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The Requirements for New Tools for Use by Pilots and the Aviation Industry to Manage Risks Pertaining to Work-Related Stress (WRS) and Wellbeing, and the Ensuing Impact on Performance and Safety

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Abstract: Work is part of our wellbeing and a key driver of a person's health. Pilots need to be fit for duty and aware of risks that compromise their health/wellbeing. Recent studies suggest that work-related stress (WRS) impacts on pilot health and wellbeing, performance, and flight safety. This paper reports on the advancement of new tools for pilots and airlines to support the management of WRS and wellbeing. This follows from five phases of stakeholder evaluation research and analysis. Existing pre-flight checklists should be extended to enable the crew to evaluate their health and wellbeing. New checklists might be developed for use by pilots while off duty supporting an assessment of (1) their biopsychosocial health status and (2) how they are coping. This involves the advancement of phone apps with different wellness functions. Pending pilot consent, data captured in these tools might be shared in a de-identified format with the pilot's airline. Existing airline safety management systems (SMS) and flight rostering/planning systems might be augmented to make use of this data from an operational and risk/safety management perspective. Fatigue risk management systems (and by implication airline rostering/flight planning systems) need to be extended to consider the relationship between fatigue risk and the other dimensions of a pilot's wellbeing. Further, pending permission, pilot data might be shared with airline employee assistance program (EAP) personnel and aeromedical examiners. In addition, new training formats should be devised to support pilot coping skills. The proposed tools can support the management of WRS and wellbeing. In turn, this will support performance and safety. The pilot specific tools will enable the practice of healthy behaviors, which in turn strengthens a pilot's resistance to stress. Healthy work relates to the creation of positive wellbeing within workplaces and workforces and has significant societal implications. Pilots face many occupational hazards that are part of their jobs. Pilots, the aviation industry, and society should recognize and support the many activities that contribute to positive wellbeing for pilots. Social justice is a basic premise for quality of employment and quality of life.

Keywords: mobile technologies; behavior change; healthy behavior; work-related stress (WRS); health monitoring; pilot wellbeing; pilot mental health; stress coping; self-management of health; flight safety; resilience; privacy; COVID

1. Introduction

1.1. Introduction to the Problem

As suggested in the 'triple bottom line' accounting framework, human activity (including work) should not compromise the long-term balance between the economic, environmental, and social pillars [1–3]. Further, as defined by the tripartite labor collaboration [4] and 'responsible work' concepts, work should be designed to benefit all stakeholders. This includes employers, employees, and society. This follows from the argument that social justice is a basic premise for quality of employment and quality of life and associated concepts such as 'corporate social responsibility' (CSR), 'decent work' [5] and tripartism [6].

Commercial aviation is a 24/7 business. Pilots' anti-social working hours and continuously changing schedules present barriers to maintaining 'healthy lifestyle' routines and accessing help if needed. The airline industry and public expectations (flight scheduling and ticket prices) have changed dramatically in the last 15 years. The effects of these changes on the health and well-being of pilots, along with pilot performance and flight safety, is only recently being understood and documented.

Like other remote and shift workers, pilots experience many physical, emotional, and environmental stressors [7]. Recent research indicates that given the demands of the job (i.e., anti-social work hours, disturbed sleeping patterns/fatigue, etc.) and nature of the work (i.e., sedentary work, with little or physical activity, mix of high and low stress periods, isolation), pilots are potentially more at risk for developing mental health issues [7].

Pilots need to be fit for duty and aware of risks that compromise their health/wellbeing, performance, and flight safety. Pilot wellbeing influences the nature and quality of their relationships with others, thereby influencing the wellbeing of those around them. This spans a pilot's family, friends, and work colleagues (including their fellow co-pilot while on duty). Further, pilot wellbeing impacts on human performance (i.e., awareness, decision making, and concentration) both inside and outside work. Importantly, how pilots perform as aviation professionals impacts on flight safety [8].

Since the Germanwings 9525 accident in 2015, the question of pilot mental health and managing mental health issues amongst pilots has been gaining increased attention. In 2019, the European Aviation Safety Agency (EASA) introduced new rules pertaining to the management and assessment of pilot mental health [9]. Specifically, the rules follow from the EASA-led Germanwings Task Force on the accident of the Germanwings Flight 9525 and the related safety recommendations issued by the Bureau d'Enquêtes et d'Analyses pour la Sécurité de l'Aviation Civile (BEA) [10]. The new regulations pertain to three key areas: psychological evaluation of pilots before they start the job, access to peer support, and random substance abuse testing [9]. European airlines will be required to demonstrate compliance with these rules by July 2020 [11]. To support the implementation of the new rules, EASA has prepared draft guidance material (so-called Acceptable Means of Compliance and Guidance Material—AMC/GM) [12]. Many in the industry feel that these recommendations do not go far enough. In the effort to prevent another Germanwings tragedy, there has been insufficient attention on the promotion of positive wellbeing and coping [7]. Arguably, a more holistic and preventative approach to promoting positive wellbeing [7,11], along with peer support services [13–15], is required.

Recent research investigating the use of stress coping behaviors in pilots found that nearly 60% of the pilots were using coping mechanisms to manage work-related stress (WRS) and its impact on wellbeing [7,8,16]. The use of certain coping mechanisms such as sleep management and taking physical exercise were found to be associated with lower depression severity levels [16]. This research points to the need to develop tools to better manage WRS, wellbeing, and the home-work interface. Further, it indicates that a new definition of safety behavior for pilots is required, managing the home/work interface and fostering resilience.

More recently, the EASA and aviation groups such as the Royal Aeronautical Society (RAeS) and the Flight Safety Foundation (FSF) have advocated for the practice of healthy behaviors to promote positive wellbeing, while also preventing ill health, spanning all three pillars of wellbeing

[17]. Through the Together4Safety safety promotion initiative, led by the EASA, stakeholders have been collaborating to promote a common safety agenda that is mindful of the diverse stakeholder goals, needs, and challenges [18].

The recent COVID-19 outbreak has put increased stress on pilots and airlines. The airline industry has experienced a decrease in capacity of roughly 60–80% at major carriers [19]. Many pilots have lost their jobs and/or are on extended leave, which presents some new challenges [20]. Now, more than ever, there is a need to advance tools to support pilot coping and resilience. Pilots will need to be 'cleared for take-off' on returning to work [15]. This will require self-awareness, acceptance, and developing new routines and behaviors that enable and foster resilience.

This paper reports on a new tool framework and associated tools concepts supporting the management of wellbeing and WRS issues for pilots at different levels (i.e., pilots, airline and aviation industry, and society). Specifically, it focuses on the requirements for new checklists and digital tools for use by pilots both in and outside work and how these might relate to tools used by other stakeholders (for example, airline staff involved in flight planning, crew rostering and safety/risk assessment, and aeromedical examiners), linking to wider operational and safety management processes. This research follows from several phases of human factors research, involving deep participation with pilots and industry stakeholders. This research has been structured into five parts. Aspects of the first two parts of this research have been reported in earlier papers. This includes a subset of the pilot wellbeing behavior model (i.e., preliminary lived experience model and impact scenarios) [7,8] and the high-level requirements for new tools supporting pilot wellbeing management at both pilot and airline levels [7]. Accordingly, this paper reports on the outcomes of the latter three parts (i.e., parts 3, 4, and 5). First, the theoretical background to this study is presented. Following this, an overview of pilot wellbeing, coping strategies, airline approaches to performance/safety management, existing tools, and the COVID-19 context is presented. The methodological framework for this study along with the research methodology is then outlined. This is followed by an overview of research results. This includes results in terms of problem framing, the pilot wellbeing behavior model, sources of WRS associated with COVID, the three operational scenarios defined by the Flight Safety Foundation (FSF), the proposed tool framework (hereafter referred to as tool 1, 2, 3, 4, and 5), the specific requirements and prototype concepts associated with Tool 1 and 2, and issues pertaining to data protection and pilot safeguards. The results are then discussed and some conclusions drawn.

1.2. Theoretical Background

1.2.1. Wellbeing

As proposed in Engel's 'biopsychosocial' model of health and wellbeing, a combination of physical, psychological, and social factors (including working conditions) contribute to a person's health and wellbeing [21]. Certain lifestyle factors have direct and well understood influences on each of the three pillars of wellbeing as defined in the 'biopsychosocial model' [21]. Physical health is very much affected by diet, physical activity, and sleep. Our behavior, attitudes, stress management and coping techniques have a profound impact on our mental health. Lastly, social health is very much affected by our support networks including the quality of our relationships with family, friends, and work colleagues.

Some argue that the biopsychosocial model leads to eclecticism [22], while others argue that it does not sufficiently deal with 'complexity theory' [23]. More recently, the social aspect of Engel's model has been expanded to include ideas related to spirituality and the arts/culture and an understanding of health as a dynamic system [24].

1.2.2. Stress and Work-Related Stress (WRS)

Stress is mental or emotional strain and tension resulting from adverse or demanding circumstances, which creates physical and psychological/emotional imbalances within a person [25–27]. Stressors refer to any activity, event, or other stimulus that causes stress. These can be internal

(cognitive or physical) or external (environmental) to the individual [28]. Personal stressors include issues or events outside the workplace, like family problems, health challenges, or financial issues, that can contribute to stress. Although stress is a state and not an illness, prolonged or excessive stress can lead to mental and physical health conditions [29].

1.2.3. Work-Related Stress (WRS)

Work-related stress (WRS) is the negative response people have to excessive pressures or other types of demands placed on them at work. Typically, such demands do not fit the person's capabilities (i.e., knowledge and abilities) and challenges their ability to cope [30]. WRS can be worsened by personal stressors. As proposed in the 'job strain model', the highest stress and stress-related health problems will occur for jobs with high demands and low decision latitude [31].

1.2.4. Stress Coping Styles and Strategies

The development of stress-coping skills and the routine practice of stress-coping strategies are necessary for high stress occupations. Coping strategies involve behavioral and psychological efforts that individuals use to overcome, accept, reduce, and/or minimize internal and external stressors [32].

People react differently when exposed to a stressor. The way in which a person appraises the situation (i.e., the level of threat associated with the stressor and their ability to cope with it) impacts on the type of stress experienced [33].

The literature distinguishes active and avoidant coping methods. Active methods are used to alter the nature of the stressor and/or to change a person's perception of it. Two types of active strategies are distinguished. This includes problem-solving and emotion-focused methods. The type of stressor and coping style of the individual has an influence on which of these two methods is used [32]. Avoidant strategies involve the practice of unhealthy behaviors (such as alcohol use or binge eating) or various defense mechanisms (for example weeping or denial), without confronting the actual stressors [32].

Therapeutic interventions focus on replacing avoidant and/or maladaptive coping behaviors with active and/or adaptive coping behaviors [34]. Typical strategies include physical exercise, the practice of relaxation techniques, seeking social support and/or social participation, and engaging in hobbies, creative/arts activities, and spiritual practices.

1.2.5. Mental Health

Mental health (MH) is part of our health and wellbeing. The World Health Organisation (WHO) defines mental health as 'a state of well-being in which every individual realizes his or her own potential, can cope with the normal stresses of life, can work productively and fruitfully, and is able to make a contribution to her or his community' [35].

1.2.6. Management of Mental Health Problems

A variety of therapeutic frameworks and approaches have been proposed in relation to managing mental ill health [36–38]. The National Institute for Health and Clinical Excellence (NICE) recommends the 'Stepped Care Model' [39]. Stepped care is a five-step system of delivering and monitoring treatments for people with depression and anxiety disorders. The most effective and least resource intensive treatment is first provided to the patient. Acritical component of this is the benefit of in person/face to face support for those experiencing serious difficulties (i.e., beyond self-management).

1.2.7. Mental Wellbeing at Work

Mental wellbeing at work is determined by the interaction between the working environment, the nature of the work, and the individual [40]. Work has an important role in promoting psychological wellbeing. However, it can also have negative effects on mental wellbeing, leading to stress [40].

1.2.8. Stress and Wellbeing Management in the Workplace

'Stress management initiatives' (SMI) and 'workplace wellbeing programs' (WWP) address health and wellbeing in the workplace, including the management of stress, the promotion of psychological wellbeing, and strategies to bolster human resilience. SMIs focus on restoring employee health and wellbeing in cases where resources have already been depleted [41]. Wellness programs are more preventive, focusing on behavior change and the practice of healthy behaviors to manage wellbeing and the home/work interface. From a strategic perspective, both SMI and WWP attempt to reduce the costs associated with lack of employee engagement, employee healthcare, and sick-leave absences [41].

Interventions can be classified into three types: person-directed, person-work interface, and organizational interventions [42]. Some argue that workplace wellness and stress management initiatives should go beyond employee training and the provision of support at individual and group levels to include both work reorganization (i.e., task design, communication systems, and technology support) and the external socio-economic environment [43].

A recent systematic review provides an alternative classification of interventions [44]. These are educational interventions, multicomponent interventions, counselling interventions, physical activity interventions, and organizational interventions. Overall, there is mixed evidence in relation to the success of workplace wellness programs [44,45].

1.2.9. Resilience and Self-Efficacy

In Aristotelian ethics, the concept 'eudaimonia' refers to the condition of human flourishing or 'living well' [46]. This concept is taken up in 'positive psychology' frameworks. For example, Seligman draws attention to enabling the positive aspects of the human experience that make life worth living and developing resilience [47].

Resilience is defined as the 'demonstration of positive adaptation in the face of significant adversity' [48]. It is a response to stressful circumstances, as opposed to a trait or capacity residing in the person [48].

Self-efficacy is defined as a 'person's belief that they can succeed in a specific situation' [49]. One's sense of self-efficacy can play a major role in how one approaches goals and challenges. Research indicates that a high level of self-efficacy can help employees cope more effectively with WRS [50]. In addition, the promotion of self-efficacy is central to managing wellbeing and avoiding depressive symptoms as we age [51].

1.3. Pilot: Stress, Sources of Stress and Stress Coping

1.3.1. Types and Sources of Stress

The literature distinguishes three types of stressors for pilots. This includes physical stressors (i.e., extreme temperature and humidity, noise, vibration, and lack of oxygen), physiological stressors (i.e., fatigue, poor physical condition, hunger, disease), and psychological stressors (i.e., emotional factors such as a death or illness in the family, business worries, poor interpersonal relationships with family or boss, financial worries, etc.) [52,53].

From an operational focus, much of the literature examines the relationship between stress and workload. Studies indicate that stress is highest during high workload phases of a flight such as take-off and landing [54]. Further, stress increases during complex situations such as go-around maneuvers [54] and when pilots are fatigued [55].

The impact of critical incidents on pilot stress is also examined along with the benefits of critical incident stress management (CISM) programs [56]. Post-traumatic stress (PTS) and post-traumatic stress disorder (PTSD) have also been studied in relation to military pilots [57].

Three high level causes or sources of stress are also proposed. This includes environmental/physical stressors, work-related stressors, and personal stressors [28].

1.3.2. Impact of Stress

Sources of WRS have effects on the physical, psychological, and social health of pilots [7]. In relation to human performance, stress (arising from stressors both inside and outside work) impacts on the socio-cognitive dimensions of performance including decision making, teamwork, and communication [52,53]. Recent research indicates that many pilots have normalized WRS and associated health problems and often fail to identity that they are suffering [7,8].

1.3.3. Pilot Stress Coping Styles

Stress coping is an important psychological construct which moderates/mediates the relationship between stressors and behavioral outcomes such as flying performance [32]. This in turn has an impact on aircraft states [32]. Pilot coping styles have been examined in relation to military pilots. An early study found that military pilots predominantly coped with disruptive emotions and life crises by seeking constructive solutions [58]. In a study of the stylistic coping strategies of military pilots in the Unites States of America, researchers found that pilots were more given to active, problem-solving coping strategies, as compared with the general population [59]. A more recent study of 160 Indian military pilots suggest that pilots use flexible problem and emotion focused coping strategies [32].

1.3.4. Pilot Coping Factors and Stress Coping Strategies

In a 1985 study of the stress coping strategies reported by commercial airline pilots, the dominant stress coping factors included spousal support and the stability of the marital relationship and home life [60]. The positive support provided by a spouse has been evidenced in other studies [61]. Further, an ethnographic study of the lived experience of flying operations highlights the benefits of social support obtained from fellow pilots [62].

In a 2019 survey exploring WRS and pilot stress coping mechanisms, nearly 60% of respondents indicated that they use coping mechanisms to manage WRS and its impact on wellbeing [16]. The top strategies associated with lower depression severity rates included fatigue and sleep management, physical exercise, and diet management [16]. This research suggests that pilots are coping and adopting effective stress management strategies. As pointed out by the authors, there is much to be learned by both pilots and the aviation industry in relation to using coping strategies to foster resilience and recovery [16].

Mindfulness training is being introduced in military aviation. In a recent study, this training has been demonstrated to reduce anxiety for military pilots [63].

1.4. Pilot Wellbeing and Mental Health

Traditionally, studies of pilot wellbeing have focused on fatigue and its implications for performance and flight safety. Shift work and long hours of duty contribute to crew drowsiness and fatigue [64]. This in turn has an impact on crew attention and can increase the risk of errors [64].

Recently, there has been a focus on pilot mental health. Psychological problems in pilots include adjustment disorder, mood disorder, anxiety and occupational stress, relationship problems, sexual dysfunction, and alcohol problems [65]. Studies have focused on measuring the prevalence of depression and other common mental disorders (CMD) in pilots, along with investigating the work-related factors that contribute to depression—such as fatigue. A 2012 study of commercial airline pilots in Brazil found the prevalence of pilots with common mental disorders to be 6.7% [66]. A 2016 study of pilot mental health found that 12.6% of respondents met the threshold for experiencing depression in the last fortnight [67]. A recent systematic review of twenty studies examining depression in commercial pilots found that the prevalence of major depressive disorder ranged from 1.9% to 12.6% [68]. A 2019 survey of 1150 commercial pilot indicates that pilots are suffering from the same MH challenges as the overall population [16]. However, as indicated in this research, not all pilots are suffering. Over half met the threshold for mild depression, while a low number of

respondents were found to have moderately severe depression (4.38%) or severe depression (1.58%) [16].

Further, the relationship between fatigue and aspects of mental health is receiving increased attention. A cross-sectional survey of >700 pilots investigating self-reported anxiety and depression reported that respondents who typically spent longer hours on duty per week (>40 h vs. <25 h) were three times more likely to report feeling anxious or depressed [69].

1.5. Safety Management Systems, Performance Monitoring, and Safety-II

As mandated by the European Union Aviation Safety Agency (EASA), airline safety management systems (SMS) are designed to measure and manage safety risk [70]. The purpose of an airline SMS is to provide an organized approach to manage safety risks in flight operations [70]. As defined in the International Civil Aviation Organization (ICAO's) safety management manual, an airline SMS should incorporate four elements [71]. This includes safety policy, safety assurance, safety risk management, and safety promotion.

Overall, there is a strong culture of performance monitoring within the aviation industry. Performance monitoring forms part of an airline's safety performance management process and the 'safety risk management' component of an airline's SMS and allied technologies. Performance monitoring spans five areas. This includes (1) the aircraft, (2) the flight (i.e., voyage reporting including safety events), (3) the environment, (4) safety performance, and (5) the pilot/crew [72].

Arguably, the bulk of performance monitoring pertains to the aircraft state/health. Aircraft health monitoring includes the aircraft flight data monitoring (FDM) system, which tracks aircraft states including unacceptable aircraft states (for example, unstable approach, over-speed, and hard landings), and the aircraft technical log, which records all aircraft defects, malfunctions, block times, fuel consumption, and all scheduled and unscheduled maintenance that has occurred.

Flight reporting includes voyage reporting (fuel, flight times, routing, passengers, cargo, etc.) and reporting of any safety issues or events linked to the flight. Such reporting has relevance to different parts of the airline business, including operations management, safety, and commercial operations.

General safety systems reporting includes safety reporting from all relevant aerospace actors—including anonymous, mandatory, and voluntary reporting. This is directly linked to the 'safety risk management' component of an airline's SMS.

Monitoring of the environment includes the weather and the physical environment in which the aircraft operates. In relation to flight operations and the flight dispatch process, pilots are pilots are provided with detailed weather briefs, information about risks associated with departure and arrival airports, and associated 'notice for airmen' (NOTAMS).

The crew are the key coordinating interface both from a flight operations and safety management perspective [72,73]. However, from an operational perspective, crew health monitoring is quite limited. Largely this concerns the monitoring of crew fatigue and duty times (linking to the airline's fatigue risk management system). Currently, airline wellbeing interventions focus on the management of crew fatigue and alertness [7]. Risks pertaining to crew fatigue are monitored as part of an airline SMS [7,74]. At present, sources of WRS and wellbeing factors (including the biological, psychological, and social factors) are not accounted for within airline safety management systems [7]. Further, other dimensions of a pilot's biopsychosocial health are not monitored in real time.

The health of the pilot (including mental health) is assessed annually using official aeromedical examiners in accordance with authority requirements regarding the issuing of licenses and a pilot's fitness to fly. Airlines are required to follow specific guidelines concerning the aeromedical assessment of pilots, as mandated by the regulatory authorities. Licenses can be suspended if serious health problems are detected. This includes mental health problems. As pointed out by Atherton, given the implications for a pilot's license, mental health issues are more likely to be underreported [11].

Peer support services have been operating at airlines for many years. This includes American Airlines, British Airways, Lufthansa, KLM, and Qantas [11,75,76]. Such programs take many forms.

However, all involve features such as confidentiality, mutual respect, social inclusion, social support, and the promotion of resilience [75,76]. Social isolation combined with feelings of lack of belonging, helplessness, and hopelessness are contributory factors to suicide (including murder suicide) [13]. Thus, peer support programs are essential to the promotion and management of emotional wellbeing for pilots along with suicide prevention [13]. In this regard, 'Project Wingman', the pilot-assist program run by American Airlines represents best practice in terms of promoting pilot mental fitness and emotional well-being and fostering supportive relationships amongst pilot colleagues.

Airlines are now moving towards Safety-II practices and specifically proactive and predictive safety/risk management approaches to examine workplace factors that have the potential to contribute to safety events. Recently, this has involved the application of data driven approaches related to fatigue management in relation to flight planning [77].

1.6. Existing Tools and Interventions to Support Pilot Wellness and Stress Management

Stress management forms part of an airline's crew resource management (CRM) syllabus, as defined by the EASA [78]. CRM training focuses on understanding the factors that lead to stress, as well as how to cope with stressful situations. However, WRS and techniques for managing WRS/wellbeing issues spanning the biological, psychological, and social dimensions of a pilot's wellbeing are not alluded to. Moreover, the guidance does not address the links between the home/work interface and stress coping behaviors while on and off duty. Nonetheless, airlines have implemented stress management courses and obtained some positive effects [53].

Following crew resource management (CRM) and threat and error management (TEM) frameworks, pilots adhere to formal briefing procedures at the pre-flight, flight planning, and briefing stages [73,79]. However, the existing pre-flight briefing processes do not address factors pertaining to WRS/wellbeing. In addition, pre-flight checklists do not require pilots to assess individual crew wellbeing and the joint crew state [79].

Several pilot checklists have been advanced to address pilot risk assessment at an operational level (and fitness for flight). This includes the 'I'm Safe Checklist' [80,81], and the 'Personal Minimums Checklist' [82,83]. However, these do not address the three pillars of wellbeing.

QANTAS is now providing pilots will information on mental health and wellbeing via an app on their crew iPads [84]. In addition, Jeppesen has introduced a new pilot mobile app, 'Crew Alert', enabling pilots to risk assess their current and future alertness and fatigue levels [77,85]. Some software companies have advanced electronic flight bags (EFBs) and mobile phone apps which enable pilots to report on their fatigue levels [86]. However, reporting of crew states linking to biopsychosocial not part of the normal process—as currently conceived.

1.7. Self Monitoring, Wearables, and Health Apps

Self-monitoring is 'the process of observing one's own behavior and evaluating it in relation to goals' [87]. As part of this, a self-monitoring plan is used to track all sorts of daily behaviors, which can include exercise, diet, sleep, and mood. Wearables and other 'self-tracking devices' enable health and behavior information to be auto-harvested for later analysis [88]. There has been significant growth in relation to the development of mobile health apps (mHealth apps) and mental health apps (Mhapps) targeted at the general population to manage different aspects of a person's health and wellbeing [89]. Currently, about 40,000 apps are related to healthcare [89]. Further, smartphone apps for mental health (Mhapps) represent a new approach for the prevention and management of MH problems—in line with the 'stepped care' model. Anecdotally, it is known that such tools are used by pilots. However, the prevalence, use, and health outcomes relating to the use of these tools is not established.

1.8. The Quantified Self at Work

Corporate wellness programs are now deploying self-tracking technologies—referred to as corporate wellness self-tracking (CWST) [90]. Workers are invited to measure and manage their own

health, to improve their wellbeing, while also enhancing productivity, engagement, and performance. Such tools harness the personal goals of workers for health, fitness, happiness, and meaningful social connection, for the purpose of introducing self-disciplinary methods to enhance work performance [90]. Some argue that CWST approaches conflate work and health and increase worker anxiety levels [91,92]. Sensory tracking technologies which aim to regulate employee behavior via workplace wellness initiatives raise many ethical issues [93]. Many argue that such systems should only be used on an opt in and opt out basis [93].

1.9. Data Protection

General Data Protection Regulation (GDPR) legislation confers specific rights on individuals in terms of how their personal data is collected and used in different contexts including the workplace [94]. Special protections are conferred on certain types of personal data such as health data. These rights must be upheld by employers. Developing and using digital technologies presents many individual and organizational risks pertaining to data protection [95]. In this case, there is a duty for the organizations producing these technologies (for example, mobile applications) to ensure that consumers are protected. If these technologies are used in a work context, there are obligations also for employers. Importantly, the processing of such data in a work context (as with others) requires a lawful basis such as consent and performance of a contract [95]. Under GDPR legislation, 'public interest' is also treated as a lawful basis under which personal data may be processed. Individuals have rights to object to their personal data being processed, but such objections can be over-ridden by a 'public interest'. These issues have been discussed in the context of sharing of information about pilot mental health, particularly in relation to conflicts of interest such as protecting the pilot (i.e., privacy/confidentiality) and disclosures that are in the public interest (i.e., flight safety). In the aftermath of the Germanwings tragedy, there was much discussion of how conflicting rights and principles might be addressed. Lastly, this legislation also provides protections for individuals in relation to automated profiling and processing of private data used to evaluate and predict behaviors [94,95].

1.10. COVID-19 Crisis and Pilot Wellbeing

The current Covid-19 pandemic poses a huge occupational health and safety threat. Many pilots are either working reduced hours or not working at all. This has had a detrimental impact on their sense of purpose and financial security [19,96]. Others who are still working are working in very different environments, with additional stressors. In the 'new normal', there are significant changes to obtaining support from others, and indeed providing support. The current restrictions regarding social distancing along with existing work changes is impacting all three pillars of a pilot's health [19,96].

The Flight Safety Foundation has identified three operational scenarios to be managed during the COVID-19 crisis and beyond [17]. This includes (1) being at work during the COVID outbreak, (2) being off work, and (3) returning to work [17]. Crucially, a preventative approach is required to ensure that pilots are fit for duty when they return to work. It is likely that some pilots may develop psychological issues during the period of being off work. Social isolation and confinement may lead some pilots to develop maladaptive coping strategies. As pilots are off work, some of the occupational barriers to maladaptive coping are not there (i.e., intoxicant testing by employer). Further, the enablers of adaptive coping (i.e., support from social network, access to peer support, and access to support groups within the community) are not there.

Following a preventative and self-management approach, the Flight Safety Foundation have produced a guide to support wellbeing management and resilience for aviation professionals both during the COVID-19 crisis and after [17]. The guide invites aviation professionals to consider three key wellbeing questions: (1) how am I feeling, (2) how am I coping, and (3) what am I going to do/what am I doing [17]? Drawing upon the 'biopsychosocial' model of health and wellbeing, the guide proposes the use of specific self-management strategies. These concern six core behaviors pertaining to the three pillars of wellbeing. The selection of these behaviors follows prior research

pertaining to stress coping for pilots [7,16]. As indicated in Figure 1 below, these include activities, physical exercise, diet, sleep, stress management, and social relationships.

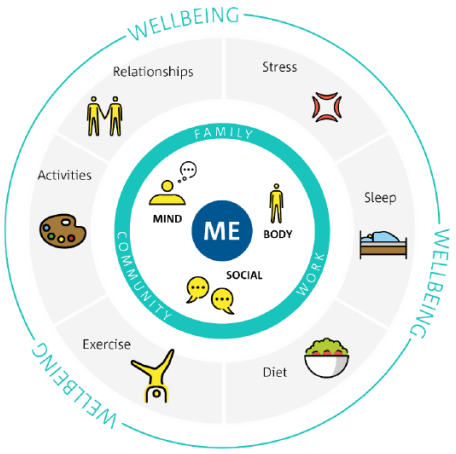

Figure 1. Wellbeing wheel (An Aviation Professional's Guide to Wellbeing, Flight Safety Foundation, 2020).

2. Materials and Methods

2.1. Methodological Framework

The methodological approach adopted in this study stems from human factors and behavior science, along with recent methodological approaches in healthcare. As defined in ISO 6385, the discipline of human factors (HF) refers to 'the practice of designing products, systems, or processes to take proper account of the interaction between them and the people who use them' [97]. The human factors approach follows a 'socio-technical systems design' perspective, which addresses the functions and benefits of technology from the perspective of all relevant stakeholders. This is an approach to organizational work design that recognizes the interaction between people/behavior, technology/tools, work processes, workplace environments, and work culture [98].

In line with socio-technical systems approaches, the advancement of new technology is situated in the context of the design of a broader socio-technical system—including training, safety culture, and the design of safety/risk processes. It is conceived as one of many behavior and organizational change interventions. Another central aspect of the 'human factors approach' is the importance it places on the person and how work processes and the overall system should be designed so that the person is set up for success.

Behavior models focus on understanding the psychological factors that explain or predict a specific behavior. Models of behavior change seek to explain the factors that contribute to behavior change and/or how to change behavior. Behavioral theory is very useful in relation to the design of new technologies. Importantly, it focuses attention on design features and broader design solutions that enable behavior change. This research draws upon the Fogg behavior model [99]. The Fogg behavior model has been applied widely to technology interventions supporting behavior change [67,68]. According to Fogg, behavior is the result of three specific elements coming together at one moment [67,68]: motivation, ability, and a prompt. As defined by Fogg, when a behavior does not occur, at least one of those three elements are missing [99,100].

Healthcare is now adapting human factors principles and concepts, and specifically the human factors concept of a 'person-centered sociotechnical system' [101]. This is evidenced by the application of the Systems Engineering Initiative for Patient Safety (SEIPS 1.0 and SEIPS 2.0) [102]. As stated in the SEIPS model, the structure of an organization (or, more generally, the work system) affects how safely care is provided (the process). Further, the means of caring for and managing the patient (the process) affects how safe the patient is (outcome). As defined in the model, technology designers must consider the relationship between outcomes for patients, service providers/care

givers, and care organization (i.e., interrelated outcomes). By implication, systems supporting pilot wellbeing and flight safety should be jointly optimized for all stakeholders (i.e., pilots, airlines, the aviation industry, and society).

2.2. Research Overview

Over the last five years, action research has been undertaken with pilots and other aviation industry stakeholders to understand the contributory factors to WRS, the outcomes of WRS, and how best to design checklists and technology tools (including mobile apps) to support pilot self-efficacy and resilience.

The specific objectives of this research include:

- Promoting an understanding of pilot lived experience and the allied wellbeing/performance/safety problems from a systems perspective
- Advancing a behavior model supporting the conceptualization of the problem, its impact, and the solution challenge
- Identifying the requirements for solutions at different levels (i.e., pilots, airlines, and other aviation stakeholders)

Specific field research with stakeholders is defined in Table 1. All subjects gave their informed consent for inclusion before they participated in the study. The study was conducted in accordance with the Declaration of Helsinki, and the protocol was approved by the Ethics Committee of the School of Psychology, Trinity College Dublin (February 2018 and August 2018)

Table 1. Research parts and phases.

Part	#	Objective and Description	Method	Stakeholder Involvement
1	A	Advancement of initial lived experience model.	Preliminary, semi-structured and explorative interviews with pilots	Pilots, (N = 103)
	B	Analysis of airline processes to manage pilot WRS and wellbeing (including MH) and associated regulation.	Literature review	N/A
	C	Validation of the lived experience model—phase 1. Assessment of the impact of WRS on pilot health, human performance, and flight safety.	Participatory workshops with pilots	Pilots (N = 33)
2	A	Analysis of problem. Specification of problem and change requirements from a systems perspective.	Modelling problem from human factors/systems perspective	N/A
	B	Validation of lived experience model—phase 2.	Survey with pilots (N = 325) —phase 1	Pilots (N = 325)
	C	Analysis of coping strategies.	Initial data analysis following first wave of survey	N/A
	D	Specification of interventions and tools requirements—airline and pilot levels. Situate concepts in relation to therapeutic/clinical approaches.	Research analysis	N/A
	E	Validation of lived experience model—phase 3.	Survey with pilots (N = 1050) —phase 2	Pilots (N = 1050)
3	A	Specification of tools framework. Specification of preliminary prototypes (Tool 1 and 2). Specification of airline process—existing and to be.	Preliminary prototype development Process mapping—as is and future process Analysis and advancement of tool framework	N/A
	B	Preliminary validation of tools framework with stakeholders. Preliminary validation of Tool 1 and 2 with stakeholders.	Preliminary validation research with airlines Preliminary validation research with software companies Preliminary review with regulatory authority (European Aviation Safety Authority (EASA) and Irish Aviation Authority (IAA)	(N = 7)
	C	Business analysis and development of business model canvas (BMC) about the aviation industry. Analysis of customer need. Analysis of customer journey.	Specification of business logic and allied tools concept from perspective of stakeholder need Specification of existing and future customer journey	N = 1
4	A	Refinement of problem analysis from a systems perspective.	Analysis of problem Application of Fogg model of behavior change to	N/A

		Specification of problem and solution in context of a behavior change framework.	problem and solution specification.	
	B	Understanding pilot use of coping strategies in relation to depression severity. Specification of risk algorithm.	Analysis of survey findings (N = 1050) Regression model and odds ratio	N/A
	C	Further specification of tools.	Prototype development using Balsamiq	N/A
5	A	Review of problem in context of COVID need.	Collaborative workshops/discussion with stakeholders Documentation of problems	Panel of pilots and industry experts (N = 9)

Collectively, the studies have produced evidence-based recommendations for technologies and other socio-technical interventions (i.e., process change, training, culture, and so forth) to promote wellbeing in the workplace, both at a pilot self-management level and airline operational and safety management level. To date, this research has been structured into five parts. Table 1 below provides an outline of research parts and phases. A description of specific field research methodologies is provided in Appendix A. Much of parts 1 and 2 of this research has been previously reported as indicated in Appendix B. This paper focuses on reporting the outcomes of parts 3, 4, and 5.

2.3. Part 1

The first part of this study focused on advancing a preliminary specification of the wellbeing problem and its impact. This comprised three research phases. In the first phase, semi-structured interviews were undertaken with pilots (N = 103). A scoping literature review was undertaken to identify existing airline processes to manage pilot WRS and wellbeing and any gaps therein. This included an examination of specific operational and safety processes. The existing regulation in relation to aeromedical assessment and supporting pilot wellbeing was analyzed. Following this, three participatory workshops were undertaken with commercial pilots (N = 33). Appendix A provides an overview of the methodology for both the interviews and workshop sessions. The detail of this research is reported in an earlier paper [8].

2.4. Part 2

In part 2, there was a deeper dive into the problem definition and potential solution in relation to the goals, experiences, and requirements of one stakeholder group—pilots. Overall, the purpose was to identity how sources of WRS and wellbeing issues might be better managed both from a pilot and airline perspective. This comprised five stages of research. In the first stage, the wellbeing problem was mapped from a systems perspective. As part of the analysis, the different systems relevant to the problem definition were mapped along with the associated contributory factors. In the second stage, the initial 'pilot lived experience' model was further validated using an anonymous online survey. The first wave of data analysis (N = 365) focused on modelling (1) contributory factors and outcomes and (2) coping mechanisms. Following this, the collective evidence from part 1 and part 2 was integrated and analyzed to identify the requirements for solutions at a pilot and airline level. The proposed solutions were situated in terms of the new IR outlined by the EASA (i.e., in line with IR, gap in relation to IR/extending existing IR), along with therapeutic approaches to managing wellbeing (including mental health). Further, they were classified in terms of different types of socio-technical intervention. This includes process redesign, training, new technology, culture change, and so forth. In parallel to this, a second wave of survey data were collected. The survey methodologies and data analysis approach are defined in Appendix A. The detail of this research is reported in an earlier paper [7].

2.5. Part 3

The objective of part 3 was to further elaborate on the requirements for solutions at different levels and to validate such solutions with aviation industry stakeholders. In particular, the purpose was to identity how emerging technologies might be used to develop solutions to enable pilots and other airline and aviation stakeholders (for example, an airline Employee Assistance Program (EAP), airline flight rostering/flight safety, and aeromedical examiners) collect and share information, so that wellbeing issues and risks might be better managed from a systems perspective.

This involved three phases of research. In the first phase, the high-level solution requirements defined in part 2 were further elaborated in terms of a proposed 'tools framework' encompassing five interrelated tools. Following this, preliminary prototypes for Tool 1 and 2 were modelled using the prototyping tool Balsamiq Process maps were then advanced to define the existing process and the location of these tools in a future improved process (i.e., the 'to be' process). The process maps were elaborated from process maps advanced by the researcher in a prior research project [72]. Specifically, the maps addressed four pertinent processes: (1) flight planning and crew rostering, (2) real-time flight operations process, (3) quality and safety management process, and (4) processes pertaining to human resource management, aeromedical assessment, the EAP function, and health promotion.

In the second phase, the tools framework, prototypes, and process maps were validated with a panel of stakeholders. A series of individual participatory workshop/co-design sessions were undertaken with industry stakeholders (N = 7). As part of the sessions, the researcher presented the background to this research, the tools framework, and the indicative prototypes for Tool 1 (pilot off duty) and Tool 2 (pilot on duty). Participants were invited to provide feedback about the overall tools framework and specific features of Tool 1 and 2. This included the logic and ethos, behavior change motivations, enablers and barriers, and implementation requirements (both short and longer term). The panel included the Senior Aeromedical Officer of the Irish Aer Corps, a safety manager from an Irish airline, representatives from the national aviation authority (IAA) and EASA, the CTO of an aviation software company responsible for the electronic flight bag (EFB) and mobile app solutions, the product owner of an aviation software company responsible for pilot app solutions and fatigue risk management software, and the CEO of an aviation training company.

The third stage addressed the production of a business model canvas (BMC) for the emerging tools. This followed the requirement to justify tool concepts both from a human factors/ethical perspective and a business perspective. The BMC followed the paradigm developed in Osterwalder's business model canvas [103]. The purpose of this analysis was to articulate and locate the emerging tools framework and concepts, in terms of the diverse needs of different actors in the aviation industry (for example, pilots, airlines, families of pilots, aeromedical examiners, aviation software developers, companies providing training support to airlines, the regulator, and so forth). As part of this, the researcher engaged in a series of participatory sessions with (1) an aviation industry expert and (2) a business analysis expert, to define the value proposition for different stakeholders and how the individual tools would address this. Three sessions were undertaken with (1), while two sessions were undertaken with (2). The output of this included a refinement of the tools framework in relation to the needs of the aviation community, a BMC for the proposed tools, a specification of the customer journey from the perspective of the two primary stakeholders (i.e., the pilot and the airline), and an analysis of implementation motivations, enablers, and barriers. In relation to motivations, specific dimensions of the value proposition were integrated with prior research addressing the problem framing and an allied model of six interacting systems.

2.6. Part 4

The research in part 4 focused on further validation of the problem definition, the behavior model, and the emerging solution. This comprised three analysis stages. In the first stage, the problem was further specified from a systems perspective and assessment in relation to the needs of the aviation industry/community. This included additional elaboration of the six interacting systems which contribute to the problem space, the potential solution, and the implementation case (i.e., including both human/ethical and business considerations). Further, the behavior change model was

elaborated. As part of this, additional motivations, enablers, and barriers were specified in relation to each of the six systems impacting on the problem definition and solution.

In the second stage, the second wave of survey data was analyzed. The purpose of the data analysis was to (1) identify sources of WRS and wellbeing impact, (2) measure depression levels in pilots, (3) examine the use of coping strategies (CS), and (4) examine the relationship between coping strategies used by pilots and their mental health, specifically in terms of depression severity levels. Sources of WRS and wellbeing impact were reported based on pilot self-reported data. Depression levels were scored using the depression severity scale [104]. The prevalence of pilots using CS and the most frequently used CS were also examined. An ordered logistic regression model was advanced to explore the relationship between the PHQ-9 scores and each of the coping strategies for WRS (i.e., those listed in the survey). The objective was to model the relationship between each frequency level of each coping strategy and PHQ-9 scores. Following this, the odds ratio was interpreted, to assess statistically significant coping strategies. Appendix A provides further detail on the analysis approach.

In the third stage, the prototypes for Tool 1 and 2 were further elaborated, using Balsamiq Further, a preliminary risk algorithm was specified.

2.7. Part 5

Part 5 refers to our most recent research with stakeholders, as part of the COVID response for pilots and other aviation professionals led by the Flight Safety Foundation (2020). Two members of the research team participated in a series of remote workshops/discussion sessions with a panel of stakeholders, to support the specification of a wellness guide for aviation professionals (Flight Safety Foundation, 2020). As part of this, the team presented a subset of research findings relevant to the production of the wellbeing guide. This included findings in terms of framing the problem, the biopsychosocial approach and allied pilot lived experience model, the behavior model, the relationship between stress coping and depression, the tools framework, and specific checklist ideas. Although these sessions did not focus on evaluating the 'lived experience' approach and/or the tools framework and specific concepts, the panel provided useful feedback on this. Overall, the panel included pilots and industry experts (N = 5), stakeholders involved in safety promotion (N = 2), a stakeholder involved in aeromedical assessment (N = 1), and a stakeholder involved in the promotion of healthy behavior (N = 1).

3. Results

3.1. Understanding the Problem

As indicated in Table 2, the problem of pilot wellbeing exists at six different levels. These are:

1. Pilot level (lived experience, practices/behavior, culture)
2. Airline level
3. Community level (i.e., social system)
4. Health and safety regulation
5. Aviation regulation
6. Broader aviation system

Research indicates that each of these levels should be treated as a system to be managed. However, there are also inter-relationships between these system levels. As such, we also need to model the inter-relationship between factors within and across the six different levels/systems and assess how these might be better managed in terms of new technologies and wider socio-technical considerations. As highlighted by stakeholders, any solution will need to consider the design of each of these systems and their role in relation to contributing to the problem and supporting a solution that is acceptable to all stakeholders and adopted and sustained over time.

Table 2. Different levels and problems.

#	Level	Description	Example Problems
1	Pilot level (lived experience, practices/behavior, culture)	In work Outside work Home/work interface	Attitudes to mental health Health behaviors amongst pilots Machoism and culture Reporting and disclosure culture
2	Airline	Sociotechnical system level—processes, training, technologies, business model, and culture and values Link to wider aviation community and industry	Inflexible working schedules Presenteeism, restrictions on sick leave and difficulties reporting sick Machoism and culture Reporting and disclosure culture Nature of airline Employee Assistance Programe (EAP) and access to support Design of existing safety management system (lack of focus on risks relating to the human factor)
3	Community and social system	Public expectations, pricing, 24/7, health system, and access to support	Public expectations, pricing, 24/7, also health system and access to support
4	Health and safety in work (regulator/regulation)	Health and safety authorities at national and European level	Current strategy for evaluating WRS Current strategy for managing psychological wellbeing in work and associated stress
5	Aviation regulator and regulation	Aviation authorities at national and European level	Regulation pertaining to safety/risk management, HF management, wellbeing and mental health monitoring and assessment Design of existing regulation—mental health assessment, aeromedical assessment
6	Broader aviation industry	Technology providers, aircraft manufacturers, insurance companies	Current process for insuring airlines—flight safety, human assets/pilots Available technology to support wellness management for pilots

3.2. Pilot Wellbeing Behavior Model

As indicated in Figure 2, the behavior comprises four interrelated layers: (1) the lived experience model, (2) the impact model and scenarios, (3) the model of coping, and (4) the analysis of behavior change (including motivations, enablers, and barriers). This follows from the analysis and integration of several phases of literature analysis and field research with stakeholders.

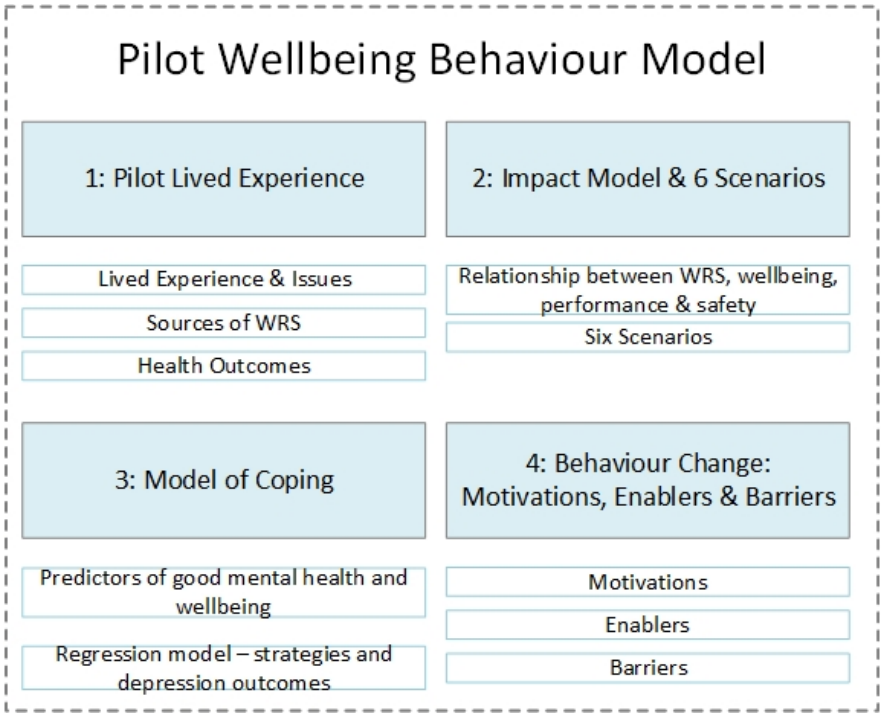

Figure 2. Pilot wellbeing behavior model.

The first strand of the behavior model is the model of pilot lived experience. This is represented in a series of infographics which depict the lived experience of pilots in terms of the three pillars of wellbeing and associated issues, sources of WRS/contributory factors, and health outcomes. Appendix C provides an overview of the high-level model. Appendix D provides a summary of the sources of WRS.

The second layer is the impact scenarios. As indicated in Figure 5, six impact scenarios are proposed reflecting much diversity in terms of the 'pilot lived experience', along with a spectrum of impact (i.e., spectrum of impact in terms of the pilot's wellbeing, performance, and flight safety). The six impact scenarios include:

1. Pilot mostly coping well
2. Pilot mostly coping well but impact on physical health
3. Pilot experiencing difficulties but mostly coping well
4. Pilot mostly coping but long-term impacts
5. Pilot not coping
6. Extreme cases

As suggested by workshop participants (part 1, phase 3 research), wellbeing interventions should primarily focus on addressing routine suffering (scenario 1 and 2), the avoidance of scenario 3 (i.e., pilot not coping on the day with potential implications for flight safety) and scenario 5 (i.e., pilot suffering which leads to self-harm). Scenario 6 specifically pertains to a person who might have a pre-existing MH issue. Currently, such a person is not obtaining adequate support at an airline level. Participants noted that such a scenario is comparable to the Germanwings accident. Figure 3 provides an overview of the impact scenarios.

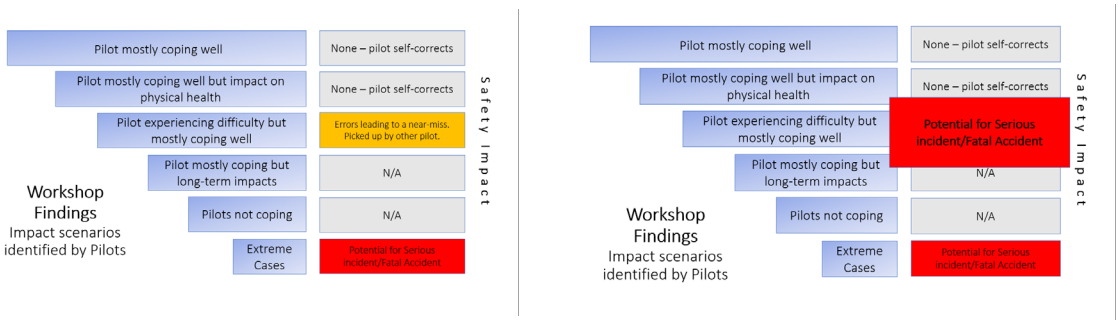

Figure 3. Impact scenarios.

In relation to conceptualizing the impact of wellbeing on performance and flight safety, participants noted that there are many factors to consider, and the specific impact of these factors on performance and flight safety is hard to quantify. Participants remarked that (a) the specific spread of factors occurring at any one time (i.e., general features of job/WRS, personal stressors, the operational situation), (b) how these factors might interact in real time, and (c) how these factors might potentially impinge on wellbeing and by implication performance and flight safety is hard to predict. This is also complicated by individual differences in relation to pilot coping ability. Further, as observed by participants, although positive, pilot coping can lead to a false impression of actual system risk.

The third layer is the model of coping. This includes two interrelated parts: (a) predictors of good mental health and wellbeing (see Table 3 below) and (b) analysis of coping strategies in relation to depression severity.

Table 3. Influencing factors.

#	Factor	Positive	Negative	None	TBD
1	Use of coping mechanisms—sleep, exercise, supports, diet	*			
2	Awareness of issue/challenges/suffering	*			
3	Normalisation of problem/suffering		*		
4	Concern for own health (self or family)	*			
5	Positive attitude to seeking help/support	*			
6	Pre-existing MH issue				*
7	Existing health and wellbeing (if fatigue, burnout/exhaustion)		*		
8	Shift pattern/shift time			*	
9	Work contract			*	
10	Type of operation			*	
11	Male/Female				*
12	Social capital and network	*			
13	Existing habits and behaviours (sleep, diet, exercise)	*			
14	Interest in physical exercise	*			
15	Convenience and access (24/7)	*			
16	Pilot education and awareness schemes	*			
17	Social acceptability and demonstration of 'socially desirable' values and practices (self-care)	*			

* has an influence.

The fourth and final layer is the model of behaviour change in relation to motivation (see Table 4), enablers (see Table 5), and barriers (see Table 6). As indicated in Table 4, these are linked to the different systems as defined in relation to modelling the problem space.

Table 4. Motivations.

Description	System Level
Pilot interest in developing/augmenting their health and wellbeing	1, 2
Health attitudes of family and social network	1, 3
Social supports from family and social network	3
Improved experience of home/work interface	1, 2
Public acceptability—addressing MH and wellbeing challenges	1, 2, 3
Flight safety	2, 3
Work policy	2
Commercial reasons—reduction in costs of absenteeism, operational changes, flight cancellations, due to pilot illness	2
Work incentives and rewards	2
Social acceptability	2
Productivity and reduction in absenteeism costs	3
Normalisation of health and wellbeing supports across all industries	4
Regulatory support	5
Aviation industry embrace requirement for change	6
Integrated approach across the aviation industry—solve the problem at different levels (actors, process, operational timeline, etc.)	6
Acceptance that these issues exist for all workers and not just pilots and must be addressed	6

Table 5. Enablers.

Description	System Level
Piot advocacy	1, 2
Culture change at pilot level—normalisation of MH, acceptability of self-care	1, 2
Use of new digital tools for pilots—supporting awareness, monitoring, and self-management of health	1, 2
Culture change at airline industry level	2
Airline support—new training, enhancements to airline safety management systems SMS, wellbeing supports/EAP	2
Acceptance of holistic model of pilot wellness (including factors pertaining to all three pillars)	2
Management of pilot wellbeing as a risk within an airline safety management system	2
Acceptance of MH and wellbeing challenges—community	3
Change in terms of public expectation—24/7 and low cost	3
Enhancements to existing health systems—public and private	3
Normalisation of health and wellbeing supports across all industries	4
Regulatory support—particularly in area of data protection	5
Availability of new technologies supporting stress coping and healthy behaviour	6
Transparency in terms of technology design in relation to how data is shared and data protection	6

Table 6. Barriers.

Description	System Level
Pilot awareness of need to develop resilience and cope	1
Culture of presenteeism	1
Pilot attitudes to health and wellbeing and practice of resilience	1
Managing privacy issues	1, 2
Pilot trust in system	1, 2
Airline business models and work contracts for pilots	1, 2
Existing pilot culture (not declaring suffering, presenteeism, macho culture)	1, 2
Existing industry culture (stigma around MH and wellness challenges)	3
Lack of support within community for pilots—impact of job on wellbeing	3
Public expectations—expectation of low costs flights, 24/7 operations, flexibility for consumer	3
Existing approach across all industries re management of health and wellbeing in work—lack of focus on psychosocial dimensions	4
Aviation regulatory requirements	5
Lack of transparency in terms of technology design—specifically, in relation to how data is shared and data protection	6

3.3. Challenges Associated with COVID-19

As indicated in Appendix E, different pressures and sources of stress can be associated with the three scenarios, as outlined by the FSF (2020). There are wellbeing and safety risks for those currently in work. Those off work face significant challenges. Sleep and diet may have improved, but there are increased pressures in relation to financial insecurity, physical confinement, and social isolation. Furthermore, there are many risks once a pilot returns to work. The pilot must be able to assess their own wellbeing and fitness for a flight, along with that of their co-pilot and broader crew. Further, new assessment processes may be required to manage the gap in operational practice, along with the assessment of pilot wellbeing. Airlines' EAP staff will need to identity what normal is, bearing in mind that the landscape has fundamentally changed. EAP and peer support staff will require assessment metrics and data to identify pilots that are coping well and others that are at risk or in need of immediate crisis support. In line with a stepped care approach, this will support processes which identity those who fit the criteria for EAP support and those who require referral to specialist services provided by trained clinicians.

3.4. Proposed Technologies and Behaviour Change

As indicated in Table 7 below, behaviour targets and the means of achieving them (for example, motivation, ability, and prompt) can be defined in the context of the Fogg model [99,100] while considering the six intersecting systems and sociotechnical systems theory (for example, the interrelationship between people, process, technology, culture, and training).

Table 7. Behaviour targets and Fogg model.

Target Behaviour	WRS and wellbeing awareness and education	Increased awareness of WRS and wellbeing (including MH)
	Acceptability of MH/self-management of wellbeing and MH	Increased acceptability of MH Normalisation of MH Acceptability of self-care
	Self-management behaviour	Promote coping Shift to self-management Cultural change
	Safety behaviour	Interface between life in and outside work
Motivation	Safety, health and wellbeing, work policy, health attitudes, social acceptability, work incentives and rewards, etc.	
Ability	Health, time availability, work flexibility, family support	
Prompt	(1) Mobile apps + (2) airline tools—profiles info and model of behaviour/trends (artificial intellgience + machine learning—available to airlines to direct rostering/planning + tools for other stakeholders (EAP, aeromedical examiner etc.)	

3.5. Tool Concepts and Framework

The combined field research justifies the requirement to advance tools to (1) promote and maintain wellbeing for pilots (i.e., practice of healthy behaviors, coping strategies, and resilience), (2) prevent the development of wellbeing/MH issues, and (3) support pilots experiencing wellbeing/MH problems. Five integrated sets of tools for different stakeholders are required: (1) self-management tools for pilots (off duty), (2) pilot operational tools (on duty), (3) tools for aeromedical examiners, (4) tools for airline staff working in employee assistance roles (i.e., EAP), and (5) tools for airline staff working in flight planning, crew rostering, safety management, and safety promotion roles.

Pending user consent, information captured in one tool could be made use of by different actors/stakeholders using other tools. Research indicates that Tool 1 (self-management for pilots while off duty) could be used without any integration with the other airline or aero-medical tools and systems. However, there are potential benefits to linking up information flows across these tools, pending user agreement and appropriate protections. This is discussed in a later section.

Stakeholder validation research indicates that the tools will transform the existing process and require full specification in relation to this process transformation. Appendix G provides an overview of the existing process and the future process involving the application of these tools. This is a preliminary and high-level process specification and requires further elaboration with stakeholders.

3.6. Wellness Assessment Concept Underpinning Technologies/Tools

A key structuring principle underlying the proposed tools, is the conceptualization of wellbeing in relation to the biospychsocial model of health and wellbeing. As such, wellness reporting and assessment is undertaken from the perspective of the relationship between factors within and across the three pillars of wellbeing. The overall wellness assessment framework is indicated in Table 8.

Table 8. Wellbeing assessment: three pillars. H = high, M = medium, L =low.

Wellbeing Pillar	**Example**	**High Level Assessment H M L**
Biological	Sleep, diet, exercise	
Psychological	Stress management, attitude, emotions, how feeling	
Social	Seeing and talking to other people, getting help when needed	
Overall rating		

Survey analysis indicates that certain coping strategies are associated with lower depression levels. These include sleep management, physical exercise, and diet/nutrition management. As such, from a reporting perspective, reporting of certain biological factors is critical (i.e., sleep, exercise, and diet). Pilot social interaction with others has a large impact on their wellbeing. In addition, obtaining support from others is critical. This too will need to be factored into the wellness assessment. Each pilot is different and has a specific baseline stress level. This baseline level will need to be calculated for different pilots and then factored into the risk assessment. The specific weighting of factors will need to be determined. An algorithm is being developed to determine how this might be implemented in practice. Preliminary validation research with stakeholders indicates that a simple assessment technique might first be trialed/demonstrated. As the adoption of self-monitoring strategies and the use of wearable and mobile self-monitoring technologies grows, this approach might be scaled up to include tracking of additional factors. This might include the pursuit of hobbies, creative activities (for example, the practice of art, music, and dance) and spiritual activity, along with a more sophisticated assessment of the relationship between such factors. For more information, please see Appendix G.

3.7. Data Protection, Privacy, and Pilot Safeguards

Preliminary validation with stakeholders indicates that a core implementation challenge will be ensuring that pilot rights in relation to privacy and data protection are upheld (i.e., privacy by design). Critically, a pilot's license depends on a positive evaluation of their health and wellbeing as part of annual aeromedical assessment processes. Further, pilots are required to present for work 'fit to fly'. This includes an assessment of their fatigue status (undertaken by flight planning and operations personnel in relation to crew roster and duty times), their own self-assessment of fitness pre-flight, and routine alcohol/drugs testing and monitoring, in line with regulatory requirements. As emphasized by stakeholders, safeguards need to be defined in relation to providing access to and enabling the use of any data (1) collected about a pilot and/or (2) collected by the pilot and shared with others. This pertains to information collected in Tool 1 (off duty) and Tool 2 (on duty).

As noted previously, data collected by pilots might feed into tools used by different airline personnel (airline safety and operational functions) and by aeromedical examiners. In relation to the airline level, it is suggested that this information should be de-identified. This would be in keeping with established norms in the aviation industry regarding the use of aircraft and flight data (i.e., flight data monitoring—FDM). Information might be aggregated at a fleet level but should not identify individual pilots. As highlighted by pilots and aviation industry stakeholders, this system might be part of an overall strategy to foster a wellbeing culture and allied wellbeing component within the airline's safety management system. To achieve this, pilots and pilot data must be protected. As such, the airline could not have access to health monitoring information and the routines/behaviors of individual pilots. Nonetheless, pilots might be able to compare his/her data against cohort norms (i.e., pilots flying specific fleets or operation types). In relation to the aeromedical examiner level, a pilot might opt to share a range of data in different formats with the aeromedical examiner. Some of this data might be identifiable (for the purpose of supporting individual assessment and support as part of the aeromedical assessment process), while other data might be de-identified (i.e., for trends analysis). This might be integrated with the new requirements for aeromedical assessment—including the focus on stress coping behaviors and activities. Again, this information would be used to gain insights about pilot behaviors and routines (at different levels—individual/group level, with relevant protections), to strengthen aeromedical assessment and support pilots (for example, understanding of norms and benefits of specific coping strategies). It should not be used in a punitive manner. In both cases, protection of personal data would need to be enshrined in law and follow established protections such as general data protection rules (GDPR).

3.8. Tool 1: Pilot Self Management (Off Duty)

3.8.1. Objectives and Functions

Stakeholder research indicated the requirement to advance new digital tools to support pilot self-management of their health and the home/work interface, while off duty. The point of an 'off duty' tool is to nudge the pilot towards healthy behavior (to keep them well), to prevent the onset of problems, and to provide the right support/tools if problems arise and in line with the stepped care approach as described earlier. The tool can also be used to share de-identified information about the pilot's state with the airline to support safer rostering and flight planning practices. Further, it can be used to report near misses and safety events (linking to SMS processes).

In terms of scenarios, the off-duty tool addresses issues around routine suffering and their impact on both wellbeing (i.e., scenarios 4 and 5) and safety (i.e., scenarios 1, 2, and 3). It also supports the management of psychological distress (scenarios 5 and 6)—providing access to crisis supports following from the 'stepped care' approach.

Stakeholder feedback indicates that the proposed tools might include a range of functionality including

1. Wellness tracking, assessment, and reporting
2. Provision of general resources/information and relaxation exercises
3. Personalized tips/information, assessment, and wellness plans
4. Self-assessment tools
5. Virtual coaching and access to support
6. Link to airline information systems (for example, roster, notices, safety information)
7. Link to airline SMS
8. Reporting of wellness issues and safety events

In terms of wellness monitoring, reporting, and assessment, stakeholder feedback suggests that such tools should not increase pilot workload and related cognitive and social burdens. Ideally, data might be auto harvested from any existing wearables used by the pilot. For example, this might include Fitbits or Garmins which capture information associated with the biological pillar—such as sleep and physical exercise data. Additional information pertaining to the other two pillars might be self-reported by pilots. Appendix H provides additional information about what data might be auto harvested and/or self-reported.

3.8.2. Wellbeing Assessment and Associated Checklists

Checklists have been specified to promote awareness and prompt action. The checklist concept enables assessment in relation to (1) self-awareness and acceptance and (2) coping. This links to the two core questions identified in this research: (1) how am I feeling, and (2) how am I coping/what am I doing and/or going to do to support coping for myself and others? As highlighted by stakeholders, risk exists both in relation to (1) awareness/acceptance and (2) coping practices. In relation to (1), if issues are avoided or hidden, this can lead to problems. In relation to (2), if the person is doing nothing and/or adopting maladaptive practices (i.e., binge eating, taking intoxicants, withdrawing from others, and engaging in negative self-talk), then there is also a risk. Table 9 below provides an example of an early stage prototype for such a checklist. As indicated, the checklist covers all three pillars of wellbeing and each pillar is sub-divided into core areas which require the practice of healthy behaviour.

Table 9. Self-assessment checklist.

Wellbeing Pillar	Area	Current Status: How Am I Feeling/Doing? Rating? H M L	What I Am Going to Do? What Am I Doing? H M L	Overall Risk Rating H M L
Biological	Sleep and fatigue Physical Exercise Diet			
Psychological	How feeling (stress) Emotional stability and mood			
Social	Talking to others/seeing people			
Overall rating				

Further, as indicated in Figure 4, the checklist could also feature on a mobile app.

Figure 4. Prototype of mobile app.

3.8.3. Wellbeing Management: Weekly Plan and Review

Supporting healthy behaviour requires the development of plans and targets and the monitoring of one's achievement in relation to this. Table 10 below provides an example of an indicative weekly plan and review chart.

Table 10. Example wellness weekly plan and review.

Wellbeing Pillar	Area	Current Status	What I Am Going to Do? Weekly Plan—Target Actions for This Week	Review (Day 7)—How Did I Get on? Implications for Next Week.
Biological	Sleep Physical Exercise Diet			
Psychological	Managing stress Attitude and Mood			
Social	Talking to others, seeing people, getting help if needed			

Again, the wellness plan and review chart could feature on a mobile application. Further, as indicated in Figure 5 below, the pilot could track their progress and obtain customized feedback as to key focus areas. Appendix I provides some additional examples.

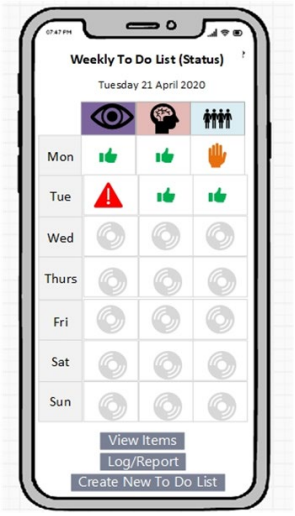

Figure 5. Tracking progress on wellbeing plan and targets.

3.9. Tool 2: Pilot Operational Tools (On Duty)

The analysis of stakeholder research indicates the requirement to advance tools to support pilots while on duty. Here, the goal is to manage wellbeing issues among pilots and address performance/safety implications, while in work. Such a tool might involve several different functions—for example:

1. Enable joint assessment of crew state at the pre-flight stage
2. Enable reporting in relation to WRS and wellbeing threats
3. Enable safety reporting
4. Reporting of WRS/wellbeing issues and safety event (in flight)
5. Enable access to support services within airline
6. Provide support in crisis situations

In relation to (1), existing pre-flight checklists might be augmented to enable the crew to evaluate their health and wellbeing. This would represent a step beyond the existing regulatory guidance for managing wellbeing/MH at an operational level (i.e., assessment of fatigue and pre-flight testing of

pilots for alcohol and drugs). It is proposed that the checklist items would link to the findings of this analysis in terms of assessment of (1) their biopsychosocial health status (i.e., three pillars of wellbeing) and (2) how they are coping/using coping strategies. Appendix J provides an example of an adaption of the existing 'I'm Safe Checklist' from this perspective. This includes assessment in relation to current emotional (including mood and attitude) and social state, not just physical health. Stress coping is included alongside stress levels. Further, physical exercise is also incorporated. It should be noted that this might be done at an individual level (in advance of the flight and the joint crew meeting) and at a joint crew level. Both crew members would need to be briefed on their respective crew member's health and wellness.

As highlighted by stakeholders, the specific implementation of this tool at an operational level requires careful consideration. Potentially, a pilot might review the checklist and 'make a decision as to their fitness' at least eight hours before the flight. This would allow the airline sufficient time to manage the staffing consequences (i.e., substitute the pilot). Further, this necessitates a supportive culture, at an airline and pilot level.

3.10. Safety Promotion and Training Tools and Technologies

A fundamental aspect of the airline SMS is safety promotion. Stakeholder feedback indicates that existing training needs to be extended to include training in relation to coping and promoting resilience (i.e., preventative wellbeing and mental health approaches). This training should increase a pilot's ability to cope. Educational strategies are required to promote learning about personal health, maintaining work family balance, wellbeing/MH risk assessment, and managing stress. Critically, stress management strategies need to suit both the person and the occupational demand. Instruction might go beyond traditional classroom formats. For example, it could include online formats. Pilot-specific serious games might be developed, relevant to the two high level contexts: (1) on duty and (2) off duty. Pilots might also benefit from training in medication and mindfulness. This might be pilot specific and include opportunities for practicing mindfulness while in the cockpit. Further, pilots might benefit from participating in an interactive game or virtual challenge. Existing wearables might be used to track their own health and wellness. As part of this, pilots might obtain points for achieving wellness goals and/or demonstrating different levels of behaviour change.

4. Discussion

4.1. Framing Problem, Need for Stakeholder Engagement, and Behaviour Change

As indicated in Figure 6, the 'pilot wellbeing problem' can be framed in relation to the six interacting systems and model of diversity, as identified in this research. Evidently, this problem is worsened by the current COVID-19 context and requires consideration in relation to the three scenarios outlined by the Flight Safety Foundation (2020).

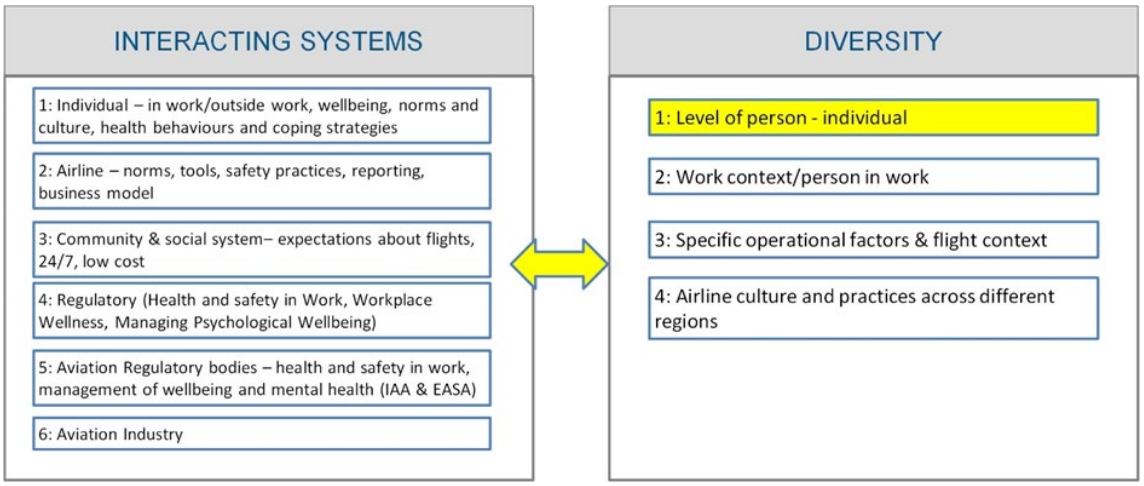

Figure 6. Framing Problem—six systems and COVID scenarios.

Overall, pilots, the aviation community (i.e., airlines, the aviation industry, and the aviation authority), and society must accept their role and responsibilities in relation to supporting pilot wellbeing and enabling behavior change. Stakeholders will have differing goals and perspectives on the problem. These perspectives will influence how the problem is framed and how the emerging solution is conceived. Thus, all stakeholders must be engaged in finding a solution.

Improved working environments necessitate behavior change on the part of employers, employees, and society. This means changing how we conceptualize work and how we design systems to promote wellness, resilience, and safety. As illustrated in this research, such behavior change needs to be framed in the context of the six interacting systems. It is argued that behavior change for airlines will be driven by change at a pilot level. Furthermore, it will be driven by what happens at levels three (society/community), four (health and safety regulation), five (aviation regulators), and six (aviation community and industry). As noted previously, we are focusing on pilots first. This is premised on a view that the development of a wellbeing culture starts with pilots first. This has already been demonstrated by peer support programs. Nonetheless, it needs support from airline management and the regulator. If a growing number of pilots are practicing behavior change and adopting technologies capturing data around their wellness, then this may drive change at an airline level in terms of making use of the data collected by these tools. In line with the technology-mediated behavior change as outlined by Fogg (2020), these new digital tools will provide a trigger for pilot assessment of wellness, along with motivating and supporting the individual and organizational behavior required. In addition, the above tools will provide a link into societal/community supports and enabling change at a societal level.

The pilot's 'lived experience' and associated home/work interface needs to be designed so that the pilot is set up for success. However, this requires a fundamental rethinking of the design of the overall aviation system and the human role within it. More progress is required to ensure that the person (i.e., the human factor) is at the center of the system. From an airline operations and safety management perspective, pilot interaction with different aspects of the socio-technical system (i.e., training, culture, process, tools) at different career time points (i.e., training, early stage career, mid-career with family and mortgage, etc.) and at different operational points (i.e., while on duty and off duty) must be considered. Following a systems approach, change at an organizational level will be multicomponent and at different levels (i.e., culture, training, process design, etc.). As part of this, the motivations, enablers, and barriers, as defined in the pilot wellbeing behavior model, will need to be addressed.

In addition, the social model which underpins the 'human factor' needs to be mapped and addressed. In terms of examining social interactions and relationships, attention must be given to the quality and value of a pilot's interactions with those who (1) provide support to the pilot (i.e., pilot wellbeing benefiting from support from social network, health providers, and colleagues) and (2) those the pilot provides support to (i.e., pilot wellbeing benefiting from support given to others, volunteering, and contributing within their social community). On the flipside, this social community can potentially create barriers to identifying wellbeing problems, accepting the need for change, fostering wellbeing behaviors, maintaining wellbeing, and providing sincere and credible support for the routine practice of healthy behaviors.

Overall, we are seeking to change the relationship between the individual and employer and other aviation stakeholders (for example, the aeromedical examiner) and societal actors (i.e., families and those people providing support to pilots in the community, etc.). This includes information sharing relationships (for example, sharing information about our personal health, lifestyle, and fitness for duty). In many cases, regulation also needs to change and/or catch up. Evidently, such information is sensitive and ethical dimension such as consent, autonomy, and protection of the personal sphere must be considered.

4.2. Tripple Bottom Line and Ethics/Business/Legal Case

Healthy work relates to the creation of positive wellbeing within workplaces and workforces and has significant implications at an individual (i.e., pilot) and societal level. In line with 'responsible

work concepts', airlines have a responsibility to pilots (i.e., their employees), to shareholders, and to society. Specifically, airlines and the aviation industry need to engage with ideas around the 'triple bottom line' and enabling social justice in the workplace (i.e., decent work agenda). By practicing corporate citizenship, airlines and the industry can become aware of the impact they are having on different aspects of society and proactively address the challenges associated with WRS and pilot wellbeing.

There is a moral, business, and legal case for addressing issues pertaining to WRS, pilot wellbeing, and healthy work practices (including the management of the home/work interface). First, employers have a duty of care to their employees in terms of the promotion of healthy and safe work. Such duties are legally enshrined in workplace legislation. The operating environment and terms of work should not adversely impact an employee's wellbeing and/or create the conditions conducive to the onset of wellbeing issues (including MH issues) and/or contribute to the worsening of a pre-existing issue. Workplace systems and practices should foster trust and engagement, the promotion of wellbeing (including psychological wellbeing), and the avoidance of work-related stress (WRS) and burnout. Moreover, the operating environment should not present a threat to the person's safety or that of other stakeholders (for example, other aviation workers and the travelling public).

Society and the travelling public expect and have a right to transparency in relation to how safety is managed including the measurement and assessment of human capital. It is expected that all risks (including human factors risks) are adequately managed. Further, given the significant challenges faced by pilots and the aviation industry in terms of COVID-19, the public have (or will have) legitimate concerns around the fitness to fly of pilots who are re-entering the workforce. On the flipside, we (as a society) have responsibilities to pilots. We need to accept our role in relation to supporting the wellbeing of pilots. Further, we need to consider the implications of public expectations for low cost flights and 24/7 flight schedules. This is discussed in more detail below.

This is not to minimize the contribution of individuals to harmful work practices. As stated previously, workplace wellbeing relates to the creation of positive wellbeing within both workplaces and workforces. Employees also need to understand their role and responsibilities here. As with their employers, pilots must be educated about boundaries between our life inside and outside of work and managing conflicting demands.

Psychological problems amongst aircrew present a threat to flight safety, given the ensuing impairments to task performance. Factors such as stress, physical state (for example, fatigue), and emotional state (for example, anxiety and depression) are considered to substantially increase the likelihood of human error. This presents a risk both from a flight safety and commercial perspective (i.e., potential for injuries and aircraft damage, brand damage, legal exposure, and associated costs). Pilot absenteeism along with the impacts of absenteeism on flight operations (i.e., replacing crew, flight delays, flight operations changes) represents a significant cost to airlines. This is likely to be a significant motivating factor for airlines to address the development of a wellbeing culture, along with addressing wellbeing as part of the wider safety management system.

4.3. Problem to be Addressed and Impact Scenarios

This research raises questions as to where the problems and/or risks are and, by implication, where the focus of attention should be. Arguably, the greatest needs and risks pertain to the 'human factor'. To this end, the map defining operational and safety needs (and allied risk quantification) needs to be redrawn.

From the perspective of the research evidence collected, the aviation industry/community should focus on promoting and supporting positive wellbeing while also addressing different types and levels of suffering. Specifically, the focus needs to be on routine suffering (scenarios 2 and 3), and not simply extreme events (scenario 6). Overall, scenario 3 is most critical. This is where there is a potential for something more serious/a safety event.

As highlighted in this research, pilots are practicing stress managing strategies and supporting each other (i.e., scenarios 1, 2, and 3). However, this fact should not be used to underestimate the impact of routine suffering and/or sources of WRS (from minor to more severe) and the potential

safety risk. Although positive, such coping can be interpreted as a potential safety risk. Moreover, it gives the impression that all risks are identified and properly managed. Risk is managed within the context of a functional safety management system, which makes safety assessments in relation to different timeframes (i.e., past, present, future), using a diversity of evidence pertaining to different subject elements (i.e., crew, aircraft, environment), and the socio-technical system. A resilient and robust safety management system does not rely on opportunistic and/or ad hoc prevention. It is not acceptable to depend on coping (i.e., the identification and correction of a slip or error by the co-pilot in real time—impact scenarios 1, 2, and 3). Moreover, important outcomes linked to pilot wellbeing and suffering (from minor to severe) are not being managed (see scenarios 2, 4, and 5).

4.4. Safety Quantification and Wellbeing Culture

Wellbeing challenges are real. Further, they are being compounded in the current COVID-19 crisis. As highlighted in this research, existing proactive risk/safety management fail to consider pilot wellbeing and associated factors (including factors linked to sources of WRS and the home/work interface) as a risk to be managed in the SMS. To this end, it can be argued that a significant number of safety risks are not being adequately identified and managed. Based on the evidence collected in this research, it seems prudent to question the apparent avoidance of integrating 'biopsychosocial' wellbeing issues into the existing airline safety/risk assessment approach (i.e., beyond fatigue). Arguably, the current frameworks and associated risk assessment metrics result in an incomplete picture of (1) routine performance (i.e., variability in relation to pilots coping with stress and safety being maintained), (2) the contributory factors to accidents, and (3) flight safety/risk estimates. From this perspective, there are significant vulnerabilities in the existing risk/safety management approach and allied safety quantifications. If we were to use different metrics (for example, Key Performance Indicators (KPI) linked to factors pertaining to the three pillars of wellbeing and WRS), this might yield different conclusions.

Addressing scenario 3 requires the advancement of a wellbeing culture—in the same way as 'just culture'. This should be bolstered by tools which foster and nurture wellbeing. These are discussed in more detail below. Further, it requires the specification of a minimally acceptable standard for pilots to be fit to fly. This includes the COVID-19 time and beyond.

4.5. Concept of Pilot, Professionalism, and Wellbeing Culture

The pilot is conceived as an agent of change in relation to (1) managing their own health and wellbeing and (2) contributing to the advancement of a wellbeing culture.

In relation to (1), there needs to be a strong focus on self-efficacy and fostering/nurturing resilience. This is not to underestimate the impact of the significant challenges that some pilots are facing. Further, it is accepted that a self-management approach is not appropriate for those experiencing acute difficulties and are in crisis situations. In line with the stepped care approach, such pilots will need additional support, beyond the practice of healthy behaviors and support from their social network.

In relation to (2), the development of a wellbeing culture needs to be embedded in concepts of professionalism and flight safety. The existing culture will take time to change. As with the advancement of a 'just culture', the development of a new 'wellbeing culture', will require support in terms of airline leadership and the authorities. However, pilots have a huge role in relation to fostering this culture. Through increased awareness of the home/work interface and the practice of self-care and associated self-management strategies, pilots have an opportunity to lead the way in terms of fostering this culture and demonstrating the relationship between wellbeing, performance, and safety. This of course depends on the provision of robust protections for pilots in relation to privacy and data protection.

4.6. Theoretical Foundations for Tools

The proposed tools have their theoretical underpinnings in frameworks used in health management and behavior change and those used in industry (i.e., airline safety/risk management concepts). In relation to health management and behavior change, this includes concepts of wellbeing, self-efficacy, self-management of health, acceptance, and behavior change and associated therapeutic approaches. In this way it is credible from a therapeutic perspective. In terms of industry concepts, it also has its theoretical underpinnings in the concepts and lexicon of crew resource management (CRM), threat and error management (TEM), Safety II, and predictive risk management.

As stated, the 'biopsychosocial' model of health and wellbeing underpins the wellness management approach. Mental health is not assessed in isolation from the other dimensions of health and wellbeing. Further, wellbeing is addressed from different perspectives. This includes health promotion, maintaining positive wellbeing, and addressing wellbeing challenges (including mental health difficulties and illness).

The proposed tools are framed in relation to safety/risk assessment and link to EASA's rulemaking in terms of managing pilot wellbeing and mental health (and specifically advisory material/best practice which focuses on improving existing safety behavior and culture). There are links across all five tools in relation to end user workflows and information flows. Pending permissions and data protection safeguards, information captured in one tool can be made use of by different actors/stakeholders using other tools. Further down the line, this technology might be customized for other occupations that have similar sources of WRS. For example, other aviation staff (cabin crew, ATM, airport operators, maintenance, and ground personnel), truck drivers, healthcare workers, and first responders.

4.7. COVID and Need for Resilience and Immediate Changes

Post Covid-19, the aviation industry will not be the same. Further, much will have changed for those who remain working in the industry. Airline peer support services will need to be stepped up. Further, pilots will require some level of 'return to work' evaluation. In relation to wellbeing for pilots, the industry and the regulator will need to define a minimally acceptable standard for pilots, in terms of fitness to fly (Dickens, 2000). However, the adoption of healthy behaviors will go some away to preventing the onset and/or worsening of wellbeing problems, including psychological wellbeing. In the short-term, pilots can pose the key questions: (1) how I am feeling and (2) how I am coping/what am I and/or can I do for myself (and others)? These link to the core practices of self-awareness, self-assessment, and self-management. From a pilot perspective, the checklists and digital tool concepts arising from these questions can be implemented in paper format. Further, we need to investigate creative ways in which the community (including the aviation community) can provide help to those who are suffering.

As stated previously, the FSF have defined three operational scenarios during the COVID-19 crisis. This includes in work, not in work, and returning to work. Given the demands on global health systems, some pilots may not be getting the support (public or private health service support) that they previously obtained. This is separate to what may have been provided by their airline EAP or peer support process. Overall, a preventative approach is required. Interventions are required now for pilots to mitigate issues arising during scenarios 1 and 2, which may potentially increase the risk associated with scenario 3. This might involve certain small steps. Pilots might be invited to use their existing technology (for example, Fitbits) to monitor their wellbeing. The checklists proposed in this research might be adapted for the COVID context. In addition, an adaption of the 'Dutch reach' for pilots might be implemented in different contexts (both on duty and off duty). This would involve a physical gesture to either draw attention to wellbeing and/or signal wellbeing issues. Overall, such initiatives might empower pilots and support self-efficacy and resilience while also considering existing attitudes to health promotion and self-declaring wellness challenges.

4.8. Relevance to Other Aviation Professionals and Others

Many of the sources of work-related stress examined in pilots are common to other aviation workers, who are also shift-workers, such as cabin crew, ground staff, engineers, and air traffic controllers to name but a few. Hence, it is reasonable to conclude that many of these lifestyle factors and coping strategies adopted by the resilient group of pilots, might also offer substantial benefits to other worker groups within aviation.

4.9. Limitations and Areas for Further Research

Study limitations should be considered. Workshop and survey participants were recruited using social media. As such, issues pertaining to the self-selection of candidates and the potential for bias in terms of interest in wellbeing and/or experience of suffering should be considered. Survey data were self-reported. There may be discrepancies between the person's actual health and experience of WRS and their perception of this. Further, as survey data is cross-sectional, the results can only be used to evaluate the sample for this time period. As such, a cause-and-effect relationship cannot be inferred. Additional research is required to unpack the specific WRS issues and wellbeing factors as reported by stakeholders across the different studies.

Primarily, this research reflects the perspective of one stakeholder group (namely pilots). Validation with other stakeholder groups is at an early stage. In addition, further research is required in relation to advancing a road map for the implementation of solutions at an airline level. This would need to include the participation of representatives from both airlines and relevant authorities.

There may be different challenges in terms of tool acceptability and adoption and use for different cohorts (for example, younger and older pilots). Further, the existing impact scenarios may require additional specification, in terms of the COVID 19 context and the challenges pertaining to the three scenarios defined by the FSF (i.e., in work, out of work, and returning to work).

Moreover, the wellbeing algorithm requires further analysis and specification. In particular, the weighting of factors within and across the wellbeing pillars will need to be determined. Further, the baseline level will need to be calculated for different pilots, and then factored into the risk assessment.

4.10. Next Steps

The proposed tool concepts are preliminary and require additional validation with stakeholders. This will require in-depth co-design activities with pilots and other aviation industry stakeholders. Currently, the focus is on Tool 1 and 2. Further attention will need to be given to the design of Tool 3, 4, and 5—including addressing privacy issues. As noted earlier, from the perspective of the tools framework, there are two contexts in which privacy challenges need to be addressed. In the airline context, this includes the potential to share pilot information (in a de-identified format) with the airline EAP, safety department, and with crew rostering and flight planning. The second context includes potential sharing of pilot data with aeromedical examiners.

In relation Tool 1 and 2, a subset of this functionality will be further explored. Early stage prototypes will be evaluated with a small group of pilots. As part of this, we will address the practice of specific stress coping activities (for example, creative activities, hobbies, and spiritual activity) and how these might be monitored, assessed, and supported. The specific implementation of these tools at an operational level requires further research. We will also address issues regarding device usability, social acceptability, and ethics (including issues pertaining to managing privacy).

In relation to airline solutions, broader stakeholder evaluation-based research will be undertaken to validate the preliminary solutions and address their specific implementation at an airline level. Lastly, additional field research will be undertaken with other aviation professionals (i.e., cabin crew, Air Traffic Control [ATC], maintenance engineers, and ground operations).

5. Conclusions

Pilots face many occupational hazards that are endemic to their jobs. Pilots, the aviation industry, and society should recognize and support the many activities that contribute to positive wellbeing for pilots.

The aviation community needs the right tools to safeguard the wellbeing and mental fitness of pilots and ensure flight safety. Overall, work should be designed to benefit all stakeholders. Airlines and the aviation industry need to be socially accountable. Behavior change is required at an individual, organizational, and societal level. Further, this change needs to be conceptualized from a socio-technical perspective and deliver benefits to employers, employees, and society.

There is a moral, legal, and business case for supporting pilot resilience and addressing wellbeing factors within an airline's safety management system. Post Covid-19, the aviation industry will not be the same, and nor will those who remain working in the industry. Solutions are required for pilots and other stakeholders to address (1) the new requirements proposed by EASA [9] (2) gaps in relation to existing regulatory requirements and enabling a preventative and holistic approach to wellbeing management and supporting resilience, (3) the existing evidence on pilot wellbeing challenges, the prevalence of suffering, and the use of coping strategies, and (4) the immediate COVID need and allied three scenarios defined by the flight safety foundation.

Pilots are adapting to the job and managing wellbeing issues. However, there is much variation in relation to coping ability. This variation needs to be considered in terms of (1) operational safety risk assessments and (2) designing wellbeing interventions at pilot and airline levels. Pilot wellbeing needs to be treated from a holistic perspective (biopsychosocial). Pilots, airlines, and the regulator can learn from the existing use of coping strategies as evidenced in this research. New tools are required at different levels (i.e., pilot, airline, aeromedical examiners) to support pilot self-management of their health and wellbeing.

In support of the EASA directives, best practice in relation to preventative approaches to health management, predictive risk management, and associated data driven approaches, preliminary concepts and prototypes for tools have been advanced. These prototypes pave the way for rethinking how pilots and airlines effectively manage issues pertaining to WRS and its impact on pilot wellbeing/mental health, pilot performance, and flight safety. Stress cannot be eliminated from the work life of pilots. However, the proposed tools can support the management of pilot WRS and its effects on pilot wellbeing, performance, and safety. The tool concepts are predicated on significant field research and validation with pilots and the industry. The concepts emerge from a framing of the wellbeing problem from a systems perspective and a focus on addressing outcomes (i.e., impact scenarios). Further, they are linked to behavior change frameworks and practices, at an individual, organizational, and societal level.

Existing pre-flight checklists should be extended to enable the crew to evaluate their health and wellbeing. New checklists might be developed for use by pilots while off duty, supporting an assessment of (1) their biopsychosocial health status (i.e., three pillars of wellbeing) and (2) how they are coping/using coping strategies. This research underscores the need to introduce digital tools to enable pilot self-management of wellbeing and safety behavior. This might involve the advancement of a phone app with different wellness functions. Data captured in this tool might be shared in a de-identified format with the pilot's airline.

Tools to support pilot coping and resilience are recommended. Nonetheless, airlines must also manage these risks. This might involve the adoption of Safety II approaches—predicated on data driven risk assessment. To this end, there is a requirement for corresponding tools for other stakeholders. Existing airline SMS and flight rostering/planning systems might be extended to make use of pilot data from an operational and safety management perspective. Fatigue risk management systems (and by implication airline rostering/flight planning systems) need to be extended to consider the relationship between fatigue risk and the other dimensions of a pilot's wellbeing. This requires making use of a pilot's wellbeing data within the airline SMS and raises significant issues pertaining to privacy rights and the protection of personal data. In addition, a new training format should be devised to support pilot development of coping skills. Pilot information might also be

shared with the airline EPA to support coping and the targeting of interventions at a cohort/fleet level. Moreover, information might also be shared with aeromedical examiners.

The proposed tool concepts are preliminary and further validation research is planned with pilots and other stakeholders. As part of this, specific information sharing roles, processes, and safeguards will need to be defined, in line with legal frameworks and societal values.

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Conflicts of Interest: The authors declare no conflicts of interest.

Appendix A: Field Research and Data Analysis Methods

Table A1. Field Research & Data Analysis Methods**.**

Part 1: A	Semi-Structured Interviews with Pilots	Semi-structured scoping interviews were conducted with N = 103 commercial pilots. The interviews were conducted opportunistically by Captain Paul Cullen and took the form of a casual conversation between peers. Participants obtained an informal briefing and verbal consent was established. Written consent was not elicited. Participants were informed that interview data was not being shared with others and that the findings were to be used to advance a model of the lived experience of being a pilot. Pilots were asked open ended questions about sources of WRS and the lived experience of being a pilot. They were also asked about the health impact/outcomes of these issues. These interviews were conducted on a preliminary exploratory basis. Research findings were documented after the event and not at the time.
Part 1: C	Participatory Workshops with Pilots	The workshops had two objectives: To validate the preliminary model of pilot lived experience in relation to sources of WRS To map the relationship between WRS, pilot wellbeing, pilot performance, and flight safety. Workshop participants were recruited using word of mouth and through social media (advertisements posted with the Irish Airline Pilots Association (IALPA) and on Irish-based pilot discussion boards). The sample composition is made up of pilots flying from Ireland only. Overall, 33 commercial pilots (spanning three airlines) attended the workshops. Workshop participants had on average 9,178 h of flying experience and included 20 captains and 13 first officers. Of the 33 participants, 7 were female and 26 were male. Eight participants had part-time work contracts, while 25 were working full-time. In terms of flight operations, this included 4 short range, 7 long range, and 22 mid-range pilots. Three workshops were undertaken with 33 commercial pilots (workshop 1: N = 12, workshop 2: N = 10, workshop 3: N = 11). The workshops were undertaken between March and May 2018. A workshop presentation was compiled for each of the three workshops. This presentation provided the structuring framework for each of the workshops and guided the interaction between the workshop facilitator and the workshop participants. In the case of all three workshops, the

		workshops started with a short presentation about project goals and concepts. Participants were then invited to provide written consent for their participation in the workshop. There were some differences between the workshop structure/format and specific questions posed to participants in workshop 1, 2, and 3. In workshop 1, specific pilot personae were presented to participants. Each participant received a printed page with the personae information. These included descriptions of three different pilots—with different situations and each experiencing a spectrum of suffering. The workshop facilitator reviewed the different persona and invited feedback. Participants were then presented with the preliminary definition of the sources of WRS—grouped in terms of the biopsychosocial framework. In relation to sources of WRS, participants were invited to review and edit the list of sources presented. Following this, participants were presented with a preliminary safety case and three worked examples, corresponding to the biopsychological framework of health and wellbeing. Participants discussed the safety case and associated worked examples. There was then a group discussion concerning the relationship between WRS, pilot wellbeing, pilot performance, and flight safety. Workshop 2 was designed to address the findings of workshop 1. There were two format changes. First, the personae were not presented to pilots. Secondly, the preliminary safety case and worked example was replaced with a definition of six impact scenarios which emerged in workshop 1.Participants were invited to review/validate the six scenarios. Participants were invited to provide feedback about the scenarios defined in workshop 1—specifically in relation to impact on (1) wellbeing, (2) performance, and (3) safety. This was followed by a group discussion concerning the relationship between WRS, wellbeing, performance, and safety. In workshop 3, the integrated findings of workshop 1 and 2 were presented to participants. In relation to the six impact scenarios, participants also provided an estimation of the frequency in which such a situation would arise. In all three workshops, participants were invited to complete a homework exercise. At the end of each workshop, there was a full participant debriefing. The workshops were led by two human factors researchers (JC and PC). During each of the three workshops, the researchers alternated roles between leading the workshop and recording workshop notes. This followed the structured agenda. In each case, the researcher recorded workshop notes on their computer. Ethics approval for the workshops and additional interviews (to happen after the workshops) was granted by the School of Psychology, Trinity College Dublin (TCD) – in February 2018.
Part 2: E	Survey Design	This involved an anonymous web-based survey targeted at commercial pilots. The survey ran over a fifteen-month period (between 7th November 2018 and the 24 January 2020). The survey examined the effects of work-related stress (WRS) on pilot wellbeing and the associated impact on both pilot performance and flight safety. The survey also investigated pilot coping methods and pilot perception of the airline role in relation to managing WRS and wellbeing issues. The survey incorporated several standardized instruments to measure levels of common mental health issues. This includes the Patient Health Questionnaire-9 (PHQ-9), the Oldenburg Burnout (OLBI 8), and the Oldenburg Burnout (Modified Instrument). First, pilots received a short briefing about the study and its background. The electronic consent was then completed. Following this, relevant survey questions were answered. This was followed by a debriefing.

		Pilots were recruited using social media platforms such as LinkedIn and Twitter. The survey was powered by the SurveyMonkey service and did not collect any identifying information about the person. Further, no internet protocol (IP) addresses were collected. It was assumed that each participant was a pilot and only completed one survey. Several questions in the survey required knowledge that would only be readily available to pilots. An active pilot (co-author in this study: PC) reviewed surveys for potential non-pilot participants. All surveys passed this screening. Ethics approval was granted by the School of Psychology, Trinity College Dublin (TCD), in August 2018.
		The purpose of the data analysis was to (1) identify sources of WRS and wellbeing impact, (2) measure depression levels in pilots, (3) examine the use of coping strategies (CS), and (4) examine the relationship between coping strategies used by pilots and their mental health—secifically depression severity levels.
	Survey: Data Analysis	In relation to (1), sources of WRS and wellbeing impact were reported based on pilot self-reported data. In relation to (2), depression levels were scored using the depression severity scale (Kroenke, Spitzer and Williams, 2001). In relation to (3), we examined the prevalence of pilots using CS and the most frequently used CS. In relation to (4), an ordered logistic regression model was advanced to explore the relationship between the PHQ-9 scores and each of the coping strategies for WRS (i.e., those listed in the survey).
Part 4 B	Ordered Logistic Regression Model and Interpreting the Odds Ratio	The objective was to model the relationship between each frequency level of each coping strategy and PHQ-9 Scores. Following this, we interpreted the odds ratio, to assess statistically significant coping strategies. Logistic regression is a statistical method for analyzing a dataset in which there are one or more independent variables that determine an outcome. The outcome is measured with a dichotomous variable (in which there are only two possible outcomes). The response variable Y is assumed to be binary (i.e., either a failure or success). In our case, we took the two outcomes of the response variable to be: (1) pilot has a PHQ-9 score below 10 (Y_i = 0) or (2) pilot has a PHQ-9 score of at least 10 (Y_i = 1). We are interested in drawing inferences on coping strategies and how they are related to depression severity levels, that is co-relation not causality (coping strategy causing the PHQ score to be below 10 or vice versa). This analysis does not consider interaction between different coping methods. Interpretation of results addressed the odds ratio. If the odds ratio is less than 1, then it is associated with a probability of having a lower depression severity level. Statistically significant coping strategies were set at $p = 0.05$. For more, please see Appendix 3, 4, and 5. It should be noted that the p-value tells us only whether a coping strategy at a certain frequency level was statistically significant. The odds ratio is what tells us whether that coping strategy is associated with a higher (if > 1) or lower (<1) depression severity level.

Appendix B

Table A2. Research parts and phases.

Part	#	Objective and Description	Method	Stakeholder Involvement	Outcomes	Date	Status	Key References
1	A	Advancement of initial lived experience model	Semi-structured interviews with pilots	Pilots, (N = 103)	Lived experience model 1	May 2015 to June 2017	Complete	
	B	Analysis of airline processes to manage pilot WRS and wellbeing (including MH) and associated regulation	Literature review	N/A	Airline process mapping Evaluation of regulation	January 2016 to June 2017	Complete	[7]
	C	Validation of lived experience model—phase 1 Assessment of impact of WRS on wellbeing, performance, and safety	Participatory workshops	Pilots (N = 33)	Lived experience model 2 Preliminary impact model Impact scenarios	April to May 2018	Complete	[8]
2	A	Analysis of problem	Modelling problem from human factors/systems perspective.	N/A	Problem Definition	June 2018 to December 2018	Complete	[7]
	B	Validation of lived experience model—phase 2	Survey with pilots (N = 325)—phase 1	Pilots (N = 325)	Lived experience model 3 Preliminary assessment of coping strategies	Jan to April 2019	Complete	[7]
	C	Analysis of coping strategies	Initial data analysis	N/A	Preliminary assessment of coping strategies	April to May 2019	Complete	[7]
	D	Specification of interventions and tools requirements—	Research analysis	N/A	Interventions and tools requirements—airline level Interventions and tools requirements—pilot level	April to July 2019	Complete	[7]

		airline and pilot levels Situate concepts in relation to therapeutic/ clinical approaches						
	E	Validation of lived experience model – phase 3	Survey with pilots (N = 1050) – phase 2	Pilots (N = 1050)	Lived experience model 4	March 2019 to January 2020	Complete	
3	A	Specification of tool framework Specification of preliminary prototypes (Tool 1 and 2) Specification of airline process	Preliminary prototype development Process Mapping—as is and future process Analysis and Advancement of tool framework	N/A	Tool framework (Tool 1, 2, 3, 4, and 5) Prototypes for Tool 1 and 2 Process maps (as is/future)	August 2019 to September 2019	Complete	N/A
	B	Preliminary validation of tools framework with stakeholders Preliminary validation of Tool 1 and 2 with stakeholders	Preliminary validation research with airlines Preliminary validation research with software companies Preliminary review with regulatory authority (EASA and IAA)	N = 7	Updated framework Updated prototypes for Tool 1 and 2	September to October 2019	Complete	N/A
	C	Analysis of customer/ airline need and customer/ airline journey	Specification of existing and future customer journey	N = 2	Customer journey maps	December 2019	Complete	N/A
4	A	Specification of problem/change requireme	Analysis of problem Application of Fogg	N/A	Definition of problem in relation to five interacting systems	Jan to Feb 2020	Complete	[16]

		nts from systems perspective Specification of behaviour change framework Further specification of tools	model of behaviour change Prototype development using Balsamiq		Behaviour change framework Prototypes for Tool 1 and Tool 2 Checklist specifications			
	B	Understanding pilot use of coping strategies—specifically in relation to depression severity	Analysis of survey findings (N = 1050) Regression model and odds ratio	N/A	Analysis of coping strategies	January 2020 to April 2020	Complete	[16]
	C	Further specification of tools Specification of risk algorithm	Prototype development using Balsamiq	N/A	Tool 1 and 2 specification Preliminary risk algorithm	January 2020 to April 2020	Complete	N/A
5	A	Review in context of COVID need	Interviews with stakeholders/experts in the field Collaborative workshops with stakeholders	Panel of pilots, industry experts, aeromedical assessment experts (N = 9)	Tools framework Review of coping strategies and associated tools concepts Checklist specification	March to April 2020	Complete	N/A

Appendix C: Lived Experience Model (High Level)

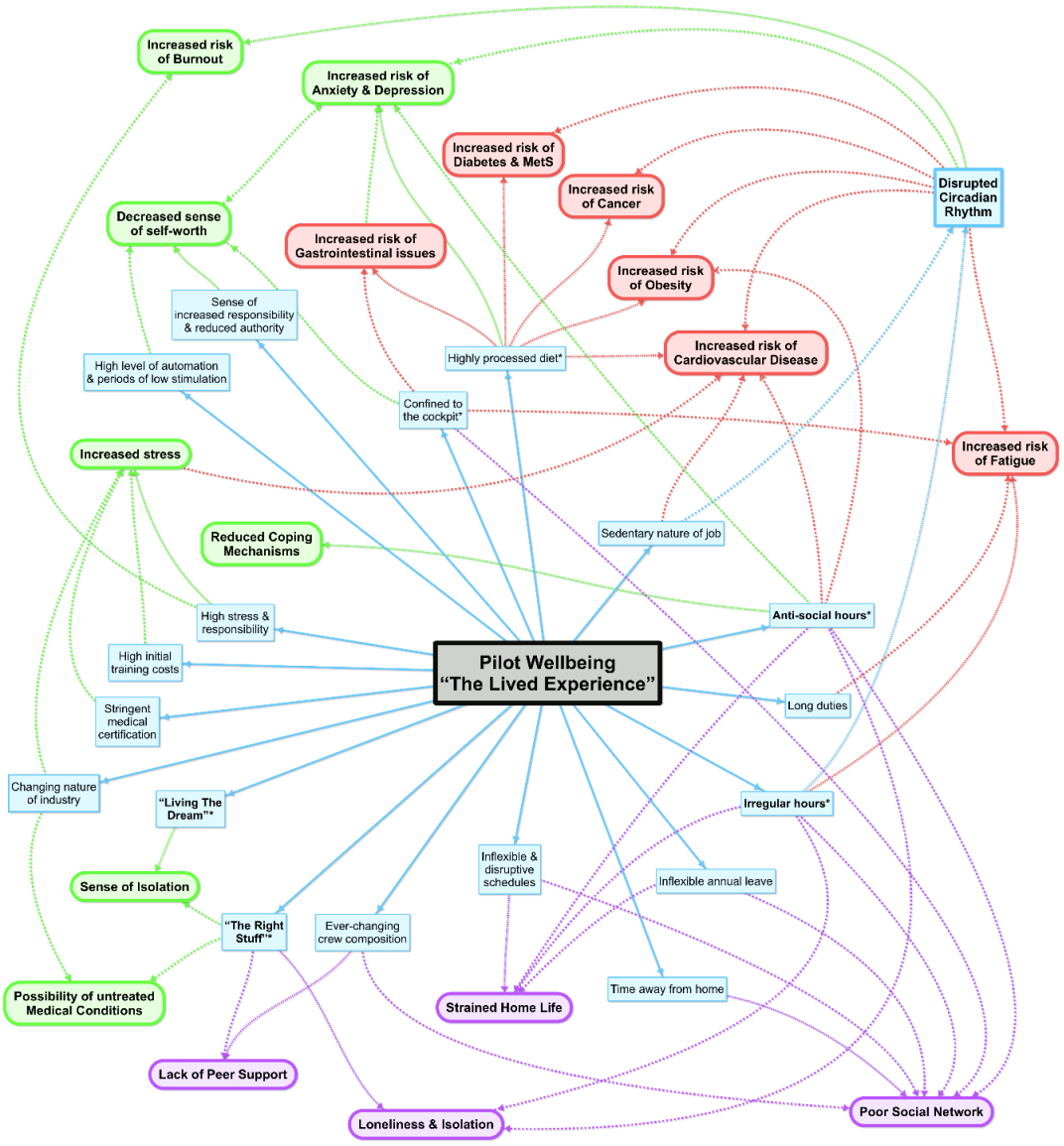

Figure A1. Lived experience model (Cahill et al., 2019).

Appendix D: Sources of WRS (Pre COVID-19)

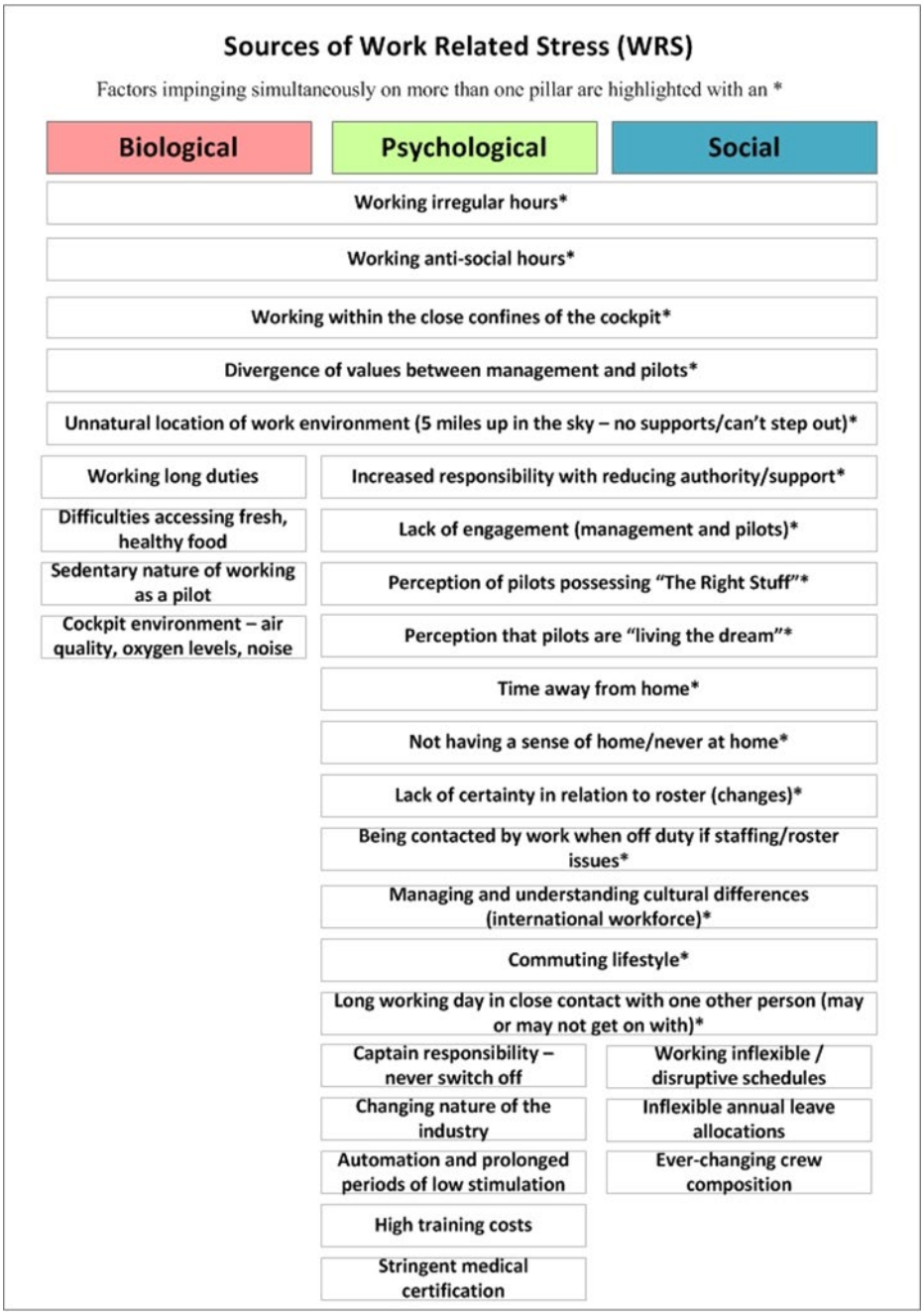

Figure A2. Sources of WRS, Pre COVID-19 (Cahill et al., 2019).

Appendix E: COVID-19, Wellness Positives and Challenges

Table A3. COVID-19, pilot wellness positives and challenges.

#	Operational Scenario	Wellness Positives	Wellbeing Challenges and Sources of Stress
1	In work	Salary and financial wellbeing Getting out of the house Purpose obtained from job	Flying in a different environment Keeping track of changing schedule Managing childcare while working Financial wellbeing—reduced salary Uncertainty as to future financial security Different treatment of colleagues—guilt, discrimination Uncertainty about status of co-pilot (severity of suffering) Potential bereavement Social isolation Loss of social network Difficulties maintaining social network Potential illness/health challenges in family
2	Out of work	Improved sleep Improved diet More time with family Opportunity to take exercise (albeit limited with government rules/2 km)	Financial wellbeing—reduced salary or unemployment Uncertainty as to financial security Social isolation Loss of social network Difficulties maintaining social network Loneliness Not enough 'me time' Too much time with family Lack of routine Emotional instability Social isolation Loss of social network Difficulties maintaining social network Potential illness/health challenges in family Potential bereavement
3	Returning to work	Getting out of the house Purpose obtained from job Social interaction	Emotional instability Loss of social network Job proficiency and potential loss of confidence Training and competency—out of practice Ability to assess own wellbeing and MH If suffering, confidence in own ability to do the job safely Uncertainty about status of co-pilot (severity of suffering)

	Potential bereavement Bereavement Health challenges in family

Appendix F: Tools and Processes

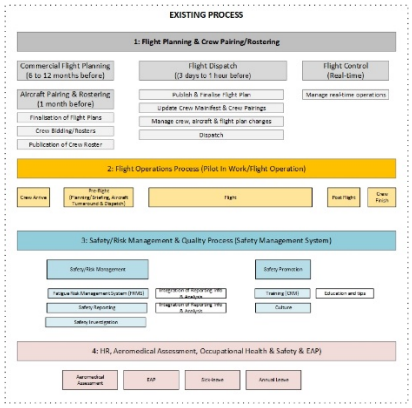

Figure A3. As Is Process.

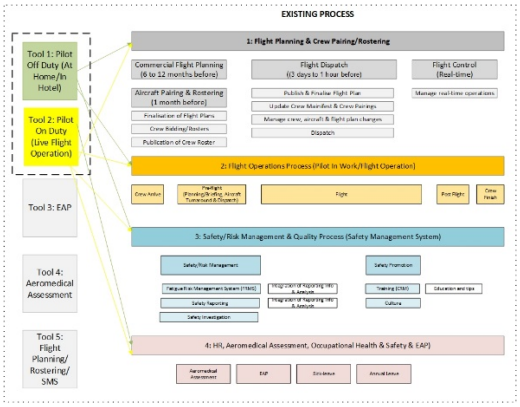

Figure A4. Future process.

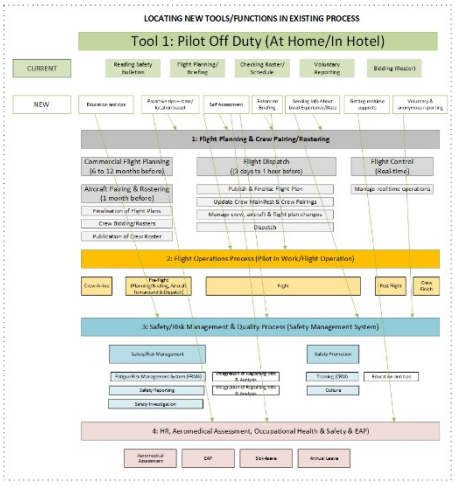

Figure A5. Pilot on duty: Tool 1 and process, Tool 1 (pilot off duty).

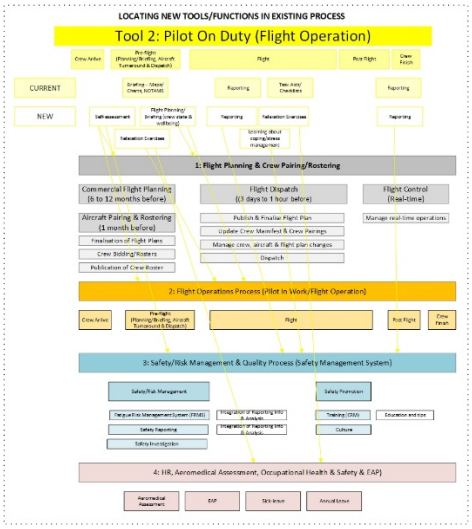

Figure A6. Pilot off duty: Tool 2 and process, Tool 2 (pilot on duty).

Appendix G: Provisional Risk Assessment Algorithm

Table A4. Provisional risk assessment algorithm.

Classification	Factor	Factor	Risk Rating (Based on Data Picture)		
			H	M	L
Biological	1	Sleep and fatigue			
	2	Physical Exercise			
	3	Diet			
Psychological	4	How feeling (stress)			
	5	Emotional stability and mood			
Social	6	Talking to others/seeing people			
Overall Biological Rating		H M L			
Overall Psychological Rating		H M L			
Overall Social Rating		H M L			
Overall Wellness Risk Rating		H M L			

Appendix H: Auto Harvesting Pilot Wellness Information

Table A5. Auto harvesting pilot wellness information.

Classification	Factor	Factor	Specific Info	Wellness App or Other App (Auto Harvesting)	Example Other Apps/Auto Harvesting
Biological	1	Sleep and fatigue	No. of hours sleep Sleep deficit Sleep disruption Sleep displacement	If using other, get from that Otherwise, 1 or 2 questions	From Crew Alert (if using) Or Garmin or Fitbit
	2	Physical Exercise	No of steps		Garmin or Fitbit
	3	Eating	1 question?		
	4	Hydration	1 question?		
Psychological	5	How feeling (stress)	Heartrate Perceived stress (self-report)	If not other app, 1 question each day?	Garmin has heartrate If using MH app, take self-report from that
	6	Emotional stability and mood		If not other app, 1 question each day?	If using MH app, take from that
Social	7	Taking to/contact with family			
		Talking to others/seeing people		1 question each day? If using mobile phone calendar, quick question about what penciled in—did you do X?	

Appendix I: Prototype Examples (Tool 1)

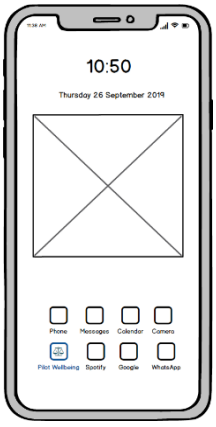

Figure A7. Pilot phone: dashboard.

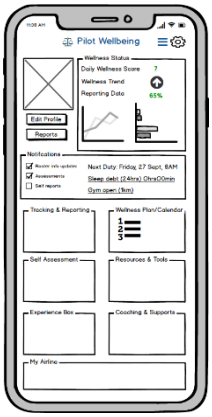

Figure A8. Tool 1: dashboard.

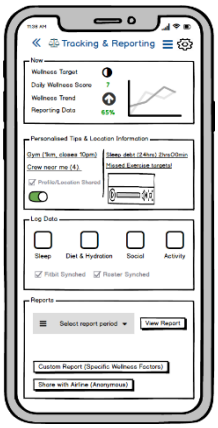

Figure A9. Tool 1: Tracking and reporting dashboard.

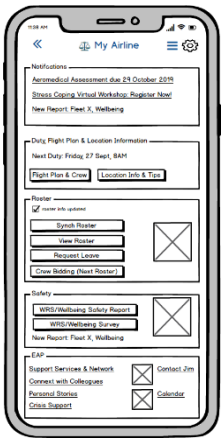

Figure A10. Tool 1: my airline dashboard.

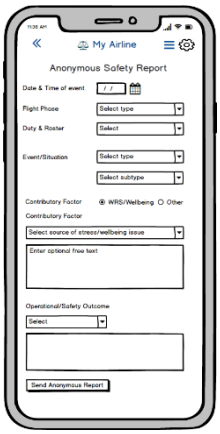

Figure A11. Tool 1: anonymous safety reporting.

Appendix J: Extended I am Safe Checklist

Table A6. Extended I am Safe Checklist.

I	Illness and Wellbeing	Do I have an illness or any symptoms of an illness? Am I feeling good/well? How is my overall health and wellbeing? Physical health? Emotional/Psychological Health? What is my mood and attitude like? Social Health? Have I seen family/friends? Getting help/support if needed?
M	Medication	Have I been taking prescription or over-the-counter drugs?
S	Stress and Stress Coping	Am I under psychological pressure from the job? Worried about financial matters, health problems or family discord? Am I actively managing my stress? Exercise? Social? Do I need help?
A	Alcohol	Have I been drinking within eight hours? Within 24 h?
F	Fatigue	Am I tired and not adequately rested? Have I been managing my sleep?
E	Eating and Exercise	Am I adequately nourished and hydrated? Am I taking physical exercise?

References

1. Elkington, J. Enter the Triple Bottom Line. 1994. Available online: https://johnelkington.com/archive/TBL-elkington-chapter.pdf (accessed on 11 October 2019).
2. Elkington, J. *Cannibals with Forks: The Triple Bottom Line of 21st Century Business*; Capstone: Oxford, UK, 1999.
3. Elkington, J. *25 Years Ago I Coined the Phrase "Triple Bottom Line." Here's Why It's Time to Rethink It*; Harvard Business Review; 2018. Available online: https://hbr.org/2018/06/25-years-ago-i-coined-the-phrase-triple-bottom-line-heres-why-im-giving-up-on-it (accessed on 11 October 2019).
4. Sengenberger, W. *The International Labour Organization: Goals, Functions and Political Impact*; Friedrich Ebert Stiftung: Berlin, Germany, 2013.
5. International Labour Organisation. Decent Work Agenda. 2020. Available online: https://www.ilo.org/global/topics/decent-work/lang--en/index.htm (accessed on 24 April 2020).
6. Rodgers, G.; Lee, E.; Swepston, L.; Van Daele, J. The International Labour Organization and the Quest for Social Justice, 1919–2009 (PDF). Geneva: International Labour Organization. 2019. Available online: https://www.ilo.org/wcmsp5/groups/public/@dgreports/@dcomm/@publ/documents/publication/wcms_104643.pdf (accessed on 23 January 2020).

7. Cahill, J.; Cullen, P.; Gaynor, R. Interventions to support the Management of WRS & Wellbeing Issues for Commercial Pilots. *Cogn. Technol. Work* **2019**, doi:10.1007/s10111-019-00586-z.
8. Cahill, J.; Cullen, P.; Gaynor, K. Estimating the Impact of Work-Related Stress on Pilot Wellbeing and Flight Safety'. In Proceedings of the 2nd International Symposium on Human Mental Workload: Models and Applications (H-WORKLOAD 2018), Netherlands Aerospace Centre (NLR), Amsterdam, The Netherlands, 20–21 September 2018.
9. European Aviation Safety Agency (EASA) rules European Union Aviation Safety Agency (EASA). (2019). Commission Regulation (EU) No 965/2012 on Air Operations and associated EASA Decisions (AMC, GM and CS-FTL.1), Consolidated version for Easy Access Rules, Revision 12 March 2019. Part ORO, Annex II, Part ORO, ORO.GEN.200 Management Systems and associated Acceptable Means of Compliance (AMCs) and Guidance Material (GMs). Available online: https://www.easa.europa.eu/sites/default/files/dfu/Air%20OPS%20Easy%20Access%20Rules_Rev.12_March%202019.pdf (accessed on 2 May 2018).
10. Bureau d'Enquêtes et d'Analyses pour la Sécurité de l'Aviation Civile (BEA). Accident on 24 March 2015 at Prads-Haute-Bléone (Alpes-de-Haute-Provence, France) to the Airbus A320-211 registered D-AIPX operated by Germanwings. Final Report. March 2016. Available online: https://www.bea.aero/uploads/tx_elydbrapports/BEA2015-0125.en-LR.pdf (accessed on 2 May 2018).
11. Atherton, M. A question of psychology. 2019. Available online: https://www.aerosociety.com/news/a-question-of-psychology/ (accessed on 6 March 2019).
12. European Union Aviation Safety Agency (EASA). (2017). Part-ORO—Organisation Requirements for Air Operations. Available online: https://www.easa.europa.eu/acceptable-means-compliance-and-guidance-material-group/part-oro-organisation-requirements-air (accessed on 17 July 2019).
13. Anthony, T. Avoiding another Germanwings. Proceedings of the International Pilot Peer Assist Conference (IPPAC)—October 25-26, 2019, Texas USA. Available online: http://pilotpeerassist.com/international-pilot-peer-assist-conference/ (accessed on 13 May 2020).
14. Atherton, M. Mental Wellbeing & Human Performance Seminar. Published by the RaeS. 2020. Available online: https://youtu.be/pT8uB7fVV44 (accessed on 11 May 2020).
15. Dickens, P. Cleared for Take-off. A Pilot's Guide to Returning to Flying. 2020. Available online: https://www.core-ap.co.uk/challenging-times (accessed on 11 May 2020).
16. Cahill, J.; Cullen PAnwer, S.; Gaynor, K.; Wilson, S. Pilot Work Related Stress (WRS), Effects on Wellbeing and Mental Health, and Coping Methods. Part of the Mental Wellbeing & Human Performance Seminar. Published by the RaeS. 2020. Available online: https://youtu.be/pT8uB7fVV44 (accessed on 11 May 2020).
17. Flight Safety Foundation. An Aviation Professional's Guide to Wellbeing. 2020. Available online: https://flightsafety.org/wp-content/uploads/2020/04/Guide-to-Wellbeing.pdf (accessed on 11 May 2020).
18. European Union Aviation Safety Agency (EASA). Together 4 Safety. 2020. Available online: https://www.easa.europa.eu/easa-and-you/safety-management/safety-promotion/ (accessed on 11 May 2020).
19. Josephs, L. American Airlines cutting international summer schedule by 60% as coronavirus drives down demand. CNBC News, 2 April. Available online: https://www.cnbc.com/2020/04/02/coronavirus-update-american-airlines-cuts-summer-international-flights-by-60percent-as-demand-suffers.html (accessed on 30 April, 2020).
20. Sobieralski, J. COVID-19 and Airline Employment: Insights from Historical Uncertainty Shocks to the Industry. 2020. Available online: https://www.sciencedirect.com/science/article/pii/S2590198220300348 (accessed on 30 April 2020).
21. Engel, G. The need for a new medical model: A challenge for biomedical science. *Science* **1977**, *196*, 126–129.
22. Ghaemi, S. The rise and fall of the biopsychosocial model. *Br. J. Psychiatry* **2009**, *195*, 3–4. doi:10.1192/bjp.bp.109.063859.
23. Borrell-Carrió, F.; Suchman, A.L.; Epstein, R.M. The biopsychosocial model 25 years later: Principles, practice, and scientific inquiry. *Ann. Fam. Med.* **2004**, *2*, 576–582, doi:10.1370/afm.245.
24. Lehman, B.J.; David, D.M.; Gruber, J.A. Rethinking the biopsychosocial model of health: Understanding health as a dynamic system. *Soc. Pers. Psychol. Compass* **2017**, *11*, e12328.
25. World Health Organisation. Mental Health. 2019. Availble from https://www.who.int/mental_health/en/ (accessed on 23 January 2019).

26. Flinchbaugh, C.; Luth, M.; Li, P. A Challenge or a Hindrance? Understanding the Effects of Stressors and Thriving on Life Satisfaction. *Int. J. Stress Manag.* **2015**, *22*, doi:10.1037/a0039136.
27. Houtman, I.; Jettinghoff, K. Raising Awareness of Stress at Work in Developing Countries a modern hazard in a traditional working environment. In *WHO Protecting Workers Health, Series 6*; WHO Press: Geneva, Switzerland, 2007.
28. Skybrary. Stress and Stress Management. Available online: https://www.skybrary.aero/index.php/Stress_and_Stress_Management (OGHFA_BN) (accessed on 12 May 2020).
29. Lazarus, R S. Theory-based stress measurement. *Psychol. Inq.* **1990**, *1*, 3–13.
30. Leka, S.; Griffiths, A.; Cox, T. Work Organisation & Stress: Systematic Problem Approaches for Employers, Managers and Trade Union Representatives. (Protecting Work-ers' Health Series: No. 3). World Health Organization: Geneva, Switzerland, 2003.
31. Theorell, T.; Karasek, R.A. Current issues relating to psychosocial job strain and cardiovascular disease research. *J. Occup Health Psychol.* **1996**, *1*, 9–26.
32. Joseph, C. Stress Coping Strategies in Indian Military Pilots: Preliminary Observations. *Int. J. Aviat. Aeronauctics Aerosp.* **2016**, *3*, doi:10.15394/ijaaa.2016.1147.
33. Lazarus, R.; Folkman, S. Stress, Appraisal, and Coping. Springer: New York, NY, USA, 1984.
34. Morimoto, H.; Shimada, H. The Relationship between Psychological Distress and Coping Strategies: Their Perceived Acceptability Within a Socio-Cultural Context of Employment, and the Motivation Behind Their Choices. *Int. J. Stress Manag.* **2015**, *22*, 159–182, doi:10.1037/a0038484.
35. World Health Organisation (WHO). Mental Health. Available online: https://www.who.int/mental_health/en/ (accessed on 12 May 2020).
36. Clark, D.M. Realizing the Mass Public Benefit of Evidence-Based Psychological Therapies: The IAPT Program. *Annu. Rev. Clin. Psychol.* **2018**, *14*, 159–183.
37. Ijaz, S.; Davies, P.; Williams, C.J.; Kessler, D.; Lewis, G.; Wiles, N. Psychological therapies for treatment-resistant depression in adults. *Cochrane Database Syst. Rev.* **2018**, doi:10.1002/14651858.CD010558.pub2.
38. Pompoli, A.; Furukawa, T.A.; Imai, H.; Tajika, A.; Efthimiou, O.; Salanti, G. Psychological therapies for panic disorder with or without agoraphobia in adults: A network meta-analysis. *Cochrane Database Syst. Rev.* **2016**, doi:10.1002/14651858.CD011004.pub2.
39. National Institute for Health and Clinical Excellence (NICE). Common Mental Health Problems: Identification and Pathways to Care. Clinical Guideline [CG123] Published date: 25 May 2011. Available online: https://www.nice.org.uk/guidance/cg123/chapter/1-guidance (accessed on 12 May 2020).
40. National Institute for Health and Clinical Excellence (NICE). Mental Wellbeing at Work. Public health guideline [PH22] Published date: 05 November 2009. Available online: https://www.nice.org.uk/guidance/ph22 (accessed on 12 May 2020).
41. Tetrick, L.; Winslow, C. Workplace Stress Management Interventions and Health Promotion (April 2015). Annual Review of Organizational Psychology and Organizational Behavior, Volume 2, Issue 1, pp. 583–603, 2015. Available at SSRN: https://ssrn.com/abstract=2594246 (accessed on 20 May 2020).
42. Ruotsalainen, J.; Serra, C.; Marine, A.; Verbeek, J. Systematic review of interventions for reducing occupational stress in health care workers. *Scand. J. Work Environ. Health* **2008**, *34*, 169–178, doi:10.5271/sjweh.1240.
43. Karasek, R. Stress prevention through work reorganization: A summary of 19 international case studies. In *ILO: Conditions of Work. Digest—Preventing Stress at Work*; International Labour Organisation, Geneva, Switzerland. 1992; Volume 11, pp. 23–41.
44. Tarro, L.; Llauradó, E.; Ulldemolins, G.; Hermoso, P.; Solà, R. Effectiveness of Workplace Interventions for Improving Absenteeism, Productivity, and Work Ability of Employees: A Systematic Review and Meta-Analysis of Randomized Controlled Trials. *Int. J. Environ. Res. Public Health* **2020**, *17*, 1901.
45. Odeen, M.; Magnussen, L.H.; Maeland, S.; Larun, L.; Eriksen, H.R.; Tveito, T.H. Systematic review of active workplace interventions to reduce sickness absence. *Occup. Med.* **2013**, *63*, 7–16.
46. Kenny, A. *Aristotle: The Eudemian Ethics*; Oxford University Press: Oxford, UK, 2011.
47. Seligman, M. *Authentic Happiness: Using the New Positive Psychology to Realize Your Potential for Lasting Fulfillment*; Free Press: New York, NY, USA, 2002.

48. Fikretoglu, D.; McCreary, D.R. Psychological Resilience: A Brief Review of Definitions, and Key Theoretical, Conceptual, and Methodological Issues. Technical Report DRDC Toronto TR 2012-012. 2012. Available online: www. cradpdf.drdc-rddc.gc.ca/PDFS/unc121/p536951_A1b. pdf (accessed on 3 July 2018).
49. Bandura, A. Self-efficacy mechanism in human agency. *Am. Psychol.* **1982**, *37*, 122–147.
50. Jordan, T.R.; Khubchandani, J.; Wiblishauser, M. The Impact of Perceived Stress and Coping Adequacy on the Health of Nurses: A Pilot Investigation. *Nurs. Res. Pract.* **2016**, *2016*, doi:10.1155/2016/5843256.
51. Blazer, D.G. Self-efficacy and depression in late life: A primary prevention proposal. *Aging Ment. Health* **2002**, *6*, 315–324.
52. Harris, D. *Human Performance on the Flight Deck*; Ashgate Publishing Limited, Taylor & Francis Group, Surrey, England: 2011.
53. Moriarty, D. *Practical Human Factors for Pilots*; Academic Press: London, UK, 2015.
54. Roscoe, A.H. Stress and workload in pilots. *Aviat. Space Environ. Med*.**1978**, *49*, 630-633.
55. Stokes, A.; Kite, K. *Flight Stress: Stress, Fatigue and Performance in Aviation*; *Routledge, London.* 1994.
56. Eurocontrol. Human Factors Module Critical Incident Stress Management. Available online: https://www.skybrary.aero/bookshelf/books/4578.pdf (accessed on 11 June 2020).
57. Civil Aviation Authority. Aeronautical Information Circular. Post-Traumatic Stress. Available online: https://www.skybrary.aero/bookshelf/books/2628.pdf (accessed on 11 June 2020).
58. Fine, P.M.; Hartman, B.O. Psychiatric strengths and weaknesses of typical Air Force pilots. In *Brooks Air Force Base*; Report No SAM- TR-68-121; USAF School of Aerospace Medicine: Texas, USA, 1968; doi:10.1037/e479742008-001.
59. Picano, J. An empirical assessment of stress-coping styles in military pilots. *Aviat. Spaceenviron. Med.* **1990**, *61*, 356–360.
60. Cooper, C.; Sloan, S. Occupational and psychological stress among commercial airline pi-lots. *J. Occup. Med*. **1985**, *27*, 570–576.
61. Karlins, M.; Koss, F.; McCully, L. The spousal factor in pilot stress. *Aviat. Space Environ. Med.* **1989**, *60*, 1112–1115.
62. Bennett, S.A. A longitudinal ethnographic study of aircrews' lived experience of flying operations at a low-cost airline. *Risk Manag. Int. J.* **2006**, *8*, 92–117.
63. Meland, A.; Fonne, V.; Wagstaff, A.; Pensgaard, A.M. Mindfulness-based mental training in a high-performance combat aviation population: A one-year intervention study and two-year follow-up. *Int. J. Aviat. Psychol.* **2015**, *25*, 48–61.
64. Caldwell, J. Fatigue in the aviation environment: An overview of the causes and effects as well as recommended countermeasures. *Aviat. Space Environ. Med.* **1997**, *68*, 932–938.
65. Bor, R.; Eriksen, C.; Oakes, M.; Scragg, P. (Eds.) Pilot mental health assessment and support. In *A Practitioner's Guide*; Routledge: Abington, UK, 2016.
66. Feijó, D.; Luiz, R.R.; Camara, V.M. Common mental disorders amonst civil aviation pilots. *Aviat. Space Environ. Med.* **2012**, *83*, 509–513.
67. Wu, A.C.; Donnelly-McLay, D.; Weisskopf, M.G.; McNeely, E.; Betancourt, T.S.; Allen, J.G. Airplane pilot mental health and suicidal thoughts: A cross-sectional descriptive study via anonymous web-based survey. *Environ. Health* **2016**, *15*, 1–12, doi:10.1186/s12940-016-0200-6 9.
68. Pasha, T.; Stokes, P. Reflecting on the Germanwings Disaster: A Systematic Review of Depression and Suicide in Commercial Airline Pilots. *Front. Psychiatry* **2018**, *9*, 89, doi:10.3389/fpsyt.2018.00086.
69. O'Hagan, A.D.; Issartel, J.; Nevill, A.; Warrington, G. Flying into Depression. *Workplace Health Saf.* **2017**, *65*, 109–117.
70. International Civil Aviation Authority (ICAO). Annex 19—Safety Management. 2013. Available online: https://www.icao.int/safety/SafetyManagement/Documents/Annex%2019%20-%20ICAO%20presentation%20-%20self%20instruction%2024September2013.pdf (accessed on 17 July 2019).
71. International Civil Aviation Authority (ICAO). Safety Management Manual (SMM), Document 9859. Third Edition. Available online: https://www.skybrary.aero/bookshelf/books/644.pdf (accessed on 2 May 2020).
72. Cahill, J.; McDonald, N.; Losa, G. Enhancing human performance and overall flight safety through improvements in airline system information flow. In Proceedings of the 28th Conference of the European Association for Aviation Psychology, Valencia, Spain, 27–31 October 2008.
73. Cahill, J. Flight Crew Task Performance and the Requirements for a New Tool Supporting the Pre-flight, Flight Planning and Briefing Task. 2010. Doctoral dissertation, Trinity College Dublin, Dublin, Ireland.

Thesis 9479.1, TCD E-Thesis Access. Available online: http://stella.catalogue.tcd.ie/iii/encore/record/C__Rb16723129__Scahill%2C%20joan__Orightresult__U__X4?lang=eng&suite=cobalt (accessed on 19 January 2020).
74. Skybrary. Fatigue Risk Mangement Systems. 2019. Available online: https://www.skybrary.aero/index.php/Fatigue_Risk_Management_System(FRMS) (accessed on 23 January 2019).
75. Gibbs, S. Peer support programme for pilots. In *Pilot Mental Health Assessment and Support*; Bor, R., Eriksen, C., Oakes, M., Scragg, P., Eds.; Routledge: Abington, UK, 2016.
76. Spencer-Thomas, S. Up on the High Wire: Promoting Resiliency during Tough Times. Proceedings of the International Pilot Peer Assist Conference (IPPAC)—25–26 October 2019, Texas USA. Available online: http://pilotpeerassist.com/international-pilot-peer-assist-conference/ (accessed on 12 May 2020).
77. Jeppesen. Crew Fleet Crew Alert. Available online: http://ww1.jeppesen.com/industry-solutions/aviation/commercial/crew-fleet-CrewAlert.jsp (accessed on 12 May 2020).
78. European Union Aviation Safety Agency (EASA). Guidance for CRM implementation. 2017. Download from: https://www.easa.europa.eu/document-library/general-publications/crm-training-implementation (accessed on 17 July 2019).
79. Cahill, J.; Mc Donald, N.; Losa, G. Intelligent Planning and the Design of a New Risk Based, Intelligent Flight Plan. *Cogn. Technol. Work* **2011**, *13*, 43–66.
80. Federal Aviation Authority (FAA). Single Pilot Crew Resource Management. 2015. Available online: https://www.faa.gov/news/safety_briefing/2015/media/SE_Topic_15_03.pdf (accessed on 12 May 2020).
81. Houston, S. Pilot Risk Management: There's a Checklist for That! 2019. Available online: https://www.thebalancecareers.com/the-i-m-safe-checklist-282948 (accessed on 12 May 2020).
82. Federal Aviation Authority (FAA). Personal Minimums Checklist' Federal Aviation Authority. (2009). PAVE—Personal Minimums Checklists (2020). Available online: https://www.faa.gov/training_testing/training/fits/guidance/media/personal%20minimums%20checklist.pdf (accessed on 12 May 2020).
83. Federal Aviation Authority. PAVE - Personal Minimums Checklists. 2020. Available online: https://www.faa.gov/regulations_policies/handbooks_manuals/aviation/phak/media/02_phak_toc.pdf (accessed on 12 May 2020).
84. Ironside, R. Germanwings' crash report sees Qantas bid to help gauge pilots' mental health. Available online: https://www.heraldsun.com.au/technology/germanwings-crash-report-sees-qantas-bid-to-help-gauge-pilots-mental-health/news-story/ae6b6efb5428033fcca134ff40c39471?from=herald%20sun_rss (accessed on 12 May 2020).
85. Ingre, M.; Van Leeuwen, W.; Klemets, T.; Ullvetter, C.; Hough, S.; Kecklund, G.; Karlsson, D.; Åkerstedt, T. Validating and Extending the Three Process Model of Alertness in Airline Operations. *PLOS* 2014, doi:10.1371/journal.pone.0108679.
86. Flightman. Our Products. 2020. Available online: http://www.flightman.com/our-products/ (accessed on 12 May 2020).
87. Kudret, S.; Erdogan, B.; Bauer, T. Self-Monitoring Personality Trait at Work: An Integrative Narrative Review and Future Research Directions. *J. Organ. Behav.* **2018**, doi:10.1002/job.2346.
88. Koo, S.H.; Fallon, K. Explorations of wearable technology for tracking self and others. *Fash Text* **2018**, *5*, 8, doi:10.1186/s40691-017-0123-z.
89. Boulos, M.N.K.; Brewer, A.C.; Karimkhani, C.; Buller, D.B.; Dellavalle, R.P. Mobile medical and health apps: State of the art, concerns, regulatory control, and certification. *Online J. Public Health Inform.* **2014**, *5*, e229.
90. Till, C.; Petersen, A.; Tanner, C.; Munsie, M. Creating "automatic subjects": Corporate wellness and self-tracking. *Health Interdiscip. J. Soc. Study Healthilln. Med.* **2019**, *23*, 418.
91. Hull, G.; Pasquale, F. Toward a critical theory of corporate wellness. *BioSocieties* **2018**, *13*, 190–212. .
92. Moore, P.; Robinson, A. The quantified self: What counts in the neoliberal workplace. *New Media Soc.* **2016**, *18*, 2774–2792.
93. Moore, P.; Piwek, L. Regulating wellbeing in the brave new quantified workplace. *Empl. Relat.* **2017**, 308–316, doi:10.1108/ER-06-2016-0126.
94. European Parliament. Directive (EU) 2016/680 of the European Parliament and of the Council of 27 April 2016 on the Protection of Natural Persons with Regard to the Processing of Personal Data by Competent

Authorities for the Purposes of the Prevention, Investigation, Detection or Prosecution of Criminal Offences or the Execution of Criminal Penalties, and on the Free Movement of such Data, and Repealing Council Framework Decision 2008/977/JHA. Available online: https://eur-lex.europa.eu/eli/dir/2016/680/oj/eng (accessed on *12* May 2020).

95. Data Protection Commission. Quick Guide to the Principles of Data Protection. 2020. Available online: https://www.dataprotection.ie/sites/default/files/uploads/2019-11/Guidance%20on%20the%20Principles%20of%20Data%20Protection_Oct19.pdf (accessed on 12 May 2020).
96. Cullen, P.; Cahill, J.; Gaynor, K. Turbulent Times. 2020. Available online: Data Protection Commission (2020). Quick Guide to the Principles of Data Protection Available online: https://www.dataprotection.ie/sites/default/files/uploads/2019-11/Guidance%20on%20the%20Principles%20of%20Data%20Protection_Oct19.pdf (accessed on 12 May 2020).
97. International Standards Organisation (ISO) (2020). Standard 6385. Ergonomics principles in the design of work systems. 2016. Available online: https://www.iso.org/standard/63785.html (accessed on 12 May 2020).
98. Baxter, G.; Sommerville, I. Socio-technical systems: From design methods to systems engineering. *Interact. Comput.* **2011**, *23*, 4–17, doi:10.1016/j.intcom.2010.07.003.
99. Fogg, B.J. *The Small Changes that Change Everything*; Houghton Mifflin Harcourt, Boston, 2020
100. Fogg, B.J. A Behaviour Model for Persuasive Design. In *Proceedings of the 4th International Conference on Persuasive Technology. Persuasive '09*; ACM: New York, NY, USA, 2009; pp. 40:1–40:7, ISBN 9781605583761, doi:10.1145/1541948.1541999.
101. Waterson, P.E. A critical review of the systems approach within patient safety research. *Ergonomics* **2009**, *52*, 1185–1195.
102. Carayon, P.; Schoofs Hundt, A.; Karsh, B.T.; Gurses, A.P.; Alvarado, C.J.; Smith, M.; Flatley Brennan, P. Work system design for patient safety: The SEIPS model. *Qual. Saf. Health Care* **2006**, *15* (Suppl 1), i50-8.
103. Osterwalder, A.; Pigneur, Y.; Clark, T. *Business Model Generation: A Handbook for Visionaries, Game Changers, and Challengers*; Strategyzer Series; John Wiley & Sons: Hoboken, NJ, USA, 2010.
104. Kroenke, K., Spitzer, R.L.; Williams, J.B. The PHQ-9: Validity of a brief depression screening measure. *J.* Gen. *Intern. Med.* **2001**, *16*, 606–613.