Stepping Down Fatigued or Not: What Makes Flight Crews Decide to Step Down from Duty.

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ABSTRACT

With the emergence of industrialisation, the work-life balance has become a point of discussion in many industries, among which the aviation industry. Distortions in the work-life balance became especially apparent when 24/7 economies evolved, and industries made a transition to facilitate and serve these economies. Incidents and accident have since then been related to fatigue more than before. The aviation industry and regulators have so far primarily attempted to deal with this imbalance via prescriptive rules and guidelines based on hours-of-service principles, post hoc measurements, and reports. Science in the meantime, pointed out that fatigue, especially in complex environments, can be related to a large number of factors of influence. So far, however, this has not resulted in shifts in regulative approaches. In the end the regulations remained focused, primarily, on the measurement of quantitative, and almost purely physiological, aspects of fatigue. Unknown, however, is, for instance, whether these measurable factors of fatigue always result in individuals being (or experiencing) fatigued, whether these measurable and regulated aspects could hold as the norm for everyone, and whether the decision to step down fatigued is always and with everybody based on the same factors? This study attempts to provide some answers to these question through the acquiring of an in-depth understanding of the individual process of crew members in their decision to step down. The study started with a literature study into the phenomenon of fatigue, elaborating thereby especially on what aspects are fatiguing or may contribute to recovery from fatigue. Thereafter, a field study has been performed among flight crews to get insight in how they deal with fatigue, how the aspects of fatigue are weighed, and how they come to a decision whether to step down. The conclusions drawn after analysis are that fatigue is more than the summation of fatiguing factors. Furthermore, the pre-decision process and the final decision whether to step down is mainly based on individual experiences and assessment. Finally, the interaction between and interdependencies of the influential factors of fatigue, in combination with the context at the time of the decision-making process, make that the individually made decision is very hard to predict.

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INTRODUCTION

History

The emergence of commercial flights – and the issue of work-rest ratio

December 17th, 1903 marked the starting point of a new era in human mankind. The era of humans being able to execute powered flight. Although, flying fascinated many people and scientists for centuries, it was not till that day in 1903 when Orville Wight completed successfully a powered flight of 12 meter in distance.

From that moment onwards, aviation has grown from a single pilot flight with no passenger(s) to a billion-dollar industry flying more than 4.3 billion passengers around the world in 2018 (ICAO, 2019). Aviation has become accessible for virtue everyone and flights depart and arrive around the clock, each day.

In the early days, flying was a governmental military business, but slowly a demand for passenger and freight flights originated and the first commercial airlines were founded. These airlines were initially funded and supported by governments. Competition between these government-run airlines was almost non-existent. Till the second world war, commercial aviation was mainly a privilege for the wealthy people. But, the rapid technological developments during the years of the war resulted in new aircraft being built with jet engines and pressurised cabins. Aircraft could now carry more people at a higher more fuel-efficient altitude with greater distance. A larger capacity also resulted in lower prices and flying became a more affordable means of transportation. From the fifties onwards, commercial aviation is characterised by rapid growth. Despite large growth rates and still being (mainly) government owned, commercial aviation had a marginal profitability (Doganis, 2002).

In the early days, commercial aviation was seen as a 'public service' and preference was given to the availability of air services between cities and countries instead of to competitive fares. In the 1980's and 90's, however, this gradually changed, and aviation became subject to liberalisation. This invited for a more and open competition in the aviation industry. As a result of the "gradual removal of tariff controls" (Doganis, 2002, p. 14) by governments that followed, a price competition was created. The liberalisation of the aviation market, therefore, introduced a continuous drive to operate more and more efficiently. Airlines were forced to cut costs in order to maintain profitable. Labour costs (for example salaries and social chargers), however, "were largely externally determined" (Doganis, 2002, p. 117). In order to reduce and control costs, airlines therefore focussed on increasing the productivity of the work force (Doganis, 2002).

Liberalisation of aviation also accelerated the introduction of new business models, such as low-cost business models, which strengthened the drive for efficiency in aviation. These business models have the benefit of a higher labour productivity. Downsides, however, are that pilots have to produce more or longer flights within a working period, that they have to fly in shifts, and that they have fewer days off. The work-rest ratio changed accordingly.

The upcoming of prescriptive work-rest regulations

During the industrialisation of society, the balance between work and rest became a point of discussion between employers and employees, and later also of unions. In the United Kingdom (UK), for instance, the first attempt in history of regulating the quality of working life was the 'Factory Act'. This Act, which was implemented in the 19th century attempted to "balance working conditions and remuneration" (Gander, Hartley, Powell, Cabon, Hitchcock, Mills, & Popkin, 2011, p. 574). During the following years, the 'Factory Act' has been updated several times considering production balance, return on investment, wages, quality of life and safety.

During the early 20th century demands to better regulate the work (and rest) limitations increased further. This was mainly because of two perspectives on how to reorganise work limitations, namely worker safety, and secondly the labour – capital balance (Jones, Dorrian, Rajaratnam, & Dawson, 2005). Other countries than the UK, like Australia, France, Germany and the United States of America, developed regulations to limit working hours. These kinds of regulations can be categorized as "Hours of Service" (HOS) models, which basically contained regulator (government) prescriptions for acceptable working and resting hours (Jones *et al.*, 2005).

Questions put to prescriptive work-rest regulative efforts in a 24-hour economy

At the time of the development of these first prescriptive systems, commercial aviation did not exist, nor did 24/7 flight operations. Around the 19070's, it was acknowledged, furthermore, that prescriptive HOS systems alone were limited in their an attempt to balance the factors of productivity, quality of life, and safety (Gander *et al.*, 2011), especially in high-risk industries such as the nuclear industry and aviation. These industries are characterised as complex, intractable and tightly coupled systems (Hollnagel, 2014; Perrow, 1984), which makes it very difficult to prescribe in detail how work in these complex systems should be done. This increase in complexity of the environment in which work is done, combined with the gradual, but persistent, shift to 24/7 operations, asked for a more complex approach of fatigue. Attempts were made to map influential factors, and of how these tend to interact, with each other, and with the system. Subsequently, determining acceptable working hours became more complex too, as it was acknowledged that identifying risks is not so straight forward in these industries. The National Transportation Safety Board (NTSB) added to this that measuring a phenomenon like fatigue is rather difficult. It cannot be measured like alcohol or drugs levels in blood (NTSB, 1999).

The transition to a 24-hour economy has slowly, but steady, been formed from the 1980's and onwards. In order to keep pace with the fast technological evolution, various professions and industries became dependant on "round-the-clock operations" (Rosekind, Gander, Miller, Gregory, Smith, Weldon, Co, McNally, & Lebacqz, 1994, p. 327). Others, such as the aviation industry, were to facilitate these 24/7 operations. The result was a growing group of people working in some kind of "non-standard or altered work schedules" (Office of Technology Assessment (1991) as cited in Rosekind *et al.*, 1994, p. 327).

Together with this gradual change to a 24-hour economy, many regulators developed new legislation where more responsibility was shifted to the employer and employee in an attempt, as they argued, to "foster greater ownership of safety" (Gander *et al.*, 2011, p. 575) by the industry. General regulations were issued. However, how to exactly follow and/or interpret these modernized regulations was left to the industry. Much of the work-rest regulations in this time frame was based on a performance based approach (Gander *et al.*, 2011; Jones *et al.*, 2005), in which work was required to meet "certain safety standards" (Gander *et al.*, 2011, p. 575). These 'safety standards' have its basis in desired and measurable safety outcomes which are identified by the company, or operator, and as such accepted and supervised by oversight authorities (e.g. EASA) (European Cockpit Association, 2015).

Fatigue regulation in the aviation sector

In the aviation sector, the 24-hour economy and the associated 'introduction' of irregular working hours and shift work caused the NTSB to perform, in the 1980's and 1990's, a large safety research project on operator fatigue in transportation (aviation, highway, railroad and maritime). The final report of 1989 resulted in recommendations to reduce fatigue related incidents and accidents (NTSB, 1999). Also, operator fatigue was put on the list of 'Most Wanted Transportation Safety Improvements' of the NTSB (1999). Also in a second (evaluation) report issued by the NTSB (1999), furthermore, the significance of managing fatigue was brought to the attention. Despite the recommendations issued, however, little improvement on reducing operator fatigue was found in the decade thereafter. In aviation alone "21 percent of the reports in the Aviation Safety Reporting System (ASRS) were related to general issues of fatigue" (NTSB, 1999, p. 7).

With the 'urge' to undertake action against fatigue, and simultaneously acknowledging the complexity of the subject, the United Nations (UN) International Civil Aviation Organization (ICAO) initiated a process to develop a performance-based Fatigue Risk Management System (FRMS). The two major aviation regulators in the world, (the Federal Aviation Authority (FAA) and the European Aviation Safety Agency (EASA)) trailed the initiative. ICAO (re)defined fatigue by operationalising fatigue in measurable factors of influence on fatigue from a broader spectrum then before, including items such as sleep loss, extended wakefulness, circadian phase, and (mental and/or physical) workload (ICAO, 2016). The focus, in this, shifted from predicting general fatigue risk based on information and conclusions from (scientific) studies on fatigue, to a focus "on managing the actual fatigue risk in the operations to which it applies" (ICAO, 2016, p. 2). In other words, the focus shifted from general, high level, concepts on prescriptive (input) factors to daily operational feedback on fatigue and factors of influence on fatigue (output factors) that became part, as such, of the data set used to assess fatigue risk.

One could argue that regulators, acknowledging the many (operational) factors involved, embraced here a complexity view on fatigue to a certain extent. However, although they do seem to adhere to a broader definition of fatigue than in the past, they continue to emphasise the 'measurable' aspects of fatigue in their discourse. For example, regulations concerning crewmember responsibility mainly address measurable effects of fatigue such as sleep deprivation, number of flown sectors and time zone changes (European Parliament, 2018, Annex IV, 7.5). Also, the fundamental aspects of FRMS consist basically of quantifiable and prescriptive aspects such as "flight time, flight-duty periods, duty and adapted rest periods" (European Parliament, 2018, p. 101), taking into account the "number of sectors flown, time-zone crossing, disruption of circadian cycles and night hours" (European Parliament, 2018, p. 101). Sometimes they even seem to simplify the large number of factors involved into one simple measure again, such as EASA who states that quantitative sleep is "the only effective countermeasure" of fatigue (EASA, p. 2).

Reviewing present regulations about fatigue and fatigue management indicates that the aviation sectors' main focus is still on 'managing' quantitative sleep measures, preferably referring to aspects of physiology, or 'human performance and limitations', rather than, for instance, to other health- and wellbeing-related disciplines, such as, psychology. The fatigue management system in aviation is mainly based on the measurable aspects such as maximum working hours and minimum rest requirements, in an attempt to maintain human performance within acceptable limits . The only actual shift that has taken place in fatigue management is that now both the operator and the crewmembers have a shared and mandatory responsibility to report when crew members step down from active duty due to fatigue (European Parliament, 2018). This reporting is, however, nothing more than a retrospective measure that, above all, seems to neglect the complexity of the phenomenon called 'fatigue' and how individuals manage their fatigue.

What such reporting does not do, for instance, is providing insight in issues such as whether these measurable factors of fatigue always result in individuals being (or experiencing) fatigued, whether these measurable and regulated aspects could hold as the norm for everyone, and whether the decision to step down fatigued is always and with everybody based on the same factors?

Research question

In the past few decades, fatigue apparently has become an important subject in the aviation industry. It is currently mentioned as an important 'contributing factor' in incidents and accidents reports (NTSB, 1999). Other industries think fatigue is an important issue also. A lot of research has been performed in these industries in order to understand the concept and phenomenology of fatigue. Aviation regulators have used this research in an attempt to develop rules for operators to manage fatigue, and to provide both strict rules and guidelines about a shared responsibility to be fit for work.

Despite the fact that fatigue is considered a complex phenomenon in which many different factors tend to interact, regulators today, in the aviation industry at least, still tend to refer to fatigue as controllable through one or a small number of measurable denominators. Regulations and management systems, like the FRMS, are designed and implemented to be applied to the collective, moreover, in this particular case pilots and cabin crew in the aviation industry. Apparently, there is a mismatch between what is known about the complexity around fatigue and the instruments developed to assess and control the phenomenon. Unknown, above all, whether these measurable factors, fed by individuals, are then applicable for a the collective, whether interpersonal variability and local situation is taken into account sufficiently? This research therefore aims to provide insights that can change this. Focus thereby is not so much on the phenomenon of fatigue, or on the issuing of some kind of rule or guideline that can be applied to the mass, but on the individual process of crew members in their decision to step down from fatigue or not. The aim of this is to provide insights on fatigue in the aviation sector, an on how to regulate it, from a focus on the considerations and actions following the development of fatigue, the actual step-down process.

The main focus in this study is on how the individual flight crew member, in the context of the decision to step down or not, copes with fatigue, the experience of fatigue and with recovery from fatigue. What factors do they consider and weigh, what is the influence of individual and professional characteristics and norms, and is this process the same each time when fatigue is apparent? Moreover, is the definition of fatigue the same for everyone and at all levels? In case of a conversation about fatigue between a pilot and company representative, a crew controller for example, are they talking about the same fatigue?

Summarizing, the research question of this research is:

> **What makes flight crew members decide to step down from flight duty due to fatigue?**

As a starting point for this research, a literature study is provided on the phenomenon of 'fatigue'. The second part of this research reports on interviews with several pilots on how they experience fatigue, but especially on why they decide to step down or not. The aim of this is to get insights in how they manage fatigue individually, based on their own perspective, on their own definition of fatigue. The results on the different interviews are, with the literature research in mind, compared to each other to identify similarities and contraries. Subsequently, an analysis will be performed on how the individual pilots manage their fatigue, its influential factors they identify, so as to get insight in the individual decision-making process of stepping down. Conclusions are drawn on the analysis. The report will end with a discussion about what the outcomes of this research can add to fatigue management.

The study has been performed, for practical reasons, with pilots only, flying short haul operations (flight times up to 4 hours) within a time-zone enclosing not more than two hours. The focus of this study has been on male pilots. Cabin crew has not been involved in this study.

FATIGUE IN LITERATURE

In this chapter an overview will be given on scientific studies on the subject of fatigue and its phenomenology. The purpose of this literature review is to gain insight in the present knowledge in fatigue research.

What is Fatigue?

Present scientists studying fatigue have not found consensus about a universal definition of fatigue (yet) (Williamson, Lombardi, Folkard, Stutts, Courtney, & Connor, 2011). One of the main reasons is the 'multi-disciplinary' or 'multi-dimensional' aspect of fatigue (Akerstedt, Knutsson, Westerholm, Theorell, Alfredsson, & Kecklund, 2004; Janssen, Swaen, Janssens, & Schröer, 2003; Jones *et al.*, 2005; Ream & Richardson, 1996). More specifically, scientists encounter difficulty in finding agreement on the aetiology of fatigue (why fatigue manifests), on its ontology (what is fatigue), and on how it is measured (Noy, Horrey, Popkin, Folkard, Howarth, & Courtney, 2011). The issue, therefore, is that addressing the complexity of dealing with fatigue and its phenomenology of individuals during their daily activities, is difficult when reviewing it from the context of a single expertise. It is, therefore, problematic to use these single-expertise-definitions of fatigue in general, or for a theoretical basis in a field study. Various scientific fields of research, nevertheless, define fatigue such that it closely relates to their own expertise (Noy *et al.*, 2011). For example, physiologist refer to the physical performance imposed by fatigue, pathologists relate fatigue to a disease, and psychologists associate fatigue with mental performance (Ream & Richardson, 1996).

Two definitions reflect a more holistic and thus a more general view on fatigue. The first is given by Ream and Richardson (1996, p. 527):

> *Fatigue is a subjective, unpleasant symptom which incorporates total body feelings ranging from tiredness to exhaustion creating an unrelenting overall condition which interferes with individuals' ability to function to their normal capacity.*

This definition illustrates why a universal definition of fatigue is difficult to agree upon. Fatigue is a "subjective, unpleasant symptom which incorporates total body feelings" and "…interferes with individual's ability…". What this says is that fatigue is a phenomenon that is individually experienced and dealt with. Therefore, fatigue incorporates interpersonal variability (Mroczek, Spiro III, & Almeida, 2003), which makes it difficult to arrive at an universal definition unambiguously.

Gander *et al.* (2011) point, in another definition, at the ambiguity and subjectivity in the manifestation of the phenomenon:

> *Fatigue is the inability to function at the desired level due to incomplete recovery from the demands of prior work and other waking activities. Acute fatigue can occur when there is inadequate time to rest and recover from a work period. Cumulative (chronic) fatigue occurs when there is insufficient recovery from acute fatigue over time. Recovery from fatigue, i.e., restoration of function (particularly of cognitive function), requires sufficient good quality sleep.*

The ambiguity and subjectivity lie primarily in the use of terms such as inability, incomplete, …...What, for instance, would be norms for "…incomplete recovery…", "…inadequate time…"? All these concepts are subject to individual interpretation. The absence of universally defined norms means that there is room for multiple interpretations.

Fatigue, apparently, inevitably incorporates some kind of 'interpretational space'. Subjectivity and individual interpretation, then, is part of the understanding of fatigue.

Despite this difficulty to agree upon a universal definition of fatigue (Akerstedt *et al.*, 2004; Ream & Richardson, 1996) scholars do seem to agree more or less on the expressions of fatigue. Items that are mentioned in this regard recurrently in the literature are (in random order).

1. General fatigue – feeling tired, bushed or exhausted
2. Mental fatigue – experiencing cognitive or mental impairment. Mental fatigue is also co-related psychological morbidity (Pawlikowska, Chalder, Hirsch, Wallace, Wright, & Wessely, 1994).
3. Physical fatigue - feeling tired after physical exercise
4. Sleepiness - feeling the tendency to fall asleep
5. Motivation, or lack of activity – poorly motivated to perform a task

As the aim of this study is to do something new, namely, to explore the actions following fatigue in the step-down procedure rather than fatigue or fatiguing factors, this study will hold to a broad definition of fatigue. It will address therefore, as a starting point at least, all the above-mentioned expressions of fatigue. In the next paragraph, these expressions are connected to a number of sources of fatigue, which will point out, as we will see, that individuals may experience a large variety in whether and how fatigue surfaces from a particular source.

Factors that Generally Induce Fatigue

In the literature on fatigue, several factors of influence on the level of fatigue experienced by individuals can be identified, with either a negative or a positive effect on fatigue. Also, some factors appear to have a negative influence on fatigue for one individual, while having a positive influence on fatigue for others (Saksvik-Lehouillier, Bjorvatn, Hetland, Sandal, Moen, Mageroy, Akerstedt, & Pallesen, 2013), which points out once more the complexity of the phenomenon. Appendix I provides an overview of all the factors found during this study. Succinct descriptions are provided below.

The first factor that tends to induce fatigue is the issue of *disturbed sleep*. For mankind, even doing nothing costs energy, because of which people requires recovery. Sleep is such a means of recovery (see next paragraph also). Adults require between 7 to 9 hours of sleep a day (ICAO, 2016). Too little sleep has a negative influence on someone's level of fatigue. Besides the need for sufficient hours of (quantitative) sleep, qualitative good sleep is found to be a crucial factor in fatigue also (Akerstedt *et al.*, 2004; Sonnentag, Binnewies, & Mojza, 2008). Examples of factors that might degrade sleep quality are:

- Difficulty falling asleep due to various reasons, such as, environmental temperature, noises and sounds, having something on the mind.
- Repeated awakenings
- Premature or difficulty to awake. Being awake just before the alarm clock starts or sleeping through the alarm.
- Not well rested. Having had sufficient hours of sleep, but still having a desire for more sleep.
- Nightmares
- Heavy snoring. Although not directly noticeable by the person who snores. It is found to have impact to what extend that person is able to recover.

Like disturbed sleep, an imbalance between the demands of work and the rewards gained from it (*the demands-reward imbalance*) can induce fatigue also. A dualistic effect can be seen here as working is often regarded rewarding on the one hand, while it drains energy on the other hand. The balance can have a significant impact on fatigue. It is also considered to have a de-motivational

effect that in turn can lead to exhaustion, hence fatigue (Akerstedt *et al.*, 2004). A relationships has, furthermore, been found between fatigue that is the result of a demand-reward imbalance and a burnout (Akerstedt *et al.*, 2004) or sickness absence (Janssen *et al.*, 2003; Michie & Williams, 2003) on the longer term. Effects of a demand-reward imbalance will be worse, moreover, when specific factors are concerned, such as work demand (e.g. long working hours, high workloads, pressure), disinvolvement in decision-making processes, role ambiguity (not knowing what is exactly expected), and conflicting demands (Michie & Williams, 2003). A most prominent factor in this appears to be whether the particular person regards work rewarding.

Social support is another factor that affects fatigue. People live and work in communities where the social structure of these communities, dependent on to what extend individuals participate in these communities, is found to influence the mental well-being and health of these individuals. Social support is not limited to one's family for instance. Social support can in fact be received from (and given to) anyone in an individual's social network, for example, friends, family, co-workers and managers. Insufficient or poor social support, however, has been related to increased levels of stress, fatigue and psychological ill health (Akerstedt *et al.*, 2004). It is very difficult to determine to what extend (a lack of) social support actually affects fatigue though, because of the many variables that may be present in the "design, duration, timing and types of social support interventions" (Kawachi & Berkman, 2001, p. 464). For potential providers of social support, furthermore, it is difficult to assess an individual's needs at a particular moment. What is interesting to mention though, is that the perception whether support is available has more impact than whether one actually receives that support (Thoits, 1995). This is especially the case for emotional support.

A relation has furthermore been found in the literature between fatigue and the organisation and the scheduling of work. Especially *irregular work hours* and *shift work* seem to be of influence. Shiftwork "usually covers a wide variety of working time arrangements, including all working hours that are outside the normal daytime ones" (Knutsson, 2009, p. 1038). Shiftwork, in other words, concerns the working in blocks that may shift from for example mornings to afternoons to night. Working irregular, or nonstandard, working hours, regards working on hours that typically fall outside the standard daytime working period (Albertsen, Rafnsdóttir, Grimso, Tómasson, & Kauppinen, 2008), not necessarily in shifts. The working schedules of the pilots that participated in this study include a combination of both shiftwork and irregular working hours. Since aviation is a 24-hour business, flight crews have to work outside regular (eight to six) office hours, in various time zones, and work in a continuous system of days 'on duty' followed by days 'off duty'. Shiftwork and irregular working hours, therefore, have been combined in the aviation industry to facilitate productivity over a larger part of the day. In this study, therefore, the combination of shiftwork and irregular working hours has been called 'irregular shiftwork'.

Relations between the factors

The literature also provides some insights in how the factors mentioned above relate to each other.

A relationship is found, for instance, between shiftwork, biological (Akerstedt, 2003) and social rhythms, and life-work balance (Albertsen *et al.*, 2008). Biologically, for instance, the shiftwork distorts the circadian rhythm (the internal biological process that regulates the sleep-wake cycle), while the amount of distortion depends on the nature of the shift (early, or late) (Akerstedt, 2003). The work-life balance is predominantly based on a perceived insufficiency in time and energy available for combining work and social life successfully (Amelsvoort, Jansen, Swaen, Van den Brandt, & Kant, 2004). On the labour-side of the balance an influential factor is the work schedule. For example, the length of the shifts, irregular working hours, or the shifts rotating to an earlier or later schedule influence the work-life balance perception negatively (Albertsen *et al.*, 2008; Amelsvoort *et al.*, 2004). This can be countered though, by providing the employee with

more control over his (or her) own working schedule and hours, e.g. working only part-time, as this is associated with an improved work-life balance (Costa, G., Åkerstedt, Nachreiner, Carvalhais, Folkard, Dresen, Gadbois, Gaertner, Sukalo, Härmä, Kandolin, & Silvério, 2003). The social life side of the balance is strongly influenced by factors such as, for example, distance between home and work, child care facilities, family support and income (Albertsen *et al.*, 2008).

Not all research on these issues is unambiguously. For example, several studies on rotating shifts concluded that shift rotation has no influence on fatigue and on the recovery of fatigue (Akerstedt, 2003, 2007), which contradicts studies that show that rotation and the direction of rotations of shifts do affect fatigue (Albertsen *et al.*, 2008; Amelsvoort *et al.*, 2004; Signal & Gander, 2007). Moreover, the impact of shiftwork, irregular working hours, and thus, plausibly, also of irregular shiftwork on the work-life balance is found to vary also. Overall, it can be said that the organization of work hours influences an individual's life, but that the eventual effects are greatly dependent on many more factors.

All in all, although aspects of disturbed sleep, working hours, shifts, and irregularity could perhaps be measured quantitively somehow, the effects of it on fatigue cannot. These indicators, therefore, seem to have a lack of power in the regulation of fatigue. After all, the extent to which interventions in this regard will actually influence fatigue, will differ individually, especially when the social context is taken into account, which differs for each person also.

Recovering Factors

So far, this chapter has provided insights in how various factors can influence fatigue, or the perception of being fatigued. In this, the negative effects on fatigue have primarily been highlighted. Apart from these fatigue-inducing factors, however, the literature also identifies several factors that may help in the recovery from fatigue, or in the experience of recovery.

A number of factors mentioned in the former section are related to work. Indeed, it is assumed that working in general and working in the presence of stressors can result in "strain reactions" (Sonnentag *et al.*, 2008, p. 675). Recovering from this is basically realised by doing the opposite of that which results in strain reactions. In general, two aspects of recovery are used. Recovery while off-duty (Sonnentag *et al.*, 2008) and recovery strategies that can be used while on-duty, at work, or that are otherwise work related (Albertsen *et al.*, 2008).

Sonnentag *et al.* (2008) identified four off-duty aspects or "recovery experiences", which are:

- *Psychological detachment.* Etzion, Eden & Lapidot define psychological detachment as "an individual's sense of being away from the work situation" (as cited in Sonnentag *et al.*, 2008). Psychological detachment is about taking some distance from work, about the ability to stop being physically and mentally occupied with work. It is about not being at work, not having to a work-related task and not even think about work.
- *Relaxation.* Relaxation results in lower heart rate, decreased muscle tensions and a lower breathing rate, i.e. it decreases the activity of the autonomous nerve system. Relaxation works both on the mental and on the physical state of an individual.
- *Mastery Experience.* Mastery Experience is about gaining a feeling of satisfaction, competence and/or proficiency, which can be achieved by, for example, winning a sports game, accomplishing a physical workout, or learning a new hobby. "Mastery experience refers to challenging off-job experiences that provide opportunities for learning and success" (Sonnentag *et al.*, 2008, p. 675). In contrast to psychological detachment and relaxation, mastery experience does require some physical or mental effort. However, this experience is associated with "positive activation and serenity" (Sonnentag *et al.*, 2008, p. 676).

- *Sleep Quality*. Qualitative good sleep is necessary to replenish resources for self-regulation purposes (Sonnentag *et al.*, 2008). Self-regulation is, for example, coping with stress, resisting temptations, but also vigilance. In other words, qualitative good sleep is required to 'charge the battery' in order to be able to cognitively and physically cope with the challenges of a new day. Qualitative sleep differs from quantitative sleep. Quantitative sleep is measurable in, for example, hours of sleep. Qualitative sleep is more difficult to measure. A good night of sleep depends on how the individual experiences a night of sleep. Disturbances like, difficulty falling asleep, repeated or premature awakenings (for whatever reason) and night mares influence how qualitative sleep is experienced (Akerstedt *et al.*, 2004).

The first three recovery experiences do not compensate for a bad night of sleep. Difficulty to detach from work after a long working day is in turn not to be compensated by qualitative good sleep (Sonnentag *et al.*, 2008).

As opposed to Sonnentag *et al.* (2008), Albertsen *et al.* (2008) provide recovery strategies that are work related. Recovery from fatigue in a working environment, in general, can be facilitated by means of work-breaks, evenings off, weekends, or vacations. Basically, anything works according to Albertsen *et al.* (2008). That is not related with the profession, or work of the individual and provides the ability to focus on something different than work. What also works, is to give people more control over their working schedules, to allow them to work part-time, and to provide them with the desired work-life balance (Albertsen *et al.*, 2008; Costa, G. *et al.*, 2003). All these means contribute, they argue, to recovering from fatigue and gain (mental and physical) tolerance against fatigue. At the same time though they conclude that, although a lot of literature is available about the impact of adverse and long working hours on fatigue, very little is known about the total workload experience from an individual and/or family perspective.

Fatigue Resilience

So far, general factors of influence on fatigue, and on the recovery of fatigue, have been identified. This section will address factors of resilience that have been derived from the literature, factors that are supposed to help people counter fatigue.

In the late 1970's the term Shift Work Tolerance (SWT) was introduced by Andlauer and colleagues, which basically describes in how far an individual is able "to work shifts without experiencing negative consequences thereof" (Saksvik-Lehouillier *et al.*, 2013, p. 1137). Costa, Giovanni (2004) subsequently performed a study of the aspects of tolerance to shiftwork in relation to health and well-being. He identified several dimensions regarding this:

- *Individual Characteristics* related to aspects such as age, gender, physical fitness and characteristics, such as:
    - *Morningness*; the individual's daily rhythm preference, which ranges from morningness to eveningness.
    - *Languidity,* the behavioural characteristics concerned with the amplitude of the circadian rhythm of the individual. A high languidity score means a low circadian rhythm amplitude, associated with lower levels of alertness and higher sleep needs.
    - *Flexibility,* the behavioural characteristics concerned with the stability of the circadian rhythm of the individual. A high flexibility score shows that an individual has a good ability to sleep and work at unusual times.
    - *Hardiness,* the individual's resilience, or ability to deal with stress and illness.
- *Family and Social Conditions* such as, marital status, number and age of children, housing and the partners' job.

- *Social conditions*, where income, participation in social and community activities, accessibility to public services, social protection and labour markets are mentioned.
- *Work organisations*, meaning issues such as job demands, working schedules and hours.

The dimensions mentioned here seem to refer to individual characteristics that are strictly personal and which may vary over time, especially when people are doing shift-work or when irregular working hours are influencing the professionals. Moreover, individuals live their own lives and experience the environment in which they live and work differently. How information and environmental stimuli are experienced, weighed and prioritised, furthermore, depends on many different factors. The dimensions mentioned therefore cannot be considered as (single) 'options' to choose from to determine the level of tolerance to shiftwork. Costa, Giovanni (2004) emphasizes in that regard that the interdependencies and interactions between the dimensions are perhaps of a greater importance when the level of tolerance to shiftwork is considered, than the mentioned aspects individually, or calculated cumulatively.

The tolerance to shiftwork is not unlimited. Reinberg and Ashkenazi (2008) identified the following physical and mental expressions related to (a developing) intolerance to shiftwork:

- *Digestive troubles;* Indigestion and gastric ulcer, for example, might be signs of shiftwork intolerance. These symptoms, however, can be an expression of many more health-related issues.
- *Persisting fatigue;* prolonged periods of feeling fatigued is not normal and are an indication that the available periods of rest (weekends, off-days and holidays) are not sufficient to recover from fatigue.
- *Changes in behaviour*; unusual or unexpected irritability, or verbal aggressiveness and sensitivity to external stimuli such as, noise, light and people crowds.
- *Persisting sleep alterations*; Sleep alterations are an aspect of shiftwork. Prolonged sleep alterations are found to have influence on difficulty in, for example, falling asleep, quality of sleep, repetitive awakenings and variability in sleep duration.
- *Use of sleep medications;* The reliance on (self) prescribed medication aids in an attempt to have sufficient sleep.

Like with the fatigue inducing factors and the recovery factors, fatigue resilience factors seem to include personal characteristics, because of which how these factors work out at the level of the individual, will vary. Moreover, it was shown that the amount of resilience people may have can vary over time.

Complexity and Individual Variety

In particular, the literature on fatigue seems to have arrived at a consensus that it is impossible to relate the factors of influence linearly and causally to fatigue (Noy *et al.*, 2011; Ream & Richardson, 1996), which is congruent with the complicating issues identified in the paragraphs above. Various studies show that the factors found have an influence, but the extend of it appears to be highly dependent on the contextual circumstances in which an individual works and lives, as well as on the inter-personal variability, or "within-person variation" (Mroczek *et al.*, 2003, p. 262).

Fatigue, and especially the experience of fatigue, is, therefore, not determined by external factors of influence alone. Individual characteristics interact with these external factors. Furthermore, the extent to which an individual is able to cope with fatigue and fatiguing factors such as disturbed sleep (Akerstedt *et al.*, 2004; Sonnentag *et al.*, 2008), non-standard working schedules (Saksvik-Lehouillier *et al.*, 2013), will vary therefore in the end, from person to person, as will, subsequently, whether and how people recover from fatigue (Sonnentag *et al.*, 2008).

METHOD

Before explicating the method that I used for this study, a brief introduction of myself would be appropriate. In daily life, I am a commercial pilot flying short-haul flights within Europe. Besides my flying activities I got interested in how safety investigations of incidents and accidents in aviation were performed. I was given the opportunity to become a safety investigator for the airline I fly for, which I took with both hands. In the subsequent years I received training and gained experience in doing safety investigations. With the growing experience and expertise also came more questions about, for example, how flightcrew members made certain decisions, what was logic for them to do and what made certain situations not that straight forward as it might look like from a distance? In an attempt to find answers on these questions in an application for the study Human Factors and System Safety. During one of the classroom sessions I had a conversation with professor James Nyce about interaction between people and their environment and how to study this. He, subsequently, suggested to have a look in the phenomenon of fatigue as a possible subject for a thesis study. Although it might sound quite fatiguing, I got interested in the subject, especially when related to aviation. A major advantage for me studying the subject of fatigue is that I have experience with fatigue while on flight duty, which helped me a lot while interviewing colleagues about their experiences with fatigue. Another advantage is that the conversations with my colleagues were very open and in a good atmosphere, because we both have actual operational experience and know each other. My flying experience, on the other hand, could also be a challenge to note the story of the participant and the participant only, without making assumptions from my side.

For this thesis project qualitative fieldwork was performed. The participants have been asked to log, in the context of their decisions whether or not to step down, their individual (experienced) levels of fatigue, and what factors of influence (both positive and negative), they think, affected their fatigue. Also, they have been asked to log what countermeasures they have been taken to prevent further fatigue, to recover from fatigue and what the effect was on the decision-making (process) whether to step down or not. The participants were asked, furthermore and apart from what was logged, to mention (fatigue related) issues or events that happened prior the logging period, which influenced their future assessment of fatigue and subsequent decision.

One option for this research was to perform a broad field study amongst various types of flight operations (short, medium, long haul), or amongst different airlines in an operational setting. That variety then would, however, have made it very hard to derive which factors would influence fatigue. Therefore, the choice has been made to ask pilots who work under quite similar conditions for their experience.

The participants were, at the time this study was conducted, all active flight crew member for a European short-haul airline. Other, more or less, constant conditions were:

- They all work for the same airline
- All flight crew members work in the same type of flight operations, namely short haul passenger transport.
- All flight crew members work under the same Collective Labour Agreement (CLA)
- All flight crew members are rostered for flight duties by the same scheduling system.
- All flight crew members have the same tools and possibilities to request leave, or report fatigued or sick.

The logs were kept for four consecutive weeks in the period of July up to and including September 2017. All participants were, furthermore, men in the age-group of 30 to 45. The reason for this was the drive to pursue homogeneity in respondents as both gender and age influence on how fatigue is experienced and is dealt with (Akerstedt *et al.*, 2004; Albertsen *et al.*, 2008; Cohen & Wills, 1985). Both Akerstedt *et al.* (2004) and Albertsen *et al.* (2008), for instance,

identified differences in the impact of influential factors of fatigue between the female and male gender and how both sexes deal with fatigue. Because of this, it was decided not to investigate a too diverse group.

After the logging period was completed, semi-structured interviews were held with all the participants in order to get a richer understanding of the perspectives of the pilots, and also to collect possible additional information that could enrich the context. The semi-structured interview protocol contains one question about the participants background and six questions about how the participants experience fatigue and on how they had decided to step down (See Appendix II for an overview of the questions).

It must be addressed that the function of the logs turned out to be a different one than anticipated for during the set-up of the study. After the logging period I received logs that varied from very detailed day-to-day descriptions, to a list with a few keywords. Instead of using the logs as main source of data and information, enriched with context gained from the semi-structured interviews, I decided to use the interviews as the main source for information where the logs served as reference and trigger for the information given by the participants.

During the interviews I made notes in an attempt to reflect on the thoughts and considerations of the participants. The interview duration was 1 to 2 hours per participant.

The results were mapped in a matrix and highlighted so as to get an overview of the various factors of influence on fatigue and what considerations were made to step down fatigued, or not. In turn, these results have been related back to the consulted literature, which is discussed in the analysis section.

Ethical Considerations

This thesis project used human intelligence on fatigue and their decision-making (process). The ethical issue here is that a researcher should question whether using this private information weighs against what it will deliver, in this case possible improvements in fatigue management in the aviation industry. Because of the privacy issues concerned here the data has been anonymised in the thesis report. Still, people may feel uneasy providing this very private information. Therefore, the participants had the opportunity to withdraw their input in this study at any time, which one participant actually did.

STEPPING DOWN, OR NOT. AN ANALYSIS

This section provides an outline and analysis of the information retrieved from both the logs and the semi-structured interviews. The information retrieved has been related to the literature. Analysed is how the pilots tend to deal with fatigue, recover from it, and how fatigue interacts with their decision-making process on whether to continue their duty, or not. The data matrix on the interview results can be found in appendix III.

Composition of the group of participants

As addressed in the method chapter, all participants are male and fly under the same operational procedures and organisational infrastructure. Besides this uniformity, the personal lives of the participants vary of course. Furthermore, three of the participants work under a full-time contract (100%), while the others work under contract percentages of 90% (two) respectively 80% (three). Variation between the participant lies moreover in their family compositions. Six participants have a young family with children of the age under five years old.

Within this airline, it is possible for pilots to apply for an additional job within the company. These are, in general, office jobs created for, or specifically applicable for pilots (e.g. flight instructors). Of the participants, eight have an additional function within the company, besides flying. It must be addressed, however, that time spend to both flying and an additional function is all done within the contractual percentage that the participants have.

In total 10 pilots were asked to participate in this study, of which one withdrew his input. A summary of the variances in the group of participants is given in table 1 below.

Contract percentage (%)	Additional function	Children < 5 years old
100% : 3	Yes: 8	Yes: 6
90%. : 2	No :1	No : 3
80%. : 4		

Table 1. Composition of group of participants studied.

Determining the fatigue limit

The participants were asked about their own definitions of fatigue. Examples of the answers given include "when more than one night of good sleep is required to fully recover from fatigue"; "when being unable to reach the desired level of concentration"; "when it becomes noticeable that more 'little mistakes' are being made"; "when being unable to guarantee flight safety for whatever reason"; "an assessment based on an own interpretation of the Samn-Perelli Scale (SPS) as used within the company". This variety in definitions is congruent with the literature on fatigue, which holds many different definitions. They all seem to refer though, to some combination of mental and physical fitness, which fits the general definition of fatigue that tends to refer to a combination of mental and physical fitness in relation to desired performance.

The cues and phenomena the participants gave as an indication for an increased level of fatigue, were numerous likewise. A brief overview of the cues mentioned most by the participants are presented in table 2 below.

Physical	Mental
• Irritating eyes • Yawing • Head nodding • Desire to sleep • Feeling of exhaustion • Susceptible for diseases and illness	• Difficulty to interact in a social context • Frustration and irritation about normally insignificant issues. • Slower reaction times • Lost short-term memories • Losing oversight

Table 2. Physical and Mental Cues Possibly Indicating an Increased Level of Fatigue.

Interestingly, most of the participants reported that once they had crossed their fatigue limit, they were better able to relate (subtle) mental and physical phenomena in themselves with fatigue in future situations. Except for one (eight out of nine), all participants reported the experience realising that they had passed a certain limit, at least, once. They were able to memorise, in other words, and to refer to a situation where, in hindsight, they should have made the decision to step down. Reality, however, was that they continued working.

One participant, for example, encountered extremely difficulty to stay awake during a descent and final approach of a flight inbound to an airfield. It took significant effort and energy, he reported, to fight against this sleepiness, at the expense of the required attention and concentration for the flight. Another example regarded a participant who was unable, after landing, to recall what the course of the flight had been. He could not even remember anymore what he had done or said during the flight.

These kinds of experiences, the participants reported, help to get insight in what their individual acceptable fatigue boundary, in what their personal limit is. These experiences help thereby, to assess their current level of fatigue and to build and enrich their own definition of fatigue. The participants reported moreover that, once having experience crossing the line, they felt more able to subsequently take counter measures[1] proactively (e.g. by actively stepping down, asking for a roster change, cancel social activities, take more rest), and to prevent, in this way, to cross that line again.

It is, not required, however, that such experiences have to be encountered during flight duty. One of the participants, for instance, explained that, while in military service, his group had to march for several days without any sleep, which helped him later on in his assessments of his fatigue level while on flight duty. Another example regarded a situation in which one of the participants' family members required a medical intervention. Although the date of the medical intervention fitted perfectly in the flight roster of the participant, he noticed, coming closer to the date, that the upcoming date had a larger impact on his fitness than he had anticipated earlier. In hindsight the mainly mental impact on his level of fatigue was large, and he questioned if it was a wise decision to continue performing his flight duties during the days preceding the medical intervention.

[1] counterweights (compensating or recovering from fatiguing factors) and countervalues (reducing the fatiguing aspects)

Factors of Influence

During the logging period as well as during the interviews, the participants mentioned numerous factors, that they think impact their level of fatigue and the recovery from fatigue. The table below is an overview of both positive and negative factors mentioned by the participants.

Positive factors	Negative factors
• Quantitative and qualitative good sleep • Balanced diet • Physical exercises / sports • Non-work-related activities • Working climate – social click with colleagues • Family life • Private time / activities • Part-time contract (work-life balance) • Influence on roster • Solidarity to company • Company support in obvious situations	• (Cumulated) operational disturbances • External factors, out of own influence, disturbing quantitative and qualitative rest. • (Disturbed) work-life balance • No, or little, influence on social life agenda • Family life issues (little kids, argument with relative or partner, etc.) • Flying rosters (long duties, early to late shifts). • Solidarity to company • (Limited) social support from company • Hierarchic position within the flightcrew

Table 3. Positive and Negative Factors in Influence on Fatigue

First of all, what becomes apparent from the table above is that both sides contain, up to a certain extent, similar items, i.e., the participants mentioned factors of influence that can influence fatigue both in a negative, and in a positive sense.

The work-life balance mentioned in the right column is such an example, although that may not immediately become clear from the table. It does become clearer, however, when taking the definition of work-life balance into account, as is defined in the paragraph of 'Factors that Generally Induce Fatigue'. It is the individual needs between time allocated for work and time spend on other aspects in life, such as family, sports etc., which are aspects that are mentioned in the left column. A proper work-life balance is necessary to spend time to these activities. When a participant experiences an imbalance in this, he can, to some extent, influence the work-life balance by changing his rosters. He can request the company, for example, whether he is allowed to work part-time, resulting in more time available for the participant to spend on other things than work. The other way around is, of course also possible. In this study, 6 out of 9 participants worked on a part-time basis. The participants indicated that they considered restoring the work-life balance an important factor in the decision to request for part-time labour. Whether one's work-life balance is unbalanced and how this can be solved is a personal issue, depends on what will suit their personal life best, which expressed itself in the variation of contracts. In this study, some of the participants were full-time contractors, others had a contract of 80% or 90%.

A second example of a mutual influential factor of influence is solidarity to the company. One participant mentioned, for instance, that in several occasions his solidarity to the company helped him to regain energy to complete his duty. His argumentation was that he is part of the company and its performance, thus, also part of the success of the company. A successful company, he argued, contributes to his work satisfaction, which helps him to regain and maintain energy. Another participant, however, brought up that because stepping down from duty means that the company has to call a colleague out from standby, and that most likely the flight has to be delayed, which is costly and can spread the delay towards other flights of the company that day, he chose to continue his duty, despite the level of fatigue he experienced.

Stepping down, a complex process

According to the participants, situations in which they have to consider stepping down or not can be straightforward the one time and complex the other. The 'obvious' or straightforward situations regarded those situations in which they clearly can recognize (due to previous experiences) the cues and phenomena related to approaching the 'fatigue limit', or when their 'fatigue limit' was crossed.

The participants reported to experience the more complex situations in cases that their decision to step down is not made at one single point. Instead, they experience that these decisions are the result of a rather continuous and dynamic process of assessments of the situation, that includes, above all, the prioritising and weighing, individually, of all the various factors of influence involved in a particular context.

One of the participants provided an example of such a complex process, which handles about a situation in which the participant was on a 5-day trip. The social click with the crew was good. The weather conditions were quite unpredictable, however, which resulted in a lot of operational disturbances and delays. The working day was long and messages from home learned that his children were rebellious, upsetting thereby their mother. The participant became quite fatigued during the course of the day with one final leg to fly. Based on his previous experience on mental and physical cues of him getting fatigued, the participant considered to step down. The present situation at home, however, which would tire him even more, made him decide to execute the last flight, despite his level of fatigue because then he would have the prospect of a long night sleep in a hotel without any disturbances. The respondent thought it was a choice between two bads. A similar situation occurred to him several months later. This time, the participant decided to go home instead because one of his children was now ill while the social click with the crew was ok, but no more than that.

This example shows that the decision to step down, is not always a straightforward one and an evolving process in which past events, the present situation, and available information are used at best to anticipate on what to expect next. Based on the uncertainties that come with this, pilots need to determine what option (i.e., continue working or step down) would be best for them to do at that time. What this example shows moreover is that the factors of influence are not easily assessed separately. The identified factors of influence after all, when taken separately, appear to have little influence on the level of fatigue. The influential factors that have been mentioned before in the theoretical section, and which have also been brought to the fore by the participants, appear not to have any predetermined impact or fixed value on the level of fatigue of the participant when they emerge. Even with one person, this example shows, similar aspects do not always lead to a similar decision. The participant in one case decided to step down but chose to continue flying in another situation that could, from the outside, be regarded as similar. This is illustrative for complex systems where system components are interacting with each other and are context dependent (Dekker, 2011)

The example above, in short, illustrates the variability of influential factors of fatigue that can lead to different decisions by a single person. It can be expected, though, that variety will also exist between individuals. Interpersonal differences and variability might even increase the possibilities of how influential factors of fatigue will manifest, and also of how these are weighed and of what decisions will be taken.

Considerations to step down, or not

So far results have illustrated the complexity of the concept of fatigue, and why fatigue tend to result in a variety of responses, both between individuals and within individuals. The question is, now, how do participants assess and judge the impact of influential factors of fatigue that lead to the decision whether to step down from duty? What decision-making strategy do they use?

Rational choice

A well-known decision making strategy is the Rational Choice Method (RCM) (Green, 2002), which proposes decision making as a process in which options are compared. First a list of supposedly all alternative options is prepared, after which the options are compared and the best solution is selected. To actually use this method, however, several conditions have to be met, such as that people are able to identify all known alternatives and that goals can be isolated from, and assessed independently of the context. Another condition is that the outcomes of the options selected can be accurately estimated by the decision-maker (Klein & Calderwood, 1991).

A number of studies, however, point out that it is questionable whether people in actual work situations use the method of rational choice, especially when experienced workers are considered. A similar question could therefore be raised regarding the participants, whether they will actually use a rational choice strategy in their decision-making process on whether to step down fatigues or not. So far, the prerequisites for using RCM do not seem to fit too well with the complexity with which the participants seem to experience fatigue.

Because of this complexity, a participant will never be able to know all the possible alternatives. Also, the decision-making process of the participant is dependent on the available information at that moment. Decisions are thus more likely based on some local rationality (Dekker, 2017), i.e. on the interpretation of the individual person of limited information in a context of uncertainty, above all, on how things will interact with each other and develop later on. This is congruent with Dekker (2011), who points out that in complex systems, it is impossible for one person to have full knowledge of everything in the whole system. The examples given above show illustrate, moreover, that the context can be central in weighing the various factors of influence. This is contrary to the prerequisite of RCM in which goals are supposedly assessed independently of the context. Finally, as limited and unambiguous information means uncertainty (Klein, 2009), the outcomes of the participants' decisions are difficult to estimate accurately, something that would not fit the RCM model also.

In particular during the interviews, the participants elaborated most and emphasized the interaction of various influential factors on fatigue, as well as the context of the situation that preceded their decision whether to step down. They hardly discussed (the moment of) the decision itself. They even explained that especially in complex situations, they experienced their decisions to step down or not as a continuous and dynamic process of assessments of the situation rather than as some kind of decision made at one single point. Decision-making in the context of the participants, in other words, seems to be a continuous process in which dynamic characteristics of the situations are weighed and prioritised, and re-weighed and re-prioritised over time (Klein & Calderwood, 1991). Especially the example mentioned in which a participant was faced with messages about his rebellious children at home while on duty with, is exemplary in this. His decision (to continue with flying duty) was not one made at one particular moment in time. He elaborated instead that his decision followed from some continuous assessment and re-assessments of the situation, while that situation developed, and new information became available. A pre-decision process strongly dependent on the developing context of the situation is not supported by a Rational Choice Method.

Satisficing

Fatigue, according to the participants, appears to gradually evolve over time when they are faced with fatiguing aspects and while undertaking fatigue recovering measures. This is, they bring up, an ongoing and largely unconsciously proceeding process. None of the participants reports to 'measure' their fatigue level, let alone that they repeat this over and over again during their decision process. The process as the respondents report it, can rather be regarded as some

continuous and more or less gradually and unconsciously proceeding process, in which it is known that arriving at any accurate assessment is hard to establish.

At the same time, participants did record at least some conscious elements in the process. New events, or those that were obviously unanticipated, as well as situations in which the order or duration of tasks at hand was changed significantly were regarded to trigger a conscious deliberation of fatigue. Examples of such triggers are a new operational delay, or a message from home that a child has been awake all night. Also, mental and physical clues were mentioned, such as head nodding, missing radio calls, or making more little mistakes than desired (See also Table 1). Such cues are often considered as weak signals that do not easily get noticed. The participants, however, reported that, especially when the intensity or occurrence of these cues increased, chances will increase that these kinds of cues will trigger some conscious deliberation on the level of fatigue. This was also the case, they said, when they had experienced these and similar signal before as a sign of a build-up of fatigue. Former experiences of fatigue, in short, are very important for pilots, as they are reported to be used for future assessments whether to step down, or not.

This cycling in unconscious and conscious processing of the level of fatigue, seems to resemble much of what Klein (2008, 2009) called Recognition Primed Decision making (RPD). According to Klein especially experts "combine intuition with analysis" (Klein, 2009, p. 91) in decisions in a context of emerging situations. Such a decision strategy is based on satisficing rather than rationality as intuition draws on cues and experiences of previous situations. Following this familiarity, after all, an expert usually does not collect all possible actions. Rather, the recognition recalls a pattern that generates in turn a proposal for action, after which the action script belonging to that proposal goes through a mental simulation (analysis). Only when the mental simulation appears too ill-structured to meet the situation at hand; alternatives will be recalled. As soon as the simulation fits the present situation though, no other alternatives are generally explored anymore – which is called satisficing – and the respective action is executed (See Figure 1 for an illustration of the RPD) (Klein, 2009).

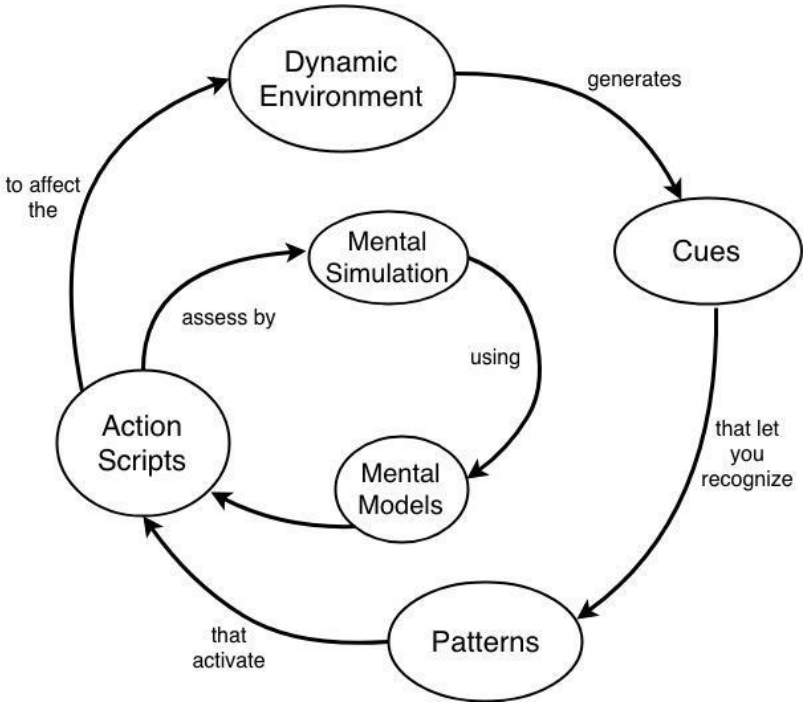

Figure 1: The Recognition-Primed Decision (RPD) model. Reprinted from Streetlights and Shadows: Searching for the Keys to Adaptive Decision Making (p.90), by G. Klein, 2009, MIT Press. Copyright 2009 by Massachusetts Institute of Technology. With permission.

RPD matches much more with the decision-making process that the participants report they go through in their process of stepping down or not than the rational model. First of all, the participants reported the process as a continuous assessment rather than as some process with a fixed starting and endpoint, or as a specific decision moment. Such continuity in the process matches best with the RPD model. Perhaps even more convincing, however, are the reports of the participants on how they tend to base their considerations on earlier experiences. These gained experiences, they argued, help them to enrich their patterns, and are, therefore able to perform mental simulations quicker and with considering fewer other options, something that Klein (2009) referred to as intuition from which experts can draw.

The RPD model might explain, furthermore, that participants report that influential factors of fatigue alone have no predetermined value in their assessments of their levels of fatigue. As we have seen, even when similar cues are encountered, the final assessment, even by the same person, can differ. Relating this to some context-dependency would be too easy, because in that case it would be a matter of "just" understanding the context a bit better. Results, however, point instead towards an interaction of factors, with each other, and with the environment, which results in some unique blend for each situation. Situations that might look similar from a distance, actually tend to differ in detail due to the variability in interactions and interdependencies, hence in the outcomes, which cannot be known or calculated with great precision on forehand. Anticipations on what to expect, therefore, are difficult to arrive with. This variability and uncertainty are typical characteristics of complex systems (Dekker, 2011; Ward, Schragen, Gore, & Roth, 2018) and therefore, apparently, also of the decision-making process of pilots on whether to step down.

DISCUSSION

In this discussion I will elaborate on the limitations and the methodology of this study, as well as on the possible consequences that the insights of this study might have on fatigue risk management, both from an organisational, and from an individual viewpoint. I end with proposing a measure that seems popular for individuals to have own control over their work-life balance.

This study showed that what makes an individual to decide to step down are not independent factors that have a predetermined influence on the level of fatigue. Rather, the process seems to be regarded a continuous assessment of interdependent factors in a dynamic environment, which includes both conscious and unconscious elements. The assignment for the participants, however, to consciously and explicitly log thoughts and assessment (which they normally do not do), could therefore have unconsciously influenced their assessment and subsequent decision-making. After the interviews, however, this particular item was discussed with the participant, from which it turned out that they regarded that the logging assignment had had little influence on their assessments. Two participants indicated, moreover, that they thought that the logging assignment had enriched their view on fatigue.

Even with an enriched view on fatigue, however, and although this study suggests that the value of personal assessments of fatigue should be valued, fatigue related incidents (and accidents) will not be completely prevented in the future. This study shows, after all, that the determination of the fatigue limit, be it individually or collectively, is based on experiences of weak and ambiguous signals. There will always be a certain level of uncertainty that cannot be anticipated on.

Another issue that became apparent during the course of this study is the difficulty to encompass the complexity of the decision-making process that the participants go through in this study. A larger group of participants should, therefore, participate in attempts to gain more insights in the complexity and depth of the cognitive processes and the dynamic character of this subject.

With respect of the content of this study, the uncertainty of the context in which pilots manage fatigue seems to add a new dimension to fatigue management, especially when taking the FRM-systems into account that are currently in place, or the wider developments by regulatory bodies and operators. Although in most FRM-systems fatigue has been re-defined to include more factors of influence and with more emphasis on the dynamics of daily operations, the Key Performance Indicators (KPI) of these systems are still based on measurements of collective and 'hard' fatigue numbers, resulting mainly in a dashboard that has been fed by data which has been drawn out of context. This study shows that such fatigue measurements, based on the measurement of general indicators for the collective, contain little managerial information. Context and personalization, this study reveals, is important, and fatigue management appears to be a much more individual process than this has so far been recognised. It invalidates as such the determination of some supposed universal acceptable level of fatigue. Managing fatigue, would be served much better, in short, with methods other than those ensuring sufficient hours of rest, and duty rosters that fit within legal requirements, as these, although these might allow a certain minimum level of safety, do not say much about how things will turn out for the individual in a particular context.

This study suggests, all in all, that the management of fatigue could evolve by taking into account more the personal needs of individuals. Where feasible, fatigue management should facilitate mental and physical fitness, for instance with more flexibility of supporting systems, such as rostering and ad hoc support of crews. When this is translated specifically to the FRMS discussed in the introduction, then a more suitable FRMS would be a collection of completely personalized programs, which are adapted to the specific needs and preferences of the individual. Such a personalized collection of programs could, this study suggests, contain more reliable information

about the present (mental and physical) fitness of a group than general measures aimed at the measurement of the collective.

For companies, such a personalized system of fatigue management might not be feasible though. Determining the mental and physical fitness of each individual separately, for instance, is quite labour intensive when this process is centralised within the company. Such an individual approach would moreover result into a very large number of KPI's that then have to be managed upon. Facilitating a 'custom fit' support for each individual will, therefore, be virtually impossible, especially for larger operators. Still, a balance could undoubtedly be found between the ideal and what the operator is able to facilitate.

Although the study focused on the assessment of fatigue, participants also talked about measures. One particular measure that I encountered during the study I want to address specifically, namely, to work part-time in order to reduce fatigue. 6 out of 9 participants decided, at various moments in their career, to continue working part-time. This decision, they reported, influenced their decision-making process significantly. They reported an improved work-life balance, for instance, which in turn, they felt, significantly increased their tolerance against irregular shift work, both objectively and subjectively. Working part-time created more time, they argued furthermore, to spend on activities that can help one to recover from fatigue, such as rest, sports, and social activities. It allowed them, all in all, to build up a more resilient individual capacity to cope with fatigue, both on the short and on long term.

Conclusively, many fatigue studies in the past have been executed in controlled environments of laboratories (Klein & Calderwood, 1991; Rosekind *et al.*, 1994; Signal & Gander, 2007). Fatigue is, however, a complex phenomenon, dependent of many aspects that interact, with each other, with other aspects, and with the environment, both in predictable and in unpredictable ways. Fatigue, in short, results from a combination of measurable and immeasurable factors. It is questionable, therefore, whether results of lab research can be transitioned into regulations that can support fatigue management unproblematically. This study has therefore been performed in the field, providing as such a deeper understanding in how factors of influence on fatigue interact with each other and in the decision-making during daily "operational realism" (Signal & Gander, 2007, p. 883). It does not, however, provide all the answers on fatigue related issues and subsequent decision-making whether to step down. It is desirable, therefore, to get a further understanding of fatigue, and of how to facilitate its management, which requires, perhaps, a balanced combination of both laboratory and field research.

CONCLUSION

The following conclusions can be drawn from this study:

- Fatigue is more than a summation of some influential factors of fatigue identified. Fatigue is, above all, a personal and continuous complex process of conscious and unconscious assessments of recognised mental and physical cues, which are weighed and prioritised in the context of a limited knowledge about the present situation and uncertainty about future developments.
- The process resembles much of Klein's RPD, which describes how experts tend to use a satisficing rather than a rational strategy when they make decisions in complex emergency situations. Instigators of fatigue are, like with RPD and largely because of the levels of uncertainty involved, assessed in some continuous and mainly unconsciously proceeding process. During this process cues are recognized from past experiences and weighed against both personal and professional norms and values, and the context encountered.
- Earlier experiences do not only provide individuals with personal fatiguing cues and countermeasures, but also help them to establish a personal fatigue norm flexible enough to serve them successfully in future complex decisions about fatigue.
- Decisions to step down, turn out to be highly personalised, something that seems to be of value for future regulations.

Answering the research question (*'what makes flight crew members decide to step down from flight duty due to fatigue?'*), all in all, based on the data gained in this study from pilots, comprises the whole process that participants go through in their decision to step down or not, which includes both developments at work and developments at home.

Regulators, in the meantime, often rely on regulations based on some fixed and measurable quantitative indicators of fatigue. What this study suggests, is that such regulations will be ineffective because such indicators are not able to account for the personal varieties that seem to exist between people, both in how they build-up fatigue, and in how they tend to assess fatigue. To be able to draw such a conclusion with certainty, however, additional research is needed.

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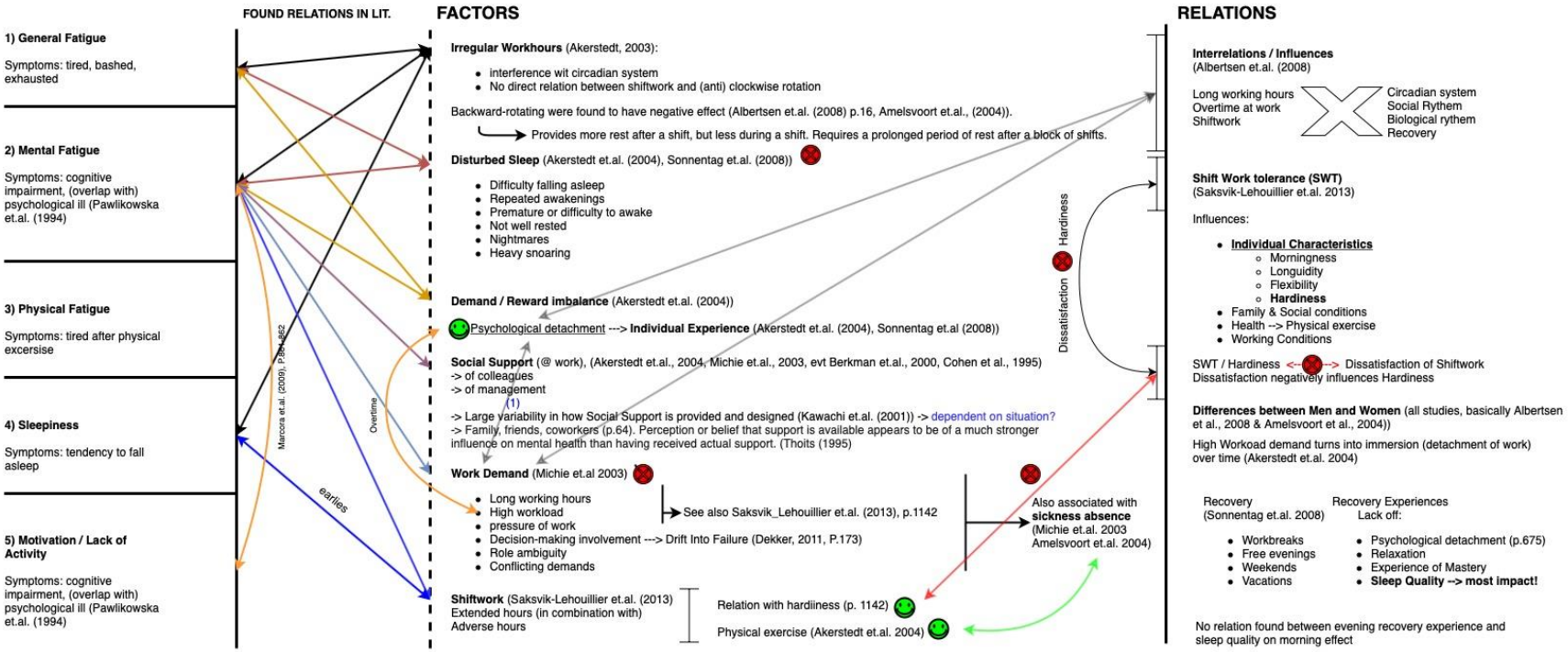
APPENDIX I: INFLUENTIAL FACTORS OF FATIGUE

5 Principles of Fatigue and Relating Factors of Influence

Definition ref: Akerstedt et.al. (2004), Williamson et.al. (2011), Ream et.al. (1996)



(1) Work demand interferes with psychological detachment (Amelsvoort et al., 2004, p.432)

"Notion of individual differences in performance impairment is an important issue" (Akerstedt, 2007, p.209)
The relation Fatigue <--> Safety/Risk is not lineair (Gander, 2011)

APPENDIX II: QUESTIONS OF SEMI-STRUCTURED INTERVIEW

1. Personal data; Can you tell something about yourself?
    a. Age
    b. Working percentage
    c. Kids & kids <5, "nevenfunctie", other structural private/work/natural circumstances that may affect fatigue

2. How did you experience the 4 weeks of logging fatigue related issues and to consciously have to make fatigue related decisions?
    a. Did you like it? Why?
    b. Did you think it difficult? Why?
    c. Do you think that the consciousness in the logging and decision making caused you make other decisions than normally? How and Why? (last question)

3. What is your definition of fatigue?
    a. Why?
    b. Is it a unidimensional concept or more complex?

4. when is your fatigue limit/border crossed?
    a. How do know your limit/border?

5. What factors are of influence with you on fatigue, both negatively and positively, explain per item why and how (examples of factors of influence given below)
    a. Relaxing
    b. Sporting
    c. Kids
    d. Rosters, (rotating) shifts
    e. Social support
    f. Influence on roster
    g. Job satisfaction
    h. Operational issues (delays, AOG etc.)
    i. What I cannot think of ;-)

6. How do you weigh the various factors in the decision-making to step down? In what context?
    a. Is it one of more factors that normally make you decide whether you are fatigued?

7. What do you think of the fatigue system with your organization?
    a. Does it cover what you think is fatigue / what you think causes fatigue?

APPENDIX III: INFORMATION RETRIEVED DURING SEMI-STRUCTURED INTERVIEWS

Pilot	Employment (%)	Add. Function	Children < 5y.o.	Definition of Fatigue	'Fatigue Limit'	Negative Factors of Influence	Positive Factors of Influence	Weighing Factors and Priorities to Step Down	Company Support
1	100	Yes	No	When a few nights of good sleep are not sufficient anymore to have the desired mental and physical fitness.	When it becomes difficult to support the social welfare of the crew. Become self-centred When it becomes difficult to step over operational irritations that are out of influence. Irritating eyes.	Irritation about in-transparent operational issues. Long lasting struggles of neighbour nuisance. Apparently easy things not organised well, resulting in delays Inability to have influence on own social life	Balanced diet Sufficient sleep (7-8 hours a night) Sports Taking time alone.	Home situation and company interests have little influence deciding to step down or not. The decision to continue is influenced by direct factors of influence that give 'energy'. A good working atmosphere amongst crew members.	Only supportive about quantitative sleep. Company is unable or unwilling to support individual requests to recover from fatigue.
2	Withdrawn from this study.								
3	100	Yes	No	Unable to deliver a self-desired performance	When, during a moment of reduced work demand, feeling the energy draining and a strong desire to sleep.	Rostering disturbances, long waiting hours in between flights.	Nice working atmosphere between colleagues. Nice colleagues.	Personal: How to get to a bed within minimum time and least hassle. Work: possible effects on delays, 'buddy-bid', nice roster.	Little. It seems the company is only willing to provide support when Flight Time limitations are busted

Pilot	Employment (%)	Add. Function	Children < 5y.o.	Definition of Fatigue	'Fatigue Limit'	Negative Factors of Influence	Positive Factors of Influence	Weighing Factors and Priorities to Step Down	Company Support
4	100	Yes	Yes	A combination of mental and physical factors resulting in fatigue.	Physical exhausted. Developed a medical issue, while continued flying. Yawing Bad or broken night Too short night Slow(er) reaction time Decision-making requires more time than used to.	Factors (e.g. parties, noise) that prevent from having qualitative and quantitative sufficient rest. Insufficient time for social life and non-work-related social activities. Less time available to recover in between rostered flight weeks.	Social click with other crewmembers. Good team-spirit and working mentality. Having a drink after a day of work. Going out, just to be amongst others. As long as it is non-work related. Sports. Social context and working atmosphere are key factors against fatigue	A deliberation between personal and company related factors. Personal as in what are factors to be expected that negatively influence own fatigue or fitness. Company as in a certain loyalty not willing to face the company with a situation that might result in large operational delays or disturbances.	Good. The few times that supports actually was needed; a solution was found.

Pilot	Employment (%)	Add. Function	Children < 5y.o.	Definition of Fatigue	'Fatigue Limit'	Negative Factors of Influence	Positive Factors of Influence	Weighing Factors and Priorities to Step Down	Company Support
5	80	Yes	Yes	Basically, a feeling of mentally fatigued. When being unable to concentrate on the work and tasks. Constant feeling discouraged.	When, after a flight, there were no memories of what happened during that flight.	Many crew changes Large breaks in between flights No 'social click' with other crew members. Bad nights of sleep Leaving home for a flight duty after an unsolved argument. No influence on social life agenda.	Spending time with family Sports Social click with other crewmembers Nice flight pairing. Part-time schedule. Major influence on work-life balance and fitness.	Weighing factors are night at hotel, mental and physical impact of operational disturbances, home situation. How many nights with good rest. Loyalty to company, don't want to abuse the possibility to step down. Responsibility of function as captain.	The situations in which support was requested, the company asked a favour in return. Not experienced as very supportive.
6	80	Yes	Yes	Being awake, but mentally absent. Difficulty to remember what happened in the past few hours.	Several weeks at home, reported sick. Unable to perform flying duties and having difficulty to oversee situation at home.	Repetitive (technical) complaints Extra operational issues (WX, Delays, PAX, Crew issues) Crew interaction, especially when it costs energy to maintain cooperation.	Part-time schedule. Restoring the work-life balance. Time alone when enroute (especially when kids at home) Activities (alone) not related to flying No, or little alcohol.	Operational integrity Commercial pressure Situation at home Does family require support, or prevails resting enroute? Decision to step down usually made during a flight when own limit is reached.	Level of support is dependent on which company representative is handling the request. Support only offered when no other solution is available anymore. In general, pro-active support concerning

							Sleep		fatigue issues is not available.

Pilot	Employment (%)	Add. Function	Children < 5y.o.	Definition of Fatigue	'Fatigue Limit'	Negative Factors of Influence	Positive Factors of Influence	Weighing Factors and Priorities to Step Down	Company Support
7	90	Yes	Yes	When performance is lagging, compared to what is normally used to	When unable to perform tasks without active support or coaching from a colleague. When someone else suggests taking a rest.	Disturbed work-life balance Accumulating operational factors	Part-time schedule. Sports Social activities with friends and family	The short and long term social and work agenda Questioning if physically or mentally fatigued?	Support based on physical fatigue is present and good. There is no, or occasionally, mental or social support. Depending on the person who is asked for support.
8	90	Yes	Yes	A feeling in which performing as desired costs a lot more effort. Noticed by: heavy feeling little mistakes lagging	Head nodding, sleepiness. Never had the experience yet of crossing a fatigue border.	An additional function requiring a lot of effort. Long working days. Little kids Captains responsibility.	Part-time schedule. Disciplined diet and extra sleep on days off. Living abroad. No societal activities besides family life at home	A balance between loyalty to the company (good well payed job) and professionalism.	In general, no bad issues experienced. One occasion suggested 'out of the box' flexibility was impossible.

Pilot	Employment (%)	Add. Function	Children < 5y.o.	Definition of Fatigue	'Fatigue Limit'	Negative Factors of Influence	Positive Factors of Influence	Weighing Factors and Priorities to Step Down	Company Support
9	80	No	Yes	When based on own judgement it is concluded that flight safety cannot be guaranteed. Can also be influenced due to non-work-related issues.	Fatigue limit is very subjective. Experienced a few times that in hindsight stepping down was de best option. When a powernap is required. Unable to stay awake Unable to memorize what just happened / microsleep.	Disturbed work-life balance: Heavy rosters Few days off Fit social life in just 2 days Absence at family gatherings No weekends off. Long waiting in-between flights Operational disturbances Minimum rests preventing to relax.	Part-time schedule. On time to bed Watching a movie or reading a book.	To step down fatigued is only based on own preservation, own interest. A threshold to step down is present though. Company pressure to continue operations. Loyalty to the company. Reflecting previous experiences of fatigue with present situation.	Continuous pressure is experienced from the company to continue. Little trust in company intentions with FRMS implementation.
10	80	Yes	No	The fatigue rating scale used by company. However, fatigue is a subjective experience.	Almost fell asleep during work. Requiring all mental and physical effort to stay awake.	Imbalanced work-life balance. Operational disturbances (i.e. weather, technical and passenger issues) Loyalty. Early rosters	Part-time schedule. Disciplined life: Little alcohol Sufficient sleep Sports Being able to mentally detach from work.	The effect on personal life in the short and long term. Operational disturbances that can be expected in the following days	Short term ad-hoc support (i.e. stepping sown fatigued) is good Long term support (i.e. request for late check-in rosters) is denied.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