoretical lens for investigating the joint effects of overload and underload, we extend the JD-R model by drawing on motivation-based approaches which explain fatigue by changes in motivation, attention, and goal-directed effort, as opposed to energy depletion (Hockey, 2011). According to Hockey’s (2011) motivational control theory, fatigue is an adaptive motivational control mechanism that prevents fixation on unrewarding activities. For example, as people expend effort on “have-to” tasks (e.g., work tasks), increased feelings of fatigue prompt a cost-benefit analysis. This results in people either continuing to sustain efforts on the current task because they expect particular rewards or fear negative consequences of not continuing, or redirecting their effort and attention elsewhere towards “want-to” tasks with less costs and more benefits. We use this motivational perspective, where fatigue is not a consequence of demands per se, but rather of sustained effort to maintain goals that are under threat from environmental/task factors or competing motivational tendencies to develop the hypotheses for the present study.

3.3.2 The Present Study

In the present study we examine how the combination of overload and underload in a job impacts fatigue related outcomes. We consider the unique and joint effects of overload and underload on chronic fatigue and psychological wellbeing. In addition to chronic fatigue, we also examine how the demands impact psychological wellbeing because the “depressive element” of chronic fatigue, should impact longer-term psychological wellbeing (Winwood et al., 2005, p. 597).

In line with previous research that has found links between elements of overload (i.e., time pressure) and fatigue (e.g., Andrei et al., 2020; Grech et al., 2009), we expect overload to be related to higher fatigue and lower wellbeing in our sample. Overload occurs when individuals feel pressured by excessive workloads, difficult deadlines, and a general inability to meet goals and expectations in the time available (Perrewe & Ganster, 1989). When goals cannot be attained with a reasonable level of effort, motivational control theory suggests people will be increasingly reluctant to continue engaging in these goals, and other inherently enjoyable and easier pursuits (e.g., rest) will become increasingly attractive. Consequently, the sustained effort and self-control required to maintain the “have to” goal (e.g., facing and responding to overload) and resist alternative “want to” goals, results in feelings of fatigue. Consistent with these arguments, there is evidence that overload may be associated with shifts in goal-directed attention, for example, workers who experience overload also tend to withdraw or disengage from their work (Ganster & Schaubroeck, 1991). Hence, we hypothesise that:

H1a: Overload positively predicts chronic fatigue

H1b: Overload negatively predicts psychological wellbeing

Underload has been proposed to be an unrewarding and even aversive experience, associated with feelings of boredom, dissatisfaction, and frustration

(Karasek, 1979). For example, Ainslie (2013) argues that monotonous tasks are even less rewarding than sitting idle and doing nothing at all, because even in idleness individuals can generate their own rewards and stimulation (e.g., daydreaming), whereas boring and monotonous tasks are characterised by a “structured attention that restricts it” (p. 679). In line with this notion, research has found that boring tasks are associated with more frustration under situations of low versus high task autonomy (van Hooft & van Hooff, 2018). Indeed, underload in many work environments takes the form of monitoring/supervisory control tasks (e.g., sustained attention to detect infrequent signals), which are argued to have low levels of task autonomy (Karasek, 1979; Parker & Grote, 2020). Therefore, we can understand underload in terms of a continuous investment of effort in the face of low motivational value. In line with these arguments, we propose that:

H2a. Underload positively predicts chronic fatigue

H2b. Underload negatively predicts psychological wellbeing

Finally, we examine the combination of overload and underload. Previous research has found that high levels of multiple demands amplifies negative worker reactions (Jimmieson et al., 2017; van Woerkom et al., 2016). These findings are usually explained by Conservation of Resources Theory (CoR) (Hobfoll, 1989), which suggests that as workers expend energetic resources to deal with high levels of one demand, this lessens their ability to cope with high levels of other demands, thereby intensifying strain and fatigue. Under this resource-based assumption, we may not expect concurrently high levels of overload and underload to exacerbate fatigue, as underload involves the experience of few demands. However, under a motivational control approach where fatigue is not caused by the amount of demand in and of itself, but rather by sustained effort to maintain goals under threat from competing motivational tendencies, we might expect a different pattern of results. That is, because overload and underload both involve high effort investment in the face of competing goals, we expect concurrently high levels of overload and underload to be most detrimental for chronic fatigue and psychological wellbeing.

H3a: A two-way interaction between overload and underload will be related to chronic fatigue. The interaction will show an accentuating effect, with higher levels of overload and underload strengthening the positive relationship with chronic fatigue.

H3b: A two-way interaction between overload and underload will be related to psychological wellbeing. The interaction will show an accentuating effect, with higher levels of overload and underload strengthening the negative relationship with psychological wellbeing.

3.4 Method

3.4.1 Sample and Procedure

This study was conducted in a maritime context with seafarers operating on international commercial ships. Data was collected using a self-report survey that was distributed physically (90.3%) or electronically (9.7%). Paper and pen surveys were handed out by research assistants during regulator port inspections on ships, training sessions ashore, and at seafarer welfare centres. Third-party organisations (i.e., pilotage) also assisted data collection by distributing surveys to ships. In total, 1026 seafarers completed a questionnaire. The average seafarer age was 34.5 years (SD = 10.64). The sample was made up of 924 (90.1%) males, 20 females (1.9%), and 82 (8.0%) did not report their gender. Seafarers had an average tenure in the seafaring industry of 9.76 years (SD = 8.77).

3.4.2 Measures

All constructs investigated in this study were assessed via self-reports from participants. Alpha-Cronbach reliability for each measure is illustrated in Table 3.1. Unless otherwise specified, items were rated on a five-point Likert scale ranging from 1 (Never) to 5 (Always). Full measures are provided in Appendix 3b.

Overload was measured with three items from the 11-item “Pace and Amount of Work” subscale of the Questionnaire on the Experience and Evaluation of Work (Veldhoven & Meijman, 1994). These items assessed how frequently participants perceived they had too much work to do or had to work very quickly. Example item: I have to work very fast.

Underload was measured using a three-item adapted version of a measure for vigilance demands developed by Andrei et al., (2020). We adapted the scale to focus more broadly on situations in which workers have fewer demands, as opposed to work involving vigilance tasks specifically. Example item: I do not have enough work to do.

Chronic fatigue was measured using the four-item chronic fatigue subscale of the Occupational Fatigue Exhaustion Recovery (OFER) measure (Winwood et al., 2005). The subscale measures the mental, physical, and emotional components of persistent fatigue (e.g., When working at sea, my job at sea takes all my energy from me). The wording of items was adapted to be suitable for shipboard work (e.g., we added an anchor to all items, “When working at sea…”). Responses were rated on a five-point rating scale (1 = Strongly disagree to 5 = Strongly agree).

Psychological wellbeing was measured using a six-item subset of the 14-item Mental Health Continuum Short Form (Lamers et al., 2011). Participants were asked to rate how often over the past month they felt/perceived a range of emotions and thoughts (e.g., that you felt good about yourself).

3.4.3 Statistical Analyses

To test our hypotheses, we conducted structural equation modelling using Mplus version 8.2 (Muthén & Muthén, 2017). We used a two-step procedure for estimating latent moderated structural equations (LMS) which accounts for issues of construct validity and measurement reliability, thereby improving the accuracy of detecting interaction effects, compared to traditional approaches (Klein & Moosbrugger, 2000). Models were estimated with the XWITH command, using full information maximum likelihood with robust standard errors. As per Mplus defaults, latent variables were scaled by fixing the loading of the first item to 1.0. For each hypothesised interaction effect, we first assessed the fit of the measurement model and then conducted a log-likelihood ratio test comparing the loglikelihood values of a main-effects model (no interaction term) with Model 1 (the model with the interaction term).

3.5 Results

3.5.1 Descriptive Statistics

Table 3.1 presents the means, standard deviations, intercorrelations and Alpha-Cronbach scale reliabilities for all the variables included in the study.

Table 3.1. Means, standard deviations, Alpha-Cronbach reliabilities, and bivariate correlations among study variables (after listwise deletion, N = 887)

Variable	*M*	*SD*	1	2	3	4
1. Overload	3.00	0.86	(.80)			
2. Underload	2.34	0.81	.27**	(.65)		
3. Chronic Fatigue	2.36	1.02	.30**	.44**	(.88)	
4. Psychological Wellbeing	4.26	0.62	-.09*	-.24**	-.28**	(.91)

*$p < .05$, **$p < .01$ (2-tailed)

3.5.2 Measurement Model

Confirmatory factor analysis (CFA) was conducted to examine the construct validity of our study variables. In the CFA we included the four study variables: overload (3 items), underload (3 items), chronic fatigue (4 items), and psychological wellbeing (6 items). This four-factor model showed adequate fit to the data: $\chi^2(98) = 354.25$, Root Mean Square Error of Approximation (RMSEA) = .05, (95% CI = .05 - .06), Comparative Fit Index (CFI) = .96, Standardised Root Mean Square Residual (SRMR) = .03. All indicators loaded significantly onto their intended latent factor (all factor loadings >.25; $p < .001$).

3.5.3 Latent Interaction Effects Between Overload and Underload on Chronic Fatigue

The main effects model fit the data well: χ^2 (32) = 127.21, RMSEA = .06 (95% CI= .05 - .07), CFI = .96, Tucker-Lewis Index (TLI) = .95. Both overload and underload positively predicted chronic fatigue ($\beta = 0.16$, $p < .001$, and $\beta = 0.51$, $p < .001$, respectively) (*Hypothesis 1a* and *2a* supported). The model explained 34.7% of variance in chronic fatigue. Testing for improvement of model fit, log-likelihood ratio tests yielded a loglikelihood difference value of D = 0.08 ($p > .05$), indicating that Model 1 was not a better data approximation, relative to the main effects model. As shown in Table 3.2, the underload × overload interaction effect was not significant ($\beta = -0.01$, SE = .03, $p > .05$) (*Hypothesis 3a* not supported).

3.5.4 Latent Interaction Effects Between Overload and Underload

on Psychological Wellbeing

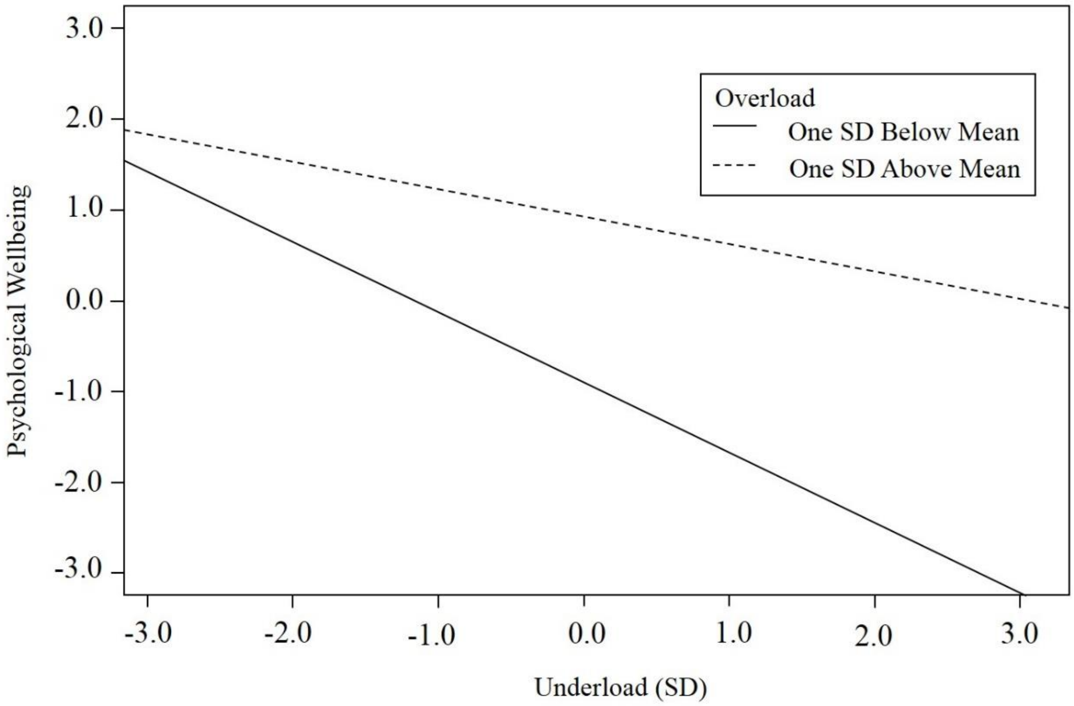
The main effects model fit the data well: χ^2 (51) = 176.49, RMSEA = .05 (95% CI= .04-.06), CFI = .97, TLI = .96. Results showed that overload did not significantly predict psychological wellbeing (β = 0.02, *p* > .05) (*Hypothesis 1b* not supported), while underload negatively predicted psychological wellbeing (β = -0.35, *p* < .001) (*Hypothesis 2b* supported). The model explained 12.00% of variance in psychological wellbeing. Testing for improvement of model fit, log-likelihood ratio tests yielded a loglikelihood difference value of D = 14.99 (*p* < .001), confirming a significantly better data approximation for Model 1 relative to the main effects model. As shown in Table 3.2, the underload × overload interaction effect was significant (β = 0.13, SE = .03, *p* < .001). The interaction effect explained an additional 3.60% of variance in psychological wellbeing. To further analyse the specific form, we plotted the interaction by inserting high (1 *SD* above the mean) and low (1 *SD* below the mean) values for overload (see Figure 3.1). The interaction while significant, was in an unexpected direction in that the negative relation between underload and psychological wellbeing became weaker as overload increased (*Hypothesis 3b* not supported).

Table 3.2. Results of Latent Moderated Structural Equation Modelling

	DV = Chronic Fatigue		DV = Psychological Wellbeing	
Predictor	*β*	*SE*	*β*	*SE*
Overload	0.16***	0.05	0.05	0.05
Underload	0.51***	0.05	-0.38***	0.04
Underload x Overload	-0.01	0.03	0.13***	0.03
Main effects model: R^2		.35***		.12***
Model 1: R^2		.35***		.15***
ΔR^2		0.00%		3.60%

N = 943, **p* < .05, ***p* < .01, ****p* < .001.

Figure 3.1. Plot of the two-way interaction of underload and overload on psychological wellbeing.



3.6 Discussion

Our research adds to the job demands literature by investigating how overload and underload relate to chronic fatigue and psychological wellbeing, separately as well as in combination. This is an important contribution to job demands research which has been criticised for not exploring the effects of combinations of job demands (Bakker & Demerouti, 2017). Overload and underload are seldom explored concurrently in the same context, despite both being suggested as risks factors for worker fatigue (Andrei et al., 2020). By revealing some of the complex interactions between demands, we answer the call for improving the understanding of how constellations of working conditions affect worker outcomes.

Overall, our findings illustrate that overload and underload play important roles in affecting chronic fatigue and psychological wellbeing. In terms of main effects, higher frequencies of underload in a seafarer’s job predicted higher levels of chronic fatigue, as well as lower psychological wellbeing. Overload however, only predicted chronic fatigue and not psychological wellbeing in our models. Our results are not only in line with previous research suggesting that both demands present risks for worker fatigue (e.g., Grech et al., 2009), but also extend by demonstrating different relationships with outcomes. Although not hypothesised, we found that underload showed a stronger association to chronic fatigue and psychological wellbeing, compared to overload. Similar effects were also observed in a recent study looking at another group of seafarers (Andrei et al., 2020). This is notable for two reasons.

First, our findings partially contradict typical JD-R assumptions that high job demands lead to fatigue. However, according to motivational control theory (Hockey, 2011), these findings may be explained by the notion that boredom and monotony associated with underload produces a greater shift in attention and motivation (i.e., unwillingness to exert further effort), compared to the pressure and stress of overload. Indeed, some researchers have posited that exertion of effort in response to demands may generate opportunities for internal rewards such as the subjective experience of self-efficacy and competence or inherent interest/enjoyment in a task itself (Charney, 2013). This finding also supports early research that has found ‘passive work’ with lower demands is associated with greater dissatisfaction than work with higher demands (Karasek, 1979). This may also explain why we did not find a significant association between overload and psychological wellbeing, suggesting overload is not a straightforward construct and has a more ambivalent nature compared to underload. However, as we did not directly assess any motivational mechanisms (e.g., attention, intrinsic motivation) we can only infer that a motivational process accounts for the effects of overload and underload. More research is needed to better understand and test these assumptions.

Second, our results support arguments that the consequences of underload are at least as serious as those of overload (Hancock & Parasuraman, 1992). As underload has been overlooked by the job demands research and is projected to increase across various industries due to automation (Cummings et al., 2016), a better understanding of the consequences and mechanisms associated with it is needed.

In terms of interaction effects, although we found a significant interaction on psychological wellbeing, it was in an unexpected direction. We hypothesised that high levels of overload and underload should accentuate negative outcomes, however our results show that higher overload had a compensating effect on the negative relationship between underload and psychological wellbeing. In other words, we found that work characterised by frequent periods of low demands and boredom, with few periods of high demands and time pressure, was most harmful to wellbeing. This is an intriguing finding because it suggests that while certain demands might be experienced as fatiguing and stressful in isolation, when experienced in combination with another demand it may instead have a buffering effect. The direction of the interaction is not counterintuitive when considering that our results revealed overload had a weaker and more inconsistent relationship with negative outcomes compared to underload. One possibility is that underload may be such a universally aversive experience that having moments of high intensity (i.e., overload) interspersed throughout work to increase engagement and stimulation is preferable to sustained underload. This explanation fits with motivational control theory (Hockey, 2011), and recent experimental research that has found participants in conditions of active effort tend to rate their tasks as less fatiguing, more rewarding, and more interesting when compared to participants in a boredom condition (Milyavskaya et al., 2019).

However, it is important to consider the role of the occupational context for this significant interaction. Seafarers are exposed to unique psychosocial stressors for extended periods of time (e.g., up to several months), for instance, separation from family, limited options for recreational activities, and environmental stress (e.g., noise and vibration) (Andrei et al., 2020; Grech et al., 2009). As such, we can expect seafarers to prefer high demands interjected into conditions of boredom and monotony to ‘make time go faster’ at sea, as indicated by evidence that long ship tours result in feelings of restlessness and irritation (Turgo, 2020). Future research should examine if this effect generalises to other occupational contexts.

We note that no significant interaction was observed for the outcome of chronic fatigue. This may be because we did not exhaustively consider other characteristics of the working environment such as resources and environmental constraints. For example, although we focus solely on interactions between demands in this study, it is still important to recognise the role of resources such as social support which have been found to buffer the negative effect of demands on fatigue and other outcomes (Andrei et al., 2020). Furthermore, the nature of seafarers’ working environment means there are several other factors that can affect fatigue, such as the watchkeeping schedules, sleep quality, or available leisure activities.

Future research should attempt to capture a more complex picture of the nature of work, accounting for how particular resources and/or environmental constraints may affect interactions between job demands.

3.6.1 Limitations and Future Research

We highlight several potential limitations. First, this study's cross-sectional design limits insights regarding the direction of causation. This is important because some theory suggests the relationship between demands and fatigue is reciprocal, with changes in fatigue producing changes in perceived demands (Schaufeli & Taris, 2014). Despite this limitation, this study provides important initial evidence for underload as a demand that is deserving of more attention. Future research should disentangle issues of causality by measuring specific demands and worker reactions on multiple occasions across a workday (i.e., experience sampling).

Second, our use of self-report measures might pose issues for common method variance (CMV). To address this, we conducted tests recommended by Podsakoff et al., (2003), and the results suggest CMV is not likely to be a serious problem in this study. It is also unlikely that our results are an artefact of CMV, as CMV cannot create an artificial interaction effect, but rather deflates the magnitude of true interaction effects (Siemsen et al., 2010).

Third, our measure of underload could have been improved as the coefficient alpha (.65) was barely acceptable (Nunnally, 1978). The low reliability suggests underload is more difficult to measure than other demands (i.e., overload), and this is corroborated by previous research that argues underload is more difficult to detect than overload because the underlying mechanisms are not as well understood (Young et al., 2015). We encourage future research to address this issue through further development in the theory and measurement of underload.

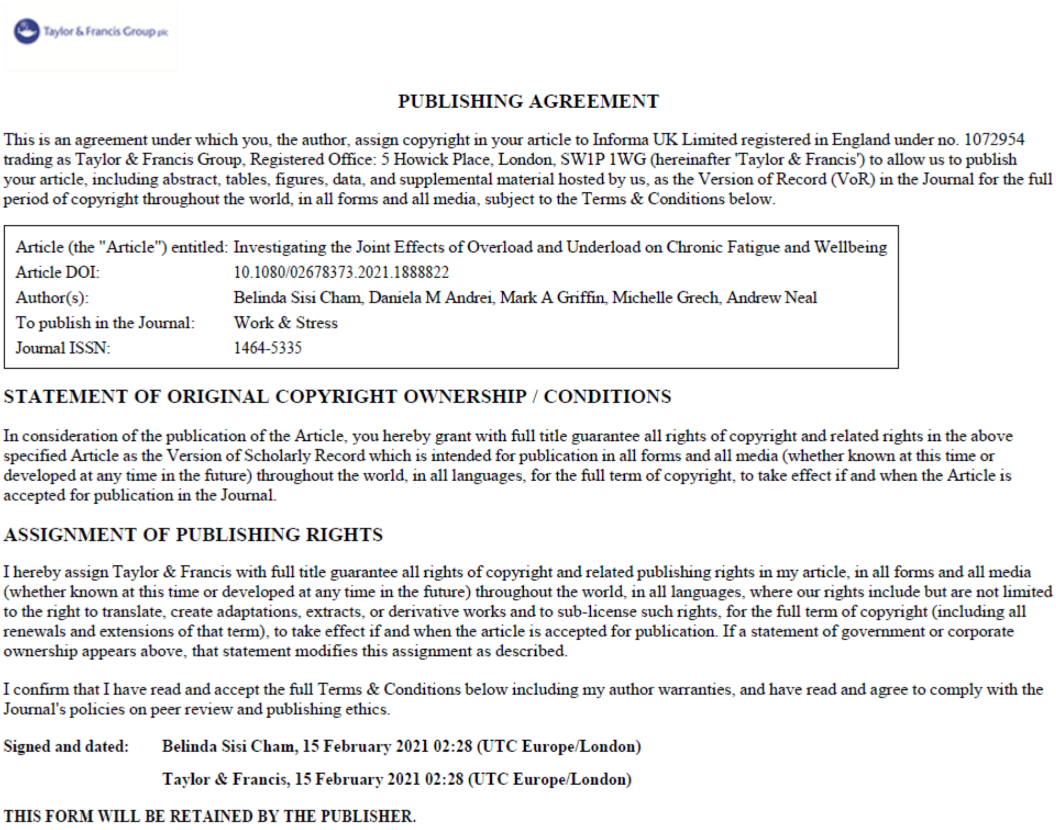
Lastly, seafarers in our study reported relatively high levels of psychological wellbeing ($M = 4.26$). However, psychological wellbeing showed expected relationships with other variables in the study, e.g., higher levels of overload, underload, and chronic fatigue were associated with lower psychological wellbeing. As such, range restriction would likely have resulted in an underestimation, rather than overestimation of the true associations between job demands and psychological wellbeing.

3.6.2 Practical Implications and Conclusion

The current study provides a systematic evaluation of the independent and interactive relationships between overload and underload, and chronic fatigue and psychological wellbeing. Although overload and underload had deleterious effects individually, this pattern changed when the joint effects were considered. With the nature of work becoming increasingly complex and dynamic, the results of the present study might present two important practical implications for reducing risks associated with chronic fatigue.

First, our study indicates that reducing demands (e.g., automating tasks and processes) to increase efficiency may present risks to performance, safety, and wellbeing if it leads to increased underload. Therefore, organisations will have to either manage the negative implications of underload, (e.g., implementing shorter shift periods, more breaks or task rotation) or prevent them by paying attention to the early design stage of new technologies and work systems so that technology is designed for optimal human and machine performance. Second, since we show that a combination of multiple demands has unique consequences for workers, any possible intervention should consider the joint effects of these demands (Jimmieson et al., 2017), as an attempt to reduce only one of the demands may be ineffective or even detrimental.

3.7 Appendix 3A



Taylor & Francis Group plc

PUBLISHING AGREEMENT

This is an agreement under which you, the author, assign copyright in your article to Informa UK Limited registered in England under no. 1072954 trading as Taylor & Francis Group, Registered Office: 5 Howick Place, London, SW1P 1WG (hereinafter 'Taylor & Francis') to allow us to publish your article, including abstract, tables, figures, data, and supplemental material hosted by us, as the Version of Record (VoR) in the Journal for the full period of copyright throughout the world, in all forms and all media, subject to the Terms & Conditions below.

Article (the "Article") entitled:	Investigating the Joint Effects of Overload and Underload on Chronic Fatigue and Wellbeing
Article DOI:	10.1080/02678373.2021.1888822
Author(s):	Belinda Sisi Cham, Daniela M Andrei, Mark A Griffin, Michelle Grech, Andrew Neal
To publish in the Journal:	Work & Stress
Journal ISSN:	1464-5335

STATEMENT OF ORIGINAL COPYRIGHT OWNERSHIP / CONDITIONS

In consideration of the publication of the Article, you hereby grant with full title guarantee all rights of copyright and related rights in the above specified Article as the Version of Scholarly Record which is intended for publication in all forms and all media (whether known at this time or developed at any time in the future) throughout the world, in all languages, for the full term of copyright, to take effect if and when the Article is accepted for publication in the Journal.

ASSIGNMENT OF PUBLISHING RIGHTS

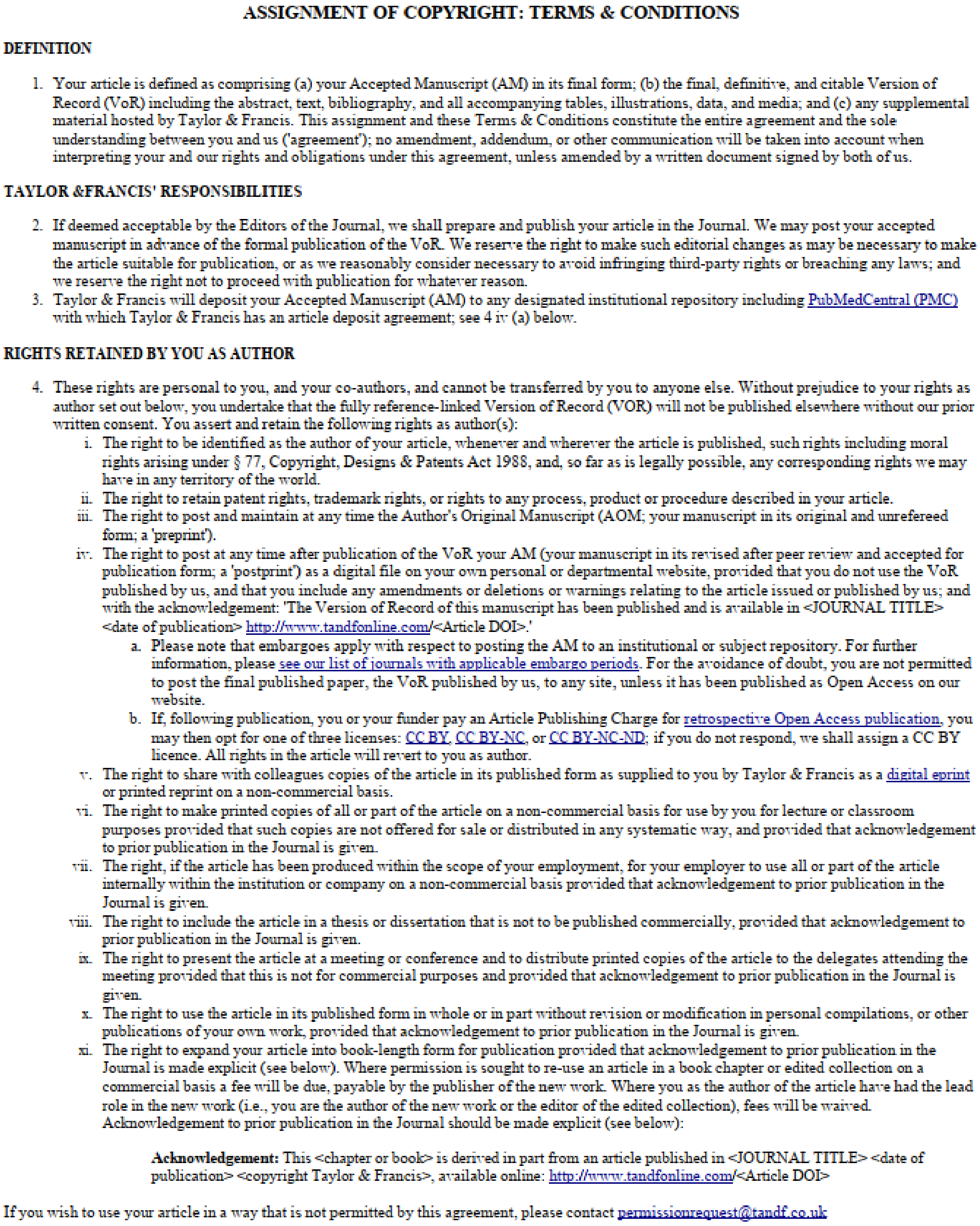
I hereby assign Taylor & Francis with full title guarantee all rights of copyright and related publishing rights in my article, in all forms and all media (whether known at this time or developed at any time in the future) throughout the world, in all languages, where our rights include but are not limited to the right to translate, create adaptations, extracts, or derivative works and to sub-license such rights, for the full term of copyright (including all renewals and extensions of that term), to take effect if and when the article is accepted for publication. If a statement of government or corporate ownership appears above, that statement modifies this assignment as described.

I confirm that I have read and accept the full Terms & Conditions below including my author warranties, and have read and agree to comply with the Journal's policies on peer review and publishing ethics.

Signed and dated: **Belinda Sisi Cham, 15 February 2021 02:28 (UTC Europe/London)**

Taylor & Francis, 15 February 2021 02:28 (UTC Europe/London)

THIS FORM WILL BE RETAINED BY THE PUBLISHER.



ASSIGNMENT OF COPYRIGHT: TERMS & CONDITIONS

DEFINITION

1. Your article is defined as comprising (a) your Accepted Manuscript (AM) in its final form; (b) the final, definitive, and citable Version of Record (VoR) including the abstract, text, bibliography, and all accompanying tables, illustrations, data, and media; and (c) any supplemental material hosted by Taylor & Francis. This assignment and these Terms & Conditions constitute the entire agreement and the sole understanding between you and us ('agreement'); no amendment, addendum, or other communication will be taken into account when interpreting your and our rights and obligations under this agreement, unless amended by a written document signed by both of us.

TAYLOR &FRANCIS' RESPONSIBILITIES

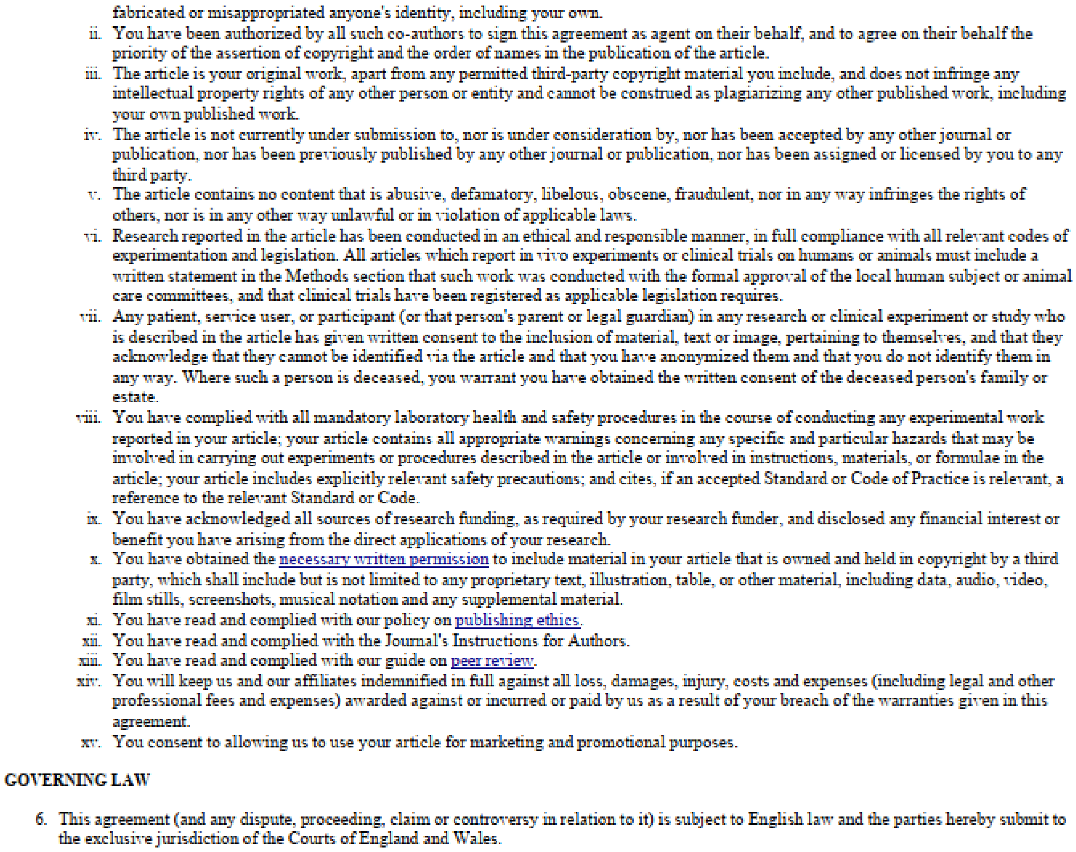
2. If deemed acceptable by the Editors of the Journal, we shall prepare and publish your article in the Journal. We may post your accepted manuscript in advance of the formal publication of the VoR. We reserve the right to make such editorial changes as may be necessary to make the article suitable for publication, or as we reasonably consider necessary to avoid infringing third-party rights or breaching any laws; and we reserve the right not to proceed with publication for whatever reason.
3. Taylor & Francis will deposit your Accepted Manuscript (AM) to any designated institutional repository including PubMedCentral (PMC) with which Taylor & Francis has an article deposit agreement; see 4 iv (a) below.

RIGHTS RETAINED BY YOU AS AUTHOR

4. These rights are personal to you, and your co-authors, and cannot be transferred by you to anyone else. Without prejudice to your rights as author set out below, you undertake that the fully reference-linked Version of Record (VOR) will not be published elsewhere without our prior written consent. You assert and retain the following rights as author(s):
    i. The right to be identified as the author of your article, whenever and wherever the article is published, such rights including moral rights arising under § 77, Copyright, Designs & Patents Act 1988, and, so far as is legally possible, any corresponding rights we may have in any territory of the world.
    ii. The right to retain patent rights, trademark rights, or rights to any process, product or procedure described in your article.
    iii. The right to post and maintain at any time the Author's Original Manuscript (AOM; your manuscript in its original and unrefereed form; a 'preprint').
    iv. The right to post at any time after publication of the VoR your AM (your manuscript in its revised after peer review and accepted for publication form; a 'postprint') as a digital file on your own personal or departmental website, provided that you do not use the VoR published by us, and that you include any amendments or deletions or warnings relating to the article issued or published by us; and with the acknowledgement: 'The Version of Record of this manuscript has been published and is available in <JOURNAL TITLE> <date of publication> http://www.tandfonline.com/<Article DOI>.'
        a. Please note that embargoes apply with respect to posting the AM to an institutional or subject repository. For further information, please see our list of journals with applicable embargo periods. For the avoidance of doubt, you are not permitted to post the final published paper, the VoR published by us, to any site, unless it has been published as Open Access on our website.
        b. If, following publication, you or your funder pay an Article Publishing Charge for retrospective Open Access publication, you may then opt for one of three licenses: CC BY, CC BY-NC, or CC BY-NC-ND; if you do not respond, we shall assign a CC BY licence. All rights in the article will revert to you as author.
    v. The right to share with colleagues copies of the article in its published form as supplied to you by Taylor & Francis as a digital eprint or printed reprint on a non-commercial basis.
    vi. The right to make printed copies of all or part of the article on a non-commercial basis for use by you for lecture or classroom purposes provided that such copies are not offered for sale or distributed in any systematic way, and provided that acknowledgement to prior publication in the Journal is given.
    vii. The right, if the article has been produced within the scope of your employment, for your employer to use all or part of the article internally within the institution or company on a non-commercial basis provided that acknowledgement to prior publication in the Journal is given.
    viii. The right to include the article in a thesis or dissertation that is not to be published commercially, provided that acknowledgement to prior publication in the Journal is given.
    ix. The right to present the article at a meeting or conference and to distribute printed copies of the article to the delegates attending the meeting provided that this is not for commercial purposes and provided that acknowledgement to prior publication in the Journal is given.
    x. The right to use the article in its published form in whole or in part without revision or modification in personal compilations, or other publications of your own work, provided that acknowledgement to prior publication in the Journal is given.
    xi. The right to expand your article into book-length form for publication provided that acknowledgement to prior publication in the Journal is made explicit (see below). Where permission is sought to re-use an article in a book chapter or edited collection on a commercial basis a fee will be due, payable by the publisher of the new work. Where you as the author of the article have had the lead role in the new work (i.e., you are the author of the new work or the editor of the edited collection), fees will be waived. Acknowledgement to prior publication in the Journal should be made explicit (see below):

> **Acknowledgement:** This <chapter or book> is derived in part from an article published in <JOURNAL TITLE> <date of publication> <copyright Taylor & Francis>, available online: http://www.tandfonline.com/<Article DOI>

If you wish to use your article in a way that is not permitted by this agreement, please contact permissionrequest@tandf.co.uk



fabricated or misappropriated anyone's identity, including your own.

ii. You have been authorized by all such co-authors to sign this agreement as agent on their behalf, and to agree on their behalf the priority of the assertion of copyright and the order of names in the publication of the article.
iii. The article is your original work, apart from any permitted third-party copyright material you include, and does not infringe any intellectual property rights of any other person or entity and cannot be construed as plagiarizing any other published work, including your own published work.
iv. The article is not currently under submission to, nor is under consideration by, nor has been accepted by any other journal or publication, nor has been previously published by any other journal or publication, nor has been assigned or licensed by you to any third party.
v. The article contains no content that is abusive, defamatory, libelous, obscene, fraudulent, nor in any way infringes the rights of others, nor is in any other way unlawful or in violation of applicable laws.
vi. Research reported in the article has been conducted in an ethical and responsible manner, in full compliance with all relevant codes of experimentation and legislation. All articles which report in vivo experiments or clinical trials on humans or animals must include a written statement in the Methods section that such work was conducted with the formal approval of the local human subject or animal care committees, and that clinical trials have been registered as applicable legislation requires.
vii. Any patient, service user, or participant (or that person's parent or legal guardian) in any research or clinical experiment or study who is described in the article has given written consent to the inclusion of material, text or image, pertaining to themselves, and that they acknowledge that they cannot be identified via the article and that you have anonymized them and that you do not identify them in any way. Where such a person is deceased, you warrant you have obtained the written consent of the deceased person's family or estate.
viii. You have complied with all mandatory laboratory health and safety procedures in the course of conducting any experimental work reported in your article; your article contains all appropriate warnings concerning any specific and particular hazards that may be involved in carrying out experiments or procedures described in the article or involved in instructions, materials, or formulae in the article; your article includes explicitly relevant safety precautions; and cites, if an accepted Standard or Code of Practice is relevant, a reference to the relevant Standard or Code.
ix. You have acknowledged all sources of research funding, as required by your research funder, and disclosed any financial interest or benefit you have arising from the direct applications of your research.
x. You have obtained the necessary written permission to include material in your article that is owned and held in copyright by a third party, which shall include but is not limited to any proprietary text, illustration, table, or other material, including data, audio, video, film stills, screenshots, musical notation and any supplemental material.
xi. You have read and complied with our policy on publishing ethics.
xii. You have read and complied with the Journal's Instructions for Authors.
xiii. You have read and complied with our guide on peer review.
xiv. You will keep us and our affiliates indemnified in full against all loss, damages, injury, costs and expenses (including legal and other professional fees and expenses) awarded against or incurred or paid by us as a result of your breach of the warranties given in this agreement.
xv. You consent to allowing us to use your article for marketing and promotional purposes.

GOVERNING LAW

6. This agreement (and any dispute, proceeding, claim or controversy in relation to it) is subject to English law and the parties hereby submit to the exclusive jurisdiction of the Courts of England and Wales.

3.8 Appendix 3B

Overload

Thinking about your own job, how often do the following situations occur?

(1 = Never, 5 = Always)

1. I have to work very fast
2. I have too much work to do
3. I have to hurry to get things done

Underload

Thinking about your own job, how often do the following situations occur?

(1 = Never, 5 = Always)

1. I do not have enough work to do
2. I find the work boring and monotonous
3. Time passes slowly

Chronic fatigue

When working at sea…

(1 = Strongly disagree to 5 = Strongly agree).

1. I often fear waking up to another day onboard
2. I often wonder how long I can keep working at sea
3. I feel I don’t get to do anything else in my life besides work
4. My job at sea takes all my energy from me

Psychological wellbeing

Over the past MONTH, how often have you felt the following:

(1 = Never, 5 = Always)

1. That you felt good about yourself
2. That you were dealing with your responsibilities or problems well
3. That you had good relationships with other people
4. That you were interested in learning new things and improving yourself
5. Confident to think or communicate your own ideas and opinions
6. That you live a good and meaningful life

4 INVESTIGATING THE DYNAMICS OF OVERLOAD AND UNDERLOAD IN SUBMARINE OPERATIONS

4.1 Foreword

In Chapter 3, I progressed an understanding of how work demands impact endurance by conducting an initial investigation looking at the impacts of overload and underload on chronic fatigue on seafarers in the long-haul shipping industry. A key finding was that underload and overload both have implications for longer-term endurance outcomes (i.e., chronic fatigue and psychological wellbeing), with underload having more a detrimental impact than overload. However, a limitation of the study reported in Chapter 3 was the cross-sectional design which only allowed for an understanding of average levels of overload and underload (i.e., between subjects). As proposed by the endurance framework in Chapter 2, a better understanding of endurance can be achieved by taking a within-persons approach that accounts for time variation and captures how psychological states, behaviours, and the environment change over short- and long-term timeframes (McCormick et al., 2020).

Therefore, Chapter 4 will adopt a within-persons approach to investigate the dynamic relationships between overload, underload, and worker fatigue. Using longitudinal data collected in a submarine environment, I examine how overload and underload relate to short-term fluctuations in acute fatigue, as well as longer-term changes in chronic fatigue. Submarine operations provide an ideal context to investigate these short- and long-term dynamics because submariners are not only required to perform to high standards during daily shifts, but they must endure chronic exposure to work demands with limited respite across the extended duration of a mission (i.e., up to several weeks at a time) (Brasher et al., 2010; Moffitt, 2008).

This chapter is presented as a journal article manuscript. A version of this manuscript is being prepared for the *Journal of Organizational Behavior*. Note that I use the term ‘we’ throughout this chapter to refer to the collective contributions of the manuscript co-authors.

4.2 Introduction

Fatigue is a ubiquitous issue across many occupational contexts. However, it is a particularly critical issue in extreme and high-risk work environments that feature long working hours, 24-hour operations and/or shift work, such as defence, maritime, health and transportation (Banks et al., 2019). While workers in these environments must endure and maintain optimal performance over long periods for safety reasons, fatigue can be caused by a number of factors such as excessive work demands (e.g., Grech et al., 2009), a lack of inter-shift recovery (e.g., Andrei et al., 2020), and inadequate sleep (e.g., Shattuck et al., 2011). The consequences of fatigue include impaired task performance (Gillberg et al., 1996), increased errors and accidents (Dinges, 1995; Folkard & Lombardi, 2006), and impaired worker health and well-being (Cappuccio et al., 2011). As indicated in Chapter 2, fatigue is a key indicator of endurance, therefore an understanding of the predictors of fatigue in these work contexts is an important area of research.

In this study, we focus on work-related predictors of fatigue in high-risk and extreme work contexts. Specifically, we examine how overload (i.e., work with too many demands) and underload (i.e., work with too few demands) contribute to different forms of fatigue in submarine operations. The forms of fatigue we examine are acute fatigue, which can be defined as short-lived feelings of fatigue (i.e., state fatigue) and emotional reactions (i.e., state affect) after a day of hard work (Zohar, 2003), and chronic fatigue, which is an enduring form of exhaustion (i.e., burnout) (Bakker et al., 2014). The submarine context is well suited for the purpose of this study because submariners are subject to variable and unpredictable levels of overload and underload. For example, it is not uncommon for submariners to experience long periods of monotonous or boring work, interspersed with all-out response efforts that involve high time pressure (Gupta et al., 2019). Moreover, the nature of submarine operations allows for investigation of both acute and chronic fatigue because workers are not only required to perform to high standards during daily shifts, but they must endure chronic exposure to work demands with limited respite across the extended duration of a mission (i.e., up to several weeks at a time) (Moffitt, 2008). Based on earlier arguments established in Chapter 2, efforts to optimise daily performance and long-term endurance in demanding contexts such as submarine operations will benefit from an understanding of how fatigue is shaped by demands experienced during a single work shift, as well as sustained exposure to demands across an extended period such as a mission.

This study makes several contributions to the literature. First, we build on the Job Demands-Resources (JD-R) (Bakker & Demerouti, 2014) literature by concentrating on both overload and underload as causes of fatigue. The extant literature has tended to focus on overload and much less attention has been paid to how having too few demands might shape outcomes (Andrei et al., 2020; Bowling et al., 2015). Understanding how both demands contribute to fatigue is important because changing aspects of modern work will likely see increased levels of overload and underload for many jobs. For example, where automated technologies are being adopted (e.g., remote control operations), human work will involve long periods of monotony due to passive monitoring, as well as sudden periods of high intensity when emergencies occur and human intervention is required (Wickens & Huey, 1993; Young & Stanton, 2002).

Second, by examining how overload and underload relate to both chronic and acute forms of fatigue, this study addresses recent calls to examine the multidimensional nature of fatigue (Andrei et al., 2020; Geurts & Sonnentag, 2006). Previous research has proposed that workers can have acute fatigue, chronic fatigue, or both (Sagherian & Geiger Brown, 2016). While acute fatigue arising from daily work activities is short-lived and can be ameliorated relatively quickly, if workers are continually exposed to demands and do not recovery sufficiently between work shifts, this can develop into an enduring syndrome of chronic fatigue which is not easily reversible and renders workers vulnerable to future demands and stressors (Craig & Cooper, 1992; Geurts & Sonnentag, 2006; Leone et al., 2008).

Third, we answer calls to take a longitudinal approach to investigating the link between job demands and employee strain (Bakker & Demerouti, 2017). Specifically, we utilise two longitudinal approaches (a panel design and an experience sampling design) to examine the links between demands and chronic and acute forms fatigue, respectively. The experience sampling portion of this study in particular addresses recent calls to unpack microprocesses within the JD-R framework (Bakker & Demerouti, 2017; Lesener et al., 2019), by examining causal and reciprocal mechanisms between overload, underload, and acute fatigue on a day-to-day basis.

In the next sections, we provide a brief overview of past research on work demands and fatigue. We then highlight the need to consider the impacts of overload and underload on fatigue in extreme operational work environments such as submarine operations. Following this, we outline the two analytical components of this study that explore (1) changes in chronic fatigue over a submarine operation, and (2) dynamics in acute fatigue on a day-to-day basis.

4.2.1 Theoretical Development

One of the main theoretical approaches on work-related predictors of strain and fatigue is the Job Demands-Resources (JD-R) model (Bakker & Demerouti, 2014). The JD-R model proposes that job characteristics can be classified in terms of being *demands* or *resources*. Demands are the job characteristics that require sustained physical or mental effort (e.g., time pressure, emotional demands) and are therefore associated with physiological and psychological costs. By contrast, job resources (e.g., autonomy, skill variety) are the job characteristics that support work goal achievement, reduce costs associated with demands, or stimulate personal growth, learning, and development. The JD-R model proposes that demands and resources operate on human functioning via two independent processes: a health impairment process and a motivational process, respectively. The present study is interested in the relationship between demands and fatigue, and therefore focuses on the health impairment process, and not the motivational process.

The health impairment process specifies that high work demands exhaust employees' mental and physical resources, leading to energy depletion (Demerouti, Bakker, Nachreiner, et al., 2001). When demands are high, compensatory effort must be recruited to accomplish work goals and prevent decreasing performance (Hockey, 1997). However, greater compensatory effort necessitates an increase in physiological and psychological costs for the individual (e.g., fatigue and irritability after a working period). If workers are unable to recover their energy sufficiently before the next working period, they will be in a suboptimal condition to perform and will again need to invest compensatory effort to perform adequately. In the long-term, this strategy of compensatory effort is not sustainable, as repeated compensatory efforts without adequate recovery result in burnout, a form of chronic fatigue experienced as persistent feelings of exhaustion and disengagement (Bakker et al., 2014). Burnout is one of the endpoints of the health impairment process, being negatively related with performance and associated with strain outcomes (e.g., anxiety and depression) (Alarcon, 2011; Taris, 2006).

However, it remains unclear how specific demands impact the health impairment process (and subsequent energy depletion). While the JD-R model acknowledges that many demands exist across different occupations (Schaufeli & Taris, 2014), there is limited research that examines how different demands contribute to the health impairment process (for exceptions see Andrei et al., 2020; Jimmieson et al., 2017). Past research has tended to only investigate the effects of a single demand in an occupational context (e.g., Baethge et al., 2019; Widmer et al., 2012), or has combined several demands together so that their independent effects cannot be explored (e.g., Schaufeli & Bakker, 2004; Sonnentag et al., 2011). Furthermore, there is limited research to date that illuminates the causal mechanisms between specific demands and fatigue (Lesener et al., 2019); a particular gap in the literature exists in understanding the dynamic microprocesses that link specific demands with strain and fatigue on a day-to-day basis (Bakker & Demerouti, 2017). To develop a refined picture of how demands and fatigue are related in the workplace, it is important to distinguish between the effects of specific demands (Kahn & Byosiere, 1992). In terms of fatigue, this refinement is important from a practical standpoint, because an understanding of which demands contribute the most (or least) to worker fatigue would allow managers and organisations to prioritise the mitigation or reduction of specific demands in work design scenarios. To build a better understanding of how multiple demands contribute to worker fatigue, this study focuses two demands that have been identified as risks to performance and wellbeing in extreme operational work contexts: overload and underload.

4.2.2 Overload and Underload

Overload and underload are two demands that have been raised by scholars as increasingly important to understand for their impact on performance and wellbeing in operational environments (Andrei et al., 2020; Parker & Grote, 2020; Wilson et al., 2021). Overload is a function of high workload and/or high time pressure, and describes a situation in which employees have too many demands (Perrewe & Ganster, 1989). Overload is a typical demand investigated within the JD-R framework, with meta-analyses demonstrating the relationship between overload and negative outcomes such as fatigue, strain, and impaired psychological and physical health (Bowling et al., 2015; Ganster & Schaubroeck, 1991). The effects of overload are usually explained in terms of the same compensatory control mechanisms that underlie the health impairment process. High task demands that exceed a worker's capacity require the worker to engage in compensatory processes and invest additional effort to sustain task performance; continuously engaging these compensatory processes leads to fatigue and strain (Hockey, 1997).

Although not as widely studied, underload has been raised as issue for many jobs in high-risk and 24-hour operation industries where technology and automation reduce task demands, such as long-distance driving (Dorrian et al., 2007), airport baggage inspection (Hancock & Hart, 2002), and medical monitoring (Weinger, 1990). Underload involves work that requires attention and focus, but provides little stimulation in return (Young et al., 2015). Early research on 'passive work' argued that underload combined the experience of low demands with low decision latitude (Karasek, 1979). Indeed, underload in many work contexts involves monitoring/supervisory control tasks (e.g., sustained attention to detect infrequent signals), which are argued to have low levels of task autonomy (Parker & Grote, 2020). Several scholars have proposed that underload is stressful and aversive, because it generates feelings of boredom, dissatisfaction, and frustration (Ainslie, 2013; Karasek, 1979). Evidence supports this perspective, with underload being associated with many negative outcomes including greater chronic fatigue (Andrei et al., 2020), impaired task performance (Desmond et al., 1998), and impaired physical health (Melamed et al., 1995).

Despite the risks it presents to fatigue and performance, underload is not extensively studied within the JD-R framework. One reason for this is because underload is not well accounted for under the theory of compensatory control that explains the effects of other demands such as overload. According to theories of compensatory control, a situation that involves fewer demands such as underload, should not exceed a worker's capacity and require engagement of compensatory processes. Given the increasing importance of underload in future work, it is pertinent to develop a better understanding of underload and its relationship with fatigue.

4.2.3 The Present Research

The aim of the current study is to examine how overload and underload contribute to chronic and acute forms of fatigue in submarine operations. We distinguish between chronic and acute forms of fatigue because both forms of fatigue are implicated in the health impairment process (Andrei et al., 2020; Dawson et al., 2011; Winwood et al., 2007). Additionally, a more specific understanding of the predictors of acute and chronic fatigue will help to distinguish the interventions that target each type of fatigue. As part of this study, three field studies were conducted in which submarine crews completed three different experience sampling studies (i.e., intensive longitudinal design), during at-sea operational activities (i.e., in-situ). To explore how overload and underload relate to both chronic and acute fatigue, the current involves two analytical phases that each model different subsets of the data. Specifically, to examine changes in chronic fatigue (operationalised as burnout), we used a longitudinal panel approach in which key measures were sampled at study outset and completion. To examine dynamic variability in acute fatigue (operationalised as state fatigue and state affect), we utilised an experience sampling approach in which key measures were sampled twice a day (e.g., after each work shift). More details pertaining to the two analyses are presented next.

4.2.3.1 Analysis 1: Change in burnout over the course of submarine operations

In Analysis 1, we examine the extent to which submariners' burnout changes over the course of operational activities that take place over 12 to 15 days. While the literature acknowledges that burnout is dynamic (Xanthopoulou et al., 2007), it is not clear the extent to which burnout may increase in the context of submarine operations. It is possible that submariners will show no change in burnout because they are an expert workforce that have been trained to manage stress and adversity (Brasher et al., 2010). Indeed, research has found that where high stress tolerance is part of the occupational self-image, such as primary care physicians, even a one-year time-lag may not be sufficient to account for the long-term accumulating effect of job stressors (Hornung et al., 2013; Zapf et al., 1996). On the other hand, the particularly demanding nature of submarine operations may intensify the health-impairment process, in which case we may see an increase in burnout after an operational activity. It is documented that submarine operations are highly stressful events because of the intense working schedule and limited respite opportunities offered to crewmembers (McDougall & Drummond, 2010). Thus, we present the following research question.

Research Question 1: To what extent do submariners show changes in burnout over operational activities?

In addition, we examine how changes in burnout might differ across the three operational activities which varied in operational tempo and intensity. Burnout is proposed to fluctuate in response to changes in work demands (Bakker et al., 2007; Demerouti, Bakker, & Janssen, 2001), therefore, we might expect changes in burnout to differ across operational activities that feature different levels of overload and underload. There are practical reasons to believe this may have been the case, as each operational activity varied in operational tempo and featured different types of activities and tasks. The first operational activity, considered low operational intensity, was conducted during a local patrol activity and involved standard watchkeeping activities, which meant submariners were faced with long periods of time with little activity, however, sustained vigilance was required while on watch. The second operational activity, considered normal operational intensity, was conducted during a routine transit activity, and involved a combination of standard watchkeeping activities and unpredictable training drills (i.e., responding to emergency situations). The third operational activity, considered high operational intensity, involved competitive training exercises and several simulated scenarios based on events that crewmembers may be exposed to during adversarial conditions. Given the potential differences in overload and underload across the three operational activities, we pose the following research question:

Research Question 2: To what extent are changes in burnout moderated by the intensity of operational activities?

4.2.3.2 Analysis 2: Dynamic Relationships Between Overload and Underload, and State Fatigue and Affect on a Day-to-day Basis

In Analysis 2, we examine the dynamic relationships between overload and underload, and acute fatigue. This extends on Analysis 1 by taking a temporal approach and examining the within-person relationships between acute fatigue, and overload and underload as they unfold over multiple work shifts. Specifically, we concentrate on uncovering the causal and reciprocal mechanisms between demands and acute fatigue on a short-term time frame. For this analysis we operationalise acute fatigue in terms of an energetic component (state fatigue) and an emotional component (state affect). This is consistent with research that has found depletion of energetic resources after a working period has immediate consequences for energy levels and emotional reactions (Zohar et al., 2003).

Although the original JD-R model focuses on straightforward causal relations between demands and strain, there is increasing evidence that reciprocal effects in the form of negative spirals are important; not only do job demands cause job strain, but job strain is also a causal predictor of job demands (Lesener et al., 2019). For example Demerouti et al., (2009) found that hospital nurses who were confronted with high levels of demands not only reported higher levels of burnout 1.5 years later, but nurses who experienced higher levels of burnout were also confronted with more job demands over time.

Although the literature is beginning to highlight reciprocal relationships within the JD-R framework as an important topic, research to date is limited in that it tends to investigate reciprocal effects over long durations (Guthier et al., 2020; Lesener et al., 2019). These long-term negative spirals are typically explained in terms of the loss cycles proposed by Conservation of Resources (CoR) (Hobfoll, 1989). According to CoR, chronic exposure to demands leads to a cumulative loss of resources that gradually decreases a worker’s ability to cope effectively with the demands of future work, increasing the straining effects of future stressors and further depleting their resources (Demerouti et al., 2004; Hobfoll, 2002).

In contrast, there little research that informs how reciprocal effects between demands and outcomes may manifest on a shorter (i.e., within-day) basis (Bakker & Demerouti, 2017). Understanding the within-day reciprocal effects between overload, underload and acute fatigue is important because it informs how fatigue accumulates on a short-term basis. This has important implications for operational environments such as submarines where ongoing high performance for safety and wellbeing is required (Banks et al., 2019; Stanton & Roberts, 2018). Indeed, some theory suggests that in demanding performance environments (e.g., air traffic control, submarines) where there is little opportunity for recovery from the fatigue and strain, workers may experience carry-over of fatigue from one shift to the next, meaning workers have a reduced capacity to deal with demands, which in turn leads to increased fatigue (Hockey, 1997). To shed light on the within-day reciprocal effects between overload and underload, and state fatigue and affect, we pose the following research question..

Research Question 3: To what extent are overload and underload reciprocally related with state fatigue on a day-to-day basis across a submarine operational activity?

Research Question 4: To what extent are overload and underload reciprocally related with state affect on a day-to-day basis across a submarine operational activity?

4.3 Method

4.3.1 Participants

The data were collected as part of a broader research project (for further details, consult Wilson et al., 2021) involving a field study of three submarine operational activities (low, normal, and high operational intensity) that took place during 2017 and 2018. Participation in the study was entirely voluntary, informed consent was gained from all participants, and participants were free to withdraw from the study at any time. A total of 76 operational submariners from the Royal Australian Navy participated. Participating submariners were representative of the different functional job groups (e.g., platforms, command, and sensors) and ranks (e.g., Able seaman to Commander) relevant to the submarine platform. For the duration of the operational activities, participants followed either a 6-hours on, 6-hours off schedule (*n* = 55), or a 12-hours on, 12-hours off schedule (*n* = 13) (8 participants did not report their watch schedule).

An overview of operational activity duration and participant demographics (including participants who attended briefings but provided no data) is provided in Table 4.1.

Table 4.1. Overview of the three operational activities and participant demographics, including years of experience in their current role and in the Navy overall.

Operational activity	Duration	*N*	$\bar{x}$ years of experience (Role)	$\bar{x}$ years of experience (Navy)
Low intensity	12 days	N = 22	3.62 (SD = 3.06)	8.51 (SD = 7.95)
Normal intensity	12 days	N = 39	3.69 (SD = 3.98)	6.11 (SD = 6.21)
High intensity	15 days	N = 15	2.08 (SD = 1.10)	5.93 (SD = 3.80)

4.3.2 Field Study Design and Measurement Protocol Procedure

The overall field study involved two different research designs: a longitudinal panel design and an experience sampling design. The longitudinal panel design involved participants completing two surveys, one *before* the commencement of an operational activity, and one *after* the end of an operational activity. These pre/post operation surveys were used to measure burnout, a form of chronic fatigue (Bakker et al., 2014). The experience sampling design was undertaken *during* the operational activity and involved participants filling out a series of daily surveys before and after each work shift, for the duration of the operational activity. These daily diaries were used to assess dynamic fluctuations in short-term fatigue, which we operationalised in terms of an energetic component (i.e., state fatigue) and an emotional component (i.e., state affect) (Zohar, 2003).

Approximately one week prior to the commencement of each operational activity, researchers conducted a compulsory briefing session with all participants. During this briefing, informed participant consent was obtained, and participants were provided with instructions and materials for undertaking the study. All surveys were completed using paper and pen. Due to operational and space restrictions, the data collection was participant led – that is, researchers provided all instructions to participants during pre-operation briefings but were not present during data collection. At the conclusion of each operational activity (when the submarine reached the destination port), researchers met the participants to collect all surveys. Participants were offered personalised feedback reports for their participation. All survey responses were then digitised. For brevity, we have only reported the details relevant to this study (see Appendix 4A for the list of measures used).

4.3.3 Measures

4.3.3.1 Burnout (measured pre/post operation as part of longitudinal panel design)

Burnout was measured twice for each operational activity, once as a baseline before participants were deployed (α = .85) and once after completion of the operational activity (α = .86) using the 16-item Oldenburg Burnout Inventory (OLBI) (Demerouti et al., 2003). The OLBI includes eight items to measure exhaustion (e.g., "After work, I usually feel worn out and weary") and eight items to measure disengagement (e.g., "I increasingly speak negatively about my work"). The items were scored on a five-point likert scale (1 = strongly disagree, 5 = strongly disagree). High scores indicate higher levels of burnout.

4.3.3.2 State Fatigue (measured daily as part of experience sampling design)

Subjective fatigue was measured using the Karolinska Sleepiness Scale (KSS) (Akerstedt et al., 2002; Kaida et al., 2006). The single item asks, "What is your current level of sleepiness?" and is anchored from 1 (very alert) to 9 (very sleepy). The KSS was completed after each work period (e.g., participants on a 6-hour on, 6-hour off schedule rated the KSS twice per 24-hour period, approximately 12-hours apart).

4.3.3.3 State Affect (measured daily as part of experience sampling design)

Affect was measured using one item created for the study. Many existing measures of affect were unsuitable for intensive experience sampling due to the length and complexity of measures. Therefore, we constructed a simple one-item measure of affect based on the circumplex model of affect (Posner et al., 2005). The item asks participants to rate mood valence and is anchored from one (awful) to ten (great). Ratings were completed after each work period. (e.g., participants on a 6-hour on, 6-hour off schedule rated state affect twice per 24-hour period, approximately 12-hours apart).

4.3.3.4 Overload (measured daily as part of experience sampling design)

Overload was measured using a subset of three items (between-persons α = .80) from the NASA task load index (TLX) (Hart, 2006). The three items ask participants to rate subjective levels of workload along three dimensions (mental demand, physical demand, and temporal demand) on a scale of 0 (very low) to 100 (very high). High scores indicate higher levels of overload. The NASA-TLX was completed after each work period, (e.g., participants on a 6-hour on, 6-hour off schedule rated the NASA-TLX twice per 24-hour period, approximately 12-hours apart).

4.3.3.5 Underload (measured daily as part of experience sampling design)

Underload was measured using four items (between-persons α = .85) developed by Andrei et al., 2020. Two items targeted monotonous and boring aspects of work (e.g., I found the work boring and monotonous) and two items targeted attentional demands (e.g., I struggled to remain alert and vigilant). The original scale was designed to measure an overall level of underload in a job; therefore, we adapted the wording to be suitable for individual work period perceptions (i.e., assessments of underload corresponding to a particular work period). We also adapted the original frequency-based rating scale into a five-point Likert scale (1 = strongly disagree, 5 = strongly disagree). High scores indicate higher levels of underload. The underload scale was completed after each work period (e.g., participants on a 6-hour on, 6-hour off schedule rated underload twice per 24-hour period, approximately 12-hours apart).

4.4 Analytical Phase 1: Change in Burnout Over an Operational Activity

Previous research suggests burnout changes in response to demands over relatively long periods of time (i.e. several years) (e.g., Dunford et al., 2012; Xanthopoulou et al., 2007), however, it is not clear if burnout follows similar longer-term trajectories of change in extreme work environments such as submarine operations. Therefore, Analysis 1 examines how submariners' burnout changes over operational activities using a longitudinal panel approach. Specifically, the analysis seeks to uncover the extent to submariner burnout changes over the course of operational activities that take place over 12 to 15 days, and additionally, whether changes in burnout are moderated by the intensity of operational activities.

4.4.1 Sample & Measures

For this analysis we only included data from submariners who completed the pre-operation and post-operation surveys. The measures used in this analysis are pre/post burnout, overload, and underload. The respective sample sizes for each operation type are displayed in Table 4.2.

4.4.2 Results

4.4.2.1 Data Analysis Overview

All analyses were conducted using the statistical software JASP (version 0.14.1) (JASP Team, 2020) and all figures were produced using the R programming language (R Core Team, 2021). All analyses are reported with associated Bayes Factors (BFs). Bayesian analysis has several advantages including a greater robustness in small sample sizes when compared to frequentist analysis (Van de Schoot et al., 2014) and the ability to quantify the relative evidence favouring the null versus the alternative hypothesis (Kass & Raftery, 1995). We interpreted BFs using Jeffrey’s (1998) guidelines where BFs between 1 and 3 indicate weak evidence, Bayes factors > 3 indicate moderate evidence, Bayes factors > 10 are strong evidence, and Bayes factors > 30 are very strong evidence for a given hypothesis relative to an alternative. Bayes factors are represented as BF, and the subscript indicates whether the model comparison is expressed as favouring the alternative hypothesis (BF_{10}) or the null (BF_{01}).

4.4.2.2 Descriptive and Correlational Statistics

Table 4.2 shows the basic descriptive statistics for the study variables. Table 4.3 presents the correlations among the study variables. We note that burnout scores decrease for the low intensity operation but increase for normal and high intensity operations. Contrary to expectation, average overload was highest in the low intensity operation and second highest in the high intensity operation. Consistent with expectations, underload was highest for the low intensity operation, and lowest in the high intensity operation. Additionally, all variables correlate in the expected directions, with overload and underload showing significant positive associations with post-operation burnout.

Table 4.2. Descriptive statistics for all three operational activities.

Variables	N	M	SD
Low intensity			
Burnout (pre/post)	9	2.83 / 2.65	.30 /.30
Overload	13	3.98	1.35
Underload	13	2.42	.56
Normal intensity			
Burnout (pre/post)	10	2.61 / 2.66	.55 / .54
Overload	34	3.48	1.38
Underload	34	2.31	.61
High intensity			
Burnout (pre/post)	8	2.87 / 3.06	.55 / .55
Overload	15	3.89	1.09
Underload	15	2.29	.57

Table 4.3. Correlations between variables

	1	2	3	4
1. Pre-operation Burnout	-			
2. Post- operation Burnout	.83**	-		
3. Overload	.51*	.43*	-	
4. Underload	.64**	.57**	.11	-

Note. *p < .05, **p < .01 (2-tailed)

4.4.2.3 Assumption Checking

A key assumption relevant to this analysis was that the three operational activities featured different levels of overload and underload. Therefore, prior to conducting the main analysis, we ran two one-way ANOVA to examine how average levels of overload and underload differed across the three operational activities. There was moderate evidence that average levels of overload did not differ between the three operational activities, F(2,59) = 1.09, p = .34, η^2_p = .04, BF_{01} = 3.03. There was also moderate evidence that average levels of underload did not differ across the three operational activities, F(2,59) = .21, p = .81, η^2_p = .01, BF_{01} = 5.88. Figures 4.1 and 4.2 show the average levels of overload and underload respectively across the three operational activities. Despite all three operational activities showing similar levels of overload and underload, we proceeded with the main analysis to examine how burnout changed across these operational activities.

Figure 4.1. Mean ratings of overload for low, normal, and high intensity operational activities

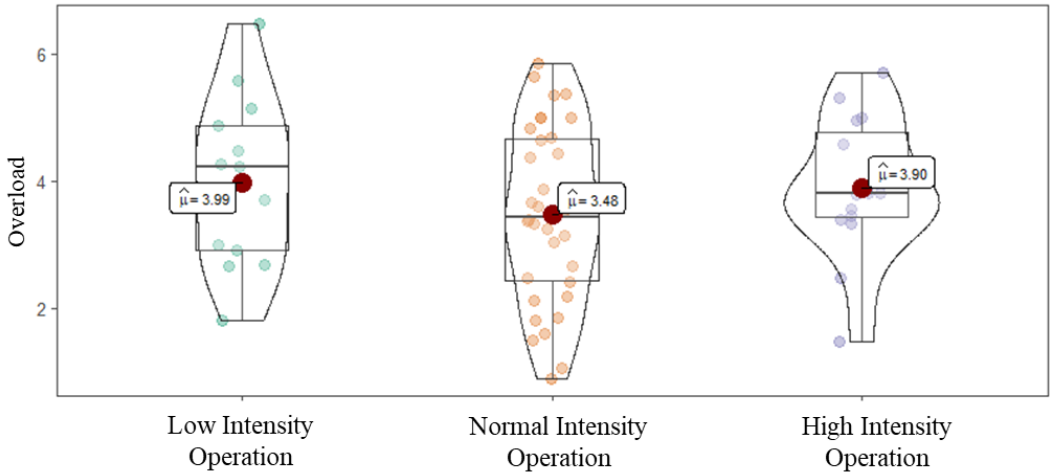
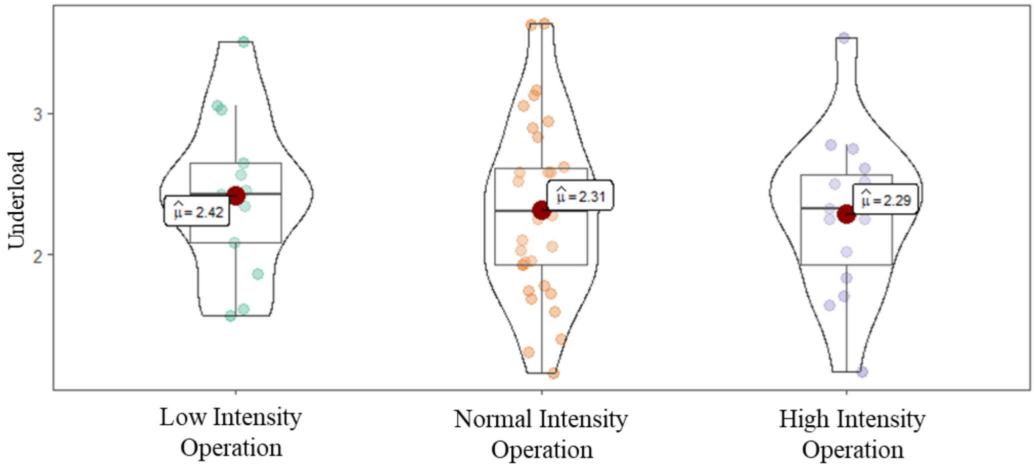


Figure 4.2. Mean ratings of underload for low, normal, and high intensity operational activities

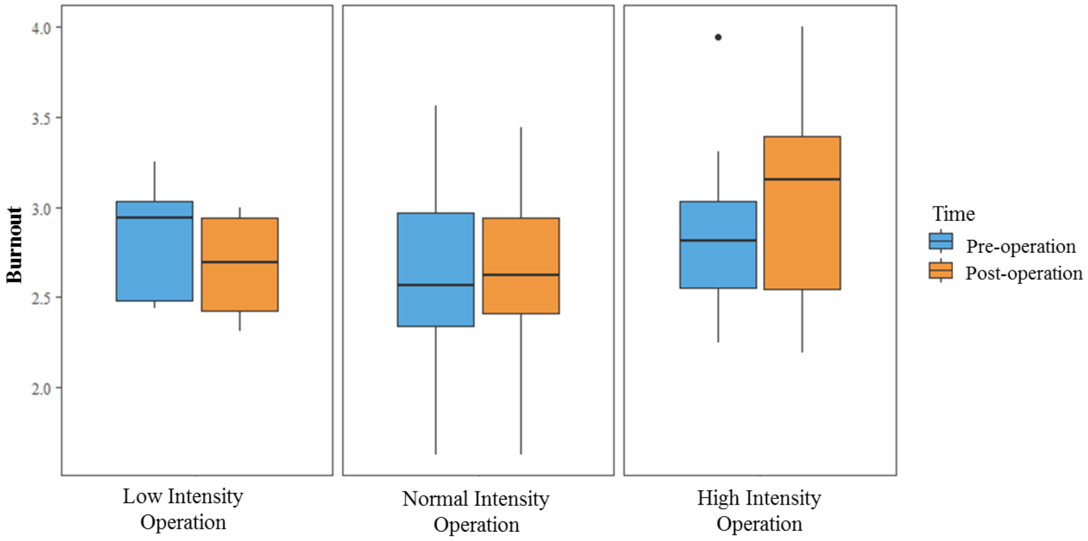


4.4.2.4 Change in Burnout Over Operational Activities

As part of Analytical Phase 1, we posed two research questions relating to submariners' burnout. The first research question asked to what extent do submariners' show changes in burnout over operational activities. The second research question asked whether and how changes in burnout may be moderated by the intensity of operational activities.

To address these research questions, we examined the difference (within-person change) in submariner's pre-operation and post-operation burnout scores for the three operational activities (between-person grouping). To do this, we ran a 2 (time: within-subjects) × 3 (operational activity: between-subjects) mixed-measures ANOVA. Sums of squares Type 3 was used in all the analyses to evenly weight cells (Tabachnick & Fidell, 2007). Levene's test suggested that the assumption of homogeneity was not violated for all analyses (all values were >.05). Figure 4.3 demonstrates the pre- and post-operation scores of submariners' burnout over the operational activities. There was moderate evidence that submariners' burnout did not change after undertaking an operational activity ($F(1,23) = 0.30$, $p = .59$, $\eta^2_p = .01$, $BF_{01} = 3.29$). There was also moderate evidence that the type of operational activity did not moderate submariners' change in burnout from pre to post operation ($F(1,23) = 3.25$, $p = .06$, $\eta^2_p = .22$, $BF_{01} = 3.40$).

Figure 4.3. Average levels of burnout measured pre-operation and post-operation across the three operational activities.



4.5 Analytical Phase 2: Reciprocal Relationships Between Overload and Underload, and State Fatigue and Affect

Following calls to establish a better understanding of the causal mechanisms and microprocesses between specific demands and fatigue (Bakker & Demerouti, 2017; Lesener et al., 2019), Analysis 2 aims to examine the dynamic relationships between overload and underload, and acute fatigue on a day-to-day basis.

Specifically, we investigate how overload and underload might be reciprocally related to state fatigue and state affect on a day-to-day basis across a submarine operational activity. As can be seen in Figure 4.4, the design of the experience sampling portion of this study was such that we obtained measurements approximately every 12-hours. Figure 4.5 provides an overview of the models tested.

Figure 4.4. Experience sampling design on the 6-on-6-off watch schedule. Overload, underload, state fatigue and state affect were measured twice a day after each work period.

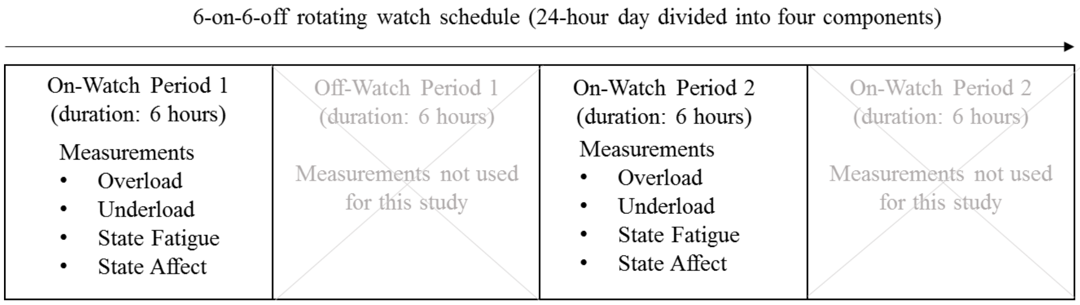
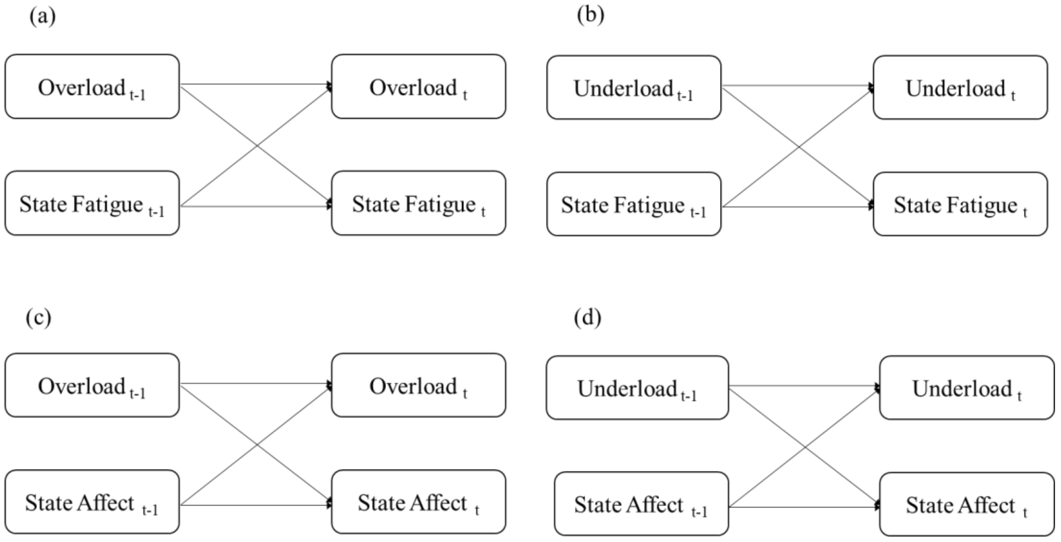


Figure 4.5. Overview of models tested. The time lag was approximately 12-hours.



4.5.1 Sample & Measures

For this study, only the daily diary data from submariners on the 6-on-6-off rotating watch schedule was used. This was important for ensuring the same time interval between surveys (approximately 12-hours). The measures included overload, underload, state fatigue, and state affect. As the operational activities were participant led, this necessitated rigorous data integrity checks with several exclusion criteria. From the total of 76 participants, 36 participants were excluded for not completing any surveys and/or not timestamping survey responses. A further five day-duties participants were removed because their survey responses were recorded once a day (i.e., 24-hour interval instead of a 12-hour interval). Lastly, eight participants were removed because their survey responses deviated substantially from the 12-hour interval (i.e., more than 6 hours outside of the 12-hour interval). A final sample size of 27 participants and a total of 476 observations were included.

4.5.2 Results

4.5.2.1 Data Modelling Approach

We conducted Dynamic Structural Equation Modelling (DSEM) in Mplus Version 8.5 (Muthén & Muthén, 2017). The DSEM framework integrates structural equation and time series modelling and allows for the parametrisation of time-varying effects such as autoregression. In this analysis we use a Vector Autoregressive Lag 1 model, denoted as a VAR(1) model, to estimate cross-lagged parameters at multiple levels (McNeish & Hamaker, 2019). The cross-lagged parameters reflect predictive relationships and potentially represent causal mechanisms, and are sometimes referred to as *spill-over*, as they represent the cascade effect of functioning or behaviour in one domain into another domain (Masten & Cicchetti, 2010). The within-subjects level includes two-autoregressive slopes and two cross-lagged paths. Variables were person-mean centered (the default in Mplus).

The DSEM model uses Bayesian estimation which is based on combining the likelihood of the data with prior distributions for the unknown model parameters to obtain posterior distributions for these unknown parameters (for details see Asparouhov et al., 2018). Estimation involves an iterative process in which parameters are sampled from condition distributions according to a Markov chain Monte Carlo (MCMC) procedure (Gelman et al., 2014). Based on Hamaker et al., (2018) we used 50,000 MCMC iterations, with a thinning of 10 iterations (i.e., only 1 of 10 iterations was used) and thus, our results are based on a total of 5000 iterations. We present parameter estimates along with 95% credible intervals (CI) which can be interpreted as analogous to 95% confidence intervals. Model convergence was checked using the proportional scale reduction (PSR) and the Bayesian trace plots (Hamaker et al., 2018; Zhou et al., 2019). PSR values close to one suggested that the number of iterations was sufficient, and trace plots showed an absence of trends, spikes, or other irregularities. Therefore, we can assume that the models converged properly.

4.5.2.2 Descriptive and Correlational Statistics

Table 4.4 shows the basic descriptive statistics for all variables. All variables were significantly correlated in the expected directions, i.e., overload and underload show significant positive correlations with fatigue, and significant negative correlations with affect. Notably, underload showed stronger relationships with affect and fatigue than overload.

Table 4.4. Means, standard deviations and correlations between analysis variables

	Mean (SD)	1	2	3	4
1. Fatigue	5.37 (1.81)	-			
2. Affect	5.71 (1.64)	-.63**	-		
3. Overload	3.27 (1.64)	.18**	. -.22**	-	
4. Underload	2.33 (.83)	.49**	-.57**	-.03	-

4.5.2.3 Dynamic Structural Equation Modelling

As part of Analytical Phase Two, we posed two research questions relating to dynamic changes in submariners' fatigue. The first research question concerned the extent to which overload and underload were reciprocally related with state fatigue on a day-to-day basis. The second question was concerned with the extent to which overload and underload were reciprocally related with state affect on a day-to-day basis. To address these research questions, the following sections examine the dynamic relationships between fatigue, overload, and underload, and between state affect, overload, and underload.

4.5.2.3.1 Fatigue and Overload

From Table 4.5, the posterior distributions show that given the observed data, there is evidence for a negative autoregressive effect for fatigue (γ_{20}= -.19, 95% CV = [-.29 - -.09]) which suggests fatigue exhibits a small degree of temporal dependence, or carryover (i.e., the ability of the intensity of a state in one moment to predict the intensity measured at a subsequent moment). This carryover effect also hardly varies between people (τ_{22}= .03, 95% CV = [.00 - .11]). There is also evidence for a positive autoregression effect for overload (γ_{30}= .23, 95% CV = [.11 - .34]) that hardly varies between people (τ_{33}= .05, 95% CV = [.00 - .17]). This suggests overload also exhibits a small carryover effect. In terms of cross-lagged relationships, there is evidence for positive cross-lagged relationships between fatigue and overload such that $Overload_{t-1}$ predicted $Fatigue_t$ (γ_{50} = .14, 95% CV = [.04 - .23]) and $Fatigue_{t-1}$ predicted $Overload_t$ (γ_{40} = .11, 95% CV = [.02 - .20]). These parameters suggest a reciprocal relationship exists between overload and fatigue, such that overload and fatigue positively reinforce each other over time. Both cross-lagged relationships barely vary between people (τ_{44}= .02, 95% CV = [.00 - .07]; τ_{55}= .05, 95% CV = [.00 - .20], respectively).

Table 4.5. Parameter estimates for multi-level VAR(1) model looking at Fatigue and Overload

Parameter		Posterior Median	Posterior SD	95% credibility interval
Within-level (standardised)				
Intercept (Fatigue $_{t-1}$ →Fatigue $_{t}$)	γ_{20}	-.19**	.05	-.29 - -.09
Intercept (Overload $_{t-1}$ →Overload $_{t}$)	γ_{30}	.23**	.06.	.11 - .34
Intercept (Fatigue $_{t-1}$ →Overload $_{t}$)	γ_{40}	.11**	.05	.02 - .20
Intercept (Overload $_{t-1}$ →Fatigue $_{t}$)	γ_{50}	.14**	.05	.04 - .23
Intercept (residual variance of Fatigue)	ω_{0}	.88**	.03	.80 - .94
Intercept (residual variance of Overload)	ω_{1}	.84**	.04	.74 - .92
Between-level (unstandardised)				
Intercept (Mean of Fatigue)	γ_{00}	5.38**	.22	4.95 – 5.81
Intercept (Mean of Overload)	γ_{10}	3.28**	.29	2.71 – 3.84
Variance (Mean of Fatigue)	τ_{00}	1.09**	.41	.58 – 2.14
Variance (Mean of Overload)	τ_{11}	1.86**	.68	1.03 – 3.68
Variance (Fatigue $_{t-1}$ →Fatigue $_{t}$)	τ_{22}	.03**	.03	.00 - .11
Variance (Overload $_{t-1}$ →Overload $_{t}$)	τ_{33}	.05**	.04	.00 - .17
Variance (Fatigue $_{t-1}$ →Overload $_{t}$)	τ_{44}	.02**	.12	.00 - .07
Variance (Overload $_{t-1}$ →Fatigue $_{t}$)	τ_{55}	.05**	.05	.00 - .20
Variance (residual variance of Fatigue)	τ_{66}	.10**	.08	.01 - .33
Variance (residual variance of Overload)	τ_{77}	2.37**	.84	1.38 – 4.58

*p < .05. **p < .01. Note: time lag was approximately 12-hours

4.5.2.3.2 Fatigue and Underload

From Table 4.6, the posterior distributions show that given the observed data, there is evidence for a negative autoregressive effect for fatigue (γ_{20}= -.18, 95% CV = [-.30 - -.05]), suggesting fatigue has a small carryover effect that barely varies between people (τ_{22}= .03, 95% CV = [.00 - .12]). There was no evidence for autoregression for underload (γ_{30}= .08, 95% CV = [-.04 - .21]), suggesting underload does not exhibit any carryover effect. No cross-lagged effects were observed in this model as *Fatigue* $_{t-1}$ showed no relationship with *Underload*$_t$ (γ_{40} = -.08, 95% CV = [-.19 - .02]) and *Underload* $_{t-1}$ showed no relationship with *Fatigue*$_t$ (γ_{50} = -.02, 95% CV = [-.13- .09]). These parameters suggest underload did not predict, nor was predicted by fatigue over a 12-hour time lag.

Table 4.6. Parameter estimates for multi-level VAR(1) model looking at Fatigue and Underload

Parameter		Posterior Median	Posterior SD	95% credibility interval
Within-level (standardised)				
Intercept (Fatigue $_{t-1}$ →Fatigue $_{t}$)	γ_{20}	-.18**	.06	-.30 - -.05
Intercept (Underload $_{t-1}$ →Underload $_{t}$)	γ_{30}	.08	.06	-.04 - .21
Intercept (Fatigue $_{t-1}$ →Underload $_{t}$)	γ_{40}	-.08	.05	-.19 - .02
Intercept (Underload $_{t-1}$ →Fatigue $_{t}$)	γ_{50}	-.02	.06	-.13 - .09
Intercept (residual variance of Fatigue)	ω_{0}	.91**	.03	.84 - .96
Intercept (residual variance of Underload)	ω_{1}	.84**	.04	.75 - .92
Between-level (unstandardised)				
Intercept (Mean of Fatigue)	γ_{00}	5.38**	.22	4.94 – 5.81
Intercept (Mean of Underload)	γ_{10}	2.36**	.12	2.12 – 2.60
Variance (Mean of Fatigue)	τ_{00}	1.14**	.42	.63 – 2.25
Variance (Mean of Underload)	τ_{11}	.30**	.03	.16 - .61
Variance (Fatigue $_{t-1}$ →Fatigue $_{t}$)	τ_{22}	.03**	.03	.00 - .12
Variance (Underload $_{t-1}$ →Underload $_{t}$)	τ_{33}	.14**	.07	.05 - .32
Variance (Fatigue $_{t-1}$ →Underload $_{t}$)	τ_{44}	.00**	.00	.00 - .01
Variance (Underload $_{t-1}$ →Fatigue $_{t}$)	τ_{55}	.11**	.13	.01 - .48
Variance (residual variance of Fatigue)	τ_{66}	.10**	.08	.01 - .33
Variance (residual variance of Underload)	τ_{77}	1.50**	.51	.86 – 2.83

*$p < .05$. **$p < .01$. Note: time lag was approximately 12-hours

4.5.2.3.3 Affect and Overload

The estimates are presented in Table 4.7. The posterior distributions show that given the observed data, there is evidence for positive autoregressive effects for affect (γ_{20}= .16 (95% CV = [.06 - .27]), and overload (γ_{30}= .22 (95% CV = [.10 - .33]). This suggest both affect and overload exhibit small carryover effects. These carry over effects vary from person to person for both affect (τ_{22}= .08 (95% CV = [.02 - .20]) and overload (τ_{33}= .07 (95% CV = [.01 - .19]). In terms of cross-lagged relationships, there is evidence for a negative cross-lagged relationship between $Overload_{t-1}$ and $Affect_{t}$ (γ_{50} = -.12 (95% CV = [-.22 - -02]) but no evidence for a relationship between $Affect_{t-1}$ and $Overload_{t}$ (γ_{40} = -.04 (95% CV = [-.13 - 05]). This suggests a one-way causal relationship, with higher perceived overload during the previous work period predicting a more negative current affective state, but not the other way around. Furthermore, the cross-lagged relationship between $Overload_{t-1}$ and $Affect_{t}$ barely varied from person to person (τ_{55}= -.03 (95% CV = [.00 - .13]).

Table 4.7. Parameter estimates for multi-level VAR(1) model looking at Affect and Overload

Parameter		Posterior Median	Posterior SD	95% Credible Interval
Within-level (standardised)				
Intercept (Affect $_{t-1}$ →Affect $_{t}$)	γ_{20}	.16**	.05	.06 - .27
Intercept (Overload $_{t-1}$ →Overload $_{t}$)	γ_{30}	.22**	.06	.10 - .33
Intercept (Affect $_{t-1}$ →Overload $_{t}$)	γ_{40}	-.04	.04	-.13 - .05
Intercept (Overload $_{t-1}$ →Affect $_{t}$)	γ_{50}	-.12**	.05	-.22 - -.02
Intercept (residual variance of Affect)	ω_{0}	.85**	.04	.77 - .92
Intercept (residual variance of Overload)	ω_{1}	.86**	.04	.77 - .93
Between-level (unstandardised)				
Intercept (Mean of Affect)	γ_{00}	5.98**	.24	5.51 – 6.45
Intercept (Mean of Overload)	γ_{10}	3.28**	.29	2.71 – 3.85
Variance (Mean of Affect)	τ_{00}	1.20**	.47	.62 – 2.42
Variance (Mean of Overload)	τ_{11}	1.87**	.68	1.04 – 2.42
Variance (Affect $_{t-1}$ →Affect $_{t}$)	τ_{22}	.08**	.05	.02 - .20
Variance (Overload $_{t-1}$ →Overload $_{t}$)	τ_{33}	.07**	.05	.01 - .19
Variance (Affect $_{t-1}$ →Overload $_{t}$)	τ_{44}	.01**	.01	.00 - .06
Variance (Overload $_{t-1}$ →Affect $_{t}$)	τ_{55}	.03**	.03	.00 - .13
Variance (residual variance of Affect)	τ_{66}	.38**	.17	.17 - .84
Variance (residual variance of Overload)	τ_{77}	2.38**	.84	1.38 – 4.58

*$p < .05$. **$p < .01$. Note: time lag was approximately 12-hours

4.5.2.3.4 Affect and Underload

From Table 4.8, the posterior distributions show that given the observed data, there is again evidence for positive autoregressive effects for affect (γ_{20}= .23 (95% CV = [.11 - .35]), and this carry over effect varies from person to person (τ_{22}= .07 (95% CV = [.02 - .19]). There is no evidence for autoregression for underload (γ_{30}= -.02 (95% CV = [-.13 - .11]). In terms of cross-lagged relationships, there is evidence for a positive cross-lagged relationship between $Underload_{t-1}$ and $Affect_{t}$ (γ_{50} = .12 (95% CV = [.01 - .22]) but no evidence for a relationship between $Affect_{t-1}$ and $Underload_{t}$ (γ_{40} = -.05 (95% CV = [-.16 - 06]). Furthermore, the cross-lagged relationship between $Underload_{t-1}$ and $Affect_{t}$ showed slight variation from person to person (τ_{55}= -.16 (95% CV = [.01 - .55]). Overall, these results suggest affect exhibits some temporal dependence, but not underload. Similar to the effects observed with overload, there is evidence for a potential one-way causal relationship, with underload predicting affect, but not the other way around. We note however that this relationship is positive (whereas it is negative with overload), suggesting higher perceived levels of underload during the previous work period predicts a more positive current affective state.

Table 4.8. Parameter estimates for multi-level VAR(1) model looking at Affect and Underload

Parameter		Posterior Median	Posterior SD	95% credibility interval
Within-level (standardised)				
Intercept (Affect $_{t-1}$ →Affect $_{t}$)	γ_{20}	.23**	.06	.11 - .35
Intercept (Underload $_{t-1}$ →Underload $_{t}$)	γ_{30}	-.02	.06	-.13 - .11
Intercept (Affect $_{t-1}$ →Underload $_{t}$)	γ_{40}	-.05	.06	-.16 - .06
Intercept (Underload $_{t-1}$ →Affect $_{t}$)	γ_{50}	.12*	.05	.01 - .22
Intercept (residual variance of Affect)	ω_{0}	.83**	.05	.73 - .91
Intercept (residual variance of Underload)	ω_{1}	.85**	.04	.76 - .91
Between-level (unstandardised)				
Intercept (Mean of Affect)	γ_{00}	5.98**	.24	5.50 – 6.45
Intercept (Mean of Underload)	γ_{10}	2.36**	.12	2.12 – 2.59
Variance (Mean of Affect)	τ_{00}	1.26**	.49	.66 – 2.55
Variance (Mean of Underload)	τ_{11}	.31**	.12	.17 - .62
Variance (Affect $_{t-1}$ →Affect $_{t}$)	τ_{22}	.07**	.05	.02 - .19
Variance (Underload $_{t-1}$ →Underload $_{t}$)	τ_{33}	.13**	.07	.05 - .31
Variance (Affect $_{t-1}$ →Underload $_{t}$)	τ_{44}	.01**	.01	.00 - .03
Variance (Underload $_{t-1}$ →Affect $_{t}$)	τ_{55}	.16**	.14	.01 - .55
Variance (residual variance of Affect)	τ_{66}	.89**	.18	.17 - .86
Variance (residual variance of Underload)	τ_{77}	1.53**	.52	.88 – 2.86

*p < .05. **p < .01. Note: time lag was approximately 12-hours

4.6 Discussion

The aim of this study was to explore how overload and underload contribute to chronic and acute forms of fatigue in submarine operations. In terms of chronic fatigue, Analysis 1 examined the extent to which burnout changed over three operational activities that took place over 12-15 days. Findings suggest that submariners did not show any consistent change in burnout over the course of these operational activities, and the intensity of operational activity was not a significant predictor of changes in burnout. In terms of acute fatigue, Analysis 2 examined the extent to which perceived overload and underload from a preceding work period predicts state fatigue and affect after a subsequent work period, and vice versa (i.e., within-day reciprocal effects). Findings suggest that reciprocal effects exist on a within-day work-period level (e.g., approximately a 12-hour time lag) between overload and state fatigue, but not between underload and state fatigue. Further to this, neither overload nor underload showed reciprocal relationships with state affect on this timeframe. We discuss the theoretical and practical implications of the study below, beginning with the findings from Analysis One.

4.6.1 Analysis One Findings: No Evidence for Change in Submariners' Burnout

Analysis One found that despite the harsh conditions that submariners must endure, burnout did not consistently increase or decrease over an operational activity. This finding has several implications for our understanding of how burnout develops and changes over time. First, these findings suggest that burnout does not change rapidly, even in demanding environments such as submarine operations. It is likely that the time frame investigated (i.e., 12-15 days) was too short for a build-up of cumulative strain to result in any substantial changes in burnout. This is in line with previous research that has found burnout scores to be relatively stable, which emphasises burnout as a chronic, rather than transient condition (Guthier et al., 2020). Further to this, it is important to consider that submariners are professionals trained to maintain performance under high stress and demanding conditions (Brasher et al., 2010; Moffitt, 2008). Previous research looking at other professions where high stress tolerance is part of the occupational self-image, such as primary care physicians, has found that burnout remains stable even over relatively long periods such as a year (Hornung et al., 2013; Zapf et al., 1996). We also highlight that the analysis may have had insufficient power to detect stronger effects due to the small sample size. We note that the trend observed in the data was in the direction expected, with the low intensity operation showing a decrease in burnout, and the high intensity operation showing the largest increase in burnout, followed by the normal intensity operation. To extend on these findings, future research should consider measuring burnout over longer periods by using a multi-wave design that spans multiple operational activities.

4.6.2 Analysis Two Findings: Overload and Underload are Associated with Different Patterns of State Fatigue and Affect

The results of Analysis Two suggest that overload and underload have different relationships with state fatigue and affect over a workday of multiple work periods. For instance, a key finding was that while reciprocal effects were observed between overload and state fatigue such that fatigue and overload reinforced each other over multiple work periods, underload, showed no causal or reciprocal effects with state fatigue at this within-day timeframe. This is notable for two reasons.

First, the reciprocal relationship between overload and state fatigue provides evidence that reciprocal effects are an important element of the health impairment process, with employees facing high demands at risk of experiencing a loss spiral of demands and exhaustion (Lesener et al., 2019; Zapf et al., 1996). Furthermore, these findings provide a novel short-term perspective on reciprocal effects between demands and strain, which have usually been studied over longer timeframes (e.g., 1 to 3 years) (Lesener, et al., 2019). The data suggest that in an extreme work environment such as a submarine, excessive work demands may lead to a carry-over of fatigue on a shift-to-shift basis. This supports arguments made in Chapter 2 that a build-up of fatigue and strain may occur more easily (and be more difficult to reverse) in constrained and demanding extreme environments and reveals overload as a risk to ongoing performance.

Second, these results suggest that underload may contribute to fatigue differently to overload. Although the lack of within-day association between underload and state fatigue in the current study runs counter to previous research that has found associations between underload and fatigue related outcomes (Andrei et al., 2020; Shultz et al., 2010), it is important to note that previous research has almost exclusively examined this link cross-sectionally. Therefore, rather than suggesting that there is no association between underload and fatigue, it is likely that underload exhibits a different relationship with fatigue at this within-day timeframe, compared to overload. Indeed, cross-sectional correlations in our data show that underload has a stronger positive association with fatigue and a stronger negative association with affect, compared to overload.

Moreover, a similar pattern was observed for state affect, with overload and underload exhibiting different within-day relationships with this outcome. Consistent with previous research that has found links between overload and distress (Bowling et al., 2015), there was a negative relationship between overload and affect such that higher perceived overload in a prior work period led to more negative affect after a subsequent work period. For underload however, there was a positive relationship with state affect, such that higher perceived underload in a prior work period led to more positive affect after a subsequent work period. Although this also seems to contradict previous research that suggests underload is associated with negative mood (Karasek, 1979; van Hooft & van Hooff, 2018), as noted above, it is important to interpret these effects with regards to the 12-hour timeframe examined.

Looking at the autocorrelation (i.e. temporal dependence) of overload and underload in the data helps to shed some light on why overload and underload may trigger different patterns of responses. Overload showed low to moderate levels of temporal dependence, with high perceived overload on average predicting higher perceptions of overload during a subsequent work period. On the other hand, underload showed effectively no temporal dependence. One potential reason may have to do with the nature of tasks that elicit underload versus overload. Overload may involve more spill-over of tasks into after-work time and rumination about unfinished work (Syrek & Antoni, 2014), whereas with underload, feelings of boredom may end as soon as focus is no longer required (e.g., end of the work period/shift), and attention can be directed towards more rewarding or engaging activities (Wolff & Martarelli, 2020). Taken together, these findings add to existing debates in the job demands literature that not all demands are created equal and may be linked to outcomes via different processes/mechanisms (e.g., Crawford et al., 2010; van den Broeck et al., 2010). However, given we only focused on a 12-hour timeframe and have speculated that underload may involve processes that unfold over a shorter time window, more research is needed to investigate the specific mechanisms and dynamics underlying these relationships. We note that a more detailed disentanglement of the relationships between overload, underload and employee reactions over time is a complex endeavor and may be a research question better suited for a controlled experimental approach, rather than field research.

4.6.3 Practical Implications

Given that the results herein suggest overload and underload may cause fatigue over time in different ways (i.e., over different timeframes), a key practical implication arising from this study is that the reduction or mitigation of fatigue from overload and underload may require different types of interventions.

Since overload and fatigue appear to reinforce each other over multiple shifts, interventions for overload should concentrate on workday design. While the concept of work design has typically focused on how specific tasks within a job can be altered to improve motivation and productivity (Parker, 2014), workday design expands the focus to consider how work (e.g., tasks during a work shift) and non-work experiences (e.g., breaks within and between work shifts) combine in order to form the overall workday experience (Brodsky & Amabile, 2018).

For instance, since our results showed that overload experienced on one shift has consequences for fatigue during the next shift, any interventions designed to reduce overload should target overload on each shift, rather than average levels of overload over a long duration operation. In terms of non-work experiences, the importance inter-shift recovery has been stressed in operational environments (Andrei et al., 2020) as high quality respite between shifts allows employees to replenish as much energy as possible before their next shift and reducing the carry-over of fatigue from previous shifts (Demerouti, Bakker, et al., 2009) Additionally, there is a burgeoning literature on the positive effect of microbreak activities, which are defined as short, informal respite activities taken voluntarily between tasks (e.g., social activities, having a snack, doing some form of physical activity). Microbreak activities have been found to reduce fatigue and have positive effects on occupational wellbeing on an hourly basis throughout a workday (Zacher et al., 2014). However, we note that microbreak activities may not always be feasible to undertake in a safety-critical operational environment such as a submarine, where individuals may be required to maintain vigilance for long periods with little to no breaks.

By contrast, if fatigue from underload is indeed more task bound as we have speculated, interventions for underload should aim to reduce fatigue by targeting the design of specific tasks and activities during a work shift. Relevant interventions include microbreaks (where operationally feasible) (Zacher et al., 2014), more formal scheduling of work tasks so that workers receive enough breaks and rests to reduce fatigue arising from monotony and boredom (Azizi et al., 2010), and/or introducing task rotation within a shift so that workers can switch to more engaging and stimulating tasks to reduce fatigue and protect performance (Gander et al., 2011)

4.6.4 Limitations and Future Directions

There are several limitations in the current study that highlight potential areas for future research. First, all measures in the current study were assessed via self-report, which may have caused common-method variance (CMV). However, many of the variables (e.g., burnout, fatigue, affect) are internal psychological states, and thus self-report is the most suitable method of measuring these constructs. Furthermore, the use of person-mean centering in analysis two removes several causes of CMV, such as differences in response tendencies and dispositional differences (Podsakoff et al., 2003). Nevertheless, obtaining more objective measures of overload and underload (e.g., physiological measurements) would have further strengthened the study.

Second, the small sample size of both analyses may have affected statistical power by increasing the risk of type-II errors, therefore reducing the ability to detect significant effects. For this reason, nonsignificant results in the current study should be treated with caution.

Third, the current study was conducted in a non-conventional context (i.e., submarine operations), therefore it is not clear how generalisable the findings are to other occupations. In analysis two, the watchkeeping routine of submariners (6 hours on-watch followed by 6 hours off-watch) allowed for an opportunity to investigate the mutual intensification of overload and fatigue over multiple work periods in a single day. More research is needed to examine if and how these reciprocal effects manifest in more conventional work structures that involve a single working period per day (i.e., 9 to 5 workday).

Lastly, the current study focused on the relationship between two work demands (overload and underload) and fatigue, and did not consider the potential moderating effect of other factors such as job resources (e.g., social support), stable individual differences (e.g., boredom proneness) and other environmental demands (e.g., sleep quality/quantity). Interestingly, in terms of individual differences, our data showed that the cross-lagged relationship between underload and state affect showed more between-person variability (τ_{55}=-.16 (95% CV = [.01 - .55]) than the relationship between overload and state affect (τ_{55}=-.03 (95% CV = [.00 - .13]). Previous research has found that the tendency to be bored easily differs from individual to individual, with those scoring higher in boredom proneness also tending to experience higher negative affect (Harris, 2000; Vodanovich & Verner, 1991). Future research could pay more attention to such characteristics and incorporate moderators relevant to the occupational context in question.

4.6.5 Conclusion

Despite the mentioned limitations, this study makes significant contribution to the understanding of work-related predictors of chronic and acute fatigue in submarine operations. In terms of chronic fatigue, this study reveals that submariners do not show significant changes in burnout over relatively short operational activities (< 15 days). In terms of acute fatigue, we found that overload and underload show different relationships with state fatigue over time. Of note, overload and state fatigue were found to reinforce each other over multiple shifts throughout a day. This has important implications for endurance. In a context where personnel are working rotating shifts with limited opportunity for respite and rest, it suggests that a vicious cycle of overload and exhaustion may easily manifest, leading to a rapid build-up of fatigue and strain which impedes ongoing performance.

4.7 Appendix 4A

Burnout

Please indicate how much you agree or disagree with the following statements.

(1 = Strongly disagree, 5 = Strongly agree)

1. I always find new and interesting aspects in my work
2. There are days when I feel tired before I arrive at work
3. It happens more and more often that I talk about my work in a negative way
4. After work, I tend to need more time than in the past in order to relax and feel better
5. I can tolerate the pressure of my work very well
6. Lately, I tend to think less at work and do my job almost mechanically
7. I find my work to be a positive challenge
8. During my work, I often feel emotionally drained
9. Over time, one can become disconnected from this type of work
10. After working, I have enough energy for my leisure activities
11. Sometimes I feel sickened by my work tasks
12. After my work, I usually feel worn out and weary
13. This is the only type of work that I can imagine myself doing
14. Usually, I can manage the amount of my work well
15. I feel more and more engaged in my work
16. When I work, I usually feel energised

Overload

Please rate your perception of overall workload for the work period just completed by circling a number for each dimension of workload

Mental Demand: How much mental activity was required (e.g., thinking, deciding, calculating, remembering, looking, searching etc.)?

Low Demand **High Demand**

0	10	20	30	40	50	60	70	80	90	100

Physical Demand: How much physical activity was required? (e.g., pushing, pulling, turning, controlling, activating etc.)?

Low Demand **High Demand**

0	10	20	30	40	50	60	70	80	90	100

Time Demand: How much time pressure did you feel due to the rate or pace at which the tasks occurred?

Low Demand **High Demand**

0	10	20	30	40	50	60	70	80	90	100

Underload

How often did you experience the following during the work period you have just completed?

(1 = Not at all, 5 = Very often)

1. I struggled to remain alert and vigilant
2. I found it difficult to concentrate
3. I found work boring and monotonous
4. Time passed slowly

State Fatigue

How are you currently feeling? Circle the relevant number below.

(1 = Very alert, 3 = Alert, 5 = Neither alert nor sleepy, 7 = Sleepy but not fighting sleep, 9 = Very sleepy, fighting sleep)

1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**

State Affect

How are you currently feeling? Circle the relevant number below.

(1 = Awful, 10 = Great)

1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**

5 GENERAL DISCUSSION

GENERAL DISCUSSION

The aim of this thesis was to advance knowledge of how the demands and constraints unique to extreme work environments impact sustained performance over time. Guided by this overarching aim, this thesis sought to: 1) establish a theoretical framework of endurance that models how human performance is sustained over time and impacted by work, non-work, and sleep factors over an intense long duration mission; and 2) to use this framework to guide initial investigations into how different types of demands impact endurance in real-world extreme work environments. In this chapter, I explain how the research in this thesis contributes to an understanding of how humans perform in both extreme and conventional work environments, and discuss how my findings stimulate the development and integration of existing theories of human work, strain, and fatigue. I will also discuss limitations and opportunities for future research. First, I provide a summary of the findings from this thesis.

5.1 Summary of Findings

In Chapter 2, I developed a theoretical framework of endurance, and defined endurance as an individual’s capacity to sustain performance at high levels for safe and effective operations over the extended duration of a mission. I argued that the concept of endurance is well suited to understanding the unique requirements and demands placed on humans that must perform in extreme work environments. In the face of chronic stress and limited opportunity for respite, the capability to endure depends on avoiding accumulation of strain as this leads to negative changes in mental and physical health, which ultimately affects future readiness to perform. An endurance-approach to performance concentrates on how a worker sustainably manages energy across daily work, non-work, and sleep (i.e., their work-life system). The theoretical framework presented in Chapter 2 integrates many literatures (e.g., work stress, recovery, and sleep) to describe ongoing performance in terms of short – and long-term energy management processes as individuals interact with their work-life system. Based on the proposed framework, I put forward several theoretical and practical implications, including the need for researchers to explore the temporal dynamics of within-person processes using intensive longitudinal data

(ILD), and recommendations for conducting applied research to inform organisational interventions for endurance.

In Chapter 3, I presented an empirical study aimed at understanding how different types of work demands impact on endurance in a real-world extreme environment - long-haul seafaring. The study examined how two demands commonly experienced in extreme environments, overload and underload, contribute separately and in combination to long-term endurance outcomes. Results showed that while overload and underload were both associated with chronic fatigue, underload showed stronger relationships with chronic fatigue and impaired psychological wellbeing compared to overload. Furthermore, overload was found to have a compensating effect on the negative relationship between underload and psychological wellbeing. That is, work that was characterised by frequent periods of low demands and boredom, with few periods of high demands and time pressure, was most harmful to wellbeing. Overall, the results revealed the importance of accounting for the separate and combined effects of overload and underload on long-term endurance, and that underload may actually present increased risks to worker fatigue and wellbeing than overload.

In Chapter 4, I extended my investigation by examining the dynamic relationship between overload, underload, and worker fatigue in a different extreme work environment – submarine operations. In this longitudinal study, I accounted for the role of time, and explored how overload and underload impacted endurance indicators over two different time frames: 1) a longer-term mission timeframe (i.e., change in chronic fatigue over the time course of a submarine operational activity), and 2) a shorter-term time frame (i.e., dynamic fluctuations in acute fatigue on a shift-to-shift basis). In terms of chronic fatigue over an operational activity, results showed that submariner burnout did not change. This suggests that submariners are enduring over at least relatively short operational activities (< 15 days), and burnout may change over longer operations, or over multiple operations. In terms of acute fatigue, overload and underload had different within-person relationships with state fatigue and state affect on a shift-to-shift basis. For example, overload and state fatigue were found to reinforce each other on a shift-to-shift basis (note: there was a 12-hour time lag between shifts), whereas underload did not predict (nor was predicted by) state fatigue. This suggests overload poses risks for accumulation of fatigue throughout an operational activity. Similarly, overload and underload exhibited different relationships with state affect such that overload showed a negative relationship with state affect ~12-hours later, while underload showed a positive relationship with state affect ~12-hours later. Overall, these results suggest that overload and underload may have different causal pathways to fatigue. Implication arising from this are that the mitigation and management of fatigue requires: 1) joint consideration of how work may elicit overload and underload; and 2) different interventions strategies targeted to overload and underload.

5.2 Theoretical Contributions

In the following section, I will explain how by developing a theoretical framework of endurance (Chapter 2) and shedding light on how multiple complex demands interact and are experienced together across multiple timeframes (Chapter 3 and Chapter 4), this thesis has advanced existing knowledge in the field. Additionally, I show how my findings integrate with the wider theoretical body of works in the literature.

5.2.1 An Integrated Approach to Understanding Performance and Functioning in Complex Work Environments

A key contribution of this thesis is the development of a conceptual model (Chapter 2) that facilitates an integrated and holistic approach to understanding the factors that impact performance and functioning in extreme work environments. One challenge posed by extreme environments is the blurring between work, non-work, and sleep life domains (Sandal et al., 2006; Suedfeld & Steel, 2000); meaning a worker's performance and functioning is closely linked to how they interact with their entire environment. To address challenges such as this, scholars have urged for more integrative and interdisciplinary efforts and approaches (e.g., Bishop, 2004; Landon et al., 2019; Sandal et al., 2006). However, limited research to date offers integrated models of human functioning relevant to extreme work environments (for exceptions see Crain et al., 2018; Landon et al., 2019). Morphew (2001) argues that this diffusion is due to researchers being spread across disciplines focused on subspecialty topics, which has promoted unidimensional research not conducive to identifying the extraneous factors that are relevant to understanding a complex phenomenon. For instance, the work recovery literature is concerned with how experiences and activities during non-work time facilitate or hinder the reduction of strain after work, however, researchers usually focus on the impact of waking activities and experiences, such as household chores (e.g., Fritz et al., 2010), leisure activities (Sonnentag et al., 2014) and psychological detachment (e.g., Chawla et al., 2020). By contrast, the role of sleep is often neglected (Crain et al., 2018; Zijlstra & Sonnentag, 2006), despite sleep being "the recovery activity par excellence" (De Lange et al., 2009, p. 375).

The endurance framework and associated concept of the work-life system (Chapter 2) helps to address limitations in previous research by providing a useful approach that integrates traditionally disparate literatures, ranging from work ergonomics (e.g., Young et al., 2015), work stress (e.g., Ganster & Rosen, 2013), recovery (e.g., Demerouti et al., 2009), and sleep science (e.g., Dawson & McCulloch, 2005). By articulating the common energy management processes that underlie work, non-work, and sleep, the endurance framework provides a theoretically valid foundation for future research to systematically incorporate a larger range of variables that explain and predict human performance in stressful and demanding working environments.

Further to this, the importance of adopting an integrated approach is reinforced by findings from Chapter 3 which revealed that different configurations of work demands should be examined to gain a more comprehensive understanding of the sources of stress in an extreme work environment. This is consistent with recent research (e.g., Riedl & Thomas, 2019; Rosen et al., 2020), that suggests there are multiple situational conditions, such as the presence and frequency of other demands in the working environment that ultimately shape how specific demands lead to worker strain and fatigue. More broadly, my findings contribute to a growing body of literature that advocates for a more contextualised approach towards understanding work roles and the work designs they imply (Griffin et al., 2007; Johns, 2006; Ilgen & Hollenbeck, 1991; Morgeson et al., 2010; Parker et al., 2017). For instance, in his seminal article on the impact of context on organisational behaviour, Johns (2006) suggested that researchers should move beyond studying features of work in an isolated and “piecemeal fashion” (p. 389) and suggested the study of configurations or ‘bundles’ of stimuli as one way to better appreciate work context.

Of note, my examination into configurations of overload and underload in a job (Chapter 3) revealed that some demands (i.e. overload) can have a positive and compensating effect in some situations. That is, although overload and underload had negative impacts individually, when examined collectively, increasing levels of overload appeared to protect the wellbeing of workers who also experienced high underload. In the few previous studies that have examined configurations of demands, high levels of multiple demands generally attenuated negative outcomes (e.g., Jimmieson et al., 2017; van Woerkom et al., 2016). For example, in several samples of healthcare workers, the negative impact of emotional demands on job satisfaction was exacerbated when both time and cognitive demands were high, creating a “triple disadvantage” of job demands (Jimmieson, et al., 2017, p. 317). As such, my findings offer a novel and expanded perspective on the different ways a complex working environment impacts human performance and functioning (see also Bakker & Demerouti, 2017; Parker et al., 2017).

5.2.2 Underload as an Under-researched but Critical Work Demand

The finding that underload is associated with fatigue and strain outcomes is an important contribution of this thesis, and warrants further attention. A consistent finding in this thesis across both seafaring (Chapter 3) and submarine environments (Chapter 4), was that while both overload and underload demonstrated significant cross-sectional associations with fatigue-related outcomes, underload showed stronger associations compared to overload. This was an important finding that provides new avenues for organisational behaviour research, because as discussed in Chapters 3 and 4, underload has typically received much less attention compared to overload (Andrei et al., 2020; Bowling et al., 2015; Fisher, 1993). For example, underload is not included in the list of job demands associated with the JD-R framework as compiled by Schaufeli & Taris (2014). The dearth of organisational research on underload is concerning, given the nature of work is changing due to widespread adoption of digital technologies which will likely reduce demands and increase underload for human operators by implementing higher levels of automation (e.g., remote control and monitoring operations) (Parker & Grote, 2020). The findings presented above suggest that organisational scholars should look beyond conventionally studied work demands to consider what novel or under-researched demands relevant to changes in current/future work (e.g., implementation of digital technologies) require more attention (see also Parker et al., 2017).

I make a related point that it is timely for organisational researchers to address underload in modern working environments by drawing on and integrating existing knowledge and methods from other disciplines (see also Parker & Grote, 2020). The issue of underload is not new and varying aspects of underload have long been investigated by other disciplines. For example, the human factors and ergonomics literatures have investigated how human operators maintain vigilance (a construct closely related to underload) in human-machine systems for several decades (e.g., Parasuraman, 1986; Warm et al., 2008; Young et al., 2015). Similarly, the cognitive psychology literature is concerned with the complex relationship between effort and fatigue (e.g., Hockey, 1997; Inzlicht et al., 2014, 2018). Moreover, boredom (a state that can be caused by underload) is receiving renewed research interest across various fields (e.g., Bench & Lench, 2019; Hooff & Hooft, 2014; van Hooft & van Hooff, 2018; Wolff & Martarelli, 2020), as scholars propose that a better understanding of the mechanisms that lead to boredom and disengagement may help advance theories of human stress and fatigue (Wolff et al., 2020).

One potential reason for the disconnect between organisational behaviour and human factors/cognitive psychology research are the differing levels of conceptualisation and analysis used between the literatures. Organisational behaviour research has mostly examined how job-level demands relate to longer-term outcomes (e.g., how general perceptions of overload and/or underload within a job role relate to burnout and wellbeing). By contrast, the human factors and cognitive psychology literatures have typically investigated task-level demands (e.g., how task-specific overload and/or underload relates to performance and fatigue during that task). From the perspective that digital technologies are not likely to replace whole jobs, but will instead lead to changes at the task-level (e.g., automation of specific tasks) (Parker & Grote, 2020), it may be relevant for organisational scholars to draw on approaches (i.e. experimental designs, short-term task-based timeframes) from the human factors and/or cognitive psychology literatures to investigate how underload at a task-level affects overall work design. However, to reiterate from Chapter 2, an understanding of both short-term task-level performance and fatigue, and long-term health and wellbeing, are critical for endurance. Therefore, future research on underload as a whole would benefit from an interdisciplinary approach that draws on different theoretical lenses to better understand how underload manifests and affects outcomes at different levels (see also Parker & Grote, 2020; Parker at al., 2017).

5.2.3 Incorporation of the Role of Time to Enrich Theory and Research

A third contribution of this thesis is the incorporation of the role of time to provide new insights on the processes that lead to fatigue and stress in extreme work environments. A large part of organisational research is concerned with the study of processes – for instance, the cognitive, energetic, motor, and social processes that underlie how people work, and how work affects people (Navarro et al., 2015). Given these processes necessarily unfold over time, a temporal lens is essential for advancing organisational research (Roe, 2008). Despite this, scholars still argue that temporal features have not received enough attention, with previous research tending to neglect the role of time in theory-building, measurement, and data analysis (Navarro et al., 2015; Shipp & Cole, 2015). For example, previous research has typically adopted a between-persons approach which answers static questions (i.e., how do individuals differ from one another?) and/or studies stable constructs (George & Jones, 2000). Accordingly, there have been calls for more research to take a within-persons approach which allows for the incorporation of the role of time as it explores how individual’s states and behaviours change as they interact with their environment over different timeframes (Dalal et al., 2020; McCormick et al., 2020).

Time plays a key role in the theoretical framework of endurance presented in Chapter 2. Given that extreme work environments require workers to sustain optimal performance every day over a long duration mission, it is useful to take a within-persons approach to focus on how performance (and the factors that impact an individual’s performance) might change or fluctuate over a mission (Roe, 2014). This reflected in the framework as constructs and their dynamic relationships are defined and specified according to various timeframes. For example, I distinguish between short-term and long-term factors in a work-life system (e.g., daily work hours vs. a work-rest pattern over a mission) and how they relate to outcomes over different time frames (e.g., daily task performance, vs. a pattern of goals over a mission). By accounting for dynamic processes that unfold and are linked over multiple timeframes, my framework offers a comprehensive and systematic approach to theorising and studying the factors that impact performance over time.

Additionally, the empirical studies conducted in Chapter 3 and 4 demonstrate how the theoretical framework can be used to generate insights about fatigue with enhanced temporal precision. One example relates to the specification of timeframes to model how different demands may involve different underlying causal pathways to fatigue. Relative to the static between-persons approach (Chapter 3), using a dynamic within-persons approach (Chapter 4) revealed that the relationships between overload and underload with fatigue are qualitatively different, suggesting these demands may not cause fatigue over time in the same way. Although overload and underload initially showed significant cross-sectional associations with long-term fatigue measures in Chapter 3, an examination of the dynamic day-to-day relationships between the two demands and acute fatigue revealed that only overload showed a significant relationship with acute fatigue. As discussed in Chapter 4, this suggests the way underload causes fatigue over a 12-hour timeframe may be different to overload. This might be due to the different nature of tasks associated with overload and underload. For overload, spill-over of tasks into after-work time and/or rumination about unfinished work may lead to longer lasting feelings of fatigue (Syrek & Antoni, 2014). However, the fatigue associated with the boredom and monotony of underload may be more task-bound and short-lived, as boredom can be alleviated as soon as the tasks ends, and attention can be redirected towards more rewarding or engaging activities (Inzlicht et al., 2014; Wolff & Martarelli, 2020).

These findings support and extend on the notion that not all job demands seem to be equal (Schaufeli & Taris, 2014). A growing body of research over the last decade argues that the category of job demands is not as homogenous as initially proposed by frameworks such as the JD-R model (e.g., Crawford et al., 2010; van den Broeck et al., 2010). For example, researchers have found that demands can be sorted into two further categories: challenge demands and hindrance demands, which each yield different relationships with burnout and engagement (van den Broeck et al., 2010). By examining how overload and underload lead to fluctuations in fatigue over a specific short-term time frame, the findings of this thesis reveal yet another way that not all demands are created equal. That is, specific demands may cause fatigue that is experienced differently over time by workers. Future research looking to expand on these findings could explore how different *patterns* of fluctuations in overload and underload are experienced over time – for example, looking at how variability and/or predictability of fluctuations moderate the relationship between overload/underload and fatigue over a period of time. Recent research suggests that a more variable patterns of demands lead to more negative outcomes compared to a stable pattern (Downes et al. 2020, Rosen et al., 2020), however it is unclear whether we could expect to see the same effects for different demands such as overload and underload.

A second related example relates to use of time series analysis techniques in Chapter 4 to examine how daily carry-over effects manifest in a stressful submarine work-life system. In Chapter 2, I argued that workers in extreme work environments may be vulnerable to a build-up of strain and fatigue due to ongoing performance requirements and limited respite opportunities. The use of ILD and time series-based analysis techniques (i.e., dynamic structural equation modelling) in Chapter 4 provided support for this argument. Specifically, overload and fatigue reinforced each other over multiple work periods within a day, meaning submariners facing high levels of demands may be at risk of experiencing higher carry-over of fatigue from one-shift to the next. These findings could not be elicited with conventional approaches, such as cross-sectional or small *t* panel designs, which typically only allow for between-person analysis at a few time points. However, by collecting many data points over a shorter observation window and examining within-person variation, showed the processes underlying how fatigue manifests and develops on a day-to-day basis.

Furthermore, this finding supports and extends on assumptions made by existing models of employee fatigue and strain such as the JD-R model (Bakker & Demerouti, 2014) and Hockey's (1997) model of compensatory control. While these models propose that demands and strain are reciprocally related (Bakker & Demerouti, 2017; Zapf et al., 1996), existing research has usually examined reciprocal effects between job demands and worker strain across longer time frames (i.e., one to three years) (e.g., Ângelo & Chambel, 2015; Ford et al., 2014; Hall et al., 2010; Houkes et al., 2008; Kinnunen & Feldt, 2013). The focus on longer-term relationships and processes is not surprising, as job demands research has typically been concerned with outcomes that are relatively stable over long periods, such as burnout (I note that in Chapter 4 submariner burnout was also demonstrated to be relatively stable over an operational activity). By contrast, studies of short-term dynamics are more common in the research of work stress and affect, where episodic approaches are used to examine how emotions fluctuate in response to specific events at work (e.g., Fuller et al., 2003; Zohar, 1999). Given extreme work environments require sustained performance across both short- and long-term periods, it is critical to understand both the long-term processes underlying how demands lead to burnout, as well as the short-term processes that generate fatigue daily.

5.3 Practical Implications

This thesis has several practical implications for human performance and well-being in both extreme and more conventional work environments. Beginning with Chapter 2, by integrating short- and long-term approaches to performance and shifting the focus to that of endurance, this thesis provides practitioners and organisations with a model they can leverage to address what has typically been two competing goals – work performance and employee well-being (Andrei et al., 2017). A common issue observed in high stress and safety critical work environments is that expert workforces are required to tackle complex demands to a high performance and safety standard, however the chronic stress experienced by these individuals leads to impaired physical and psychological functioning in the long-term (Bishop, 2004; Brasher et al., 2010; Landon et al., 2018). The theoretical framework of endurance makes clear that to enable workers to perform across both daily work episodes and across an entire career, organisations should play an active role in the design and support of a sustainable work-life system for their workers. Specifically, the framework provides organisations and practitioners guidance on the types of levers that can optimise endurance across different time frames (e.g., circadian synchronisation, work design), and the indictors and outcomes that shed light on how workers may be tracking over time.

The theoretical framework of endurance is also relevant to recent issues surrounding the increase in remote working posed by the COVID-19 pandemic. Many workers throughout 2020-2021 (and likely into the future) found themselves in situations not unlike the extreme environment of a submarine, as they experienced work, non-work, and sleep activities unfolding in a potentially isolated and confined physical space. The model of endurance presented in Chapter 2 is particularly well suited to inform how individuals and organisations can support ongoing performance and wellbeing in these situations. Where work, non-work, and sleep are highly interconnected, such as in a remote working situation, interventions for performance and wellbeing should optimise across work, non-work, and sleep experiences so that potential negative carry over effects are reduced. For example, given the lack of physical distance between office and home in a remote working situation, it is critical for employees to pursue non-work activities and boundary management practices that facilitate effective psychological detachment (Allen et al., 2021; Cho, 2020); this includes engaging in non-work activities that require full attention (e.g., specific hobbies) (Sonnentag et al., 2010) and manipulation of physical space to create physical borders between work and non-work domains (Allen et al., 2021).

The two empirical studies presented in Chapter 3 and Chapter 4 also pose implications for the mitigation and/or reduction of stress and fatigue caused by overload and underload – that is, underload and overload may require different intervention strategies. Interestingly, in Chapter 4, at a within-person level, underload was not related to state fatigue measured 12-hours later, despite underload showing significant positive cross-sectional correlations with fatigue measures across both seafarer and submariner samples (Chapter 3 and 4 respectively). This was likely due to the nature of tasks that evoke underload; fatigue from underload may be more task-bound and can be reduced rapidly when concentration on the unstimulating task at hand is no longer required. Following this line of reasoning, interventions to reduce fatigue from underload may be more effective if targeted at the design of the task (or work shift) that is causing underload. For example, scheduling tasks so that workers get enough breaks and rests to reduce fatigue arising from monotony and boredom (Azizi et al., 2010), or introducing task rotation within a shift such that workers can switch to more engaging and stimulating tasks to reduce fatigue and protect performance (Gander et al., 2011). More importantly, as underload can be caused by automated systems that relegate humans to being passive operators (Young & Stanton, 2002), organisations and system designers looking to implement automation to increase performance and safety should adopt a human-centric approach towards the design of these technologies to ensure human operators are supported, rather than replaced (Grote et al., 1995; Parker & Grote, 2020; Stanton & Young, 1998).

On the other hand, the findings of this thesis suggest the reduction of fatigue from overload may be achieved by considering the broader design of daily work, non-work, and sleep elements. In terms of work design, given results in Chapter 4 showed that overload experienced on one shift has consequences for fatigue during the next shift, interventions should target overload on each daily shift, rather than average levels of overload over a long duration operation. An example of such an intervention is the implementation of microbreak activities during work shifts, which have been found to reduce fatigue on an hourly basis throughout a workday (Zacher et al., 2014). Supporting high quality daily inter-shift recovery (by optimising non-work and sleep time) is also critical, as it may allow workers to replenish as much energy as possible before the next working period, thereby reducing the carry-over of fatigue from previous shifts, and interrupting the vicious cycle of overload and exhaustion (Sonnentag & Fritz, 2015; Zijlstra & Rook, 2016).

Lastly, the results of this thesis suggest that organisations should be mindful of not inadvertently creating conditions which increase risk of underload, in their attempts to reduce overload. For example, the significant interaction between overload and underload found in Chapter 3 suggests that overload is not detrimental to workers across all situations, and overload may in fact be able to buffer some of the negative impact of underload. This highlights that organisational interventions targeted at purely reducing overload (e.g., by automating tasks and processes) may be ineffective or even exacerbate fatigue, as workers are left with tasks that are largely monotonous, boring, and unstimulating. As mentioned earlier, organisations should prevent underload in these situations by paying attention to the early design stage of new technologies and work systems so that technology is designed for optimal human and machine performance.

5.4 Limitations and Future Directions

In the next section I note the potential limitations and corresponding future directions of this thesis. A first limitation of this thesis is in the potential to make causal claims. The first empirical study presented in Chapter 3 used a cross-sectional survey design, and therefore cannot inform causality. Although this limitation was partially addressed by employing a longitudinal design in Chapter 4 to explore the reciprocal relationships between overload and underload and fatigue on a within-day basis, it is still difficult to draw causal inferences from this second study alone. This is because although ILD afford a closer look at a phenomenon of interest, I was unable to rule out alternative explanations. For example, it is likely that there are omitted variables that vary over time and may affect both perceptions of demands and fatigue (e.g., an individual’s circadian rhythm). Unfortunately, the nature of conducting a field study in an extreme work environment precludes the ability to measure and control a range of additional variables.

Future research may be able to shed more light on causality in several ways. One possible future avenue is to employ laboratory-based experimental designs that allow a high degree of control to manipulate variables and investigate specific mechanisms. However, it is important to consider that performance decrements and worker strain are more readily observed in laboratory tasks than in naturally occurring work activities (Hockey, 1997). This is thought to be because there is a greater concern with maintaining task goals and priorities in natural work contexts (e.g., safety reasons), which encourages workers to sustain their performance (Kahneman, 1971; Teichner, 1968). To address this issue, experimental designs may benefit from the use of realistic simulations that replicate the experience of working and/or living in an extreme environment. For example, an experimental design seeking to understand the development of fatigue should not only attempt to replicate a sleeping pattern, but also ensure participants are engaged in realistic work tasks.

An additional avenue is to conduct quasi-experimental field research where endurance enhancing interventions are adopted by certain extreme teams but not others, which allows for the observation of worker states and behaviours in real-world situations but also a higher degree of control than is typically afforded in field studies. However, I note that interventions involving work tasks and activities (e.g., work re-design) may be difficult or impossible to implement in many extreme environments, because work tasks are inherently linked to mission performance and safety. For example, it is not ethical, nor operationally feasible to change the structure, type, and amount of work tasks a submarine sonar operator must complete during their work period. As such, sleep (e.g., sleep hygiene education) and/or waking recovery interventions (e.g., active vs. passive recovery activities) may be more feasible to implement and measure in quasi-experimental field study situations.

A second limitation of this thesis is the reliance on single source self-report data which presents the potential for common method variance (CMV). Common method variance is systematic error variance due to using a single reporting method and can either attenuate or disattenuate relationships found in a study (Spector, 2006). However, there are reasons to believe that the results presented in Chapter 3 and Chapter 4 are unlikely to be influenced by CMV. In terms of Chapter 3, CMV may be less of an issue as a significant interaction between overload and underload was detected, and previous research suggests CMV cannot create an artificial interaction, but rather may deflate the magnitude of true effects (Siemsen et al., 2010). In terms of Chapter 4, although all variables were self-report, the intensive within-person approach has been suggested to be less subject to issues of CMV (Foo et al., 2009; Williams & Alliger, 1994). Nevertheless, future research could build on the findings of this thesis by incorporating multiple sources of data, such as physiological measures of stress and fatigue (e.g., heart rate variability, pupillometry).

Third, it should be acknowledged that the studies contained within have focused on two specific extreme work environments: long haul shipping in Chapter 3, and submarine operations in Chapter 4. Given the specific context is crucial in shaping organisational phenomena (Johns, 2006), there are potential concerns regarding the generalisability of the samples and findings to other extreme work environments and conventional workplaces more broadly. For example, the high-risk nature of extreme environments may heighten situational strength; situational strength affecting the nature of predictor and performance relationships (Bell et al., 2018; Meyer et al., 2010). Compared to conventional work environments, the risks inherent in extreme environments may put pressure on individuals and/or teams to engage in or refrain from certain behaviours, which may then underscore the importance of particular behaviours, while minimizing the impact of other predictors (e.g., individual differences) (Bell et al., 2018).

To overcome this limitation and enable studies in specific extreme environments to be more generalisable, future research should provide clear contextual parameters within which effects are found, as well as articulate the common and unique features of a specific extreme work environment (for more detail, I refer readers to Bell et al., 2018). The more clearly communicated the features of the specific context are, the more easily subsequent research will be able to leverage the findings and/or use the findings as a basis for creating locally calibrated predictions in another context. For instance, researchers should pay attention to the degree of extremity in an environment (Maynard et al., 2018; Van Thielen et al., 2018). To illustrate, seafarers and submariners both experience isolation and confinement, however, the submarine environment involves a higher degree of extremity; a submarine is a confined capsule where workers receive no natural sunlight and must remain hidden/undetectable to the outside environment. Characterising the degree of extremity allows for more detailed explanations for how and when extreme environments might intensity or attenuate effects. This would also help researchers and practitioners to bridge findings and insights from various extreme environments to more conventional contexts.

Last, future research can adopt a phenomenon-driven research (PDR) approach to enable more generalisable insights. Compared to theory-driven research which aims to contribute to a specific (and often pre-existing) theory, a phenomenon-driven research (PDR) approach aims to capture and extend the body of knowledge within a field by focusing on a specific organisational phenomenon. (Schwarz & Stensaker, 2014). This involves describing and conceptualising real-world challenges, and leveraging and modifying existing theory, or developing new theory, to better understand and address these challenges (Mathieu, 2016; Schwarz & Stensaker, 2014). For example, by identifying the challenge of sustained performance in a submarine environment and shifting the focus to how short-term fatigue develops over multiple work shifts, I was able to develop and contribute to fundamental theories of human fatigue and strain (Chapter 4). In this way, a focus on addressing challenges identified in specific real-world contexts does not necessarily preclude generalisable findings, given findings are used to position, build and/or refine fundamental theories and addresses questions of interest to the broader field (e.g., human performance and stress).

5.5 Conclusion

This thesis aimed to develop a better understanding of how the complex demands and constrains within extreme work environments impact sustained performance over time. Chapter 2 introduced a theoretical framework of endurance that models how human performance and functioning is sustained and impacted over time by a ‘work-life system’. Chapters 3 and 4 provided empirical investigations into the work element of the work-life system and examined how overload and underload impact endurance in real-world extreme work environments. Overall, the findings of this thesis demonstrate the importance of: 1) taking an integrated and holistic approach towards understanding performance in complex extreme environments, 2) accounting for the effects of increasingly prevalent but under researched demands such as underload, and 3) incorporating temporal dynamics to better understand the mechanisms and processes that underlie endurance. I hope that the findings and concepts herein provide a useful foundation for future research and practice. Specifically, I hope this thesis will motivate a continual refinement of research theory and generation of insights in an interdisciplinary manner; and the development of solutions that will help address the complex challenges that workers in extreme work environments (and workers in increasingly demanding conventional work environments), must face and endure on a daily basis.

6 REFERENCES

Ainslie, G. (2013). Monotonous tasks require self-control because they interfere with endogenous reward. *Behavioral and Brain Sciences*, *36*(6), 679–680. https://doi.org/10.1017/S0140525X13000915

Akerstedt, T., Fredlund, P., Gillberg, M., & Jansson, B. (2002). Work load and work hours in relation to disturbed sleep and fatigue in a large representative sample. *Journal of Psychosomatic Research*, *53*(1), 235–238. https://doi.org/ 10.1016/s0022-3999(02)00447-6

Alarcon, G. M. (2011). A meta-analysis of burnout with job demands, resources, and attitudes. *Journal of Vocational Behavior*, *79*(2), 549–562. https://doi.org/10.1016/j.jvb.2011.03.007

Albers, C., & Bringmann, L. F. (2020). Inspecting gradual and abrupt changes in emotion dynamics with the time-varying change point autoregressive model. *European Journal of Psychological Assessment*, *36*(3), 492–499. https://doi.org/10.31234/osf.io/7j6dn

Alessandri, G., Borgogni, L., & Truxillo, D. M. (2015). Tracking job performance trajectories over time: A six-year longitudinal study. *European Journal of Work and Organizational Psychology*, *24*(4), 560–577. https://doi.org/10.1080/1359432X.2014.949679

Allen, T. D., Merlo, K., Lawrence, R. C., Slutsky, J., & Gray, C. E. (2021). Boundary Management and Work-Nonwork Balance While Working from Home. *Applied Psychology*, *70*, 60–84. https://doi.org/10.1111/apps.12300

Andrei, D. M., Griffin, M. A., Grech, M., & Neal, A. (2020). How demands and resources impact chronic fatigue in the maritime industry. The mediating effect of acute fatigue, sleep quality and recovery. *Safety Science*, *121*(January 2019), 362–372. https://doi.org/10.1016/j.ssci.2019.09.019

Andrei, D., Ochoa, P., & Griffin, M. (2017). Safety and employee health and welbeing: Can they really support each other? In M.-T. Lepeley & R. Bardy (Eds.), *Human Centered Management*. Greenleaf Publishing.

Ângelo, R. P., and Chambel, M. J. (2015), The reciprocal relationship between work characteristics and employee burnout and engagement: A longitudinal study of firefighters. *Stress Health*, *31*, 106– 114. https://doi.org/10.1002/smi.2532.

References

Ariga, A., & Lleras, A. (2011). Brief and rare mental “breaks” keep you focused: Deactivation and reactivation of task goals preempt vigilance decrements. *Cognition*, *118*(3), 439–443. https://doi.org/10.1016/j.cognition.2010.12.007

Asparouhov, T., Hamaker, E. L., & Muthén, B. (2018). Dynamic structural equation models. *Structural Equation Modeling*, *25*(3), 359–388. https://doi.org/10.1080/10705511.2017.1406803

Azizi, N., Zolfaghari, S., & Liang, M. (2010). Modeling job rotation in manufacturing systems: The study of employee’s boredom and skill variations. International *Journal of Production Economics*, *123*(1), 69–85. https://doi.org/10.1016/j.ijpe.2009.07.010

Baethge, A., Deci, N., Dettmers, J., & Rigotti, T. (2019). “Some days won’t end ever": Working faster and longer as a boundary condition for challenge versus hindrance effects of time pressure. *Journal of Occupational Health Psychology*, *24*(3), 322–332. https://doi.org/10.1037/ocp0000121

Bakker, A. B., & Demerouti, E. (2014). Job demands-resources theory. In P. Y. Chen & C. L. Cooper (Eds.), *Work and wellbeing: Wellbeing: A Complete Reference Guide (Vol. 3, pp. 1–28)*. John Wiley & Sons, Inc. https://doi.org/10.1002/9781118539415.wbwell019

Bakker, A. B., & Demerouti, E. (2017). Job demands – resources theory : Taking stock and looking forward. *Journal of Occupational Health Psychology*, *22*(3), 273–285. https://doi.org/10.1037/ocp0000056

Bakker, A. B., Demerouti, E., & Euwema, M. C. (2005). Job resources buffer the impact of job demands on burnout. *Journal of Occupational Health Psychology*, *10*(2), 170–180. https://doi.org/10.1037/1076-8998.10.2.170

Bakker, A. B., Demerouti, E., & Sanz-Vergel, A. I. (2014). Burnout and Work Engagement: The JD–R Approach. *Annual Review of Organizational Psychology and Organizational Behavior*, *1*, 389–411. https://doi.org/10.1146/annurev-orgpsych-031413-091235

Bakker, A. B., Hakanen, J. J., Demerouti, E., & Xanthopoulou, D. (2007). Job resources boost work engagement, particularly when job demands are high. *Journal of Educational Psychology*, *99*(2), 274–284.

https://doi.org/10.1037/0022-0663.99.2.274

Banks, S., Landon, L. B., Dorrian, J., Waggoner, L. B., Centofanti, S. A., Roma, P. G., & Van Dongen, H. P. A. (2019). Effects of fatigue on teams and their role in 24/7 operations. *Sleep Medicine Reviews*, 48, Article 101216. https://doi.org/10.1016/j.smrv.2019.101216

Barger, L. K., Flynn-Evans, E. E., Kubey, A., Walsh, L., Ronda, J. M., Wang, W., Wright, K. P., & Czeisler, C. A. (2014). Prevalence of sleep deficiency and use of hypnotic drugs in astronauts before, during, and after spaceflight: An observational study. *The Lancet Neurology*, *13*(*9*), 904–912. https://doi.org/10.1016/S1474-4422(14)70122-X

Barnes, C. M., Jiang, K., & Lepak, D. P. (2016). Sabotaging the benefits of our own human capital : Work unit characteristics and sleep. *Journal of Applied Psychology*, *101*(2), 209–221. https://doi.org/http://dx.doi.org/10.1037/apl0000042

Basner, M., Spaeth, A. M., & Dinges, D. F. (2014). Sociodemographic characteristics and waking activities and their role in the timing and duration of sleep. *Sleep*, *37*(12), 1889–1906. https://doi.org/10.5665/sleep.4238

Bass, J., & Lazar, M. A. (2016). Circadian time signatures of fitness and disease. *Science*, *354*(6315), 994–999. https://doi.org/10.1126/science.aah4965

Bell, S. T., Fisher, D. M., Brown, S. G., & Mann, K. E. (2018). An approach for conducting actionable research with extreme teams. *Journal of Management*, *44*(7), 2740–2765. https://doi.org/10.1177/0149206316653805

Bench, S. W., & Lench, H. C. (2019). Boredom as a seeking state: Boredom prompts the pursuit of novel (even negative) experiences. *Emotion*, *19*(2), 242–254. https://doi.org/10.1037/emo0000433

Bendak, S. (2003). 12-H workdays: Current knowledge and future directions. *Work and Stress*, *17*(4), 321–336. https://doi.org/10.1080/02678370310001643478

Bishop, S. L. (2004). Evaluating teams in extreme environments: From issues to answers. *Aviation Space and Environmental Medicine*, *75*(Supplement 1), 14–21.

References

Boeing, A. A., Jorristma, K., Griffin, M. A., & Parker, S. K. (2020). Surfacing the social factors early: A sociotechnical approach to the design of a future submarine. *Australian Journal of Management*, *45*(3), 527–545. https://doi.org/10.1177/0312896220920338

Boivin, D. B., & James, F. O. (2005). Light treatment and circadian adaptation to shift work. *Industrial Health*, 43(*1*), 34–48. https://doi.org/10.2486/indhealth.43.34

Bowling, N. A., Alarcon, G. M., Bragg, C. B., & Hartman, M. J. (2015). A meta-analytic examination of the potential correlates and consequences of workload. *Work & Stress*, *29*(2), 95–113. https://doi.org/10.1080/02678373.2015.1033037

Brasher, K. S., Dew, A. B. C., Kilminster, S. G., & Bridger, R. S. (2010). Occupational stress in submariners: The impact of isolated and confined work on psychological well-being. *Ergonomics*, *53*(3), 305–313. https://doi.org/10.1080/00140130903067763

Brodsky, A., & Amabile, T. M. (2018). The downside of downtime: The prevalence and work pacing consequences of idle time at work. *Journal of Applied Psychology*, *103*(5), 496–512. https://doi.org/10.1037/apl0000294

Buxton, O. M., Cain, S. W., O'Connor, S. P., Porter, J. H., Duffy, J. F., Wang, W., Czeisler, C. A., & Shea, S. A. (2012). Metabolic consequences in humans of prolonged sleep restriction combined with circadian disruption. *Sleep Translational Medicine*, *4*(129), 129RA43. https://doi.org/10.1126/scitranslmed.3003200

Cappuccio, F. P., Cooper, D., Delia, L., Strazzullo, P., & Miller, M. A. (2011). Sleep duration predicts cardiovascular outcomes: A systematic review and meta-analysis of prospective studies. *European Heart Journal*, *32*(12), 1484–1492. https://doi.org/10.1093/eurheartj/ehr007

Castro, C. A., & Adler, A. B. (1999). OPTEMPO: Effects on soldier and unit readiness. *Parameters*, *29*(3), 86–95. https://search.proquest.com/docview/198163285

Chang, Y. H., Yang, H. H., & Hsu, W. J. (2019). Effects of work shifts on fatigue levels of air traffic controllers. *Journal of Air Transport Management*, *76,* 1–9.

https://doi.org/10.1016/j.jairtraman.2019.01.013

Charney, E. (2013). Can tasks be inherently boring. *Behavioral and Brain Sciences*, *36*(6), 684. https://doi.org/10.1017/S0140525X13000964

Chawla, N., MacGowan, R. L., Gabriel, A. S., & Podsakoff, N. P. (2020). Unplugging or staying connected? Examining the nature, antecedents, and consequences of profiles of daily recovery experiences. *Journal of Applied Psychology*, *105*(1), 19–39. https://doi.org/10.1037/apl0000423

Cho, E. (2020). Examining boundaries to understand the impact of COVID-19 on vocational behaviors. *Journal of Vocational Behavior*, *119*, 2011–2013. https://doi.org/10.1016/j.jvb.2020.103437

Cohen, D. A., Wang, W., Wyatt, J. K., Kronauer, R. E., Dijk, D. J., Czeisler, C. A., & Klerman, E. B. (2010). Uncovering residual effects of chronic sleep loss on human performance. *Science Translational Medicine*, *2*(14), 14ra3. https://doi.org/10.1126/scitranslmed.3000458

Colquhoun, W. P. (1985). Hours of work at sea: Watchkeeping schedules, circadian rhythms and efficiency. *Ergonomics*, *28*(4), 637–653. https://doi.org/10.1080/00140138508963178

Cosenzo, K. A., Fatkin, L. T., & Patton, D. J. (2007). Ready or not: Enhancing operational effectiveness through use of readiness measures. *Aviation Space and Environmental Medicine*, *78*(Supplement 1), B96-B106

Craig, A., & Cooper, R. E. (1992). Symptoms of acute and chronic fatigue. In A. P. Smith & D. M. Jones (Eds.), *Hand*book *of human performance: Volume 3* (pp. 289–339). Academic Press Limited.

Crain, T. L., Brossoit, R. M., & Fisher, G. G. (2018). Work , nonwork, and sleep (WNS): A review and conceptual framework. *Journal of Business and Psychology*, *33*, 675–697. https://doi.org/https://doi.org/10.1007/s10869-017-9521-x

Crawford, E. R., LePine, J. A., & Rich, B. L. (2010). Linking job demands and resources to employee engagement and burnout: A theoretical extension and meta-analytic test. *Journal of Applied Psychology*, *95*(5), 834–848.

https://doi.org/10.1037/a0019364

Cummings, M. L., Gao, F., & Thornburg, K. M. (2016). Boredom in the workplace. *Human Factors, 58*(2), 279–300. https://doi.org/10.1177/0018720815609503

Dalal, R. S., Alaybek, B., & Lievens, F. (2020). Within-person job performance variability over short timeframes: Theory, empirical research, and practice. *Annual Review of Organizational Psychology and Organizational Behavior, 7*, 421–449. https://doi.org/10.1146/annurev-orgpsych-012119-045350

Dawson, D., & McCulloch, K. (2005). Managing fatigue: It's about sleep. *Sleep Medicine Reviews, 9*(5), 365–380. https://doi.org/10.1016/j.smrv.2005.03.002

Dawson, D., Chapman, J., & Thomas, M. J. W. (2012). Fatigue-proofing: A new approach to reducing fatigue-related risk using the principles of error management. *Sleep Medicine Reviews, 16*(2), 167–175. https://doi.org/10.1016/j.smrv.2011.05.004

Dawson, D., Darwent, D., & Roach, G. D. (2017). How should a bio-mathematical model be used within a fatigue risk management system to determine whether or not a working time arrangement is safe? *Accident Analysis and Prevention*, 99 (Part B), 469–473. https://doi.org/10.1016/j.aap.2015.11.032

Dawson, D., Ian Noy, Y., Härmä, M., Kerstedt, T., & Belenky, G. (2011). Modelling fatigue and the use of fatigue models in work settings. *Accident Analysis and Prevention, 43*(2), 549–564. https://doi.org/10.1016/j.aap.2009.12.030

De Lange, A. H., Kompier, M. A. J., Taris, T. W., Geurts, S. A. E., Beckers, D. G. J., Houtman, I. L. D., & Bongers, P. M. (2009). A hard day's night: a longitudinal study on the relationships among job demands and job control, sleep quality and fatigue. *Journal of Sleep Research, 18*(3), 374–383. https://doi.org/10.1111/j.1365-2869.2009.00735.x

Demerouti, E., Bakker, A. B., & Bulters, A. J. (2004). The loss spiral of work pressure, work-home interference and exhaustion: Reciprocal relations in a three-wave study. *Journal of Vocational Behavior, 64*(1), 131–149. https://doi.org/10.1016/S0001-8791(03)00030-7

Demerouti, E., Bakker, A.B., Geurts, S.A.E. and Taris, T.W. (2009). Daily recovery from work-related effort during non-work time. Sonnentag, S., Perrewé, P.L.

and Ganster, D.C. (Ed.) *Current Perspectives on Job-Stress Recovery (Research in Occupational Stress and Well Being, Vol. 7*), Emerald Group Publishing Limited, Bingley, pp. 85-123. https://doi.org/10.1108/S1479-3555(2009)0000007006

Demerouti, E., Bakker, A. B., Nachreiner, F., & Schaufeli, W. B. (2001). The job demands-resources model of burnout. *Journal of Applied Psychology, 86*(3), 499–512.

Demerouti, E., Bakker, A. B., Sonnentag, S., & Fullagar, C. J. (2012). Work-related flow and energy at work and at home: A study on the role of daily recovery. *Journal of Organizational Behavior*, *33*(2), 276–295. https://doi.org/10.1002/job.760

Demerouti, E., Bakker, A. B., Vardakou, I., & Kantas, A. (2003). The convergent validity of two burnout instruments: A multitrait-multimethod analysis. European *Journal of Psychological Assessment*, *19*(1), 12–23. https://doi.org/10.1027//1015-5759.19.1.12

Demerouti, E., Le Blanc, P. M., Bakker, A. B., Schaufeli, W. B., & Hox, J. (2009). Present but sick: A three-wave study on job demands, presenteeism and burnout. *Career Development International*, *14*(1), 50–68. https://doi.org/10.1108/13620430910933574

Desmond, P. A., Hancock, P. A., & Monette, J. L. (1998). Fatigue and automation-induced impairments in simulated driving performance. *Transportation Research Record*, *1628*(1), 8–14. https://doi.org/10.3141/1628-02

Dijk, D. J., & Czeisler, C. A. (1995). Contribution of the circadian pacemaker and the sleep homeostat to sleep propensity, sleep structure, electroencephalographic slow waves, and sleep spindle activity in humans. *Journal of Neuroscience, 15*(5), 3526–3538. https://doi.org/10.1523/jneurosci.15-05-03526.1995

Dinges, D. F. (1995). An overview of sleepiness and accidents. *Journal of Sleep Research, 4*(s2), 4–14. https://doi.org/10.1111/j.1365-2869.1995.tb00220.x

Dorrian, J., Baulk, S. D., & Dawson, D. (2011). Work hours, workload, sleep and fatigue in Australian Rail Industry employees. *Applied Ergonomics, 42*(2), 202–

209. https://doi.org/10.1016/j.apergo.2010.06.009

Dorrian, J., Roach, G. D., Fletcher, A., & Dawson, D. (2007). Simulated train driving: Fatigue, self-awareness and cognitive disengagement. *Applied Ergonomics*, *38*(2), 155–166. https://doi.org/10.1016/j.apergo.2006.03.006

Downes P. E., Reeves C. J., McCormick B.W., Boswell W.R., Butts M.M. Incorporating job demand variability into job demands theory: A meta-analysis. *Journal of Management*. May 2020. https://doi.org/10.1177/0149206320916767

Drake, B. G. (2009). *Human exploration of mars design reference architecture* (DRM) 5.0. (NASA/SP-2009-P-2566). https://www.nasa.gov/pdf/373665main_NASA-SP-2009-566.pdf

Driskell, T. ., Salas, E., & Driskell, J. E. (2018). Teams in extreme environments: Alterations in team development and teamwork. *Human Resource Management Review, 28*(4), 434–449. https://doi.org/10.1016/j.hrmr.2017.01.002

Driskell, J. E., Salas, E., Johnston, J. H., & Wollert, T. N. (2008). Stress exposure training: An event-based approach. In Hancock P. A. & Szalma J. L. (Eds.), *Performance under stress*, (pp. 271-286). Ashgate Publishing Ltd.

Driver, C. C., & Voelkle, M. C. (2018). Hierarchical bayesian continuous time dynamic modeling. *Psychological Methods*, *23*(4), 774–799. https://doi.org/10.1037/met0000168

Drumheller, K., & Benoit, W. L. (2004). USS Greeneville collides with Japan’s Ehime Maru: Cultural issues in image repair discourse. *Public Relations Review*, *30*(2), 177-185. https://doi.org/10.1016/j.pubrev.2004.02.004

Duckworth, A. L., Peterson, C., Matthews, M. D., & Kelly, D. R. (2007). Grit: Perseverance and passion for long-term goals. *Journal of Personality and Social Psychology, 92*(6), 1087–1101. https://doi.org/10.1037/0022-3514.92.6.1087

Eskreis-Winkler, L., Shulman, E. P., Beal, S. A., & Duckworth, A. L. (2014). The grit effect: Predicting retention in the military, the workplace, school and marriage. *Frontiers in Psychology*, *5*(Article 36). https://doi.org/10.3389/fpsyg.2014.00036

Flynn-Evans, E., Gregory, K., Arsintescu, L., Whitmire, A. & Leveton, L. B. (2016). *Evidence report : Risk of performance decrements and adverse health outcomes resulting from sleep loss , circadian desynchronization , and work overload* (pp, 1- 83). NASA, Human Research Program. https://humanresearchroadmap.nasa.gov/evidence/reports/sleep.pdf

Feuerhahn, N., Sonnentag, S., & Woll, A. (2014). Exercise after work, psychological mediators, and affect: A day-level study. European Journal of Work and Organizational Psychology, 23(1), 62–79. https://doi.org/10.1080/1359432X.2012.709965

Fisher, C. D. (1993). Boredom at work: A neglected concept. *Human Relations*, *46*(3), 395–417. https://doi.org/10.1177/001872679304600305

Fisher, G. G., Matthews, R. A., & Gibbons, A. M. (2016). Developing and investigating the use of single-item measures in organizational research. *Journal of Occupational Health Psychology*, *21*(1), 3–23. https://doi.org/10.1037/a0039139

Folkard, S. (1990). Circadian performance rhythms: Some practical and theoretical implications [and discussion]. Philosophical transactions of the royal society of London. Series B, *Biological Sciences*, *327*(1421), 543–553. http://www.jstor.org/stable/55326

Folkard, S., & Lombardi, D. A. (2006). Modeling the impact of the components of long work hours on injuries and “accidents.” *American Journal of Industrial Medicine*, *49*(11), 953–963. https://doi.org/10.1002/ajim.20307

Foo, M.D., Uy, M. A., & Baron, R. A. (2009). How do feelings influence effort? An empirical study of entrepreneurs’ affect and venture effort. *Journal of Applied Psychology*, *94*(4), 1086–1094. https://doi.org/10.1037/a0015599

Ford, M. T., Matthews, R. A., Wooldridge, J. D., Mishra, V., Kakar, U. M., & Strahan, S. R. (2014). How do occupational stressor-strain effects vary with time? A review and meta-analysis of the relevance of time lags in longitudinal studies. *Work and Stress*, *28*(1), 9–30. https://doi.org/10.1080/02678373.2013.877096

Fritz, C., Sonnentag, S., Spector, P. E., & McInroe, J. A. (2010). The weekend matters: Relationships between stress recovery and affective experiences. *Journal of Organizational Behavior*, *31*(8), 1137–1162. https://doi.org/10.1002/job.672

Fuller, J. A., Fisher, G. G., Stanton, J. M., Spitzmüller, C., Russell, S. S., & Smith, P. C. (2003). A Lengthy Look at the Daily Grind: Time Series Analysis of Events, Mood, Stress, and Satisfaction. *Journal of Applied Psychology*, *88*(6), 1019–1033. https://doi.org/10.1037/0021-9010.88.6.1019

Gander, P., Hartley, L., Powell, D., Cabon, P., Hitchcock, E., Mills, A., & Popkin, S. (2011). Fatigue risk management: Organizational factors at the regulatory and industry/company level. *Accident Analysis and Prevention*, *43*(2), 573–590. https://doi.org/10.1016/j.aap.2009.11.007

Ganster, D. C., & Rosen, C. C. (2013). Work stress and employee health: A multidisciplinary review. *Journal of Management*, *17*(2), 1085–1122. https://doi.org/10.1177/014920639101700202

Ganster, D. C., Crain, T. L., & Brossoit, R. M. (2018). Physiological measurement in the organizational sciences: A review and recommendations for future use. *Annual Review of Organizational Psychology and Organizational Behavior*, *5*, 267–293. https://doi.org/10.1146/annurev-orgpsych-032117-104613

Gelman, A., Carlin, J. B., Stern, H. S., Dunson, D. B., Vehtari, A., & Rubin, D. (2014). *Bayesian data analysis* (3rd ed.). Boca Raton, FL: CRC Press, Taylor & Francis Group.

Geisler, M., Berthelsen, H., & Hakanen, J. J. (2019). No job demand is an island - Interaction effects between emotional demands and other types of job demands. *Frontiers in Psychology*, *10*. https://doi.org/10.3389/fpsyg.2019.00873

George, J. M., & Jones, G. R. (2000). The role of time in theory and theory building. *Journal of Management*, *26*(4), 657–684. https://doi.org/10.1177/014920630002600404

Geurts, S. A. E., & Sonnentag, S. (2006). Recovery as an explanatory mechanism in the relation between acute stress reactions and chronic health impairment. *Scandinavian Journal of Work, Environment & Health*, *32*(6), 482–492. https://doi.org/10.5271/sjweh.1053

Gillberg, M., Kecklund, G., & Åkerstedt, T. (1996). Sleepiness and performance of professional drivers in a truck simulator - Comparisons between day and night driving. *Journal of Sleep Research*, *5*(1), 12–15. https://doi.org/10.1046/j.1365-2869.1996.00013.x

Glazer, S., & Beehr, T. A. (2005). Consistency of implications of three role stressors across four countries. *Journal of Organizational Behavior*, *26*(5), 467–487. https://doi.org/10.1002/job.326

Grech, M. R., Neal, A., Yeo, G., Humphreys, M., & Smith, S. (2009). An examination of the relationship between workload and fatigue within and across consecutive days of work: Is the relationshiop static or dynamic? *Journal of Occupational Health Psychology*, *14*(3), 231–242. https://doi.org/10.1037/a0014952

Grether, W. F. (1962). Psychology and the space frontier. *American Psychologist*, *17*(2), 92–101. https://doi.org/10.1037/h0042950

Griffin, M. A., & Clarke, S. (2011). Stress and well-being. In S. Zedeck (Ed.), APA *Handbook of Industrial and Organizational Psychology (Vol. 3: Maintaining, expanding, and contracting the organization)* (pp. 359–397). American Psychological Association. https://doi.org/10.1037/12171-010

Griffin, M. A., Chapman, M., Hosszu, K., Orchard, M., Parker, S., Jorritsma, K., Gagne, M., & Dunlop, P. (2019). *MAPNet: Rethinking Work Skills for the Future*. https://www.futureofworkinstitute.com.au/mapnet

Griffin, M. A., Neal, A., & Parker, S. K. (2007). A new model of work role performance: Positive behaviour in uncertain and interdependent contexts. *Academy of Management Journal*, *50*(2), 327–347.

Gross, J. J. (2015). Emotion regulation: Current status and future prospects. *Psychological Inquiry*, *26*(1), 1–26. https://doi.org/10.1080/1047840X.2014.940781

Grote, G., Weik, S., Wäfler, T., & Zölch, M. (1995). Criteria for the complementary allocation of functions in automated work systems and their use in simultaneous engineering projects. *International Journal of Industrial Ergonomics*, *16*(4–6), 367–382. https://doi.org/10.1016/0169-8141(95)00019-D

References

Gupta, C. C., Centofanti, S., Rauffet, P., Banks, S., Coppin, G., & Chauvin, C. (2019). Framework and metrics for online fatigue monitoring within submarine teams working in 24/7 environments. *IFAC-PapersOnLine*, *52*(19), 259–264. https://doi.org/10.1016/j.ifacol.2019.12.104

Guthier, C., Dormann, C., & Voelkle, M. C. (2020). Reciprocal effects between job stressors and burnout: A continuous time meta-analysis of longitudinal studies. *Psychological Bulletin*, 146 (12), 1146-1173. https://doi.org/10.1037/bul0000304

Hahn, V. C., Binnewies, C., & Haun, S. (2012). The role of partners for employees' recovery during the weekend. *Journal of Vocational Behavior*, *80*(2), 288–298. https://doi.org/10.1016/j.jvb.2011.12.004

Hall, G. B., Dollard, M. F., Tuckey, M. R., Winefield, A. H., & Thompson, B. M. (2010). Job demands, work-family conflict, and emotional exhaustion in police officers: A longitudinal test of competing theories. *Journal of Occupational and Organizational Psychology*, *83*(1), 237–250. https://doi.org/10.1348/096317908X401723

Hamaker, E. L., & Wichers, M. (2017). No time like the present : Discovering the hidden dynamics in intensive longitudinal data. *Current Directions in Psychological Science*, *26*(1), 10–15. https://doi.org/10.1177/0963721416666518

Hamaker, E. L., Asparouhov, T., Brose, A., Schmiedek, F., & Muthén, B. (2018). At the Frontiers of Modeling Intensive Longitudinal Data: Dynamic Structural Equation Models for the Affective Measurements from the COGITO Study. *Multivariate Behavioral Research, 53*(6), 820–841. https://doi.org/10.1080/00273171.2018.1446819

Han, K., Trinkoff, A. M., & Geiger-Brown, J. (2014). Factors associated with work-related fatigue and recovery in hospital nurses working 12-hour shifts. *Workplace Health & Safety*, *62*(10), 409–414. https://doi.org/10.3928/21650799-20140826-01

Hancock, P. A., & Hart, S. G. (2002). Defeating terrorism: What can human factors/ergonomics offer? *Ergonomics in Design*, *10*(1), 6–16.

Hancock, P. A., & Krueger, G. P. (2010). *Hours of boredom, moments of terror: Temporal desynchrony in military and security force operations*. National Defence University, Washington DC, Centre for Technology and National Security Policy.

Hancock, P. A., & Matthews, G. (2019). Workload and performance: Associations, insensitivities, and dissociations. *Human Factors: The Journal of the Human Factors and Ergonomics Society*, *61*(3), 374–392. https://doi.org/10.1177/0018720818809590

Hancock, P. A., & Parasuraman, R. (1992). Human factors and safety in the design of intelligent vehicle-highway systems (IVHS). *Journal of Safety Research, 23*(4), 181–198. https://doi.org/10.1016/0022-4375(92)90001-P

Harris, M. B. (2000). Correlates and characteristics of boredom proneness and boredom. *Journal of Applied Social Psychology, 30*(3), 576–598. https://doi.org/10.1111/j.1559-1816.2000.tb02497.x

Harrison, A. A., & Connors, M. M. (1984). Groups in Exotic Environments. In L. Berkowitz (Ed.), *Advances in Experimental Social Psychology (Volume 18),* (pp. 49–87). Academic Press Inc.

Hart, S. G. (2006, October). NASA-task load index (NASA-TLX); 20 years later. *Proceedings of the human factors and ergonomics society annual meeting, 50*(9), 904-908).

Hartwig, A., Clarke, S., Johnson, S., & Willis, S. (2020). Workplace team resilience: A systematic review and conceptual development. *Organizational Psychology Review, 10*(3–4). https://doi.org/10.1177/2041386620919476

Hobfoll, S. E. (1989). Conservation of Resources: A New Attempt at Conceptualizing Stress. *American Psychologist*, *44*(3), 513–524. https://doi.org/10.1037/0003-066X.44.3.513

Hobfoll, S. E. (2002). Social and psychological resources and adaptation. *Review of General Psychology, 6*(4), 307–324. https://doi.org/10.1037/1089-2680.6.4.307

Hockey, G. R. J. (1997). Compensatory control in the regulation of human performance under stress and high workload: A cognitive-energetical framework. *Biological Psychology*, *45*(1–3), 73–93. https://doi.org/10.1016/S0301-0511(96)05223-4

Hockey, G. R. J. (2011). A motivational control theory of cognitive fatigue. In P. L. Ackerman (Ed.), *Cognitive fatigue: Multidisciplinary perspectives on current research and future applications*. (pp. 167–187). American Psychological Association. https://doi.org/10.1037/12343-008

Hockey, G. R. J., Wastell, D. G., & Sauer, J. (1998). Effects of sleep deprivation and user interface on complex performance: A multilevel analysis of compensatory control. *Human Factors*, *40*(2), 233–253. https://doi.org/10.1518/001872098779480479

van Hooff, M. L. M., & van Hooft, E. A. J. (2014). Boredom at work: Proximal and distal consequences of affective work-related boredom. *Journal of Occupational Health Psychology*, *19*(3), 348–359. https://doi.org/10.1037/a0036821

Hornung, S., Weigl, M., Glaser, J., & Angerer, P. (2013). Is it so bad or am i so tired? Cross-lagged relationships between job stressors and emotional exhaustion of hospital physicians. *Journal of Personnel Psychology*, *12*(3), 124–131. https://doi.org/10.1027/1866-5888/a000088

Houkes, I., Winants, Y. H. W. M., & Twellaar, M. (2008). Specific determinants of burnout among male and female general practitioners: A cross-lagged panel analysis. *Journal of Occupational and Organizational Psychology*, *81*(2), 249–276. https://doi.org/10.1348/096317907X218197

Hülsheger, U. R., Lang, J. W. B. B., Depenbrock, F., Fehrmann, C., Zijlstra, F. R. H., & Alberts, H. J. E. M. (2014). The power of presence: The role of mindfulness at work for daily levels and change trajectories of psychological detachment and sleep quality. *Journal of Applied Psychology*, *99*(6), 1113–1128. https://doi.org/10.1037/a0037702

Ilgen, D. R., & Hollenbeck, J. R. (1991). The structure of work: Job design and roles. In M. D. Dunnette & H. L. M (Eds.), *Handbook of industrial and organizational psychology* (pp. 165–207). Consulting Psychologists Press.

Inzlicht, M., Schmeichel, B. J., & Macrae, C. N. (2014). Why self-control seems (but may not be) limited. *Trends in Cognitive Sciences*, *18*(3), 127–133.

https://doi.org/10.1016/j.tics.2013.12.009

Inzlicht, M., Shenhav, A., & Olivola, C. Y. (2018). The effort paradox : Effort Is both costly and valued. *Trends in Cognitive Sciences*, *22*(4), 337–349. https://doi.org/10.1016/j.tics.2018.01.007

JASP team. (2020). JASP (Version 0.14.1) (0.14.1).

Jeffreys, H. (1998). *The theory of probablity*. OUP Oxford.

Jiang, L., & Probst, T. M. (2015). The relationship between safety–production conflict and employee safety outcomes: Testing the impact of multiple organizational climates. *Work and Stress*, *29*(2), 171–189. https://doi.org/10.1080/02678373.2015.1032384

Jimmieson, N. L., Tucker, M. K., & Walsh, A. J. (2017). Interaction effects among multiple job demands: an examination of healthcare workers across different contexts. *Anxiety, Stress and Coping*, *30*(3), 317–332. https://doi.org/10.1080/10615806.2016.1229471

Johns, G. (2006). The essential impact of context on organizational behavior. *Academy of Management Review*, *31*(2), 386–408. https://doi.org/10.5465/AMR.2006.20208687

Kahn, R., & Byosiere, P. (1992). Stress in organizations. In M. D. Dunnette & L. M. Hough (Eds.), *Handbook of Industrial and Organizational Psychology* (pp. 571–650). Consulting Psychologists Press. https://psycnet.apa.org/record/1993-97201-010

Kahneman, D. (1971). Remarks on attentional control. In A. F. Sanders (Ed.), *Attention and performance III* (pp. 118–131). Amsterdam: North-Holland.

Kahneman, D. (1973). *Attention and Effort*. NJ: Prentice Hall.

Kaida, K., Takahashi, M., Åkerstedt, T., Nakata, A., Otsuka, Y., Haratani, T., & Fukasawa, K. (2006). Validation of the Karolinska sleepiness scale against performance and EEG variables. *Clinical Neurophysiology*, *117*(7), 1574–1581. https://doi.org/10.1016/j.clinph.2006.03.011

Karasek, R. (1979). Job demands, job decision latitude, and mental strain: Implications for job redesign. *Administrative Science Quarterly*, *24*(2), 285–

308. https://doi.org/10.2307/2392498

Karasek, R., & Theorell, T. (1990). *Healthy work: Stress, productivity, and the reconstruction of working life*. Basic Books.

Kass, R. E., & Raftery, A. E. (1995). Bayes factors. *Journal of the American Statistical Association*, *90*(430), 773–795. https://doi.org/10.1080/01621459.1995.10476572

Kelliher, C., & Anderson, D. (2010). Doing more with less? flexible working practices and the intensification of work. *Human Relations*, *63*(1), 83–106. https://doi.org/10.1177/0018726709349199

Kerrissey, M. J., Satterstrom, P., & Edmondson, A. C. (2020). Into the fray: Adaptive approaches to studying novel teamwork forms. *Organizational Psychology Review*, *10*(2), 62–86. https://doi.org/10.1177/2041386620912833

Kinnunen, U., & Feldt, T. (2013). Job characteristics, recovery experiences and occupational well-being: Testing cross-lagged relationships across 1 year. *Stress and Health*, *29*(5), 369–382. https://doi.org/10.1002/smi.2483

Kinnunen, U., Feldt, T., de Bloom, J., Sianoja, M., Korpela, K., & Geurts, S. (2017). Linking boundary crossing from work to nonwork to work-related rumination across time: A variable-and person-oriented approach. *Journal of Occupational Health Psychology*, *22*(4), 467–480. https://doi.org/10.1037/ocp0000037

Klein, A., & Moosbrugger, H. (2000). Maximum likelihood estimation of latent interaction effects with the LMS method. *Psychometrika*, *65*(4), 457–474. https://doi.org/10.1007/BF02296338

Klonek, F., Gerpott, F. H., Lehmann-Willenbrock, N., & Parker, S. K. (2019). Time to go wild: How to conceptualize and measure process dynamics in real teams with high-resolution. *Organizational Psychology Review*, *9*(4), 245–275. https://doi.org/10.1177/2041386619886674

Kozlowski, S. W. J., & Chao, G. T. (2018). Unpacking team process dynamics and emergent phenomena: Challenges, conceptual advances, and innovative methods. *American Psychologist*, *73*(4), 576–592. https://doi.org/10.1037/amp0000245

Krueger, G. P. (1989). Sustained work, fatigue, sleep loss and performance: A review of the issues. *Work and Stress*, *3*(2), 129–141. https://doi.org/10.1080/02678378908256939

Lamers, S. M. A., Westerhof, G. J., Bohlmeijer, E. T., Ten Klooster, P. M., & Keyes, C. L. M. (2011). Evaluating the psychometric properties of the mental health Continuum-Short Form (MHC-SF). *Journal of Clinical Psychology*, *67*(1), 99–110. https://doi.org/10.1002/jclp.20741

Landon, L. B., Douglas, G. L., Downs, M. E., Greene, M. R., Whitmire, A. M., Zwart, S. R., & Roma, P. G. (2019). The behavioral biology of teams: Multidisciplinary contributions to social dynamics in isolated, confined, and extreme environments. *Frontiers in Psychology*, *10(*2571*)*. https://doi.org/10.3389/fpsyg.2019.02571

Landon, L. B., Slack, K. J., & Barrett, J. D. (2018). Teamwork and collaboration in long-duration space missions: Going to extremes. *American Psychologist*, *73*(4), 563–575. https://doi.org/10.1037/amp0000260

Leon, G. R., Sandal, G. M., & Larsen, E. (2011). Human performance in polar environments. *Journal of Environmental Psychology*, *31*(4), 353–360. https://doi.org/10.1016/j.jenvp.2011.08.001

Leone, S. S., Huibers, M. J. H., Knottnerus, J. A., & Kant, I. (2008). The prognosis of burnout and prolonged fatigue in the working population: A comparison. *Journal of Occupational and Environmental Medicine*, *50*(10), 1195–1202. https://doi.org/10.1097/JOM.0b013e31817e7c05

Leone, S. S., Wessely, S., Huibers, M. J. H., Knottnerus, J. A., & Kant, I. (2011). Two sides of the same coin? On the history and phenomenology of chronic fatigue and burnout. *Psychology and Health*, *26*(4), 449–464. https://doi.org/10.1080/08870440903494191

Lesener, T., Gusy, B., & Wolter, C. (2019). The job demands-resources model: A meta-analytic review of longitudinal studies. *Work and Stress*, *33*(1), 76–103. https://doi.org/10.1080/02678373.2018.1529065

Macdonald, W., & Bendak, S. (2000). Effects of workload level and 8- versus 12-h workday duration on test battery performance. *International Journal of Industrial Ergonomics*, *26*(3), 399–416. https://doi.org/10.1016/S0169-

8141(00)00015-9

Mackie, R. R., Wylie, C. D., & Smith, M. J. (1994). Countering loss of vigilance in sonar watchstanding using signal injection and performance feedback. *Ergonomics*, *37*(7), 1157–1184. https://doi.org/10.1080/00140139408964895

Maddi, S. R., Matthews, M. D., Kelly, D. R., Villarreal, B. J., Gundersen, K. K., & Savino, S. C. (2017). The continuing role of hardiness and grit on performance and retention in west point cadets. *Military Psychology*, *29*(5), 355–358. https://doi.org/10.1037/mil0000145

Mallett, C. J., Gucciardi, D. F., Temby, P., Hanton, S., & Gordon, S. (2014). The concept of mental toughness: Tests of dimensionality, nomological network, and traitness. *Journal of Personality*, *83*(1), 26–44. https://doi.org/10.1111/jopy.12079

Mallis, M. M., & DeRoshia, C. W. (2005). Circadian rhythms, sleep, and performance in space. *Aviation Space and Environmental Medicine*, *76*(Supplement 1), 94–107.

Masten, A. S., & Cicchetti, D. (2010). Developmental cascades. *Development and Psychopathology*, *22*(3), 491–495. https://doi.org/10.1017/S0954579410000222

Mathieu, J. E. (2016). The problem with [in] management theory. *Journal of Organizational Behavior*, *37*(8), 1132–1141. https://doi.org/10.1002/job.2114

Maynard, MT, Kennedy, DM, Resick, CJ. Teamwork in extreme environments: Lessons, challenges, and opportunities. *Journal of Organizational Behavior*. 2018; *39*(6), 695– 700. https://doi.org/10.1002/job.2302

Melamed, S., Ben-Avi, I., Luz, J., & Green, M. (1995). Repetitive work, work underload and coronary heart disease risk factors among blue-collar workers: The CORDIS study. Journal of Psychosomatic Research, 39(1), 19–29. https://doi.org/10.1016/0022-3999(94)00088-M

McCormick, B. W., Reeves, C. J., Downes, P. E., Li, N., & Ilies, R. (2020). Scientific contributions of within-person research in management: Making the juice worth the squeeze. *Journal of Management*, *46*(2), 321–350. https://doi.org/10.1177/0149206318788435

McDougall, L., & Drummond, P. D. (2010). Personal resources moderate the relationship between work stress and psychological strain of submariners. *Military Psychology*, *22*(4), 385–398. https://doi.org/10.1080/08995605.2010.513231

McEwen, B. S. (2007). Physiology and neurobiology of stress and adaptation: Central role of the brain. *Physiological Reviews*, *87*(3), 873–904. https://doi.org/10.1152/physrev.00041.2006

McNeish, D., & Hamaker, E. L. (2020). A primer on two-level dynamic structural equation models for intensive longitudinal data in Mplus. *Psychological Methods, 25*(5), 610–635. https://doi.org/10.1037/met0000250

Meijman, T. F., & Mulder, G. (1998). Psychological aspects of workload. In C. De Wolff, P. J. D. Drenth, & H. Thierry (Eds.), *A Handbook of Work and Organizational Psychology (Vol 2: Work Psychology)* (pp. 15–44). Psychology Press.

Melamed, S., Ben-Avi, I., Luz, J., & Green, M. (1995). Repetitive work, work underload and coronary heart disease risk factors among blue-collar corkers - The CORDIS study. *Journal of Psychosomatic Research*, *39*(1), 19–29. https://doi.org/10.1016/0022-3999(94)00088-M

Meyer R.D., Dalal R.S., & Hermida R. (2010). A review and synthesis of situational strength in the organizational sciences. *Journal of Management*. *36*(1), 121-140. https://doi.org/10.1177/0149206309349309

Miles, S. (1960). New problems in submarine habitability. *Annals of Occupational Hygiene*, *2*(3), 224–227. https://doi.org/10.1093/annhyg/2.3.224

Miller, N. L., Matsangas, P., & Shattuck, L. G. (2008). Fatigue and its effect on performance in military environments. In P. A. Hancock & J. L. Szalma (Eds.), *Performance under Stress*. Ashgate Publishing Ltd.

Miller, N. L., Shattuck, L. G., & Matsangas, P. (2011). Sleep and fatigue issues in continuous operations: A survey of U.S. Army officers. *Behavioral Sleep Medicine, 9*(1), 53–65. https://doi.org/10.1080/15402002.2011.533994

Milyavskaya, M., Inzlicht, M., Johnson, T., & Larson, M. J. (2019). Neuropsychologia Reward sensitivity following boredom and cognitive effort :

A high-powered neurophysiological investigation. *Neuropsychologia*, *123*, 159–168. https://doi.org/10.1016/j.neuropsychologia.2018.03.033

Minkel, J. D., Banks, S., Moreta, M. C., Jones, C. W., Simpson, N. S., & Dinges, D. F. (2012). Sleep deprivation and stressors: Evidence from elevated negative affect in response to mild stressors when sleep deprived. *Emotion*, *12*(5), 1015–1020. https://doi.org/10.1037/a0026871

Moffitt, R. A. R. (2008). *Navy's response to the submarine workforce sustainability review.* https://www.navy.gov.au/sites/default/files/documents/Submarine_Workforce.pdf

Morgeson, F. P., Dierdorff, E. C., & Hmurovic, J. L. (2010). Work design in situ: Understanding the role of occupational and organizational context. *Journal of Organizational Behavior*, *31*(2-3), 351–360. https://doi.org/10.1002/job.642

Morphew, M. E. (2001). The future of human performance and stress research: A new challenge. In H. P. A & D. P. A (Eds.), *Stress, Workload and Fatigue* (pp. 259–262). Lawrence Erlbaum Associates.

Muthén, L. K., & Muthén, B. O. (2017). *Mplus User's Guide (*Eighth Ed.*)*. Muthén & Muthén. http://www.statmodel.com/download/usersguide/MplusUserGuideVer_8.pdf

Navarro, J., Roe, R. A., & Artiles, M. I. (2015). Taking time seriously: Changing practices and perspectives in Work/Organizational Psychology. *Journal of Work and Organizational Psychology*, *31*(3), 135–145. https://doi.org/10.1016/j.rpto.2015.07.002

Neal, A., Ballard, T., & Vancouver, J. B. (2017). Dynamic self-regulation and multiple-goal pursuit. *Annual Review of Organzational Psychology and Organizational Behavior*, 4, 401–424. https://doi.org/10.1146/annurev-orgpsych-032516-113156

Nelson, P. D. (1962). *Human adaptation to antarctic station life*. Navy Medical Neuropsychiatric Research Unit. San Diego, CA

Nicol, A. M., & Botterill, J. S. (2004). On-call work and health: A review. *Environmental Health: A Global Access Science Source*, *3*(15), 1–7.

https://doi.org/10.1186/1476-069X-3-15

Nunnally, J. C. (1978). *Psychometric theory* (2nd ed.). New York.

Oda, S., & Shirakawa, K. (2014). Sleep onset is disrupted following pre-sleep exercise that causes large physiological excitement at bedtime. *European Journal of Applied Physiology*, *114*, 1789–1799. https://doi.org/10.1007/s00421-014-2873-2

Parasuraman, R. (1986). Vigilance, monitoring, and search. In K. R. Boff, L. Kaufman, & J. P. Thomas (Eds.), *Handbook of perception and human performance, Vol. 2. Cognitive processes and performance* (pp. 1–39). John Wiley & Sons.

Parker, S. K. (2014). Beyond motivation: Job and work design for development, health, ambidexterity, and more. *Annual Review of Psychology, 65*, 661–691. https://doi.org/10.1146/annurev-psych-010213-115208

Parker, S. K., & Grote, G. (2020). Automation, algorithms, and beyond: Why work design matters more than ever in a digital world. *Applied Psychology*. https://doi.org/10.1111/apps.12241

Parker, S. K., & Jorritsma, K. (2020). Good work design for all: Multiple pathways to making a difference. *European Journal of Work and Organizational Psychology*, 1–13. https://doi.org/10.1080/1359432X.2020.1860121

Parker, S. K., Morgeson, F. P., & Johns, G. (2017). One hundred years of work design research: Looking back and looking forward. *Journal of Applied Psychology*, *102*(3), 403–420. https://doi.org/10.1037/apl0000106

Parkes, K. R. (2017). Work environment, overtime and sleep among offshore personnel. *Accident Analysis and Prevention*, *99* (Part B), 383–388. https://doi.org/10.1016/j.aap.2015.11.022

Perrewe, P. L., & Ganster, D. C. (1989). The impact of job demands and behavioral control on experienced job stress stable. Journal of Organizational Behaviour, 10(3), 213–229. https:// doi.org/10.1002/job.4030100303

Perrow, C. (1999). Organizing to reduce the vulnerabilities of complexity. *Journal of Contingencies and Crisis Management*, *7*(3), 150–155.

https://doi.org/10.1111/1468-5973.00108

Piasna, A. (2015). “Thou shalt work hard”: Fragmented working hours and work intensification across the EU. *Forum Socjologiczne*, *1*, 77–89.

Podsakoff, P. M., MacKenzie, S. B., Lee, J. Y., & Podsakoff, N. P. (2003). Common method biases in behavioral research: A critical review of the literature and recommended remedies. *Journal of Applied Psychology*, *88*(5), 879–903. https://doi.org/10.1037/0021-9010.88.5.879

Posner, J., Russel, J. A., & Peterson, B. S. (2005). The circumplex model of affect: An integrative approach to affective neuroscience, cognitive development, and psychopathology. *Development Psychopathology*, *17*(3), 715–734. https://doi.org/10.1017/S0954579405050340

Querstet, D., Cropley, M., & Fife-Schaw, C. (2017). Internet-based instructor-led mindfulness for work-related rumination, fatigue, and sleep: Assessing facets of mindfulness as mechanisms of change. A randomized waitlist control trial. *Journal of Occupational Health Psychology*, *22*(2), 153–169. https://doi.org/10.1037/ocp0000028

Querstret, D., & Cropley, M. (2012). Exploring the relationship between work-related rumination , sleep quality and work-related fatigue . *Journal of Occupational Health Psychology*, *17*(3), 341–353. https://doi.org/10.1037/a0028552

R Core Team. (2021). R: A Language and Environment for Statistical Computing (4.0.4). https://www.r-project.org

Rau, R., & Triemer, A. (2004). Overtime in relation to blood pressure and mood during work, leisure, and night time. *Social Indicators Research*, *67*, 51–73. https://doi.org/10.1023/B:SOCI.0000007334.20490.52

Riedl, E. M., & Thomas, J. (2019). The moderating role of work pressure on the relationships between emotional demands and tension, exhaustion, and work engagement: an experience sampling study among nurses. *European Journal of Work and Organizational Psychology*, *28*(3), 414–429. https://doi.org/10.1080/1359432X.2019.1588251

Riethmeister, V., Bültmann, U., De Boer, M. R., Gordijn, M., & Brouwer, S. (2018).

Examining courses of sleep quality and sleepiness in full 2 weeks on/2 weeks off offshore day shift rotations. *Chronobiology International*, *35*(6), 759–772. https://doi.org/10.1080/07420528.2018.1466794

Riethmeister, V., Matthews, R. W., Dawson, D., de Boer, M. R., Brouwer, S., & Bültmann, U. (2019). Time-of-day and days-on-shift predict increased fatigue over two-week offshore day-shifts. *Applied Ergonomics*, *78,* 157–163. https://doi.org/10.1016/j.apergo.2019.02.010

Roe, R. A. (2008). Time in applied psychology: The study of “what happens” rather than “what is.” *European Psychologist*, *13*(1), 37–52. https://doi.org/10.1027/1016-9040.13.1.37

Roe, R. A. (2014). Time, performance, and motivation. In Cooper C. (Eds.), *Current Issues in Work and Organizational Psychology* (pp. 87–123). Routledge, London. https://doi.org/10.4324/9780429468339

Rogers, W. P., Kahraman, M. M., Drews, F. A., Powell, K., Haight, J. M., Wang, Y., Baxla, K., & Sobalkar, M. (2019). Automation in the mining industry: Review of technology, systems, human factors, and political risk. *Mining, Metallurgy and Exploration*, *36*(4), 607–631. https://doi.org/10.1007/s42461-019-0094-2

Rook, J. W., & Zijlstra, F. R. H. (2006). The contribution of various types of activities to recovery. *European Journal of Work and Organizational Psychology*, *15*(2), 218–240. https://doi.org/10.1080/13594320500513962

Rosen, C. C., Dimotakis, N., Cole, M. S., Taylor, S. G., Simon, L. S., Smith, T. A., & Reina, C. S. (2020). When challenges hinder: An investigation of when and how challenge stressors impact employee outcomes. *Journal of Applied Psychology*, *105*(10), 1181–1206. https://doi.org/10.1037/apl0000483

Rousseau, D. M., & Fried, Y. 2001. Location, location, location: Contextualizing organizational research. *Journal of Organizational Behavior*, *22*(1): 1-13. https://www.jstor.org/stable/3649603

Sagherian, K., & Geiger Brown, J. (2016). In-depth review of five fatigue measures in shift workers. *Fatigue: Biomedicine, Health & Behavior*, *4*(1), 24–38. https://doi.org/10.1080/21641846.2015.1124521

References

Salas, E., & Oglesby, J. M. (2012). The issue of monotony and low workload in spaceflight: Considerations for the mission to mars. *Proceedings of the Human Factors and Ergonomics Society Annual Meeting, 56*(1), 1782–1786. https://doi.org/10.1177/1071181312561358

Salas, E., Tannenbaum, S. I., Kozlowski, S. W. J., Miller, C. A., Mathieu, J. E., & Vessey, W. B. (2015). Teams in space exploration: A new frontier for the science of team effectiveness. *Current Directions in Psychological Science, 24*(3), 200–207. https://doi.org/10.1177/0963721414566448

Sandal, G. M., Leon, G. R., & Palinkas, L. (2006). Human challenges in polar and space environments. Life in Extreme Environments. *Reviews in Environmental Science and Biotechnology, 5*(2-3), 399–414. https://doi.org/ 10.1007/s11157-006-9000-8

Saxby, D. J., Matthews, G., Warm, J. S., Hitchcock, E. M., & Neubauer, C. (2013). Active and passive fatigue in simulated driving: Discriminating styles of workload regulation and their safety impacts. *Journal of Experimental Psychology: Applied, 19*(4), 287–300. https://doi.org/doi:10.1037/a0034386

Schaufeli, W. B., & Bakker, A. B. (2004). Job demands, job resources, and their relationship with burnout and engagement: A multi-sample study. *Journal of Organizational Behavior*, *25*(3), 293–315. https://doi.org/10.1002/job.248

Schaufeli, W. B., & Taris, T. W. (2014). A critical review of the job demands-resources model: Implications for improving work and health. In G. F. Bauer & O. Hämmig (Eds.), *Bridging occupational, organizational andpPublic health: A transdisciplinary approach* (pp. 43–68). Springer Science + Business Media. https://doi.org/10.1007/978-94-007-5640-3

Schwarz, G., & Stensaker, I. (2014). Time to take off the theoretical straightjacket and (re-) introduce phenomenon-driven research. *The Journal of Applied Behavioral Science*, *50*(4), 478-501.

Searle, B. J. (2012). Detachment From work in airport hotels. *Aviation Psychology and Applied Human Factors, 2*(1), 20–24. https://doi.org/10.1027/2192-0923/a000019

Selye, H. (1955). Stress and Disease. *Science, 122*(3171), 625–631.

https://www.jstor.org/stable/1749664

Shattuck, N. L., & Matsangas, P. (2017). Sunlight exposure, work hours, caffeine consumption, and sleep duration in the naval environment. *Aerospace Medicine and Human Performance*, *88*(6), 579–585. https://doi.org/10.3357/AMHP.4721.2017

Shattuck, L. G., & Miller, N. L. (2006). Extending naturalistic decision making to complex organizations: A dynamic model of situated cognition. *Organization Studies*, *27*(7), 989-1009. https://doi.org/10.1177/0170840606065706

Miller, N. L., Shattuck, L. G., & Matsangas, P. (2011). Sleep and fatigue issues in continuous operations: A survey of U.S. Army officers. *Behavioral Sleep Medicine*, *9*(1), 53–65. https://doi.org/10.1080/15402002.2011.533994

Shay, J. (1998). Ethical standing for commander self-care: the need for sleep. *Parameters*, 1–10. https://press.armywarcollege.edu/cgi/viewcontent.cgi?article=1882&context=parameters

Shipp, A. J., & Cole, M. S. (2015). Time in individual-level organizational studies: What is it, how is it used, and why isn’t it exploited more often? *Annual Review of Organizational Psychology and Organizational Behavior*, *2*, 237–260. https://doi.org/10.1146/annurev-orgpsych-032414-111245

Shultz, K. S., Wang, M., & Olson, D. A. (2010). Role overload and underload in relation to occupational stress and health. *Stress and Health*, *26*(2), 99–111. https://doi.org/10.1002/smi.1268

Siemsen, E., Roth, A., & Oliveira, P. (2010). Common method bias in regression models with linear, quadratic, and interaction effects. *Organizational Research Methods*, *13*(3), 456–476. https://doi.org/10.1177/1094428109351241

Simbula, S. (2010). Daily fluctuations in teachers’ well-being: A diary study using the job demands-resources model. *Anxiety, Stress and Coping*, *23*(5), 563–584. https://doi.org/10.1080/10615801003728273

Sjostrom, M., Friden, J., & Ekblom, B. (1987). Endurance, what is it? Muscle morphology after an extremely long distance run. *Acta Physiologica*

Scandinavica, *130*(3), 513–520. https://doi.org/10.1111/j.1748-1716.1987.tb08170.x

Sonnentag, S, & Frese, M. (2012). Dynamic performance. In S. W. J. Kozlowski (Ed.), *The Oxford Handbook of Industrial and Organizational Psychology (Vol. 1)* (pp. 548–575). Oxford University Press. https://doi.org/10.1093/oxfordhb/9780199928309.013.0017

Sonnentag, S, & Fritz, C. (2015). Recovery from job stress : The stressor-detachment model as an integrative framework. *Journal of Organizational Behaviour*, *36*(S1), 72–103. https://doi.org/10.1002/job.1924

Sonnentag, S, Arbeus, H., Mahn, C., & Fritz, C. (2014). Exhaustion and lack of psychological detachment from work during off-job time: Moderator effects of time pressure and leisure experiences. *Journal of Occupational Health Psychology*, *19*(2), 206–216. https://doi.org/10.1037/a0035760

Sonnentag, S. (2001). Work, recovery activities, and individual well-being: A diary study. *Journal of Occupational Health Psychology*, *6*(3), 196–210. https://doi.org/10.1037/1076-8998.6.3.196

Sonnentag, S. (2018). The recovery paradox: Portraying the complex interplay between job stressors, lack of recovery, and poor well-being. *Research in Organizational Behavio*r, *38*, 169–185. https://doi.org/10.1016/j.riob.2018.11.002

Sonnentag, S., & Fritz, C. (2007). The recovery experience questionnaire: Development and validation of a measure for assessing recuperation and unwinding from work. *Journal of Occupational Health Psychology*, *12*(3), 204–221. https://doi.org/10.1037/1076-8998.12.3.204

Sonnentag, S., Arbeus, H., Mahn, C., & Fritz, C. (2014). Exhaustion and lack of psychological detachment from work during off-job time: Moderator effects of time pressure and leisure experiences. *Journal of Occupational Health Psychology*, *19*(2), 206–216. https://doi.org/10.1037/a0035760

Sonnentag, S., Binnewies, C., & Moj, E. J. (2011). Staying well and engaged When demands Are high : The role of psychological detachment. *Journal of Applied Psychology, 95*(5), 965–976. https://doi.org/10.1037/a0020032

Sonnentag, S., Kuttler, I., & Fritz, C. (2010). Job stressors, emotional exhaustion, and need for recovery : A multi-source study on the benefits of psychological detachment. *Journal of Vocational Behavior, 76*(3), 355–365. https://doi.org/10.1016/j.jvb.2009.06.005

Sonnentag, Sabine, Venz, L., & Casper, A. (2017). Advances in recovery research: What have we learned? What should be done next? *Journal of Occupational Health Psychology*, *22*(3), 365–380. https://doi.org/10.1037/ocp0000079

Stachowski, A. A., Kaplan, S. A., & Waller, M. J. (2009). The Benefits of Flexible Team Interaction During Crises. *Journal of Applied Psychology*, *94*(6), 1536–1543. https://doi.org/10.1037/a0016903

Stanton, N. A., & Roberts, A. P. J. (2018). Social network analysis in submarine command and control. In R. Charles & J. Wilkinson (Eds.), *Contemporary Ergonomics and Human Factors.* Chartered Institute of Ergonomics & Human Factors. https://publications.ergonomics.org.uk/uploads/Social-network-analysis-in-submarine-command-and-control.pdf

Stanton, N. A., & Young, M. S. (1998). Vehicle automation and driving performance. *Ergonomics*, *41*(7), 1014–1028. https://doi.org/10.1080/001401398186568

Stuster, J. W. (2010). *Behavioral Issues Associated with Long- Duration Space Expeditions: Review and Analysis of Astronaut Journals Experiment 01-E104 (Journals): Final Report*. NASA Johnson Space Centre. Houston, TX.

Suedfeld, P., & Steel, G. D. (2000). The environmental psychology of capsule habitats. *Annual Review of Psychology*, *51*, 227–253. https://doi.org/ 10.1146/annurev.psych.51.1.227

Syrek, C. J., & Antoni, C. H. (2014). Unfinished tasks foster rumination and impair sleeping - Particularly if leaders have high performance expectations. *Journal of Occupational Health Psychology*, *19*(4), 490–499. https://doi.org/10.1037/a0037127

Tabachnick, B. G., & Fidell, L. S. (2007). *Experimental designs using ANOVA.* Thomson/Brooks/Cole. Belmon, CA

Taris, T. W. (2006). Is there a relationship between burnout and objective performance? A critical review of 16 studies. *Work and Stress*, *20*(4), 316–334. https://doi.org/10.1080/02678370601065893

Tassi, P., & Muzet, A. (2000). Sleep inertia. *Sleep Medicine Reviews*, *4*(4), 341–353. https://doi.org/10.1053/smrv.2000.0098

Teichner, W. H. (1968). Interaction of behavioral and physiological stress reactions. *Psychological Review*, *75*(4), 271–291. https://doi.org/10.1037/h0020281

Thomson, D. R., Besner, D., & Smilek, D. (2015). A Resource-Control Account of Sustained Attention: Evidence From Mind-Wandering and Vigilance Paradigms . *Perspectives on Psychological Science*, *10*(1), 82–96. https://doi.org/10.1177/1745691614556681

Turgo, N. (2020). Temporalities at sea: Fast time and slow time onboard ocean-going merchant vessels. *Ethnography*, 1–23. https://doi.org/10.1177/1466138120923371

Urban, M. (2012). Task force black: The explosive true story of the secret special forces war in Iraq. *Small Wars & Insurgencies*, *23*(2), 376–377. https://doi.org/10.1080/09592318.2012.642199

Van de Schoot, R., Kaplan, D., Denissen, J., Asendorpf, J. B., Neyer, F. J., & van Aken, M. A. G. (2014). A Gentle Introduction to Bayesian Analysis: Applications to Developmental Research. *Child Development*, *85*(3), 842–860. https://doi.org/10.1111/cdev.12169

van den Broeck, A., de Cuyper, N., de Witte, H., & Vansteenkiste, M. (2010). Not all job demands are equal: Differentiating job hindrances and job challenges in the job demands-resources model. *European Journal of Work and Organizational Psychology*, *19*(6), 735–759. https://doi.org/10.1080/13594320903223839

van Dijk, F. J. H., & Swaen, G. M. H. (2003). Fatigue at work. *Occupational and Environmental Medicine*, *60*(90001), i1–i2. https://doi.org/10.1136/oem.60.suppl_1.i1

van Hooft, E. A. J., & van Hooff, M. L. M. (2018). The state of boredom: Frustrating or depressing? *Motivation and Emotion*, *42*(6), 931–946. https://doi.org/10.1007/s11031-018-9710-6

Van Thielen, T, Decramer, A, Vanderstraeten, A, Audenaert, M. When does performance management foster team effectiveness? A mixed-method field study on the influence of environmental extremity. *Journal of Organizational Behavior, 39*(6), 766– 782. https://doi.org/10.1002/job.2297

van Woerkom, M., Bakker, A. B., & Nishii, L. H. (2016). Accumulative job demands and support for strength use: Fine-tuning the JD-R model using COR theory. *Journal of Applied Psychology, 101*(1), 141–150. http://dx.doi.org/10.1037/apl0000033

Veldhoven, M., & Meijman, T. (1994). *Het meten van psychosociale arbeidsbelasting met een vragenlijst: de vragenlijst beleving en beoordeling van de arbeid (VBBA)*. Nederlands Instituut Voor Arbeidsomstandigheden (NIA).

Vodanovich, S. J., & Verner, K. M. (1991). Boredom Proneness: Its relationship to positive and negative affect. *Psychological Reports*, *69*(3_suppl), 1139–1146. https://doi.org/ 10.2466/pr0.1991.69.3f.1139

Warm, J. S., Parasuraman, R., & Matthews, G. (2008). Vigilance requires hard mental work and Is stressful. Human Factors: *The Journal of the Human Factors and Ergonomics Society*, *50*(3), 433–441. https://doi.org/10.1518/001872008X312152

Watson, N. F., Badr, M. S., Belenky, G., Bliwise, D. L., Buxton, O. M., Buysse, D., Dinges, D. F., Gangwisch, J., Grandner, M. A., Kushida, C., Malhotra, R. K., Martin, J. L., Patel, S. R., Quan, S. F., Tasali, E., Twery, M., Croft, J. B., Maher, E., Barrett, J. A., … Heald, J. L. (2015). Joint consensus statement of the american academy of sleep medicine and sleep research society on the recommended amount of sleep for a healthy adult: Methodology and discussion. *Journal of Clinical Sleep Medicine*, *11*(8), 931–952. https://doi.org/10.5664/jcsm.4950

Weinger, M. . (1990). Ergonomic and human factors affecting anesthetic vigilance and monitoring performance in the operating room environment. *Anesthesiology*, *73*(5), 995–1021. https://doi.org/10.1097/00000542-199011000-00030

Weybrew, B. B. (1971). *Submarine crew effectiveness during submerged missions of* *sixty or more days' duration*. Naval Submarine Medical Research Lab, Groton CT. https://apps.dtic.mil/sti/pdfs/AD0740796.pdf

Wickens, C. D., & Huey, B. M. (1993). *Workload transition: Implications for Individual and team performance*. National Academies Press. http://www.nap.edu/catalog/2045.html

Wickens, C. D., Keller, J. W., & Shaw, C. (2015). Human Factors in High-Altitude Mountaineering. *Journal of Human Performance in Extreme Environments, 12*(1), 5–8. https://doi.org/10.7771/2327-2937.1065

Widmer, P. S., Semmer, N. K., Kälin, W., Jacobshagen, N., & Meier, L. L. (2012). The ambivalence of challenge stressors: Time pressure associated with both negative and positive well-being. *Journal of Vocational Behavior*, *80*(2), 422–433. https://doi.org/10.1016/j.jvb.2011.09.006

Williams, K. J., & Alliger, G. M. (1994). Roles stressors, mood spillover, and perceptions of work–family conflict in employed parents. *Academy of Management Journal*, *37*(4), 837–868. doi:10.2307/256602

Wilson, M. D., Ballard, T., Strickland, L., Boeing, A. A., Cham, B. S., Griffin, M. A., & Jorritsma, K. (2021). Understanding Fatigue in a Naval Submarine: Applying Biomathematical Models and Workload Measurement in an Experience Sampling Design. *Applied Ergonomics*, *94*, 103412 https://doi.org/10.1016/j.apergo.2021.103412

Wilson, M. D., Strickland, L., & Ballard, T. (2020). FIPS: An R package for biomathematical modelling of human fatigue related impairment. *Journal of Open Source Software*, *5*(51), 2340. https://doi.org/10.21105/joss.02340

Winwood, P. C., Bakker, A. B., & Winefield, A. H. (2007). An investigation of the role of non-work-time behavior in buffering the effects of work strain. *Journal of Occupational and Environmental Medicine*, *49*(8), 862–871. https://doi.org/10.1097/JOM.0b013e318124a8dc

Winwood, P. C., Winefield, A. H., Dawson, D., & Lushington, K. (2005). Development and validation of a scale to measure work-related fatigue and recovery: The occupational fatigue exhaustion/recovery scale (OFER). *Journal of Occupational and Environmental Medicine*, *47*(6), 594–606.

https://doi.org/10.1097/01.jom.0000161740.71049.c4

Wolff, W., & Martarelli, C. S. (2020). Bored into depletion? Toward a tentative integration of perceived self-control exertion and boredom as guiding signals for goal-directed behavior. *Perspectives on Psychological Science, 15*(5), 1272-1283. https://doi.org/10.1177/1745691620921394

Wright, K. P., Hull, J. T., & Czeisler, C. A. (2002). Relationship between alertness, performance, and body temperature in humans. *American Journal of Physiology - Regulatory Integrative and Comparative Physiology*, *283*(6), 1370–1377. https://doi.org/10.1152/ajpregu.00205.2002

Wright, K. P., McHill, A. W., Birks, B. R., Griffin, B. R., Rusterholz, T., & Chinoy, E. D. (2013). Entrainment of the human circadian clock to the natural light-dark cycle. *Current Biology*, *23*(16), 1554–1558. https://doi.org/10.1016/j.cub.2013.06.039

Xanthopoulou, D., Bakker, A. B., Dollard, M. F., Demerouti, E., Schaufeli, W. B., Taris, T. W., & Schreurs, P. J. G. (2007). When do job demands particularly predict burnout? *Journal of Managerial Psychology, 22*(8), 766–786. https://doi.org/10.1108/02683940710837714

Young, M. S., & Stanton, N. A. (2002). Attention and automation: New perspectives on mental underload and performance. *Theoretical Issues in Ergonomics Science, 3*(2), 178–194. https://doi.org/10.1080/14639220210123789

Young, M. S., & Stanton, N. A. (2002). Malleable attentional resources theory: A new explanation for the effects of mental underload on performance. *Human Factors*, *44*(3), 365–375. https://doi.org/10.1518/0018720024497709

Young, M. S., Brookhuis, K. A., Wickens, C. D., & Hancock, P. A. (2015). State of science: mental workload in ergonomics. *Ergonomics*, *58*(1), 1–17. https://doi.org/10.1080/00140139.2014.956151

Zaccaro, S. J., Heinen, B., & Shuffler, M. (2009). Team leadership and team effectiveness. In E. Salas, G. F. Goodwin, & C. S. Burke (Eds.), *Team effectiveness in complex organizations: Cross-disciplinary perspectives and approaches* (pp. 83–112). Psychology Press.

Zacher, H., Brailsford, H. A., & Parker, S. L. (2014). Micro-breaks matter: A diary study on the effects of energy management strategies on occupational well-being. *Journal of Vocational Behavior*, *85*(3), 287–297. https://doi.org/10.1016/j.jvb.2014.08.005

Zapf, D., Dormann, C., & Frese, M. (1996). Longitudinal studies in organizational stress research: A review of the literature with reference to methodological issues. *Journal of Occupational Health Psychology*, *1*(2), 145–169. https://doi.org/10.1037/1076-8998.1.2.145

Zhou, L., Wang, M., & Zhang, Z. (2019). Intensive longitudinal data analyses with dynamic structural equation modeling. *Organizational Research Methods*, 24(2), 1–32. https://doi.org/10.1177/1094428119833164

Zijlstra, F. R. H., & Rook, J. W. (2016). The weekly cycle of work and rest : A diary study. In R. A. Roe, M. J. Waller & S. R. Clegg (Eds.), *Time in Organisational Research*. London: Routledge

Zijlstra, F. R. H., & Sonnentag, S. (2006). After work is done: Psychological perspectives on recovery from work. *European Journal of Work and Organizational Psychology*, *15*(2), 129–138. https://doi.org/10.1080/13594320500513855

Zijlstra, F. R. H., Cropley, M., & Rydstedt, L. W. (2014). From recovery to regulation : An attempt to reconceptualize ‘ recovery from work .’ *Stress and Health*, *30*(3), 244–252. https://doi.org/10.1002/smi.2604

Zohar, D. (1999). When things go wrong: The effect of daily work hassles on effort, exertion and negative mood. Jour*nal of Occupational and Organizational Psychology*, *72*(3), 265–283. https://doi.org/10.1348/096317999166671

Zohar, D., Epstein, R., & Tzischinski, O. (2003). Effects of Energy Availability on Immediate and Delayed Emotional Reactions to Work Events. *Journal of Applied Psychology*, *88*(6), 1082–1093. https://doi.org/10.1037/0021-9010.88.6.1082