Pilot Training Solutions to Enhance Resilient Performance

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Abstract
Over the years, flight safety has improved through reliable automated systems, but accidents still occur where pilots are faced with unexpected technical malfunctions without previous training. This thesis aimed to investigate possible ways to develop evidence-based training further to prepare pilots for managing unexpected events by identifying resilient promoting strategies applicable in daily flying. In addition, to what extent do airline pilots already optimise recurrent training and line flying to develop resilience, and whether experience affects. A multi-faceted approach was used, including a literature review and a quantitative survey. The literature review investigated the concept of resilience engineering in aviation and resilient performance using e-books and different search engines. Findings were consistent with previous theories about resilience, where expertise, judgment and mindfulness training may help pilots enhance resilience outside the traditional simulator training. The online questionnaire investigated pilots' current resilience development, focusing on competence and confidence. It was made available within a closed Facebook group and resulted in 60 responses. It suggested that discussion about work experience was more preferred than hypothetical problem-solving, and first officers were more willing to prepare and reflect on their performance. In general, it takes time and commitment to develop resilience, although line flying could be used as a complement combined with being unaware of the scenarios used in the upcoming training session.

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Table of Contents

Table of Tables

Table of Figures

1. Introduction

1.1 Background

Over the years, the aviation industry has improved flight safety through innovation, resulting in highly automated aircraft. However, it has provided a more complex socio-technical system and caused challenges where the pilots have been faced with unexpected malfunctions requiring quick sensemaking and decision-making (Hassall et al., 2014). The aviation industry has in the past made mitigating efforts and provided more guidance through checklists, procedures, and training. Still, these malfunctions are now difficult to predict due to their unique nature, making it more likely for pilots to be exposed to unexpected malfunctions without previous training (International Civil Aviation Organization [ICAO], 2013). Accidents of Air France Flight 447 (Bureau d'Enquêtes et d'Analyses pour la sécurité de l'aviation civile, 2012) and Lion Air Flight 610 (Komite Nasional Keselamatan Transportasi, 2019) are reminders of fatal consequences where pilots have faced unforeseen events without previous training.

The inability to prevent or recover from an unexpected event could affect physical and cognitive performance. Therefore, the International Air Transport Association (IATA, 2021) argues that pilots must improve their technical and non-technical skills by allowing airlines' training programs to optimise the enhancement of human performance. Pilots' non-technical skills have traditionally been trained in Crew Resource Management (CRM) courses, while technical skills have been trained in flight simulators (Norden & Owens, 2014). However, over time the aviation industry has realised the need for these two orientations to approach each other, as aviation accidents have often been linked to a combination of lack of skills (Norden & Owens, 2014). Since it is impossible to practice for every plausible scenario, resilience training has been promoted as a strategy to manage unforeseen events.

Resilience is a known term in aviation, but the challenge has been implementing the concept into operation (Pierobon, 2021). Research suggests that variability in responses (Casner et al., 2013) and response time (Hoffman & Hancock, 2017) are ways of identifying and measuring resilient behaviours or skills. Another study compared flight crews' performance when faced with unexpected events. The conclusion was that the flight crew that performed the best was better in leadership, teamwork, open communication, and decision-making (Field et al., 2016). These skills were included in the core technical and non-technical competencies identified as essential to ensure flight safety (ICAO, 2013). Since aviation is such a complex and dynamic world, Dekker and Lundström (2006) suggested that resilience improves the flight crew's adaptability to counteract unforeseen threats and disruptions beyond prepared abilities. The hypothesis is that resilient behaviours or skills are adaptable, appropriate, and efficient.

1.2 Purpose and scope

Resilience has become a more significant part of flight safety, where technical and non-technical skills have become critical to managing the newer generation of modern commercial aircraft malfunctions. Previous flight training focused on task-based training where evidence of accidents from early generation commercial aircraft was the foundation of events that was repeated in training programmes. However, aircraft innovation has surpassed traditional training programmes, which are now based on older generations of commercial aircraft. Since every plausible event cannot be practised, the aviation industry recognised the need to move from task-based to a more trainee-centred competence-based training to improve the ability to manage unforeseen events without previous training and build resilience. Therefore, Evidence-Based Training (EBT) was introduced to align training content with generation-specific aircraft by focusing on technical and non-technical competencies needed to face real-life threats and errors based on data collection from training results and operations.

Scenarios used in EBT are tools to develop and assess competencies within a pre-determined set of envelopes, including normal and abnormal situations in a flight simulator. However, the training may become predictable and given the few times per year that airline pilots are allowed to challenge themselves in the flight simulator, the training value of resilient performance can be questioned. At the same time, airline pilots spend hundreds of flight hours on the line where reality is complex and unpredictable. The time outside the flight simulator could therefore be a training complement to potentially develop resilience on the ground and in the air.

This thesis aims to investigate ways to develop EBT further to prepare pilots for managing unexpected and potentially threatening events. More specifically, this thesis aims to identify preventive strategies to help pilots develop resilience and the possibility of implementing such strategies in pilots' daily operations outside of the traditional simulator training. Furthermore, research how airline pilots optimise recurrent training and line flying to develop resilience, and whether their experience impacts.

2. Method

2.1 Design

The method chosen to study reality must provide relevant data to the hypotheses or questions formulated to give a manageable and meaningful picture (Backman, 2016). A literature review can provide an overview of what is known in a scientific field related to the research problem, while a survey through a questionnaire can provide quantitative observations using mathematics and statistics (Backman, 2016). Therefore, a multi-faceted approach was used to research plausible ways to expand EBT, consisting of a literature review and a survey.

2.2 Literature review

Previous research on resilience was investigated where data collection was sorted and categorised according to Backman's (2016) coding scheme. Articles older than 20 years were excluded to reduce the total number of hits. The selection of documents was divided into three stages. First, the e-book Advancing Resilient Performance (Nemeth & Hollnagel, 2022) was used to review the concept of resilience engineering, which was accessed via the Lund University Libraries website https://lubsearch.lub.lu.se/. Next, search engines at ICAO, IATA, EASA, FAA and NASA generated 20 publications, consisting of rules, manuals, research reports, project reports, safety reports, and guidance material regarding resilience training.

These documents were reviewed and generated prominent keywords used in the Mendeley search engine, consisting of references found in Scopus and ScienceDirect. The keywords were "resilience", "aviation", "training", "unexpected", "critical thinking", "stress", "performance", "management", "mental model", "naturalistic decision making", "military", "simulator", "competence". Different combinations of these keywords generated 1,129 hits, which was reduced to 482 after being filtered for peer-reviewed journal articles. Six sources of information were ultimately identified as accessible and usable in line with the purpose of this thesis. In sum, 26 documents were reviewed and categorised following Hollnagel's (2009) taxonomy of resilient characteristics known as the four cornerstones of resilience: "anticipating", "monitoring", "responding", and "learning".

2.3 Survey

An online survey through a questionnaire was used to provide quantitative data but using a questionnaire as an instrument has its advantages and disadvantages. The advantage is that the cost per respondent is limited in a questionnaire that can be done on a relatively large sample and collect data quickly (Ejlertsson, 2019). On the contrary, the respondent does not have the opportunity to ask supplementary questions, which gives rise to answers based on apparent misconceptions without the chance to correct them. The questionnaire also does not allow overly complicated questions without follow-up questions, which can be minimised with thorough work in the survey design (Ejlertsson, 2019). The choice of the online survey was made so that while the respondents answered the questionnaire themselves, the author could devote more time to other parts of the study. Furthermore, the questionnaire could be answered quickly and was supposed to be user-friendly for phones, tablets, and computers.

The questionnaire consisted of eleven questions. It was created using SurveyMonkey (https://www.surveymonkey.com) and was divided into different themes related to resilience development, focusing on competence and confidence (IATA, 2018). Questions one through three represented demographics to investigate if various aspects of experience impact the responses. Questions four and five studied the attitude among airline pilots to make the most out of some of today’s available resilience tools. Such as to what extent scenarios of recurrent training in EBT are approached as unpredictable to gain the most confidence in managing unforeseen disturbances. In addition, to what extent do airline pilots practice their competence by valuing the usage of the threat-and-error management model to anticipate potential disturbances.

Scenarios are used as a vehicle in EBT to practice competencies by managing relevant threats and errors. Therefore, questions six and seven focused on the frequency of scenario-based discussions in line flying as a low-cost approach in the absence of actual practice. Potentially enhance problem-solving and learn from each other’s experiences to improve competence and anticipation. Questions eight through ten investigated the attitude among airline pilots to what extent line flying is used as an opportunity to practice and develop some of the core competencies covered in EBT. Such as the application of knowledge and procedures by flying different approaches and enhancing manual control of aeroplane flight path management by practising instrument approaches without automated systems. Since facilitated briefing also is a vital part of trainee-centred EBT, to what extent do airline pilots reflect and learn from their performance in daily operations. In the end, question eleven also allowed respondents to elaborate their answers further as needed.

The online survey was conducted on the social media platform Facebook and lasted for two weeks. It was made available by sharing a link within a closed Facebook group representing pilots working for the same airline. To attract a sufficiently large proportion of participants, the motivational factor to respond to the survey becomes crucial (Ejlertsson, 2019). As a result, a cover letter was attached (see Appendix) reflecting the ethical principles. Furthermore, the respondents were informed about the purpose of the survey and the conditions that prevailed before participation. In addition, a reminder was posted one week after the survey was published.

The purpose of conducting an online survey was to shorten the response time, improve the response rate, and facilitate the compilation of the results. As a result, the questionnaire primarily consisted of closed multiple-choice questions except for question eleven, which provided an open answer field (see Appendix). The closed-ended questions were based on an ordinal scale, including four Likert-type questions. It is a well-known attitude scale consisting of several statements within the same subject area, which the respondents must agree with or distance themselves from, using a five- or seven-point scale (Ejlertsson, 2019). Response scale format characteristics impact how respondents respond to an online survey containing Likert scale questions. For example, online surveys offer different formats that affect the extreme response style, defined as the tendency to give extreme responses regardless of item content (Weijters et al., 2021). The vertical format of Likert scale questions indicated a high level of extreme response style, where the visual distance between response categories was more compact (Weijters et al., 2021). Therefore, a vertical scale format was used for all close-ended questions to improve response rate, time, and accuracy.

2.4 Sample

The population for the online survey was airline pilots from 18 to 64 years of age working for the same national airline. However, not all the population could be surveyed due to a lack of resources. Thus, a simple random sample is recommended to locate representatives of the population (Ejlertsson, 2019). It is the most common method, and the selection shall be made so that all persons in the population have the same probability of being included (Ejlertsson, 2019). This simple random sample was made from members of the airline pilots' closed group page on the social media platform Facebook.

The group consisted of 889 members and represented approximately 95 per cent of the pilots at this airline. The total number of responses was 60; hence the response rate was approximately seven per cent. A possible explanation could be the number of layoffs and furloughs due to the coronavirus pandemic and war in Ukraine. Ejlertsson (2019) argues that the greater the number of non-responses, the greater the risk of incorrect generalisations about the target population. However, due to the relatively evenly distributed variation of experiences among the respondents, the author decided to proceed with the data analysis.

2.5 Data analysis

The methods used in describing and analysing data differ on the type of variable. A computer is generally used for answer processing if the survey is small and includes a small number of respondents (Ejlertsson, 2019). SurveyMonkey's filtering tools were used to sort and analyse the measurement values, followed by using Microsoft Word (Microsoft 365, version 16.61) to create illustrations. The nominal scale provides qualitative variables through classification, dividing the respondents into groups without the groups being able to be ranked among themselves (Ejlertsson, 2019). Therefore, question three (see Appendix) was analysed using the nominal scale and resulted in the mode of the measurement values. The interval scale provides quantitative variables through numerical values, which gives statistics on the ranking between two measured values and the size differences (Ejlertsson, 2019). Question one (see

Appendix) was analysed based on the interval scale and resulted in the mode, arithmetic means and standard deviation of grouped data.

The ordinal scale measures qualitative variables and determines if one respondent with a specific measurement value is better than another, but nothing about the exact quantitative size differences between the respondents (Boone & Boone, 2012; Ejlertsson, 2019). It is also the usual data type in surveys that map attitudes and experiences and cannot be used in a meaningful way for calculations with any of the four calculation methods (Ejlertsson, 2019). Therefore, an ordinal scale was used to analyse questions two and four through ten (see Appendix), resulting in the mode and median of the measurement values.

2.6 Ethics

Some laws regulate ethical issues in humanities and social science research. According to section two of the Ethical Review Act (SFS 2003:460), scientific research is defined as observational, experimental, or theoretical work to acquire new knowledge and develop a scientific basis, with the exemption of graduates. However, even if such scientific research is exempted, the Ethics Review Act should be used as a guideline for what is appropriate and inappropriate (Ejlertsson, 2019). In addition, the Swedish Research Council (2017) provide ethics codes that include good research practice in specific research fields. Based on humanities and social science research, the protection of the individual applied to this thesis and consisted of four fundamental principles.

The Swedish Research Council (2002) states that the first principle is the information requirement, which means that the respondents must be informed about the purpose of the research and that it is voluntary to participate. The second principle is the consent requirement, which means that the respondents in a study have the right to decide whether to participate. Thus, the respondent has agreed to participate in a survey by responding to the online questionnaire (Ejlertsson, 2019). The third principle is the confidentiality requirement, which means that individuals of the respondents must not be able to be identified by outsiders, and all material must be stored securely. Finally, the fourth principle is the utilisation requirement, which means that material about individuals may only be used for research purposes that have been informed to the respondents. All these principles were met and described in the cover letter attached to the questionnaire (see Appendix).

3. Result

Previous research will be investigated to identify preventive strategies to help pilots develop resilience and the possibility of implementing such strategies in pilots' daily operations outside of the traditional simulator training. First, clarifying the concept of resilience and its application in aviation and, secondly, identifying skills and behaviours related to resilient performance at the individual level and in a multi-crew environment. Thirdly, suggestions for exercises that can improve such skills.

3.1 The concept of resilience

For the past 40 years, resilience engineering has significantly expanded and is a concept that promotes safety not only on an individual but also on an organisational level (Dekker & Pruchnicki, 2014; Hassler & Kohler, 2014). Resilience engineering aims to study socio-technical systems focusing on safety and efficiency to minimise hazards (Hassler & Kohler, 2014). A system operates inside a safety envelope where unexpected events reduce the safety margin and push the system closer to its boundaries (Dekker & Pruchnicki, 2014; Rasmussen, 1997). Robustness is a steppingstone toward resilience engineering since it is described as a system's ability to cope with common abnormalities (Fujita, 2006; Hassler & Kohler, 2014). Meanwhile, resilience is the system's ability to withstand stability if the boundaries of the safety envelope have been breached (Woods, 2006). Hence, resilience is "The intrinsic ability of a system to adjust its functioning prior to, during, or following changes and disturbances, so that it can sustain required operations under both expected and unexpected conditions." (Hollnagel, 2011, p. xxxvi). This means that resilience contributes to the system's adaptability to withstand various disturbances.

The approach to safety in resilience engineering has introduced a shift in the safety management field on how to mitigate risks and prevent future incidents or accidents. After an incident or accident, the traditional view has been a retrospective approach where the safety components or individual decisions affect a system's reliability (Woods, 2006). It views the system as linear, where responsibility has turned into a blame culture resulting in personal consequences and remedial training as mitigating strategies (Woods, 2005). It has been a successful approach to mitigating more familiar and predictable accidents, and in aviation, it has improved safety through reliable automation, pilot training, checklists, and procedures (Amalberti, 2001). However, the development of socio-technical systems has made it complex that variability is necessary for the system to function correctly and where management of the system requires flexibility (Hollnagel, 2011; Klein et al., 2003). Resilience engineering intends to focus more on what people do correctly than on avoiding stuff that goes incorrect by supporting people to successfully and efficiently deal with complexity (Hollnagel, 2011; Rasmussen, 1997; Woods & Hollnagel, 2006). More specifically:

> Since both failures and successes are the outcome of normal performance variability, safety cannot be achieved by constraining – or eliminating that. Instead, it is necessary to study both successes and failures, and to find ways to reinforce the variability that leads to successes as well as dampen the variability that leads to adverse outcomes. (Hollnagel, 2008, p. xii)

The practical definition of resilience is the system's ability to adjust its performance, and the quality of such ability can be presented in a taxonomy of four essential characteristics (Hollnagel, 2011). This taxonomy is illustrated in Figure 3.1 as cornerstones, and each element will be elaborated. *Anticipating* relates to knowing what to expect and the long-term prediction regarding the potential development, hazards, and probabilities (Hollnagel, 2011). *Monitoring* concerns knowing what to look for and the short-term prediction regarding the critical hazards outside and inside the system (Hollnagel, 2011). This characteristic depends more on potentially flexible ways to detect early signs of disturbance to facilitate handling acute hazards (Hollnagel, 2015).

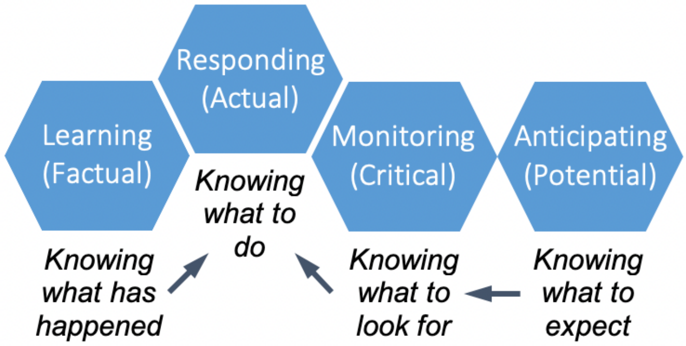

Figure 3.1. The four cornerstones of resilience. Copyright 2011 Adapted from Resilience Engineering in Practice by E. Hollnagel, J. Pariès, D. D. Woods and J. Wreathall. Adapted by permission of Taylor and Francis Group, LLC, a division of Informa plc.

Responding is knowing what to do and is about the reaction and management of the actual disturbance, either through pre-determined answers or modifying the procedure (Hollnagel, 2011). The response is necessary for enduring a system and depends on efficiency to achieve relevant results before it is too late (Hollnagel, 2015). Therefore, the system needs to detect a disturbance, assess the risk and degree of seriousness then decide how to act (Hollnagel, 2015). Adapting a current procedure might be necessary, but it also involves risks where unsafe results may occur due to a lack of knowledge of possible outcomes (Dekker, 2001). Therefore, an appropriate and effective response cannot be planned for every situation, but flexibility would allow more options, and the accuracy would depend on previous experience.

Learning is knowing what has happened and is about objectively reflecting and learning from previous experiences, regardless of whether they are good or bad (Hollnagel, 2011). Learning is a fundamental element that allows responding and monitoring unless the environment is constant and foreseeable. Consequently, learning is necessary for a complex and unpredictable environment where competence is based on the meaningful selection of experience that is adequately evaluated and comprehended (Hollnagel, 2015). Meaningful learning has traditionally been based on things that go wrong from previous incidents and accidents. However, to enhance resilience in a system, more focus must be on things that go right since it occurs more frequently (Hollnagel, 2015). Ultimately, complex systems offer a supply of experiences vital to improving the other cornerstones of resilience.

So far, resilience development in the aviation industry has been based on data collected from safety reports, flight data monitoring, and Line Oriented Safety Audit (LOSA). Later, data has been analysed to lay a foundation for proactive revaluations of current aircraft design, procedures, and training programs (Carroll & Malmquist, 2022). To put the cornerstones to practical use in aviation, the accident of US Airways Flight 1549 (National Transport Safety Bureau [NTSB], 2010) could serve as an example.

An Airbus A320 that encountered a flock of geese after departure ended with a total loss of thrust on both engines and subsequently ditched in the Hudson River, where everyone on board survived. The flight crew did not anticipate a total loss of thrust on both engines at such a low altitude but managed to prevent an adverse outcome by adapting the procedures to an unexpected event without previous training (Pruchnicki et al., 2019). The NTSB (2010) states that the captain realised the time pressure to resolve the situation and started the Auxiliary Power Unit (APU), knowing that this checklist item would come much later in the emergency checklist. "Starting the APU early in the accident sequence proved to be critical because it improved the outcome of the ditching by ensuring that electrical power was available to the airplane." (NTSB, 2010, p. 88). The aviation industry later learned from this accident as the NTSB (2010) made safety recommendations, leading Airbus to change the emergency checklist. However, the challenge remains to identify resilient behaviours that enable the flight crew to anticipate and become flexible in managing unexpected situations without previous training.

3.2 Resilient performance

In hindsight of the accident of US Airways Flight 1549, resilient performance in aviation implies recovering from an adverse event and minimising the effects by being adaptable based on competence and resources (Carroll & Malmquist, 2022; Hale & Heijer, 2006). Thus, flight crew resilience is defined as "The ability of a flight crew member to recognize, absorb and adapt to disruptions." (IATA, 2018, p. xiv). Carroll et al. (2012) suggested a model (see Figure 3.2) to illustrate resilience and was used by Campbell et al. (2017) when examining how to train the commanders of the United States Marine Corps in resilient decision-making. Figure 3.2 illustrates that when a person is faced with stressful adversity, physical and cognitive performance recovery will take different pathways (Carver, 1998). It ranges from the person succumbing to the stress to becoming resilient by recovering to previous performance level, and some might even thrive by gaining performance (Bonanno et al., 2011; Carver, 1998). Therefore, different factors may affect the trajectory and the ability to recover from acute stress induced by unexpected events.

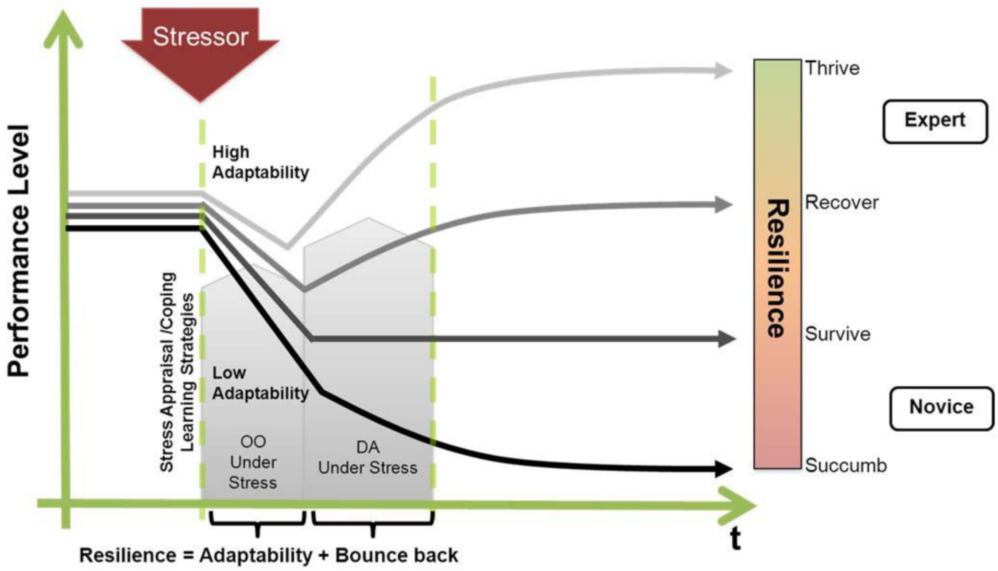

Figure 3.2. Model of resilient decision-making performance. From *Small-unit Training for Adaptability and Resilience in Decision Making (STAR-DM)* (p. 21), by G. Campbell, C. Padron, G. Surpris, M. Carroll and B. Winslow, 2017, Design Interactive, Inc (https://apps.dtic.mil/sti/pdfs/AD1032176.pdf). In the public domain. Reprinted with permission.

Performance recovery is divided into adaptability and bounceback. The first segment shows the performance drop in response to the perceived threat, followed by the time needed to regain situational awareness and adapt performance to prevent further detriment (Campbell et al., 2017; Carver, 1998). Meanwhile, the second segment shows the time needed to bounce back and recover from the performance drop by considering decision options followed by action (Campbell et al., 2017; Carver, 1998). Figure 3.2 also illustrates OO in the adaptive phase and DO in the bounce-back phase, meaning Observe, Orient, Decide and Act (Boyd, 2018). It is a decision-making process that Campbell et al. (2017) incorporated as a framework due to its common usage among military commanders. Thus, when an individual is faced with an adverse event, it may affect different parts of the decision-making process.

The performance trajectory is individually based, and research proposes different factors that affect the pathways. An individual's resilient performance may benefit from similar regular events and potentially result in more efficiency due to a minor degree of performance decline and increased rate of performance recovery (Carver, 1998). Individuals who thrive experience a sense of control, feeling more secure due to greater confidence and competence, which allow more efficient recovery on subsequent occurrences (Aldwin, 1994; Carver, 1998). In addition, research suggests that resilient and thriving individuals possess supportive traits such as personality and optimism (Bonanno et al., 2011; Carver, 1998). Task importance and confidence are two other characteristics that allow a better performance starting position and improve engagement (Carver, 1998). However, even if there are potential benefits, it is based on experiences of positive outcome as the opposite would potentially have detrimental effects. In the end, enhancing pilot resilience through simulator training by exposing individuals to fearful events may be challenging as it does not benefit everyone.

Performance trajectory may not only be affected by inter-personal traits but also by external factors. For instance, solid social bonds allow the feeling of trust and security due to social support from others (Carver, 1998). An individual's self-determination is an aspect that the surrounding environment could influence, where undermining of self-determination occurs more often in a controlling environment with deadlines and surveillance. Meanwhile, some individuals take the opportunity to show off, whereas some treat the situation as a learning experience (Carver, 1998). Individual performance can thus depend on previous experience and the impact on the surrounding environment, which affects the individual's self-confidence and the probability of an appropriate response when faced with challenges.

3.3 Adaptability strategies

Automated systems have become more reliable and complex, although it has also made it challenging for pilots to manage system malfunctions. Pilots used to make sense of a malfunction based on previous experience through a top-down or goal-oriented approach by successfully breaking down a major problem into smaller, more manageable sub-problems to solve. But now it is more likely that the pilots will gain an understanding of the data provided by the automation through a bottom-up perspective by solving more minor problems and then integrating them into a more comprehensive solution (Carroll & Malmquist, 2022; Mosier & Fischer, 2010). Therefore, pilots need to practice low-probability malfunctions to anticipate, adapt, and respond more efficiently to unforeseen situations (Carroll & Malmquist, 2022). Field (2015) argues that flight crews need to improve workload management through relevant monitoring and task management to enhance problem-solving and decision-making. The following subsections will elaborate on how sensemaking and expertise in automation could facilitate problem-solving and improve pilots' adaptive performance when faced with unexpected events.

Sensemaking

The increased use of automatic systems has improved flight safety, but it has also affected the pilots' cognitive ability to understand surprising situations. Since pilots do not actively exercise situational awareness to the same extent, understanding the automatic system might sometimes get challenging and cause automation complacency, bias, and surprise (Strauch, 2017). When appraising an uncertain situation, sensemaking is the active process of understanding the situation, including cause and effect, by mentally testing mental model types of knowledge structures (Klein et al., 2010; Kochan, 2005). By the end of the process, the goal is to identify a suitable frame that fits with perceived reality, which now gives meaning to a situation resulting in a state of awareness (Endsley, 1995; Klein et al., 2010). Also known as the perceptual cycle and could be either quick and unconscious or slow and conscious if it requires knowledge-based processing (Kahneman, 2003; Rasmussen, 1983). Eventually, the process may be more efficient if the individual is more knowledgeable since it will take a shorter time to find an accurate frame to match and make sense of an uncertain situation.

Frames used in the perceptual cycle serve multiple purposes. New frames are developed based on learning experiences through a bottom-up perspective, which can be stored in the long-term memory to be activated in a future situation (Landman et al., 2017; Salmon et al., 2008). Unlike a top-down view, frames are activated and used as filters of incoming data to establish manageable pieces of information to be perceived and bring meaning to a situation (Landman et al., 2017). Sensemaking can also be due to misunderstandings where the data is correctly perceived, and the active frame proves insufficient (Klein et al., 2010). Consequently, the insufficient frame either becomes elaborated or re-framed. Elaborating the frame rejects irregularities and locks the active frame instead of critically appraising the validity, making the individual vulnerable to bias due to motivation and emotional reactions to unexpected situations (Fischhoff, 2003; Klein et al., 2010). At the same time, re-framing requires effort to substitute an active frame with a more suitable frame or develop a new frame (Klein et al., 2010; Landman et al., 2017). In sum, frames are necessary tools to facilitate sensemaking as more structured frames make it less likely for bias.

Efficient monitoring of a dynamic and complex system needs continual mental model development. The process needs to be goal-oriented to determine relevant and valuable data to monitor and give meaning to a situation (Billman et al., 2020; Mumaw et al., 2000). The situational model is depicted in Figure 3.3, where anticipations about the current state are primarily based on mental models or previous experience. Meanwhile, the outer triangles represent different ways to monitor and compare data to update the current state of the situational model (Billman et al., 2020). The top triangle illustrates the monitoring objective by asking what information is missing in the situational model, which is answered by the right triangle that illustrates where to look and perceive meaningful data (Billman et al., 2020). Based on the updated situational model, the left triangle illustrates considerations for more monitoring to reassure the aircraft's current state or control demands to re-establish flight path. Therefore, effective monitoring is based on the context, which is difficult for engineers to anticipate. Mumaw et al. (2000) argue that operators may use different approaches to adapt the complex interface design to improve the likelihood of detecting significant changes in the socio-technical system.

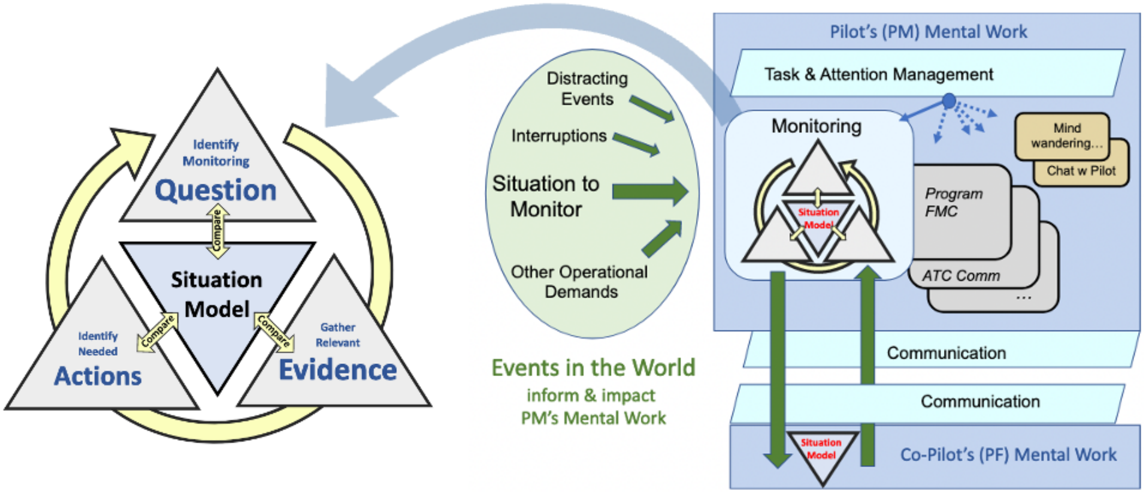

Figure 3.3. Model of monitoring as sensemaking. Adapted from "A Model of Monitoring as Sensemaking: Application to Flight Path Management and Pilot Training," by D. Billman, R. Mumaw and M. Feary, 2020, *Proceedings of the Human Factors and Ergonomics Society Annual Meeting, 64*(1). pp. 245-246 (https://doi.org/10.1177/1071181320641058). Copyright 2020 by SAGE Publishing. Adapted with permission.

First, expand information from the provided data by comparing readings and trends with other redundant system components. In addition, utilise previous experience to allow critical thinking of indications and procedures, and be selective attentive to more critical components (Mumaw et al., 2000). Self-awareness is another vital notion used in the military to improve the decision-making process to minimise the impact of bias and heuristics (Facione & Facione, 2007; Field et al., 2015; Landman et al., 2017). Secondly, create information not generally provided by the system by modifying the displays and alarms (Billman et al., 2020; Mumaw et al., 2000). For example, the pilot may modify the low fuel warning to occur at an earlier stage to allow more time to evaluate decision options. Thirdly, increase cognitive capacity by using reminders for monitoring or actions, and use more operators to monitor (Mumaw et al., 2000). For instance, pilots sometimes use an incomplete checklist to be placed in a conspicuous place, or if a vital system component is inoperative, a sticker labelled INOP is placed over the faulty instrument as a reminder. Ultimately, competence, self-awareness and reminders are suggested to optimise monitoring to improve situational awareness.

So far, much has been focusing on individual monitoring, but airline pilots usually operate in a multi-crew environment, bringing new challenges to shared situational awareness. For example, during a go-around, eye-tracking has revealed that pilot flying and pilot monitoring have different scanning patterns due to various task assignments (Dehais et al., 2017). More effort is needed in teams to establish a shared mental frame since it requires more coordination and conflict resolution, affecting the efficiency of the decision-making process (Klein et al., 2010). As illustrated in Figure 3.3, communication plays a vital role in assisting task and attention management and for both pilots to reach a mutual understanding of a situation (Billman et al., 2020; Field, 2015; Mumaw et al., 2020). To help pilots with CRM principles, the BDAR cycle (Brief-Discuss-Advocate-Resolve) was suggested to be an efficient communication strategy in problem-solving and plan development (Holt et al., 2001). Implying that pilot monitoring needs to become more involved and share perceptions verbally or non-verbally. Sensemaking in teams is also affected by the team authority setup where leadership and teamwork are dynamic depending on whether the situation is time-critical (Field, 2015).

Hence, proper communication skills are necessary for a multi-crew environment to improve sensemaking and efficiently recognise an unexpected situation, where time is a factor.

Expertise in automation

Although innovation has made automatic systems more functional and reliable, it has also resulted in more complexity, which might make sensemaking of malfunctions more challenging. Strauch (2017) argues that engineers have prioritised technological development and efficiency rather than socio-technical performance. Therefore, it is likely that pilots will not be able to comprehend these complex automated systems fully and predict surprising events (Carroll & Malmquist, 2022). Pilots need to improve their competence and become experts in systems knowledge by structuring mental models to match the system complexity and improve the efficiency of re-establishing situational system awareness (Endsley, 1995). Consequently, practising the application of mental frames is needed to make the frames more structured and permanently stored in long-term memory (Kochan, 2005). The more well-structured mental frames, the less cognitive capacity is required to adapt to an unexpected event and improve the sensemaking of automated aircraft systems.

Since resilient performance applies to both expected and unexpected events, pilots need to enhance the ability to analyse uncertain events by improving knowledge-based performance and practising more problem-solving to acquire expertise (Malmquist & Rapoport, 2017; Smith et al., 1997). Studies suggest that expertise consists of accumulated knowledge and skills gained through practice and learning experience (Landman et al., 2017). Therefore, expertise is more likely to be reached after basic training when sufficient operating experience is achieved (Strauch, 2017). Since practical reasoning is a way to avoid root knowledge where relevant knowledge is adapted to match the context, followed by self-reflection to assure more structured schematics are stored in long-term memory (ICAO, 2016; Phillips et al., 2004). Variable training by practising a variety of situations could also improve sensemaking and re-framing ability, where a high number of well-structured frames would allow more goal-oriented problem-solving (Landman et al., 2017; van Merriënboer, 2012). Thus, the individual may be less likely to act irrational and impulsive in unexpected and threatening situations (Kowalski-Trakofler et al., 2003). Studies suggest that line flying after basic training could be a vehicle to advance expertise due to its complex and unpredictable learning environment.

After basic training, certain learning principles could be applied to more efficiently advance expertise. Tactical use of knowledge was suggested as a critical learning principle where meaningful knowledge is acquired based on the operational context and linked to previous experience by building blocks of knowledge (Barshi, 2015). From this starting point, other learning principles could be integrated. Increasing task difficulty by more comprehensive learning of the system component, the effect on different systems and in the end also projection into other domains (Barshi, 2015). For example, low hydraulic system pressure could signify cavitation due to high cruising altitude. But even if a lower altitude could restore the system, it would also increase fuel flow resulting in less fuel available at the destination. Barshi (2015) claimed that line training allowed other learning principles such as proper spacing between learning occasions and variability, such as flying different approaches to the same airport. These three learning principles would lay the foundation for repetition and self-briefing to advance expertise.

Repetition could be practising physical procedures or mentally reflecting, which could be discussions with a colleague while armchair flying (Barshi, 2015). Mental repetition is vital in learning where case studies of incidents and accident reports could be used as discussion topics. In addition, practice in problem-solving and decision-making could be more efficiently achieved in low-fidelity simulations as a less-expensive option (Crichton et al., 2000; Dahlstrom et al., 2009). Since implementing CRM notions into case studies or simulations suggests improvement in confidence, teamwork, communication, and decision-making (Barshi, 2015; Crichton et al., 2000; Dahlstrom et al., 2009; Martin et al., 2011). However, advancing expertise takes time and effort. Ericsson and Charness (1994) suggested it would require at least four hours per day of practice for ten years. Time that needs to be planned to use guided activities to allow higher-order processing using case studies or understanding the rationale behind a procedure (Barshi, 2015). One of the benefits of self-produced knowledge is that it tends to become more permanent. In addition, feedback covering erroneous behaviours is also more efficient and should sometimes be conducted after a training session (Barshi, 2015; Healy et al., 2014). In sum, there are a variety of less expensive approaches to advance expertise.

Besides expertise, there is also a judgment domain to consider. The advantage of experts over beginners is that the former can retrieve relevant information related to the problem to understand cause and effect. Meanwhile, the latter can retrieve information to only answer what happened (Endsley, 1995; Glaser, 1990). However, this is not guaranteed since a study indicated that beginner pilots with judgment skills adapted and performed more efficiently when facing unforeseen aerodynamic situations (Kochan, 2005). Judgment is suggested to consist of adaptive expertise that allows flexible application of knowledge out-of-context, intuitive decision-making, cognitive flexibility through re-framing ability, and metacognition that allows awareness of own level of understanding (Kochan, 2005). Advancing expertise does not necessarily mean simultaneous advancement in judgment, as it acts as a binding force between the various knowledge forms that expertise constitutes. Such as declarative knowledge of facts, procedural knowledge of how to accomplish a task, and structural knowledge of storing, structuring, and retrieving facts. Therefore, flight training should integrate judgment and expertise where both domains should be taught independently and in context (Kochan, 2005). Although expertise allows the application of knowledge to deal with unforeseen events, it is the pilot's judgment that provides flexibility when adapting their knowledge to the context.

3.4 Recovery strategies

When situational awareness has been re-established, the second segment of the resilience model is the time necessary to make up for lost ground in performance due to an unexpected event (see Figure 3.2). Stress management is suggested as a critical factor to allow more cognitive capacity to prevent further detrimental performance in physical and cognitive skills, allowing faster recovery and more accurate decision-making (Carroll & Malmquist, 2022; Dismukes et al., 2015). The detrimental effect in both magnitude and time to recover from a performance drop may become less severe with re-occurrences of a similar situation with a positive outcome (Carver, 1998). Hence, soldiers in the United States Marine Corps are exposed to high-stress levels during training exercises to be prepared for the battlefield, which has proven to improve resilience (Carroll et al., 2014). To better understand the cause and effect of stress, the following subsections will elaborate on acute stress and its impact on decision-making, followed by robust strategies to minimise stress effects.

Definition of stress

The concept of stress has been used for a long time but has different meanings depending on the context. The transactional model addresses the interaction between the individual and the surroundings in terms of psychological stress. Defined as "…a relationship between the person and the environment that is appraised by the person as taxing or exceeding his or her resources and endangering his or her well-being. " (Lazarus & Folkman, 1984, p. 21). It proposes that stress is an individual reaction to gain from a challenge or remain safe from harm based on a subjective assessment of external circumstances. The transactional model implies that individuals could range from thriving to succumbing to stress when faced with an unforeseen event.

However, when dealing with emergencies, pilots may be exposed to high-stress levels and become more vulnerable to committing pilot errors (Dismukes et al., 2015). In addition, Kowalski-Trakofler et al. (2003) claim that more emphasis should be placed on demand exceeding resources in emergencies. Consequently, stress is "…a process by which certain environmental demands … evoke an appraisal process in which perceived demand exceeds resources and results in undesirable physiological, psychological, behavioral, or social outcomes. " (Salas et al., 1996, p. 6). The definition is more structured for acute stress, where a situation is perceived as threatening beyond resources with negative consequences (Salas et al., 1996). Therefore, the author will refer to this definition when reviewing the impact on decision-making.

Stress impact on decision-making

The accuracy of a decision may be impacted by several factors that influence the cognitive process. Contributing factors behind the poor performance are likely to occur when the situational awareness is not complete due to a lack of knowledge concerning correct action or time to resolve the situation (Endsley, 1995). Especially in a complex and dynamic system, where a large amount of information, including multiple goals and decisions, could potentially affect direct attention and working memory to capacity overload (Endsley, 1995). Attention and working memory are the cornerstones to efficiently dealing with challenging situations. Anxiety will further aggravate cognitive performance if the situation is perceived as threatening and unmanageable (Eysenck et al., 2007). Consequently, non-technical skills, such as decision-making and teamwork, will be impaired due to a lack of coordination and communication (Dismukes et al., 2015). The impact of anxiety on the decision-making process will now be broken down according to Boyd's (2018) decision-making framework and integrated with the attentional control and processing efficiency theories.

The first step of decision-making is observation (see Figure 3.2), which depends on proper attention to collect relevant data (Campbell et al., 2017). The attentional control theory generally describes how anxiety affects the balance between two attentional systems. Firstly, top-down attention control is goal-oriented and subjected to anticipation, comprehension, and objectives. Secondly, bottom-up attention control is characterised by stimulus-driven attention focusing on noticeable stimuli (Corbetta & Shulman, 2002; Posner & Petersen, 1990). Anxiety creates an imbalance where the bottom-up perspective gets prioritised resulting in lower-level functioning of the top-down attentional control system in monitoring and re-framing but mostly in inhibiting irrelevant stimuli and multi-tasking (Miyake et al., 2000). High workload levels and anxiety stress may lead to attentional narrowing and reduce the likelihood of detecting relevant cues (Staal, 2004). However, Kowalski-Trakofler et al. (2003) argue it does not have to be perceived as something negative. On the contrary, it could be a positive attribute to simplify the information processing by ignoring irrelevant data and utilising the attentional resources on what is most significant. In sum, the individual will adapt to a stressful event and mobilise attentional resources to facilitate sensemaking.

Next are the steps of orient and detect (see Figure 3.2), where higher levels of situational awareness, including generating and evaluating multiple response options, put a lot of strain on the working memory (Endsley, 1995). According to the processing efficiency theory, anxiety impairs working memory's capacity and processing ability and demands more effort to improve performance (Eysenck & Calvo, 1992). Therefore, the individual may experience more difficulty making sense of a situation and performing manageable tasks, both in terms of number and quality (Dismukes et al., 2015; Staal, 2004). The individual will potentially shift more from rational to instinctive decision-making, which is more easily influenced by bias (Kowalski-Trakofler et al., 2003). Decision-making tends to rely more on previous experience irrespective of the previous success rate of such a response (Lehner et al., 1997). Ultimately, too much stress may impair the quality of decision-making as more rapid decisions tend to increase the risk of errors.

Moderators of stress

Multiple factors may affect the amount of stress, including internal and external factors. Many of these factors are related to different states of incentive, aspiration, and alertness that tend to moderate stress effects on cognitive processing and performance (Staal, 2004). External factors could be related to social aspects where evaluation from a more significant number of critics impairs the individual's perceived ability to resolve complex tasks without previous experience, which results in degraded performance (Staal, 2004). Another aspect is the high noise environment, which may impair teamwork since individuals become more passive and less willing to step forward to help each other (Mathews & Canon, 1975). At the same time, the group authority gradient tends to be shallow in stressful situations, as the group becomes more receptive to suggestions from each other. However, stress implies that lower-status group members rely more on the group leader's decisions (Driskell & Salas, 1991). In sum, external factors are dynamic and may have mixed effects on performance.

Internal factors tend to relate to introspective abilities. Field (2015) states the need for pilots to become more socially aware and attentive to workload, where some studies suggest that higher emotional awareness moderates stress effects. For instance, Gohm et al. (2001) studied firefighters' cognitive performance in stressful events. Findings implied that individuals who could classify and understand present feelings tended to experience less cognitive difficulty, such as confusion and overlooking. More specifically, it allowed a greater sense of control and prediction of emotional reactions, allowing more attention to focus on relevant tasks. Ultimately, self-awareness tends to improve attentional control and concentration.

Mindfulness training is another stress management tool where The Royal Norwegian Air Force has conducted several studies. Mindfulness is "…a state of consciousness characterized by receptive attention to and awareness of present events and experiences, without evaluation, judgment, and cognitive filters. " (Glomb et al., 2011, p. 119). For example, one combat group had 12 months of mindfulness training and showed long-lasting effects even 24 months afterwards. Findings suggested that body scans and meditation significantly improved self-awareness, attention, and emotional control, which prevented overreaction (Meland et al., 2015). A similar study looked at social effects and showed an enhanced sense of fellowship resulting in more direct communication, composure, and recognition of other group members (Meland et al., 2021). Mindfulness training demands a lot of time and effort, including a multifaceted and group-oriented approach, where not all participants share the same positive experience (Meland et al., 2015). In the end, mindfulness training may help some pilots become more emotionally secure and consciously present by acknowledging personal thoughts and feelings.

Stress interventions are divided into two categories. Stress management aims to recover from stress exposure, whereas stress inoculation relates to preventive stress exposure to minimize the stress effects (Staal, 2004). The latter will be referred to due to the purpose of this thesis. Stress inoculation training appears to have successfully mentally prepared professional groups such as emergency and military staff to be resilient when engaging in distressful events (Meichenbaum, 2007). Ultimately, improvement of performance anxiety was more beneficial than anxiety, where the number of sessions required to reach a positive result was relative to the degree of the distressful event (Saunders et al., 1996). Subsequently, six to seven sessions improved performance anxiety, whereas anxiety improved after four to five sessions (Saunders et al., 1996). In addition, the size of the training group had different effects, with smaller groups of eight to ten participants efficiently improving anxiety. In contrast, large groups showed promising results in enhancing performance anxiety (Saunders et al., 1996). Research implies that stress inoculation training has potential positive effects and performance anxiety benefits the most.

Stress exposure training has mostly focused on anxiety, but one study combined stress training with regular task-skills training. Friedland and Keinan (1992) did a laboratory study with the Israeli military by merging these two domains into a three-phase approach. The first phase involved task acquisition; the trainees were isolated from stress exposure while knowledge and skills for a task were taught to desired proficiency. Meanwhile, the second phase solely focused on stress exposure and coping strategies without interfering with task-related knowledge. Finally, the third phase involved practice under stress exposure by combining task and stress comprehension, which seemed necessary to accomplish the desired effect in performance (Friedland & Keinan, 1992). However, the promising findings may be due to less unpredictability resulting in less anxiety due to more sense of personal control and confidence, resulting in fewer decision-making errors (Inzana et al., 1996). Findings suggest that it seems possible to combine stress and task-drills training domains even if predictability may reduce subjective stress experience in the final phase.

A few studies have been made on stress exposure training in aviation. For example, McClernon (2009) did laboratory research based on the three-phase approach in a flight simulator and induced stress through the cold pressor technique, where participants' feet were kept in ice-cold water. The results showed that the experimental group experienced less stress than the control group and performed better in the flight simulator (McClernon, 2009). However, to research if stress exposure training in aviation was transferable into reality, a follow-up study was made where the participants in the final phase were exposed to stress while flying an aeroplane. Findings were consistent in performance improvement as the experiment group flew the aeroplane much smoother, although the subjective stress experience remained the same (McClernon et al., 2011). In addition, one study showed that training involving unpredictability might increase workload more considerably in the aeroplane than in the flight simulator (Dahlstrom & Nahlinder, 2009). Even if findings made by these studies suggests improved performance, it remains unclear how stress exposure training may affect pilots in unforeseen and threatening real-life situations.

3.5 Questionnaire

IATA implies that resilience is developed through improved competence and confidence. Based on this, the questionnaire was designed to research how airline pilots optimise recurrent training and line flying to develop resilience, and whether their experience impacts. The questionnaire was used to research how airline pilots optimise recurrent training and line flying to develop resilience, and whether their experience impacts. The online survey was conducted with a group of 60 airline pilots. The completion rate was one hundred per cent on all questions, except for question eleven (see Appendix), which resulted in a 13,3 per cent completion rate ($n = 8$). The results and the analysis of the data material that emerged from the survey responses will be presented thematically based on the purpose of this thesis.

Demographics

Question 1: What is your age? Figure 3.4 shows that most of the respondents ($n = 22$) were 35 to 44 years ($M = 42.5$, $SD = 9.3$). However, none of the respondents was in the age range of 18 to 24 years.

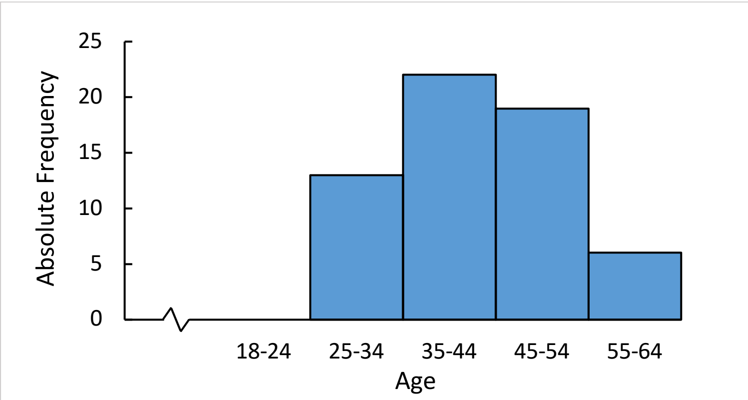

Figure 3.4. Age distribution among the airline pilots.

When cross-tabulating results from the first question about age and the third question about rank (see Appendix), Table 3.1 lists that most respondents ($n = 38$) were first officers, ages ranging from 25 to 54 years ($M = 37.9$, $SD = 7.2$). One remark is that three of the first officers had previous captain experience. Furthermore, 22 captains participated in the online survey, ages 35 to 64 years ($M = 50.4$, $SD = 6.8$).

Table 3.1.

Cross-tabulation of age and rank.

	Absolute Frequency		
Age	**Captain**	**First Officer**	**Total**
18 - 24	0	0	0
25 - 34	0	13	13
35 - 44	4	18	22
45 - 54	12	7	19
55 - 64	6	0	6
Total	22	38	60

Questions 2: Approximately how many flying hours have you flown? Figure 3.5 illustrates that most respondents (*n* = 17) had 7.501 to 10.000 flying hours.

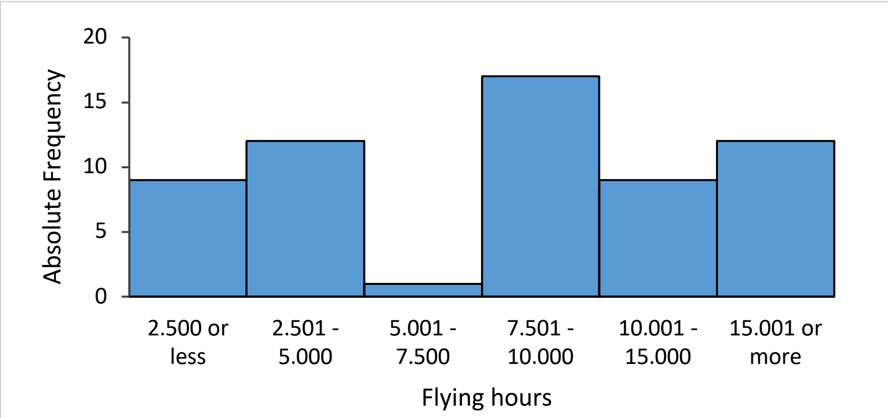

Figure 3.5. Distribution of pilots with different flying hours experience.

When cross-tabulating results from the second question about flying hours and the third question about rank (see Appendix), Table 3.2 lists that most first officers (*n* = 12) had either 2.501 to 5.000 respective 7.501 to 10.000 flying hours. However, the median first officer was in the range of 2.501 to 5.000 flying hours. Meanwhile, most of the captains (*n* = 12) had more than 15.000 flying hours.

Table 3.2.
Cross-tabulation of flying hours and rank.

	Absolute Frequency		
Flying hours	**Captain**	**First Officer**	**Total**
2.500 or less	0	9	9
2.501 - 5.000	0	12	12
5.001 - 7.500	0	1	1
7.501 - 10.000	5	12	17
10.001 - 15.000	5	4	9
15.001 or more	12	0	12
Total	22	38	60

Preparing to be unprepared

Questions 4: To prepare for my upcoming simulator check, I ask colleagues who have already done their simulator session how their Line oriented Flight Training (LOFT) scenario unfolded. During every proficiency check period, there will always be some pilots who will be first out and not know the LOFT scenario. However, the rumours will spread as more pilots become aware of the scenario in preparation for the simulator check. The survey responses in Figure 3.6 shows that most respondents (*n* = 22) agree there is a benefit of knowing how the scenario unfolded for colleagues who had already done the simulator check. However, not all respondents believe it is necessary; "To let yourself for suprises and startles those increase your recilience." (Respondent 11). Figure 3.6 shows that the median captain disagrees about the importance. Meanwhile, the median first officer neither agrees nor disagrees with the value of being aware of the scenario in preparation for the upcoming simulator check.

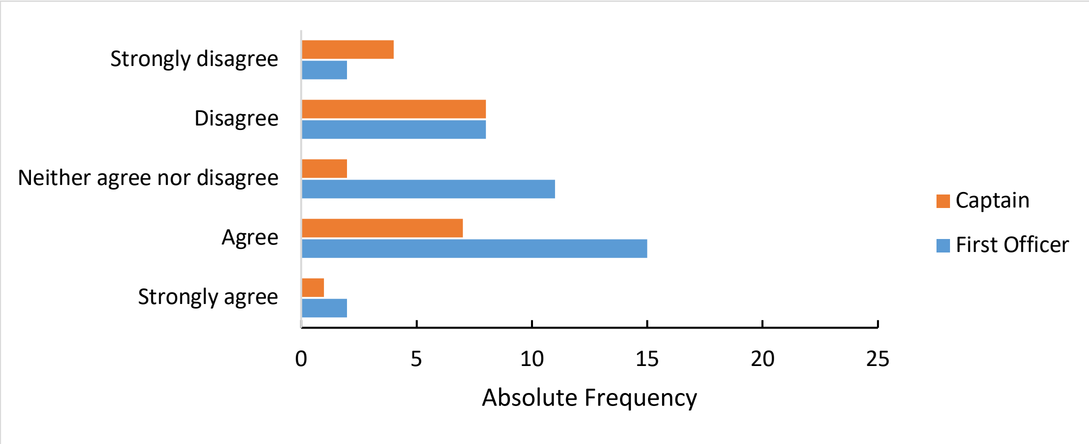

Figure 3.6. The need to know about the scenario in preparation for simulator check.

Question 5: Threat and error management is a valuable briefing tool. Threat and error management is a crew resource management tool that is relatively common when conducting briefings to establish a plan of action against threats. Figure 3.7 illustrates that most respondents (n = 41) agree that threat and error management is a valuable tool, both among captains and first officers. However, even if most respondents tend to be more positive, some comments expressed concerns about the safety culture as airline management priorities are more directed toward cost savings. Consequently, "No preparing to TEM for unexpected situations." (Respondent 17).

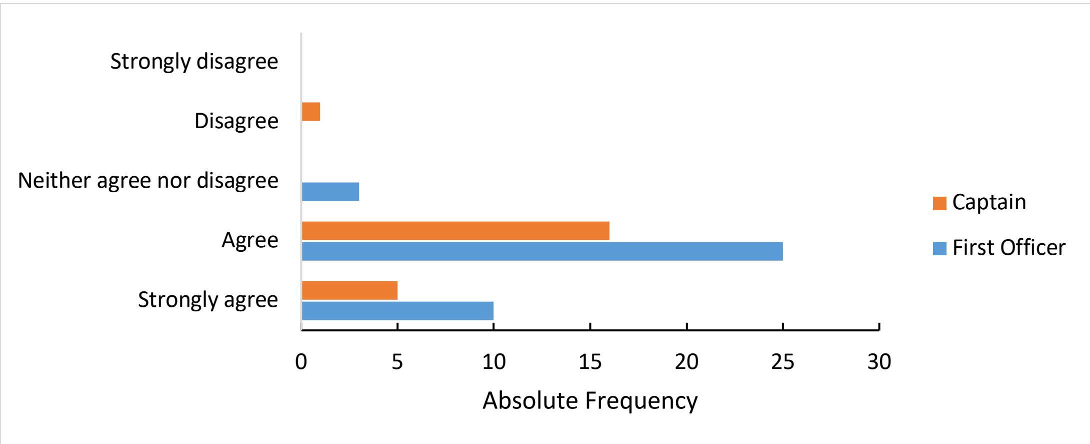

Figure 3.7. Briefing value of threat and error management.

Scenario-Based Training

Question 6: How often, if at all, do you have hypothetical discussions about unexpected events with your colleagues? (E.g. IF this happened, THEN what would you do?) Even if pilots are trained in a flight simulator, there will not be enough time to practice every possible malfunction. Therefore, the question was asked about how often the respondents have hypothetical discussions about unexpected events. Figure 3.8 shows that most of the respondents (n = 26) assume to have this type of discussion a few times a month, where the distribution between captains and first officers was relatively even.

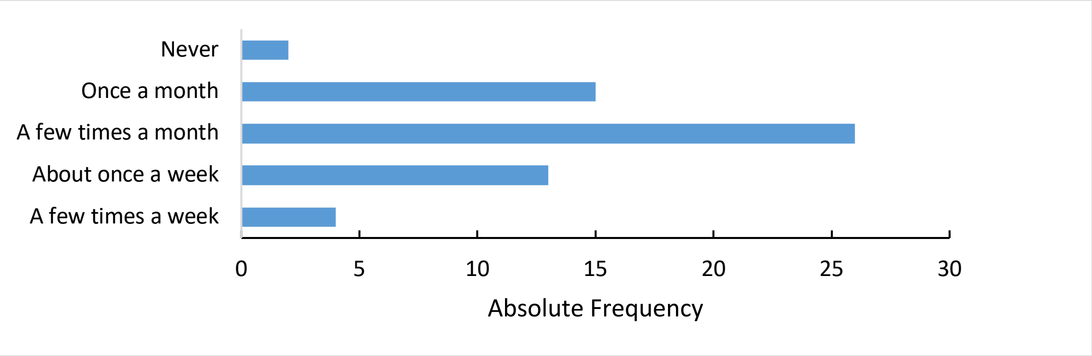

Figure 3.8. Hypothetical discussions about unexpected events.

Question 7: How often, if at all, do you share experiences from previous flights with your colleagues? (E.g. technical malfunctions, sick passenger onboard etc.). Instead of hypothetical discussions, the respondents were asked how often the flight crew shared and discussed work experiences. Consequently, the survey responses shifted more towards a higher frequency, as illustrated in Figure 3.9 that most respondents (n = 25) assume to have this type of discussion about once a week.

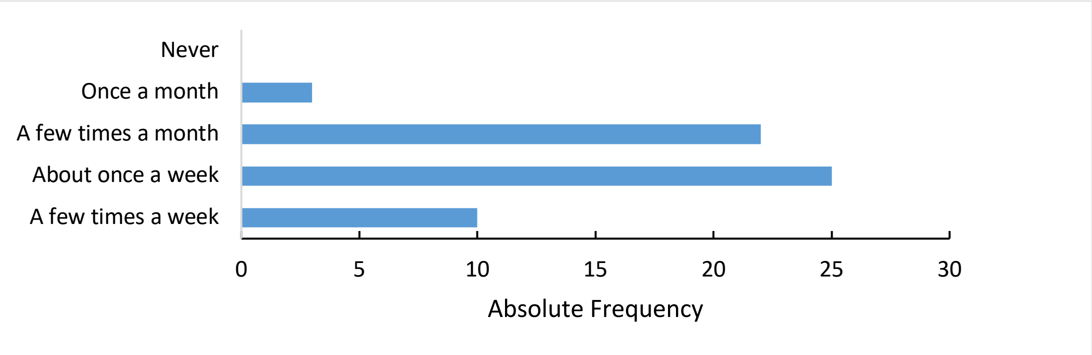

Figure 3.9. Sharing and discussing work experiences with each other.

Proactive learning

Question 8: If the conditions are favourable, I request other than ILS approaches. The respondents were asked about their attitude towards variable training during line flying to sustain or improve their level of competence. When faced with the statement that different approaches are requested under favourable conditions, Figure 3.10 shows that most respondents (n = 23) neither agree nor disagree. The same goes for the median first officer. However, it was most common among first officers (n = 16) to disagree with this statement.

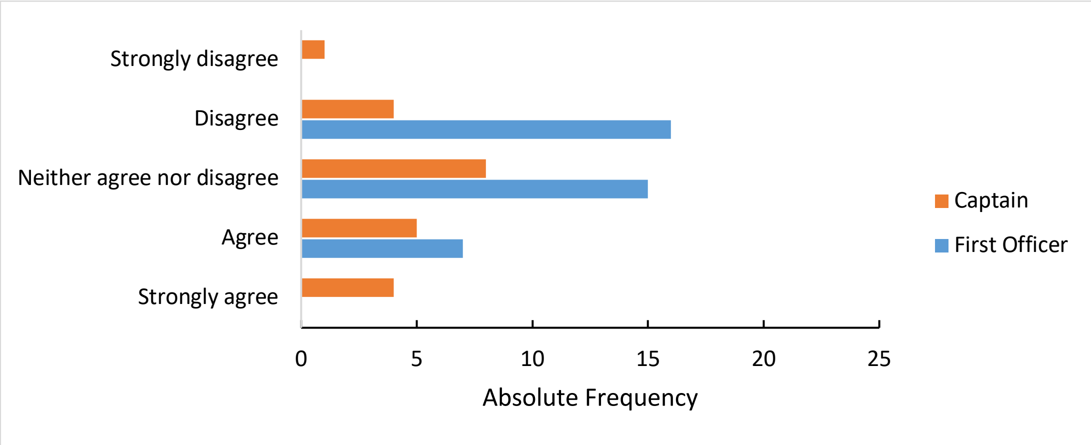

Figure 3.10. Attitude towards requesting different approaches.

Question 9: If the conditions are favourable, I practice my manual flying skills before Final Approach Point / Final approach Fix. When the respondents were faced with a different statement concerning their attitude toward practising manual flying skills, the responses leaned more towards agreeableness. Figure 3.11 illustrates that most respondents (n = 31), both captains and first officers, agree to practise manual flying skills under favourable conditions. For example, one of the comments was:

> Usually I prefer to practice manually flying skills with visual approaches … I don't really consider disconnecting an autopilot before FAF beneficial in regard of manual flying skills. However, the regular and diverse use of manual thrust is something that is very important skill to manual flying competence -this is something I tend to do in a regular basis. (Respondent 60)

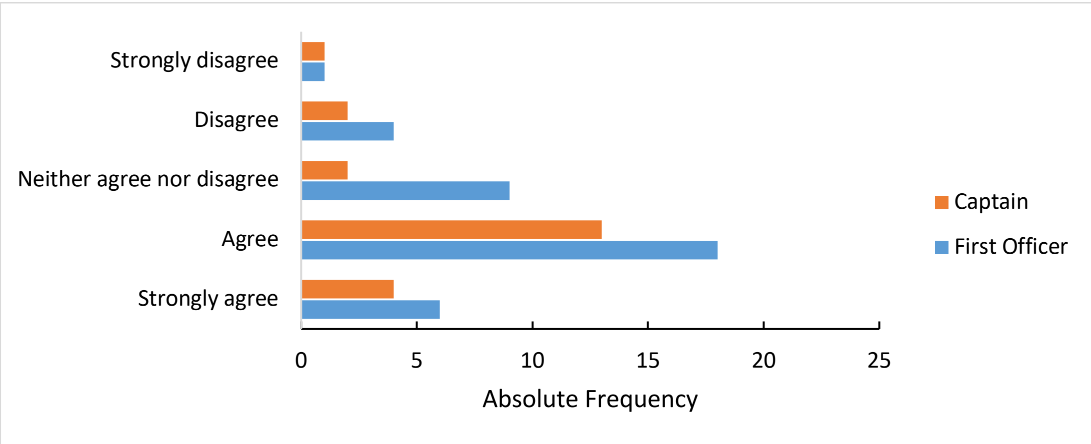

Figure 3.11. Attitude towards practising manual flying skills.

However, even in favourable conditions, some of the comments made by the respondents indicate certain conditions might impact the pilot's decision. For example, "The answers might vary if flying short or long haul flights." (Respondent 51). Furthermore, "…my company encourages us to manual flying without autothrust - some companies strongly recommend using always automation when available." (Respondent 35).

Question 10: How often, if at all, do you reflect on your own performance after a flight? Debriefing after a simulator session is part of the learning process to help the pilot understand their performance and areas of improvement. The survey responses in Figure 3.12 shows that most respondents (*n* = 19) reflect about once a week. The same goes for the median first officer. However, it was most common among first officers (*n* = 16) to reflect on their own performance a few times a week.

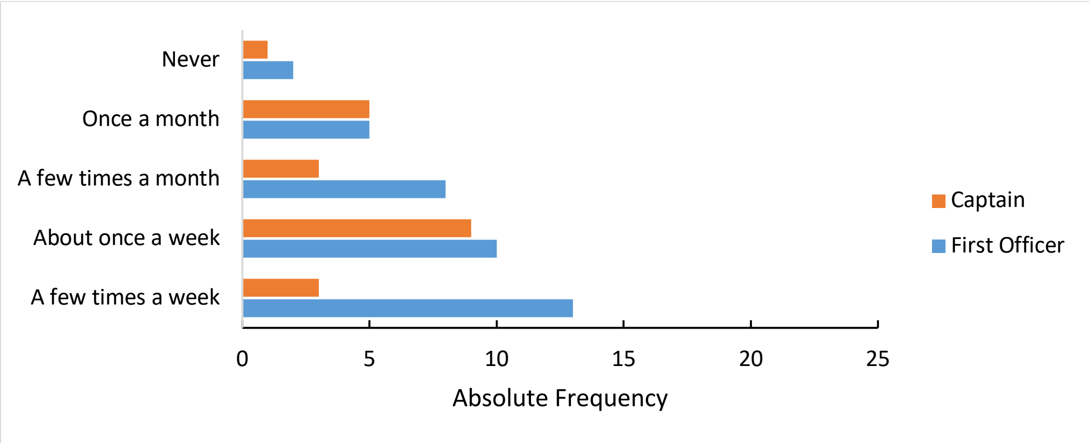

Figure 3.12. Reflecting on own performance after a flight.

Based on some of the comments, debriefing has had a positive effect: "From my own experience best results often follow by patience … Realising this has given me not just resilience but also professional self confidence." (Respondent 55). In addition, it does not always have to be self-briefing. For example, sometimes, the flight crew could debrief each other: "After flight I have a short debriefing with flightcrew about what we done and what we could do better." (Respondent 10).

5. Discussion

5.1 Method discussion

The challenge with the literature review was to filter search results due to the many available literature references. In retrospect, either the filtering was too specific, limiting the number of search hits, or it was not specific enough where many of the hits were related to resilience engineering and not aviation. The countermeasure was selecting a database limiting the number of search hits. In addition to using Mendeley's search engine, it also included a combination of the data set from both ScienceDirect and Scopus. The ScienceDirect index contains full-text articles that Elsevier primarily publishes, while the Scopus index only contains metadata from abstracts and includes both Elsevier and other publishers.

The online survey aimed to ask questions that would provide quantitative and qualitative variables. However, due to layoffs, the population consisted of active and inactive airline pilots, so the quantitative questions could not be too specific, which resulted in the validity being sacrificed for reliability. In addition, the further back in time the question applies, the greater the risk that the memory factor affects the respondent unless the experience was substantially memorable (Ejlertsson, 2019). For example, the last ten flights could mean the previous two days for a short-haul pilot, while for a long-haul pilot could mean the previous two months back in time. Consequently, the design of the questionnaire affected the data collection so that it mainly consisted of qualitative variables.

Accumulating enough respondents is challenging despite the well-thought cover letter, design, and reminders to respond to the questionnaire. The limited number of respondents made it challenging to generalise the target population due to potential higher variation, which harmed reliability. Although, since the completion rate was one hundred per cent, the argument could be made of a positive impact on face validity. Due to the limited time to write this thesis, the opportunity was not given to do a formal pilot study, which harmed reliability. Instead, a dialogue with the administrator was made to ensure the questions' appropriate design and formulation.

5.2 Literature review

This thesis aimed to investigate ways to develop EBT further to prepare pilots for managing unexpected and potentially threatening events. The literature review section of this thesis aimed to identify preventive strategies to help pilots develop resilience and the possibility of implementing such strategies in pilots' daily operations outside of the traditional simulator training. Based on the findings, there could be an argument that even if innovation may have improved flight safety, it has made it challenging for pilots to manage distressful situations. More specifically, complex socio-technical systems have made it difficult to predict, adapt and recover from disturbances since automated systems have gradually replaced pilots' higher-order thinking. Since every plausible scenario cannot be practised, findings indicate that resilience is a recommended safety approach in a complex system where increased flexibility improves efficiency.

The concept of resilience has assumed different forms depending on the context. The results confirm with Pierobon (2021) that the aviation industry is still working on ways to integrate resilience in operations. Resilient performance is believed to be the ability to reach equilibrium after a distressful situation by minimising performance loss through flexibility and recovering efficiently. These findings are consistent with Casner et al. (2013) that adaptive ability includes numerous responses and confirms findings made by Hoffman and Hancock (2017) that recovery is relevant with time. In sum, preventive strategies need to promote adaptability and recovery, where attention and working memory are vital components in distressful situations. Along with Field et al. (2016), the findings suggest that resilient performance would allow flight crew communication and coordination to reduce instinctive decision-making errors.

The results imply that advancing expertise and judgment could enhance pilots' adaptability by acquiring meaningful knowledge depending on the context and practising problem-solving using scenario-based training. Thus, pilots would benefit from learning the purpose behind checklist and procedure items applied in both normal and abnormal situations. Subsequently, followed by high-order thinking, where scenarios could be practised with a low-fidelity simulator or by a discussion with a colleague. Consequently, enable pilots to improve core technical and non-technical competencies consistent with ICAO (2013). Mindfulness training was another aspect where personal understanding of ways of thinking and feeling could make a person more secure and improve cognitive resources. Thereby allowing a more goal-oriented focus of attention, which would enhance the ability to anticipate and adapt performance in disturbing events. Findings are consistent with Dekker and Lundström (2006) that adaptive strategies would help prepare pilots to manage unforeseen events. However, despite promising results for building resilience through advanced expertise and judgment, the implications are time and effort.

Stress management was suggested as another vital part of allowing more cognitive resources. The results indicate that mental robustness could be achieved by accumulating similar recurrence of stressful situations with a positive outcome. However, individuals react differently to distressful events, and there is limited research on stress exposure training in aviation. Although flight simulators can increase the stress levels of the pilot, it will be difficult to create similar feelings of fear as in real life. Therefore, it is unclear how these positive effects are transferable to the aeroplane. It may be possible to argue that three-phase stress exposure training is an efficient way to reduce performance anxiety. Yet, the training concept is incomplete without providing a proper simulation of distressful events. Therefore, stress intervention involving mindfulness training seems to be the most promising. It also has the potential social effects of promoting a safer culture through a sense of fellowship due to its multi-faceted approach practised in small groups. However, mindfulness training does not work for everyone apart from the implications of time and effort.

In sum, the author speculates that the optimal use of time would align with the three-phase approach. Advancing expertise when flying the line, including scenario-based discussion with colleagues to practice problem-solving, combined with mindfulness training when not flying. In addition, pilots must be provided with stress coping strategies that can be practised during training sessions in the flight simulator. However, for the sake of more efficient facilitated briefing, the pilots must dare to carry out training sessions in the flight simulator without being aware of the LOFT scenario. Consequently, the pilots would potentially become more self-aware of thoughts and feelings to reduce stress effects.

5.3 Questionnaire

The questionnaire section of this thesis aimed to investigate how airline pilots optimise recurrent training and line flying to develop resilience, and whether their experience impacts. Although the low response rate did not make it possible to generalise the results, the following discussion will focus on the 60 airline pilots who responded to the questionnaire. The conclusion is that experience was relatively evenly distributed among the respondents, where age and flying hours did not significantly impact the result. However, rank seems to have had a greater influence on the responses, where approximately two-thirds of the responders were first officers compared to captains.

When overviewing the relatively similar responses between captains and first officers, it was more common among the respondents to discuss and share previous experiences than hypothetical discussions. Based on the author's experience as an airline pilot, there may be an emotional aspect where colleagues are more willing to strengthen teamwork, social bonds, and trust by sharing personal experiences from a professional perspective. However, this argument may be due to the culture that dominates the cockpit. Another reflection was the tendency for respondents to practice manual flight skills rather than fly different approaches. Based on the author’s own experience, even if pilots have the best intention of flying different approaches, air traffic control still needs to approve such requests where traffic flow into an airport plays a vital part. Meanwhile, practising manual flying skills is something pilots have more control over. However, pilots' incentives can sometimes be due to long working days and instead prioritize conserving cognitive resources by performing a well-known instrument approach to assure a safe landing.

Some questions indicated a response trend that differs between captains and first officers. For example, it was more common among first officers than captains to prepare for a simulator check by anticipating the LOFT scenario. One argument could be that simulator checks are usually predictable. Therefore, knowing the scenario ahead will give the first officer more time to prepare, study meaningful areas and mentally simulate different decision-making options. However, the captains are in command of the flight deck and would potentially benefit even more by predicting the scenario and developing a plan of action. It is possible that captains have experienced multiple simulator checks and gained sufficient experience in problem-solving and decision-making that can be referred to in upcoming simulator checks. A similar pattern can be seen where the first officer, to a greater extent than captains, reflects on their previous flights' performance. Since captains are potentially more experienced, it may be easier to learn during flight by adapting previous learning experiences. Meanwhile, first officers might need more time to reflect on what happened by dividing the flight into more manageable chunks.

The results indicate that this group of airline pilots seem to have different attitudes to daily flying and the development of resilience. Experience appears to play a vital role, as first officers tend to be more willing to gain competence by being prepared for the flight simulator session and reflecting more on previous flights. In contrast, captains may already have more high-order thinking experience and can potentially rely more on competence and judgment to increase understanding and projection.

6. Conclusion

This thesis demonstrated findings consistent with previous theories about resilience. Results suggest that expertise, judgment and mindfulness training seems to be the most prominent findings of expanding EBT beyond the traditional flight simulator training. Furthermore, the results suggest that line flying could be used as a complement to practising core competencies to advance expertise and judgment. The limitations of this thesis were the sparingly amount of literature made available and that the survey study was limited to a small sample of the same nationality. Still, the group of respondents suggest that first officers need to allow themselves not to predict the LOFT scenario during recurrent flight training. Hereby, reach a better understanding of own thoughts and feelings, which would allow more confidence afterwards and become more of a resource in a multi-crew environment.

Even though findings indicate that it takes time and commitment to developing resilience, there are potentially more cost-efficient solutions such as low-fidelity simulators and discussions with colleagues to facilitate high-order thinking. This could complement traditional flight simulator training and improve development of core competencies, allowing pilots to recognise and adapt much more efficient to re-gain situational awareness after an unforeseen event. In addition, future research needs to establish a sufficient level of expertise for automation and how technology could improve the virtual reality experience to make stress exposure training more realistic for pilots.

References

Aldwin, C. M. (1994). *Stress, coping, and development: An integrative perspective*. Guilford Press.

Amalberti, R. (2001). *Revisiting safety and human factors paradigms to meet the safety challenges of ultra complex and safe systems*. https://studylib.net/doc/7590392/achieving-successful-safety-interventions

Backman, J. (2016). *Rapporter och uppsatser* (3rd ed.). Studentlitterature AB.

Barshi, I. (2015). From healy's training principles to training specifications: The case of the comprehensive LOFT. *American Journal of Psychology*, *128*(2), 219–227. https://doi.org/10.5406/amerjpsyc.128.2.0219

Billman, D., Mumaw, R., & Feary, M. (2020). A Model of Monitoring as Sensemaking: Application to Flight Path Management and Pilot Training. *Proceedings of the Human Factors and Ergonomics Society Annual Meeting*, *64*(1). https://doi.org/10.1177/1071181320641058

Bonanno, G. A., Westphal, M., & Mancini, A. D. (2011). Resilience to Loss and Potential Trauma. *Annual Review of Clinical Psychology*, *7*(1), 511–535. https://doi.org/10.1146/annurev-clinpsy-032210-104526

Boone, H. N. , J., & Boone, D. A. (2012). Analyzing Likert Data. *Journal of Extension*, *50*(2). https://archives.joe.org/joe/2012april/pdf/JOE_v50_2tt2.pdf

Boyd, J. R. (2018). *A Discourse on Winning and Losing*. Air University Press. https://www.coljohnboyd.com/static/documents/2018-03__Boyd_John_R__edited_Hammond_Grant_T__A_Discourse_on_Winning_and_Losing.pdf

Bureau d'Enquêtes et d'Analyses pour la sécurité de l'aviation civile. (2012). *Final Report On the accident on 1st June 2009 to the Airbus A330-203 registered F-GZCP operated by Air France flight AF 447 Rio de Janeiro - Paris*. https://www.bea.aero/docspa/2009/f-cp090601.en/pdf/f-cp090601.en.pdf

Campbell, G., Padron, C., Surpris, G., Carroll, M., & Winslow, B. (2017). *Small-unit Training for Adaptability and Resilience in Decision Making (STAR-DM)*. https://apps.dtic.mil/sti/pdfs/AD1032176.pdf

Carroll, M., Hale, K., Stanney, K., Woodman, M., DeVore, L., Squire, P., & Scaring, L. (2012). Framework for training adaptable and stress-resilient decision making. *Proceedings of the Interservice/Industry Training, Simulation, and Education Conf erence (I/ITSEC) Annual Meeting.*

Carroll, M., & Malmquist, S. (2022). Resilient Performance in Aviation. In C. P. Nemeth & E. Hollnagel (Eds.), *Advancing Resilient Performance*. https://doi.org/10.1007/978-3-030-74689-6

Carroll, M., Winslow, B., Padron, C., Surpris, G., Wong, J., Squire, P., & Murphy, J. (2014). Inducing Stress in Warfighters during Simulation-Based Training Space and Naval Warfare Systems Command. *Interservice/Industry Training, Simulation, and Education Conference (I/ITSEC) 2014*. https://www.researchgate.net/publication/325631608

Carver, C. S. (1998). Resilience and Thriving: Issues, Models, and Linkages. *Journal of Social Issues*, *54*(2), 245–266. https://doi.org/10.1111/j.1540-4560.1998.tb01217.x

Casner, S. M., Geven, R. W., & Williams, K. T. (2013). The effectiveness of airline pilot training for abnormal events. *Human Factors*, *55*(3), 477–485. https://doi.org/10.1177/0018720812466893

Corbetta, M., & Shulman, G. L. (2002). Control of goal-directed and stimulus-driven attention in the brain. *Nature Reviews Neuroscience*, *3*(3), 201–215. https://doi.org/10.1038/nrn755

Crichton, M. T., Flin, R., & Rattray, W. A. R. (2000). Training Decision Makers – Tactical Decision Games. *Journal of Contingencies and Crisis Management*, *8*(4), 208–217. https://doi.org/10.1111/1468-5973.00141

Dahlstrom, N., Dekker, S., van Winsen, R., & Nyce, J. (2009). Fidelity and validity of simulator training. *Theoretical Issues in Ergonomics Science*, *10*(4), 305–314. https://doi.org/10.1080/14639220802368864

Dahlstrom, N., & Nahlinder, S. (2009). Mental workload in aircraft and simulator during basic civil aviation training. *International Journal of Aviation Psychology*, *19*(4), 309–325. https://doi.org/10.1080/10508410903187547

Dehais, F., Behrend, J., Peysakhovich, V., Causse, M., & Wickens, C. D. (2017). Pilot Flying and Pilot Monitoring's Aircraft State Awareness During Go-Around Execution in Aviation: A Behavioral and Eye Tracking Study. *International Journal of Aerospace Psychology*, *27*(1–2). https://doi.org/10.1080/10508414.2017.1366269

Dekker, S., & Lundström, J. (2006). From Threat and Error Management (TEM) to Resilience. *Human Factors and Aerospace Safety*, *6*(3), 261–273. https://psycnet.apa.org/record/2008-01243-005

Dekker, S., & Pruchnicki, S. (2014). Drifting into failure: theorising the dynamics of disaster incubation. *Theoretical Issues in Ergonomics Science*, *15*(6), 534–544. https://doi.org/10.1080/1463922X.2013.856495

Dekker, S. W. A. (2001). Follow the procedure or survive. *Human Factors and Aerospace Safety*, *1*(4), 381–385. http://sidneydekker.stackedsite.com/wp-content/uploads/sites/899/2013/01/ProcedureSurvive.pdf

Dismukes, R. K., Goldsmith, T. E., & Kochan, J. A. (2015). *Effects of Acute Stress on Aircrew Performance: Literature Review and Analysis of Operational Aspects (NASA/TM—2015–218930)*. https://humansystems.arc.nasa.gov/flightcognition/Publications/NASA_TM_2015_218930-2.pdf

Driskell, J. E., & Salas, E. (1991). Group Decision Making Under Stress. *Journal of Applied Psychology*, *76*(3), 473–478. https://doi.org/10.1037/0021-9010.76.3.473

Ejlertsson, G. (2019). *Enkät i praktiken; En handbok i enkätmetodik* (4th ed.). Studentlitteratur AB.

Endsley, M. R. (1995). Toward a Theory of Situation Awareness in Dynamic Systems. *Human Factors: The Journal of the Human Factors and Ergonomics Society*, *37*(1), 32–64. https://doi.org/10.1518/001872095779049543

Ericsson, K. A., & Charness, N. (1994). Expert performance: Its structure and acquisition. *American Psychologist*, *49*(8), 725–747. https://doi.org/10.1037/0003-066X.49.8.725

Eysenck, M. W., & Calvo, M. G. (1992). Anxiety and Performance: The Processing Efficiency Theory. *Cognition & Emotion*, *6*(6), 409–434. https://doi.org/10.1080/02699939208409696

Eysenck, M. W., Derakshan, N., Santos, R., & Calvo, M. G. (2007). Anxiety and cognitive performance: Attentional control theory. *Emotion*, *7*(2), 336–353. https://doi.org/10.1037/1528-3542.7.2.336

Facione, P. A., & Facione, N. C. (2007). *Thinking and reasoning in human decision making: the method of argument and heuristic analysis*. California Academic Press.

https://www.academia.edu/9730893/Thinking_and_Reasoning_in_Human_Decision_Making_The_Method_of_Argument_and_Heuristic_Analysis

Field, J. (2015). *6.7 - Final report of research methods and results (FP7-314765)* (A. Rankin, Ed.). NLR. https://cordis.europa.eu/docs/results/314/314765/final1-d6-4-final-report-of-operational-recommendations-v1.pdf

Field, J., Fucke, L., Correia Grácio, B., & Mohrmann, F. (2016, June 13). Flight Crew Response to Unexpected Events: A Simulator Experiment. *AIAA Modeling and Simulation Technologies Conference*. https://doi.org/10.2514/6.2016-3373

Field, J. N., Boland, E. J., van Rooij, J. M., Mohrmann, J. F. W., & Smeltink, J. W. (2015). *Startle Effect Management (NLR-CR-2018-242)*. https://www.easa.europa.eu/downloads/67174/en

Fischhoff, B. (2003). Hindsight ≠ foresight: the effect of outcome knowledge on judgment under uncertainty. *BMJ Quality & Safety* , *12*(4), 304–311. https://doi.org/10.1136/qhc.12.4.304

Friedland, N., & Keinan, G. (1992). Training Effective Performance in Stressful Situations: Three Approaches and Implications for Combat Training. *Military Psychology*, *4*(3), 157–174. https://doi.org/10.1207/s15327876mp0403_3

Fujita, Y. (2006). Resilient Systems. In E. Hollnagel, D. D. Woods, & N. Leveson (Eds.), *Resilience engineering: concepts and precepts*. Ashgate.

Glaser, R. (1990). The reemergence of learning theory within instructional research. *American Psychologist*, *45*(1), 29–39. https://doi.org/10.1037/0003-066X.45.1.29

Glomb, T. M., Duffy, M. K., Bono, J. E., & Yang, T. (2011). *Mindfulness at Work* (pp. 115–157). https://doi.org/10.1108/S0742-7301(2011)0000030005

Gohm, C. L., Baumann, M. R., & Sniezek, J. A. (2001). Personality in Extreme Situations: Thinking (or Not) under Acute Stress. *Journal of Research in Personality*, *35*(3), 388–399. https://doi.org/10.1006/jrpe.2001.2321

Hale, A., & Heijer, T. (2006). Defining Resilience. In E. Hollnagel, D. D. Woods, & N. Leveson (Eds.), *Resilience Engineering* . CRC Press. https://doi.org/10.1201/9781315605685

Hassall, M. E., Sanderson, P. M., & Cameron, I. T. (2014). The Development and Testing of SAfER. *Journal of Cognitive Engineering and Decision Making*, *8*(2), 162–186. https://doi.org/10.1177/1555343414527287

Hassler, U., & Kohler, N. (2014). Resilience in the built environment. *Building Research & Information*, *42*(2), 119–129. https://doi.org/10.1080/09613218.2014.873593

Healy, A. F., Kole, J. A., & Bourne, L. E. (2014). Training principles to advance expertise. In *Frontiers in Psychology* (Vol. 5, Issue 2, p. Article 131). https://doi.org/10.3389/fpsyg.2014.00131

Hoffman, R. R., & Hancock, P. A. (2017). Measuring Resilience. *Human Factors: The Journal of the Human Factors and Ergonomics Society*, *59*(4), 564–581. https://doi.org/10.1177/0018720816686248

Hollnagel, E. (2008). Resilience Engineering in a Nutshell. In E. Hollnagel, C. P. Nemeth, & S. Dekker (Eds.), *Resilience engineering perspectives, Volume 1: Remaining sensitive to the possibility of failure*. Ashgate.

Hollnagel, E. (2009). The Four Cornerstones of Resilience Engineering. In E. Hollnagel & C. P. Nemeth (Eds.), *Resilience Engineering Perspectives, Volume 2*. CRC Press. https://doi.org/10.1201/9781315244389

Hollnagel, E. (2011). Prologue: The Scope of Resilience engineering. In E. Hollnagel, J. Pariès, D. D. Woods, & J. Wreathall (Eds.), *Resilience Engineering in Practice: A Guidebook*. Ashgate.

Hollnagel, E. (2015). *Introduction to the Resilience Analysis Grid (RAG) RAG-Resilience Analysis Grid*. https://erikhollnagel.com/onewebmedia/RAG%20Outline%20V2.pdf

Holt, R. W., Boehm-Davis, D. A., & Hansberger, J. (2001). *Evaluation of Proceduralized CRM at a Regional and Major Carrier (R-GMU-01-P01)*. https://www.researchgate.net/profile/Deborah-Boehm-Davis/publication/237580032_Evaluation_of_Proceduralized_CRM_at_a_Regional_and_Major_Carrier/links/0deec5277f0325b8cb000000/Evaluation-of-Proceduralized-CRM-at-a-Regional-and-Major-Carrier.pdf

International Air Transport Association. (2021). *IATA Safety Report 2020* (57th ed.). International Air Transport Association. https://www.iata.org/en/publications/safety-report/

International Aviation Transport Association. (2018). *Guidance Material and Best Practices for the Implementation of Upset Prevention and Recovery Training* (2nd ed.). International Air Transport Association. https://www.iata.org/contentassets/b6eb2adc248c484192101edd1ed36015/gmbp_uprt.pdf

International Civil Aviation Organization. (2013). *International Civil Aviation Organization Manual of Evidence-based Training (Doc 9995)* (1st ed.). International Civil Aviation Organization. https://skybrary.aero/sites/default/files/bookshelf/3177.pdf

International Civil Aviation Organization. (2016). *Procedures for Air Navigation Services Training (Doc 9868)*. International Civil Aviation Organization. https://www.icao.int/APAC/RASG/eDocs/Doc%209868%20-%20Procedures%20for%20Air%20Navigation%20Services%20Training%20Second%20Edition%202016.pdf

Inzana, C. M., Driskell, J. E., Salas, E., & Johnston, J. H. (1996). Effects of Preparatory Information on Enhancing Performance Under Stress. *Journal of Applied Psychology*, *81*(4), 429–435. https://doi.org/10.1037/0021-9010.81.4.429

Kahneman, D. (2003). A perspective on judgment and choice: Mapping bounded rationality. *American Psychologist*, *58*(9), 697–720. https://doi.org/10.1037/0003-066X.58.9.697

Klein, G., Ross, K. G., Moon, B. M., Klein, D. E., Hoffman, R. R., & Hollnagel, E. (2003). Macrocognition. *IEEE Intelligent Systems*, *18*(3), 81–85. https://doi.org/10.1109/MIS.2003.1200735

Klein, G., Wiggins, S., & Dominguez, C. O. (2010). Team sensemaking. *Theoretical Issues in Ergonomics Science*, *11*(4), 304–320. https://doi.org/10.1080/14639221003729177

Kochan, J. (2005). *The Role Of Domain Expertise And Judgment In Dealing With Unexpected Events* [Electronic Theses and Dissertations, University of Central Florida]. https://stars.library.ucf.edu/cgi/viewcontent.cgi?article=1455&context=etd

Komite Nasional Keselamatan Transportasi. (2019). *Aircraft Accident Investigation Report PT. Lion Mentari Airlines Boeing 737-8 (MAX); PK-LQP (KNKT.18.10.35.04)*. http://knkt.dephub.go.id/knkt/ntsc_aviation/baru/2018%20-%20035%20-%20PK-LQP%20Final%20Report.pdf

Kowalski-Trakofler, K. M., Vaught, C., & Scharf, T. (2003). Judgment and decision making under stress: an overview for emergency managers. *International Journal of Emergency Management*, *1*(3), 278–289. https://doi.org/10.1504/IJEM.2003.003297

Lag om etikprövning av forskning som avser människor (SFS 2003:460). Utbildningsdepartementet. https://www.riksdagen.se/sv/dokument-lagar/dokument/svensk-forfattningssamling/lag-2003460-om-etikprovning-av-forskning-som_sfs-2003-460

Landman, A., Groen, E. L., van Paassen, M. M. (René), Bronkhorst, A. W., & Mulder, M. (2017). Dealing With Unexpected Events on the Flight Deck: A Conceptual Model of Startle and Surprise. *Human Factors: The Journal of the Human Factors and Ergonomics Society*, *59*(8), 1161–1172. https://doi.org/10.1177/0018720817723428

Lazarus, R. S., & Folkman, S. (1984). *Stress, Appraisal, and Coping*. Springer Publishing Company.

Lehner, P., Seyed-Solorforough, M.-M., O'Connor, M. F., Sak, S., & Mullin, T. (1997). Cognitive biases and time stress in team decision making. *IEEE Transactions on Systems, Man, and Cybernetics - Part A: Systems and Humans*, *27*(5), 698–703. https://doi.org/10.1109/3468.618269

Malmquist, S., & Rapoport, R. (2017). *Angle of Attack: Air France 447 and the Future of Aviation Safety*. Lexographic Press.

Martin, W. L., Murray, P. S., & Bates, P. R. (2011). What would you do if....? Improving pilot performance during unexpected events through in-flight scenario discussions. *Aeronautica*, *1*. https://doi.org/10.1177/0018720817723428

Mathews, K. E., & Canon, L. K. (1975). Environmental noise level as a determinant of helping behavior. *Journal of Personality and Social Psychology*, *32*(4), 571–577. https://doi.org/10.1037/0022-3514.32.4.571

McClernon, C. K. (2009). Stress Training Efficacy in an Aviation Context. *International Symposium on Aviation Psychology*, 521–526. https://corescholar.libraries.wright.edu/isap_2009/29

McClernon, C. K., McCauley, M. E., O'Connor, P. E., & Warm, J. S. (2011). Stress training improves performance during a stressful flight. *Human Factors*, *53*(3), 207–218. https://doi.org/10.1177/0018720811405317

Meichenbaum, D. (2007). Stress inoculation training: a preventative and treatment approach. In P. M. Lehrer, R. L. Woolfolk, & W. E. Sime (Eds.), *Principles and practice of stress management* (3rd ed.). Guilford Press. http://www.brown.uk.com/anxiety/stress-inoculation.pdf

Meland, A., Fonne, V., Wagstaff, A., & Pensgaard, A. M. (2015). Mindfulness-Based Mental Training in a High-Performance Combat Aviation Population: A One-Year Intervention Study and Two-Year Follow-Up. *The International Journal of Aviation Psychology*, *25*(1), 48–61. https://doi.org/10.1080/10508414.2015.995572

Meland, A., Hoebeke, E., Pensgaard, A. M., Fonne, V., Wagstaff, A., & Gaden Jensen, C. (2021). A Sense of Fellowship: Mindfulness Improves Experienced Interpersonal Benefits and Prosociality in A Military Aviation Unit. *International Journal of Aerospace Psychology*, *31*(2), 162–179. https://doi.org/10.1080/24721840.2020.1865818

Miyake, A., Friedman, N. P., Emerson, M. J., Witzki, A. H., Howerter, A., & Wager, T. D. (2000). The Unity and Diversity of Executive Functions and Their Contributions to Complex "Frontal Lobe" Tasks: A Latent Variable Analysis. *Cognitive Psychology*, *41*(1), 49–100. https://doi.org/10.1006/cogp.1999.0734

Mosier, K. L., & Fischer, U. M. (2010). Judgment and Decision Making by Individuals and Teams: Issues, Models, and Applications. *Reviews of Human Factors and Ergonomics*, *6*(1), 198–256. https://doi.org/10.1518/155723410X12849346788822

Mumaw, R. J., Billman, D., & Feary, M. S. (2020). *Analysis of Pilot Monitoring Skills and a Review of Training Effectiveness*. http://www.sti.nasa.gov
Mumaw, R. J., Roth, E. M., Vicente, K. J., & Burns, C. M. (2000). There Is More to Monitoring a Nuclear Power Plant than Meets the Eye. *Human Factors: The Journal of the Human Factors and Ergonomics Society*, *42*(1), 36–55. https://doi.org/10.1518/001872000779656651
National Transport Safety Bureau. (2010). *Aircraft Accident Report: Loss of Thrust in Both Engines After Encountering a Flock of Birds and Subsequent Ditching on the Hudson River (NTSB/AAR-10/03)*. https://www.ntsb.gov/investigations/accidentreports/reports/aar1003.pdf
Nemeth, C. P., & Hollnagel, E. (Eds.). (2022). *Advancing Resilient Performance*. https://doi.org/10.1007/978-3-030-74689-6
Norden, C., & Owens, D. (2014). Learning from the evidence. *Safety First*. https://safetyfirst.airbus.com/learning-from-the-evidence/
Phillips, J. K., Klein, G., & Sieck, W. R. (2004). Expertise in Judgment and Decision Making: A Case for Training Intuitive Decision Skills. In D. J. Koehler & N. Harvey (Eds.), *Blackwell Handbook of Judgment and Decision Making* (pp. 297–315). Blackwell Publishing Ltd. http://www.communicationcache.com/uploads/1/0/8/8/10887248/blackwell_handbook_of_judgement_and_decision_making_-_framing_loss_aversion_and_mental_accounting.pdf
Pierobon, M. (2021). Defining Resilience. In *Flight Safety Foundation*. https://flightsafety.org/asw-article/defining-resilience/
Posner, M. I., & Petersen, S. E. (1990). The Attention System of the Human Brain. *Annual Review of Neuroscience*, *13*(1), 25–42. https://doi.org/10.1146/annurev.ne.13.030190.000325
Pruchnicki, S., Key, K., Rao, A. H., & Avers, K. (2019). *Problem Solving/Decision Making and Procedures for Unexpected Events: A Literature Review (DOT/FAA/AM-20/01)*. https://www.faa.gov/data_research/research/med_humanfacs/oamtechreports/2020s/media/202001.pdf
Rasmussen, J. (1983). Skills, rules, and knowledge; signals, signs, and symbols, and other distinctions in human performance models. *IEEE Transactions on Systems, Man, and Cybernetics*, *SMC-13*(3), 257–266. https://doi.org/10.1109/TSMC.1983.6313160
Rasmussen, J. (1997). Risk management in a dynamic society: a modelling problem. *Safety Science*, *27*(2–3), 183–213. https://doi.org/10.1016/S0925-7535(97)00052-0
Salas, E., Driskell, J. E., & Hughes, S. (1996). Introduction: The Study of Stress and Human Performance. In J. E. Driskell & S. Hughes (Eds.), *Stress and Human Performance* (pp. 1–46). Psychology Press. https://doi.org/10.4324/9780203772904
Salmon, P. M., Stanton, N. A., Walker, G. H., Baber, C., Jenkins, D. P., McMaster, R., & Young, M. S. (2008). What really is going on? Review of situation awareness models for individuals and teams. *Theoretical Issues in Ergonomics Science*, *9*(4), 297–323. https://doi.org/10.1080/14639220701561775
Saunders, T., Driskell, J. E., Johnston, J. H., & Salas, E. (1996). The effect of stress inoculation training on anxiety and performance. *Journal of Occupational Health Psychology*, *1*(2), 170–186. https://doi.org/10.1037/1076-8998.1.2.170
Smith, E. M., Ford, J. K., & Kozlowski, S. W. J. (1997). Building adaptive expertise: Implications for training design strategies. In *Training for a rapidly changing*

workplace: Applications of psychological research. (pp. 89–118). American Psychological Association. https://doi.org/10.1037/10260-004
Staal, M. A. (2004). *Stress, Cognition, and Human Performance: A Literature Review and Conceptual Framework (NASNTM-2004-212824)*. https://ntrs.nasa.gov/api/citations/20060017835/downloads/20060017835.pdf
Strauch, B. (2017). The automation-by-expertise-by-training interaction: Why automation-related accidents continue to occur in sociotechnical systems. *Human Factors*, *59*(2), 204–228. https://doi.org/10.1177/0018720816665459
Swedish Research Council. (2002). *Forskningsetiska principer inom humanistisk-samhällsvetenskaplig forskning*. Vetenskapsrådet. https://www.vr.se/download/18.68c009f71769c7698a41df/1610103120390/Forskningsetiska_principer_VR_2002.pdf
Swedish Research Council. (2017). *Good Research Practice*. https://www.vr.se/download/18.5639980c162791bbfe697882/1555334908942/Good-Research-Practice_VR_2017.pdf
van Merriënboer, J. J. G. (2012). Four-Component Instructional Design. In *Encyclopedia of the Sciences of Learning* (pp. 1320–1322). Springer US. https://doi.org/10.1007/978-1-4419-1428-6_414
Weijters, B., Millet, K., & Cabooter, E. (2021). Extremity in horizontal and vertical Likert scale format responses. Some evidence on how visual distance between response categories influences extreme responding. *International Journal of Research in Marketing*, *38*(1), 85–103. https://doi.org/10.1016/j.ijresmar.2020.04.002
Woods, D. (2006). Engineering Organizational Resilience to Enhance Safety: A Progress Report on the Emerging Field of Resilience Engineering. *Proceedings of the Human Factors and Ergonomics Society Annual Meeting*, *50*(13), 2237–2241.
Woods, D. D. (2005). Conflicts between Learning and Accountability in Patient Safety. *DePaul Law Review*, *54*(2), 485–502. https://via.library.depaul.edu/law-review/vol54/iss2/13
Woods, D. D., & Hollnagel, E. (2006). Prologue: Resilience Engineering Concepts. In E. Hollnagel, D. D. Woods, & N. Leveson (Eds.), *Resilience engineering: concepts and precepts*. Ashgate.

Appendix: Questionnaire

LUND UNIVERSITY

Training Pilots for Resilience

Ready to help the next generation of pilots?

When faced with unexpected events, pilots are commonly expected to evaluate the situation and respond quickly. Unfortunately, these events do not always have guidance in written procedures or may not be experienced during training. Yet, some crews are still able to respond adaptively to unexpected events. The survey aims to provide insight into to what extent airline pilots optimize their daily operations to enhance their resilience.

The survey should only take 2 minutes, and your participation is entirely voluntary and confidential. Your answers will help promote safety through understanding and promoting resilient skills and behaviours that can be applied in a wide range of unexpected events. Any reports or publications based on this research will use only group data and not identify you or any individual.

If you have any further questions, please feel free to contact me.

Thank you for your time and help!

Sincerely,

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Next

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Training Pilots for Resilience

1. What is your age?

- ◯ 18 to 24
- ◯ 25 to 34
- ◯ 35 to 44
- ◯ 45 to 54
- ◯ 55 to 64

2. Approximately how many flying hours have you flown?

3. What is your rank?

- ◯ Captain
- ◯ First Officer (with previous captain experience)
- ◯ First Officer

4. To prepare for my upcoming simulator check, I ask colleagues who have already done their simulator session how their Line Oriented Flight Training (LOFT) scenario unfolded.

- ◯ Strongly disagree
- ◯ Disagree
- ◯ Neither agree nor disagree
- ◯ Agree
- ◯ Strongly agree

5. Threat and error management is a valuable briefing tool.

- ◯ Strongly disagree
- ◯ Disagree
- ◯ Neither agree nor disagree
- ◯ Agree
- ◯ Strongly agree

6. How often, if at all, do you have hypothetical discussions about unexpected events with your colleagues? (E.g. IF this happened, THEN what would you do?)

- ◯ Never
- ◯ Once a month
- ◯ A few times a month
- ◯ About once a week
- ◯ A few times a week

7. How often, if at all, do you share experiences from previous flights with your colleagues? (E.g. technical malfunctions, sick passenger onboard etc.)

- ◯ Never
- ◯ Once a month
- ◯ A few times a month
- ◯ About once a week
- ◯ A few times a week

8. If the conditions are favourable, I request other than ILS approaches.

- ◯ Strongly disagree
- ◯ Disagree
- ◯ Neither agree nor disagree
- ◯ Agree
- ◯ Strongly agree

9. If the conditions are favourable, I practice my manual flying skills before Final Approach Point / Final Approach Fix.

- ◯ Strongly disagree
- ◯ Disagree
- ◯ Neither agree nor disagree
- ◯ Agree
- ◯ Strongly agree

10. How often, if at all, do you reflect on your own performance after a flight?

- ◯ Never
- ◯ Once a month
- ◯ A few times a month
- ◯ About once a week
- ◯ A few times a week

11. Do you have any other comments, questions, or concerns?

Prev Done