Introduction

Safe and efficient flights are dependent on pilots´ ability to make appropriate and timely decisions during flight (Schriver, Morrow, Wickens, & Talleur, 2008). Decision-making is an important part of the pilots' work, especially when they are forced to make decisions in unexpected situations (Wiggins & O´Hare, 1995). Although pilots are well trained and there are rules, models and standard operating procedures to use in decision-making situations, aviation accidents do occur, and errors related to pilots' judgment and decision-making has proven to be a contributing factor to over a third of the accidents in commercial aviation (Shappell et al., 2007). One reason why accidents may occur is because people sometimes decide to deviate from safe operating procedures, standards or rules. This is called a violation. Violations can have two important consequences: they can increase the probability of a subsequent error, and they can also increase the likelihood that the behavior will lead to a bad outcome (Reason, Parker & Lawton, 1998).

Violations of standard operating procedures are common among pilots (Thomas, 2004). One example of a situation when pilots are prone to violate standard operating procedures is during approach and the pilot finds the approach being unstabilized (Directorate Generale of Civil Aviation, 2008). An unstabilized approach mean that certain criteria regarding speed, aircraft configuration and checklist completion are not fulfilled at a predetermined point on the approach profile (Skybrary, 2010b). According to standard operating procedure the correct behavior is to perform a missed approach (abort the approach). However, when this situation occurs in reality, pilots often choose to continue the approach (Directorate Generale of Civil Aviation, 2008). Continuing the approach when being unstabilized may cause the aircraft to arrive at the runway too high or too fast, or to be unprepared for landing in other ways. This can result in a runway excursion, meaning that the aircraft is unable to stay within the area designed for landing (Skybrary, 2010b).

The overall aim of this thesis was to explore airline pilots' judgment and decision-making. More precisely, the aim was to explore reasons to why people sometimes decide to violate standard operating procedures. As a starting point, a particular situation to study, was chosen: the unstabilized approach situation. Why do pilots sometimes decide to continue an unstabilized approach? To answer this question a literature search was performed within the human error research, traditional judgment and decision-making (JDM), naturalistic decision-making (NDM), and aeronautical decision-making (ADM) literatures. In addition, my personal experience as an airline pilot was utilized to think of possible reasons for violation decisions. Four empirical studies were performed. Two of these studies aimed at studying the role of probability weighting and affect in decision-making and was studied among the normal population, car drivers and airline pilots. The other two studies aimed at studying different possible reasons for violating procedures among airline pilots, such as organizational and social reasons, and individual differences in decision-making style and non-technical skills.

There might be many reasons for why people sometimes decide to violate a procedure, such as the stabilized approach procedure. As a starting point a proposed framework for pilots' judgment and decision-making (aeronautical decision-making) in context can be seen in Figure 1. The assumption behind the framework is that many factors both external and internal, influence an operator's decision-making in dynamic environments, such as aircraft cockpits. The framework consists of several layers pictured as circles. Each circle may be studied in isolation. However, the circles are connected with each other at some point symbolizing that they are all interacting to determine peoples' behavior.

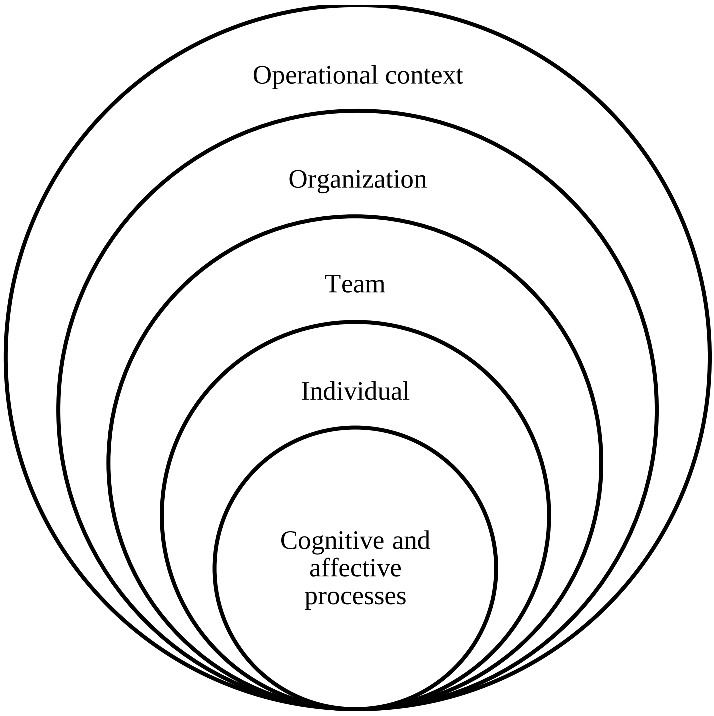

Figure 1. A proposed framework for aeronautical decision-making in context.

An airline organization is operating in an operational context that influences the organization and its members. National culture, and societal norms and values have been found to be contextual factors influencing peoples' behavior in organizations (Hofstede, 1980, 1991). At an organizational level people are influenced by the organizational culture (Cooper & Phillips, 2004; Garavan & O'Brien, 2001; Johnson, 2007; Keren, Mills, Freeman & Shelley, 2009; Reason, 1993; Zohar, 1980), and professional culture (Helmreich & Merritt, 1998; Helmreich, Wilhelm, Klinect & Merritt, 2001). People in complex systems such as aviation rarely operate solely as individuals. Pilots are part of a crew that form a team. Therefore, the social context must be taken into consideration (Kaempf & Klein, 1994; Orasanu, 1993). At the individual level, differences in decision-making style (Harren, 1979; Scott & Bruce, 1995; Thunholm, 2004), non-technical skills like cognitive and social abilities (Flin et al., 2005), and risk perception (Haisly, Kaufmann & Weber, 2010; Sitkin & Pablo, 1992; Sitkin & Weingart, 1995) has been found to be influential in people' behavior. At the core of the model cognitive and affective processes (e.g. Chaiken & Trope 1999; Kahneman, 2003; Sloman, 1996; Stanovich & West, 2000) influencing the individual can be found.

This thesis is organized as follows. In the first section, a broad review of the literature of human error, JDM, NDM, and ADM are performed. In the present thesis it is argued that the broad approach is necessary to understand how these research areas overlap to determine pilots' judgment and decision-making, and how the layers of the framework in Figure 1 interact. This is so because these areas of research described here have traditionally, although not exclusively, focused on three different phases of the decision-making process. Human error research typically focuses on outcomes and consequences and not so much on the decision per se (Reason, 1990). JDM as a research area has traditionally focused on the actual choice and NDM on the process leading up to the actual decision (Klein, 1993). In addition, the field of NDM is fairly homogenous with a group of models that are closely related to each other with a few common themes (Lipschitz, 1993a), thereby making it reasonable to take a broad approach to the field. Finally, the field of ADM has traditionally focused on the process and the outcome, but not the choice (FAA, 1991). However, these research areas also have a few things in common. The proposed framework is an attempt to bridge all these research areas and include all decision-making stages. In the second section, an overview and a detailed description of the empirical studies are given. In the third section, interpretations, conclusions, limitations, applications, and directions for future research are discussed followed by final remarks.

Human error and violations

Human error

"Knowledge and error flow from the same mental sources, only success can tell the one from the other" (Mach, 1905/1976).

"Correct performance and systematic errors are two sides of the same coin" (Reason, 1990, pp. 2).

Error-free performance might look impossible. Each step in a sequence of actions or thoughts offers many opportunities to stray away from the intended track. However, the reality is different. Human error is neither as common nor as varied as it might look. Not only are errors much less common than correct actions; they also tend to appear in very similar forms across a wide range of mental activities. Therefore, it is possible to compare errors across activities such as action, speech, perception, recall, recognition, judgment, concept formation, problem solving, and decision-making (Reason, 1990). "The accuracy of error prediction depends very largely on the extent to which the factors giving rise to the errors are understood. This requires a theory, which relates the three major elements in the production of error: the nature of the task and its environmental circumstances, the mechanisms governing performance and the nature of the individual. An adequate theory, therefore, is one that enables us to forecast both the *conditions* under which an error will occur, and the particular *form* that it will take" (Reason, 1990, pp. 4).

The view of human error and human contributing to accidents has started to change in recent years from what can be labeled: "the old view" to the "new view". According to "the old view" human error is a cause of failure and most accidents. The engineered systems in which people work are made to be basically safe, and the main threat to safety comes from the unreliability of people. Finally, safety development can be accomplished by protecting these systems from unreliable humans through methods such as selection, procedurelization, automation, training, and discipline. In contrast, "the new view", looks at human error as a symptom of trouble deeper inside the system. Safety is not inherent in systems since systems often are complex with multiple goals that people have to pursue simultaneously. People in the system have to create safety themselves. Human error is systematically related to the operational environment, and tools and task at hand. The idea is that human error is not an explanation for failure, and that countermeasures start not with individual people in the receiving "sharp" end that are victims of much latent trouble. Instead, the starting point is that error-producing conditions are present in their working environment (Dekker, 2002). Accidents can rarely be attributed to a single cause, or in most cases a single individual (Shappell & Wiegmann, 1997). People rarely have the intention to commit error. What can usually be found when looking at many accidents in complex systems is that people were doing exactly the sort of things they would usually be doing, things that usually lead to success and safety. People are doing what makes sense to them at the time, considering the situation at hand, operational environment, and organizational norms. To explain why an adverse outcome happened it is necessary to change from a search of human failure into a search for human sensemaking (Dekker, 2002).

Several perspectives on the nature and causes of human error may be taken. Within aviation there are five major perspectives: 1. Cognitive. 2. Ergonomics and system design. 3. Aeromedical. 4. Psychosocial, and 5. Organizational. The cognitive perspective is largely based on general information processing theory, which emphasizes that information progress through a series of stages, or mental operations that takes place between stimulus and response. Within this perspective, errors occur when these mental operations fail to process information appropriately. The ergonomics and system design perspective acknowledge that the human is rarely the sole cause of an error or accident. Instead, human performance involves a complex interaction of several factors. This perspective recognizes the relationship between individuals, their tools and machines, and their general work environment. In the aeromedical perspective, errors are caused by some underlying physiological condition. According to the psychosocial perspective, flight operations are best viewed as a social interaction among groups of people such as pilots, air traffic control, flight attendants, maintenance personnel, and ground crew. This interaction is influenced both by external factors such as the operating environment, and internal factors such as personality and attitudes of the individuals in each group. According to this view, errors and accidents occur when there is a breakdown in group dynamics and interpersonal communication. The final perspective is the organizational, which emphasizes the role of fallible decisions of managers, supervisors, and others in the organization, in the causation of accidents (Wiegmann & Shappell, 2001). A generative and productive organization is resistant towards error if it encourages communication, new ideas and active information search, support training, responsibilities are shared, and failure causes inquiry (Westrum & Adamski, 2010).

The literature is abundant with attempts to classify errors and a number of taxonomies exist (e.g. Baker & Krokos, 2007; Cacciabue & Cojazzi, 1995; Hooey & Foyle, 2006; O'Hare, 2000; Shappell & Wiegmann, 1997). However, there is no universally agreed classification of human error (Reason, 1990). The explanatory power of error taxonomies may also be questioned (Dekker, 2003b). Taxonomies are usually made for a specific purpose, and no single taxonomy is likely to satisfy all needs. Beyond the surface of these error taxonomies it is possible to distinguish three levels of classification attempts: the behavioral, contextual and conceptual levels. These levels correspond approximately to the "What?", "Where?" and "How"? questions about human error. The behavioral level is the most superficial where errors are classified according to some easily observable feature. This can include some formal characteristics of the error, such as omission-commission, repetition, or misordering. It can also include the immediate consequences of errors, such as the nature and extent of damage or injury. The advantage with such a classification is that observable behavior can be easily categorized and a high inter rater reliability can be achieved. However, one problem that might arise is that there might be no direct mapping of these behavioral error types onto more theoretical categories of cognitive failure. Rather, members of the same behavioral error class can arise from quite different causal mechanisms. The contextual level of classification goes beyond the behavioral level by including some limited assumptions of causality. Classifications at this level acknowledge the possible causal role of the specific context, the interaction between error type and the character of the situation or task at hand. The third level is the conceptual. Classifications at this level try to identify underlying causal mechanisms and are based more on theoretical inferences than on observable characteristics of the error or its context. The conceptual level provides the most satisfactory base to understand human error since the same mental process may produce quite different behavioral error types (Reason, 1990).

The concept of intentionality is closely related to errors and violations (Reason, 1990). Intentional behavior takes a variety of forms. Reason distinguishes between the different kinds of intentional behavior on the basis of three questions with yes-no answers regarding a given action: 1. Was there a prior intention to act? 2. Did the action proceed as planned? 3. Did the action achieve its desired end? A description of the distinctions can be seen in Figure 2 (Reason, 1990). A difference between prior and no prior intention is implied in the first question: Was there a prior intention to act? One distinction can be made between behavior with "prior intentions" and "intentions in action". "All intentional actions have intentions in action but not all intentional actions have prior intentions" (Searle, 1980, pp. 52). Actions without prior intentions can be divided into two broad classes: non-intentional and intentional actions. Non-intentional actions are involuntary actions that may be a result of an automatic reaction, such as hitting a glass on the table so that it falls to the floor after moving the arm to protect oneself against a stinging bee. As will be explained later, Reason (1990) distinguishes non-intended actions from unintentional actions. Intentional actions without prior intention can be either spontaneous or subsidiary actions. Spontaneous actions are when the intention resides only in the action itself, the action and the intention is inseparable. Subsidiary actions involve well-practiced action sequences were only the overall action is specified in the prior intention such as "I will drive to the office". We are then not likely to specify a prior intention of every single action on the way (Searle, 1980). The term error can be applied to both, actions (errors of commission) or inaction (errors of omission). Errors depend on two kinds of failure: the failure of actions to go as intended and the failure of intended actions to achieve their desired consequences. Reason (1990) distinguishes between unintended actions and intended actions or mistakes. Actions that deviate from intention fall into two classes: those that nevertheless achieve their intended goal and those that do not. While the former might be less common the latter is more common and often involves some degree of absent-mindedness. Two conditions seem to be present when such slips of action occur. The first condition is when a largely automatic task is performed in a familiar context. The second condition involves a marked degree of attention distraction by some external factor not relevant for the job at hand. Intended actions or mistakes are when the intended action proceeds as planned but still fail to achieve their intended outcome. This can then be classified as an error. In this case the problem does not lie in the intentionality but rather in the inadequacy of the plan (Reason, 1990).

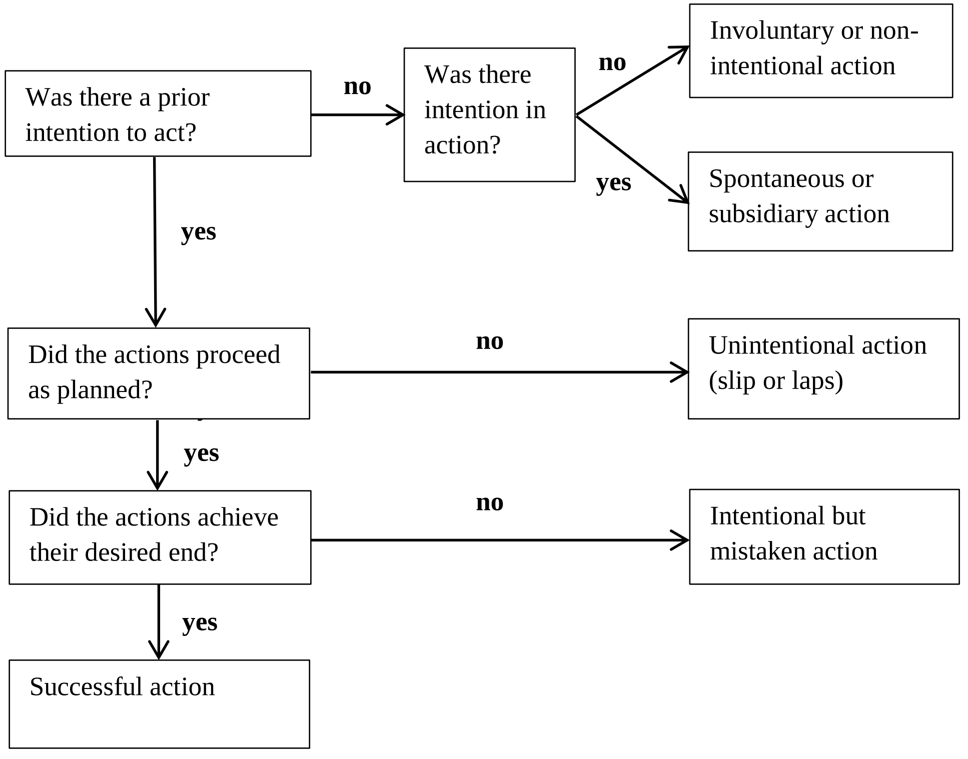

Figure 2. A model for distinguishing the varieties of intentional behavior (Reason, 1990).

Reason (1990) distinguishes between two basic error forms: planning failures (mistakes) and execution failures (slips and lapses). Mistakes, lapses, and slips occur at different cognitive stages. Mistakes occur at the planning stage, lapses at the storage stage, and slips at the execution stage. Mistakes involve a mismatch between the prior intention and the intended consequences. For slips and lapses, however, the discrepancy is between the intended actions and those that were actually executed. Planning failures are likely to arise from higher-level cognitive processes than either slips or lapses. A working definition of human error (Reason, 1990) is: "Error will be taken as a generic term to encompass all those occasions in which a planned sequence of mental or physical activities fails to achieve its intended outcome, and when these failures cannot be attributed to the intervention of some chance agency" (pp. 9). Reason makes two further working definitions: 1. "Slips and lapses are errors which result from some failure in the execution and/or storage stage of an action sequence, regardless of whether or not the plan which guided them was adequate to achieve its objective" (pp. 9). Slips are potentially observable as externalized actions while lapses are more covert, largely involving failures of memory. 2. "Mistakes may be defined as deficiencies or failures in the judgmental and/or inferential process involved in the selection of an objective or in the specification of the means to achieve it, irrespective of whether or not the actions directed by this decision-scheme run according to plan" (pp. 9). Mistakes are harder to detect compared to slips and lapses since consciousness is specifically tuned to picking up departures from intention, while mistakes can pass unnoticed for lengthy periods.

Reason (1990) further divides mistakes into two categories: rule-based and knowledge-based. This distinction is based on the framework of human performance described by Rasmussen (1986, 1993). Rasmussen describes three levels of human performance. The first is the skill-based level where human performance is governed by stored patterns of preprogramed instructions. Errors at this level are related to Reason's (1990) slips and lapses. The second level is rule-based when familiar problems are tackled in which solutions are governed by stored rules of the type *if* (state) – *then* (action). At this level errors are typically associated with misclassification of the situation leading to the application of the wrong rule or with the incorrect recall of procedures. This kind of mistakes can be described as rule-based mistakes (Reason, 1990). The third level is knowledge-based. This level comes into play in novel situations for which actions must be planned on-line, using conscious analytical processes and stored knowledge. Errors at this level arise from cognitive limitations and incomplete or incorrect knowledge. Mistakes at this level can be termed rule-based mistakes. With increasing expertise, the primary focus of control moves from the knowledge-based level towards the skill-based level. However, all levels may coexist at the same time (Reason, 1990).

Rasmussen's (1986, 1993) main contribution has been to chart the shortcuts that human decision-makers take in real-life situations. While other decision theorists represent the decision-making process in a linear fashion, Rasmussen's model is analogous to a stepladder, with the skill-based level at the bases at either side, and the knowledge-based level at the top. At an intermediate position between the skill- and knowledge-based levels, the rule-based level can be found. Shortcuts may be taken between these different stages on the ladder, where the observation of the system state may lead to automatic selection procedures without the slow and analytical intervention of knowledge-based processing (Reason, 1990).

Nagel (1988) describes a framework for pilot behavior, an information-decision-action model of piloting. According to the framework pilot behavior is governed by three basic stages. In the first stage information is acquired, exchanged and processed. In the second stage specific intents and plans are determined, and decisions are made. In the third stages actions are taken. All stages are taking place in a context of goals and are not constrained to occur in the described sequence. Errors may occur in any of these stages and methods to reduce errors follow three general approaches: 1. Errors may be avoided through design of controls, displays, and operational procedures. 2. Selection and training of crew may also reduce the likelihood that humans will make mistakes. 3. Design of error tolerant redundant systems such as multi crew operations.

The discussion so far has been focused on errors made by individuals. However, people in complex systems such as aviation, rarely operate solely as individuals. Pilots are part of a crew. Therefore, the social context must be taken into consideration when studying human error. Team errors are influenced by deficiencies in the human-machine interface, low task awareness, low situational awareness, and excessive adherence to one's own ideas, opinion, actions and decisions. Furthermore, over-reliance on factors such as warnings and indicators also influence team errors (Sasou & Reason, 1999). In addition, team error regarding decision-making, situation awareness, mission analysis, and communication skills has been found to negatively influence team performance (Merket, Bergondy & Salas, 1999).

Violations

Reason (1990) distinguishes between errors and violations. The error types; slips, lapses, and mistakes, previously discussed are restricted to individual information processing, which offers only a partial account of the possible variability of human behavior. What is missing is that, most of the time humans do not plan and execute their actions in isolation. Instead humans act in a social context. Reason states: "While errors may be defined in relation to the cognitive processes of the individual, violations can only be described with regard to a social context in which behavior is governed by operating procedures, codes of practice, rules and the like" (pp. 195).

Violations are deviations from safe operating procedures, standards or rules. Such deviations can be either intentional or unintentional (Reason, 1990). The latter are cases in which ignorance of the procedures exists or the individual is unaware that they are violating the procedure and therefore these may be defined as errors rather than violations (Reason et al., 1998). Reason (1990) defines intentional violations as: "Deliberate – but not necessarily reprehensible – deviations from those practices deemed necessary (by designers, managers, and regulatory agencies) to maintain the safe operation of a potential hazardous system" (pp. 195). However, numerous definitions of a violation exist in the literature. In a review, Alper and Karsh (2009) summarize various different definitions of a violation: "…an action that is contrary to a rule" (pp. 740).

Reason et al. (1998) distinguish between three major categories of deliberate safety violations: routine, optimizing and situational violations. In each case, the decision not to follow safe operating procedures is shaped by both organizational and individual factors. Routine violations typically involve corner cutting, taking the path of least effort. Eventually, these short cuts can become a habitual part of the person's behavioral repertoire, particularly when the work environment is one that rarely sanctions violations or reward compliance. Such routine violations are also promoted by procedures that are too complex or too effortful to comply with. Optimizing violations reflect the fact that human actions serve a variety of goals, and that some of these are quite unrelated to the functional aspect of the task. Thus, a driver's functional goal is to get from A to B, but in the process he or she can optimize the joy of speed or indulge aggressive instincts. Tendencies to optimize non-functional goals can become a part of an individual's performance style. Behavior, which achieves the personal goals of the actor, may be considered psychologically rewarding behavior. This behavior may or may not be consistent with the goals of the organization. So, for example, for one individual deviating from a rule may be psychologically rewarding as it gives rise to a sense of excitement or thrill; for a fellow worker this same deviation may produce psychologically unrewarding feelings of guilt and worry. Whereas routine and optimizing violations are clearly linked to the attainment of personal goals, situational violations have their primary origins in particular work situations. Here, non-compliance is seen as essential in order to get the job done. These violations are commonly provoked by organizational failings with regard to the site, tools and equipment. In addition, they can also provide an easier way of working. In this way these violations can become routinized. Compliant behavior is behavior that involves the following of formal rules and procedures, irrespective of whether or not the rule is a good one, or applicable in the circumstances. Compliance will not always achieve the organization's safety goals. When the rule is bad, or inappropriate, compliance is not desirable. Reason (1993) further distinguishes two additional types of violations: exceptional violations, which are one-off violations mostly dictated by unusual circumstances, and sabotage, where the individual intends both the deviation and a bad outcome. Since sabotage falls outside the scope of most accident scenarios, the violations of greatest interest are those having some degree of intentionality, but that do not involve the goal of system damage.

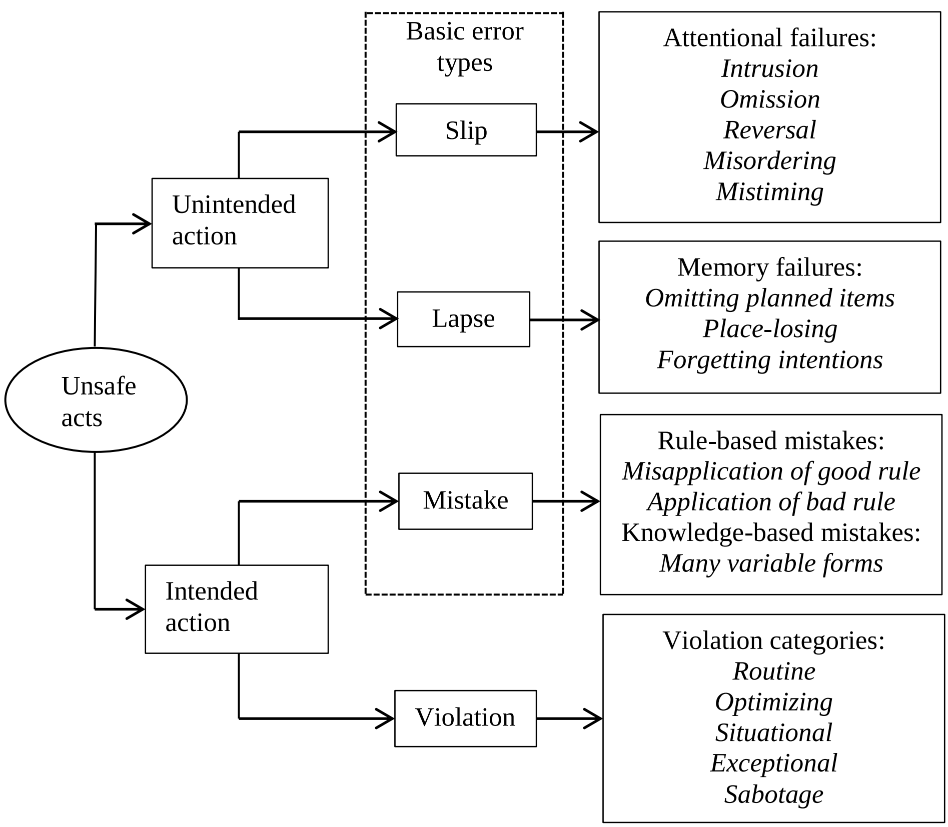

Figure 3. A summary of the varieties of unsafe acts (Reason, 1990, 1993).

Errors and violations can be grouped under the general heading of unsafe acts. An act is unsafe only if it is committed in the presence of a possible hazard. An unsafe act is therefore more than just an error or a violation – it is an error or violation committed in the presence of a potential hazard. A classification of unsafe acts can be seen in Figure 3 (Reason, 1990, 1993). Reason (1990) pointed out that active failure, in the form of unsafe acts by the operator of a system are preceded by a chain of latent failures inherent in the system, such as fallible decisions by higher management, line management deficiencies, and other psychological precursors. According to Reason, it is the combination of latent and active failures that interact with local events that may cause accidents.

Violations can have two important consequences: they can increase the probability of a subsequent error, and they can also increase the likelihood that the behavior will lead to a bad outcome (Reason et al., 1998). Numerous reasons for rule-violations in organizations operating in hazardous environments have been suggested, like individual, psychological, situational and organizational factors influencing the behavior of the individual (Alper & Karsh, 2009; Hofmann, Jacobs & Landy, 1995; Hofmann & Stetzer, 1996, 1998; Reason et al., 1998; Öz, Özkan & Lajunen, 2010). Organizational factors are often overlooked when workplace accidents are investigated. Instead investigators tend to focus on the individual most proximal to the accident (Hofmann & Stetzer, 1998). Unsafe acts and causes of accidents have often been attributed to safety climate (Cooper & Phillips, 2004; Garavan & O'Brien, 2001; Johnson, 2007; Keren et al., 2009; Reason, 1993; Zohar, 1980). This includes factors such as leadership style (Barling, Loughlin, & Kelloway, 2002; Zohar, 2002), lack of management involvement (Reason, 1993; Zohar & Luria, 2003), trust in management (Conchie & Burns, 2009) role overload (Hofmann & Stetzer, 1996; Mullen, 2004), which is the degree to which performance is affected by inadequate resources, training, and time to perform one's role. Other individual and safety climate factors affecting unsafe behavior are perceived susceptibility to risk (Reason, 1993; Vaughan, 1993; Weinstein, 1998; Weinstein, Sandman & Roberts, 1991), peer pressure (Keren et al., 2009), pressure to perform, and attitudes (Hofmann et al., 1995; Mullen, 2004). To save time workers will forgo safe working procedures and take short cuts when feeling pressure to perform quickly. These short cuts will eventually become the norm (Reason et al., 1998) since they allow workers to complete the work in a much more efficient way (Slappendal, Laird, Kawachi, Marshall & Cryer, 1993). Mullen (2004) found that socialization, attitudes, self-image, macho or tough person syndrome, need to maintain one's image as a competent worker, avoiding negative consequences such as teasing and harassment from coworkers and the boss, and finally, fear of losing a good position, highly influenced individuals' unsafe behavior. Additional violating-producing conditions includes conflict between management and staff, poor morale, group norms condoning violations, misperception of hazards, little pride in work, low self-esteem, and learned helplessness (Reason, 1993). Reasons for violating procedures are also an interaction between work experience and the complexity of procedural steps. Violations are more common among workers with intermediate experience. When senior workers violate the reason is based on the complexity of the procedural steps. Operators frequently violate procedures that involve intermediate complexity of the procedural steps (Park & Jung, 2003). Furthermore, safety is not created in isolation but interacts with other variables. Safe behavior has been found to increase if safety demands and production demands are compatible (McLain & Jarrell, 2007). A summary of violation-producing conditions can be seen in Table 1.

Table 1

Violation-producing conditions (Reason, 1993).

1. Manifestation or lack of an organizational safety culture
2. Conflict between management and staff
3. Poor morale
4. Poor supervision and checking
5. Group norms condoning violations
6. Misperception of hazards
7. Perceived lack of management care and concern
8. Little élan or pride in work
9. A macho culture that encourages risk-taking
10. Beliefs that bad outcomes will not happen
11. Low self-esteem
12. Learned helplessness
13. Perceived license to bend rules
14. Ambiguous or apparently meaningless rules

In many hazardous work environments, the important issue is not whether to violate, but when to violate. The workforce quickly learns that the violation of individual rules in isolation rarely result in any serious consequence because the combination of factors that leads to an accident seldom reoccur in precisely the same form. The separation in time and space of the individual violation from its consequent failures might serve to further reinforce a belief in the innocent nature of violations. Nearly all hazardous operations routinely involve situations when behavior lies outside the prescribed boundaries. However, the unsafe behaviors are still regarded as acceptable practice within the work group. In addition, most experienced workers think they know approximately were the edge between safety and disaster lies and do not exceed it, except in extreme circumstances. This view may be further substantiated by the cynicism of workers who see safety procedures more as a means of protecting the company in the event of an accident (Reason et al., 1998).

Error and violation countermeasures

What is regarded as correct and incorrect actions relate to how closely an individual's hazard perception is to reality. In other words, the distinction relates to the accuracy of hazard perception. Recognizing a situation as hazardous and/or a rule as inappropriate is likely to lead to the adaptation of self-protective behavior. A correct action, therefore, is one taken on the basis of an adequate hazard evaluation. Psychologically rewarding behavior is behavior that achieves the personal goals of the actor, which may or may not be consistent with the goals of the organization. Psychologically rewarding actions need not necessarily be correct actions with regard to the accuracy of the hazard assessment. Compliance is not automatically correct, nor a violation incorrect. The safety goals of an organization are assumed to be achieved when employees are correct in their choice of actions if a safety procedure is appropriate. A further distinction relates to the appropriateness of the rules to particular local circumstances. For any given situation, there may be good rules, bad rules or no rules. A good rule is one that is appropriate to the circumstances, and a bad rule is one that is inappropriate. A no rule situation is one for which no procedures are available. In order for an organization to achieve correct compliance is to encourage behavior that satisfies the goals of both the organization and the individual. Should safety rules permit the achievement of personal as well as organizational goals, there would be little need for external enforcement. Thus a meaningful evaluation of rule related behaviors require an assessment of the interaction between individual and organizational safety goals (Reason et al., 1998).

Safe operating procedures are continually being amended to prohibit actions that have been implicated in some recent accident or incident. Over time, these additions become increasingly restrictive, often reducing the range of permitted actions to far less than those necessary to get the job done under anything but optimal conditions. Workers often discover that violations lead to an easier and more efficient way of working. Ironically, then, one of the effects of continually tightening up safe working practices is to increase the likelihood of deliberate deviation from these practices: in other words, encourage violations. Many violations are created because procedures are overly specified. Thus, simply providing and enforcing prescriptive rules and procedures are not sufficient to foster safe behavior in the workplace, and supplementary methods of organizational control are needed. There are four types of organizational controls: administrative, technical, social and self-controls. Administrative controls have been defined as “those mechanisms, techniques and processes that have been consciously and purposefully designed in order to try to control the organizational behavior of other individuals, groups and organizations.” Administrative controls may involve control of process or of output. Process controls are attempts to standardize the work process using prescriptive rules and procedures, often backed up by the monitoring of behavior and by sanctions for non-compliance. In contrast, output controls entail a feedback control process based upon comparing output measures, including performance, with organizational objectives, and adjusting outputs whenever necessary. This type of control is often necessary when tasks are complex and unpredictable. Technical controls include engineered safety features. Social controls involve norms and accepted standards of behavior. Self-controls refer to the individual’s ability to manage or self-regulation (Reason et al., 1998).

Reason (1990) pointed out that errors and violations are mediated by different cognitive mechanisms. Reason (1993) therefore suggests that the actions necessary to combat errors and violations are different. Reason (1993) states that errors arise as a result of information processing problems, violations have a motivational basis. Errors may be understood in relation to a cognitive function, and may be minimized by retraining, redesign of the workplace and memory aids. Violations are a social phenomenon and can only be understood in an organizational context. Violations must be dealt with by changing attitudes, beliefs and norms and by improving morale and the safety culture.

A system may partly be protected from the negative consequences of failures and errors by barrier functions (Hollnagel, 2008; Kecklund, Edland & Svensson, 1996; Reason, 1990). According to Reason’s (1990) Swiss cheese model accidents occur because of breakdowns of a series of safety barriers. These barriers consist of factors such as managerial decision-making, engineering design, maintenance, training, procedures, and operation. The Swiss cheese metaphor depicts error as a hole in a cheese slice, the safety barrier. An accident occurs when the holes of several cheese slices are aligned, representing a breakdown or a chain of errors in the organization that allow an accident to happen in the "sharp end" (e.g. by the pilot of an aircraft). The Swiss cheese model has the advantage that it describes that accident causation may not only be found in the "sharp en", but also in the "blunt end".

The Swiss cheese model describes accident causation as a single chain of events. However, this way of looking at accidents has been questioned (Dekker, 2002; Dekker, Cilliers & Hofmeyr, 2011; Leveson, 2011; Shappell & Wiegmann, 1997; Sheridan, 2008). Barrier systems might be necessary but they are not sufficient to guarantee safety. Barrier systems represent a reactive as opposed to proactive approach. Barriers are often used to hinder something to occur again and do not account for possible new risks (Hollnagel, 2008). Causation is usually too complex to be traced backwards to a single cause since one event in the chain may have multiple causes. It is common for risk assessments in organizations to be probabilistic where risk and error is connected with probability of a particular unwanted consequence. This connection is the product of three probabilities: 1. The probability that there is an opportunity for human error. 2. The probability that an error is committed, given that the opportunity is present, and 3. The probability that no recovery is made before the undesirable consequence occurs, given both the opportunity and the actual error occurred. Often too little emphasis is given to probability 1 and 3 (Sheridan, 2008). Training programs have been developed within aviation to counter probability 3, and enhance the ability of humans at the "sharp end" to capture and mitigate errors before they lead to more serious consequences. These programs come in forms such as Crew Resource Management, CRM (Helmreich, Merritt, & Wilhelm, 1999), and Threat and Error Management, TEM (Helmreich, Klinect, & Wilhelm, 1999). Proactive error detection and management training considers cognitive strategies that are used and can be used to detect and mitigate errors. In addition, such training may benefit from incorporating other factors found to influence the error detection process, such as attitudinal and team factors (Kontogiannis & Malakis, 2009).

There has been a trend in recent years among researchers of risk and safety to move away from quantitative and probabilistic models that focus more on the "sharp end". This trend has been termed resilience engineering which focuses more on management and the organization as a whole and less on counting operator errors (Sheridan, 2008). It presupposes that human errors and machine failures will occur and are unavoidable (Perrow, 1984), and that the probabilities connecting risk and error are too imprecise. Instead a more fruitful approach would be to put emphasize on means to anticipate disturbances, recover, and restoring the system to the original state or some acceptable state that is different but still safe. Resilience engineering is something an organization does, like to avoid setting up the conditions that permit failure to occur, rather than something the organization momentarily is. Resilience engineering has a more qualitative and system approach to risk and human error (Sheridan, 2008). A safe, resilient organization is one that balances stability against resilience. Existing barriers represent stability in the system that may be improved in light of new experiences. Resilience is represented by a systems ability to adapt and survive in a dynamic environment. Stability is needed to cope with expected disturbances. Resilience is needed to survive unexpected events (Johansson & Lundberg, 2010). Instead of just looking at the separate parts and single sources of accident causation the system approach takes a more holistic standpoint by including how the whole chain of agents interacts with each other, the context and the outside world (Leveson, 2011; Pew & Mavor, 2007). To understand why humans behaved as they did as a given event unfolded, one must first take an inside perspective from the operators point of view (Dekker et al., 2011). Furthermore, organizational drift into failure is another factor to consider for an organization striving for the highest level of safety. Drift into failure is a slow, incremental movement of systems operations towards the edge of their safety envelope. This movement is driven by competitive pressure that influences decision-makers in subtle ways. This pressure may contribute to constant change of procedures towards the edge of what is actually safe. This drift is difficult to detect and people in a system are often unaware of the drift. In order for an organization to countermeasure drift into failure it must take a system approach and apply resilience-engineering principles (Dekker, 2005).

The very existence of errors has been questioned since what constitutes an error depends on who you ask. Counting errors do not say anything about causality. To say that for example errors are caused by faulty decision-making is circular since it is impossible to tell whether faulty decision-making caused error or if error caused faulty decision-making (Dekker, 2007). Furthermore, what constitutes an error depends on how errors are conceptualized: as a bad outcome following a one shot decision or a sequence of decisions and outcomes. The former is a case when a bad decision can be traced back in a chain of events. The latter is a case when decisions are made, outcomes are observed, feedback is given, and modified actions are taken. In such a context a decision might not be an error at all since it made perfectly sense to the decision maker at the time (Lipshitz, 1997). Finally, errors might not be bad since without errors no learning would occur (Skinner, 1965), and a certain level of risk may be beneficial for learning and innovations (Zeckhauser & Viscusi, 1990). Errors and failures play an essential role, and are a normal part of human performance and learning in complex socio-technical systems (Amalberti, 2001; Gilbert, Amalberti & Paries, 2007). Anticipating the evolution of hazards, an accurate evaluation of one´s own abilities in context, and the ability to learn from errors are key ingredients in developing survival skills according to the situation. Therefore, true resilience is developed through experience and continuous exposure to risk and not necessarily by means of more restrictive procedures (Gaël, Amalberti & Chauvin, 2008).

Pilot behavior

Clearly both individual and organizational factors such as safety climate play an important role to determine unsafe behavior. Yet, only a few attempts have been made to assess safety climate within aviation (Wiegmann, Zhang, von Thaden, Sharma & Gibbons, 2004). Althoug, since the Wiegmann et al. (2004) article some attempts to assess safety climate within aviation have been made (Evans, Glendon & Creed, 2007; Gibbons, von Thaden & Wiegmann, 2006). In a review, O'Connor, O'Dea, Kennedy and Buttrey (2011) found that the safety climate factors identified within aviation safety climate measurements were consistent with measures from non-aviation high reliability organizations. Pidgeon and O'Leary (1994) argue that the aviation industry may benefit from incorporating organizational climate when designing safety-enhancing measures.

A positive safety climate has been found to be related to less non-compliance with procedures within aircraft maintenance organizations (Fogarty & Buikstra, 2008; Neitzel, Seixas, Harris & Camp, 2008), and air crews (Block, Sabin & Patankar, 2007; Patankar, 2003). Furthermore, commercial pressure of managers on maintenance personnel and pilots to reduce safety margins do exist (Atak & Kingma, 2011). Inadequate procedures have been found to largely contribute to violations at work places in general (Reason, 1993; Reason et al., 1998), and to aviation accidents (Wiegmann & Shappell, 2006). In addition to procedural problems, airlines suffering accidents have also been found to have problems with training, surveillance, and supervision (Wiegmann & Shappell, 2006). Furthermore, social psychological pressure has been found to affect pilot's decision-making negatively. Such pressure can come from managers, other pilots, passengers, and from the pilots themselves (Paletz, 2009). Experience has a moderating effect on pilot's risk-taking (Wiegmann, Goh & O'Hare, 2002). Total flight time has been found to have a protective effect against violations. Pilots with a total flight time of between 5,000 and 9,999 hours are at lower risk of violating compared to less experienced pilots. However, the moderating effect of flight experience is diminishing after 10,000 hours of total flight time (Rebok, Qiang, Baker, McCarthy & Li, 2005).

Wetmore and Lu (2006) suggest that the hazardous attitudes; antiauthority, impulsivity, invulnerability, macho and resignation, have a negative relation to pilots' decision-making and crew resource management skills. However, Drinkwater and Molesworth (2010) did not find any difference in attitudes between pilots performing a risky behavior and those who did not. In addition, low risk perception (Hunter, 2003; Hunter, Martinussen, Wiggins & O'Hare, 2011; Pauly, O'Hare, Mullen & Wiggins, 2008), and greater tolerance of risk (Pauley, O'Hare & Wiggins, 2008) is related to higher degree of risk-taking among pilots. Finally, loss of face has also been identified as a possible factor influencing pilot's decision-making negatively (Murray, 1999).

Driver behavior

Since the present thesis include one experiment studying car drivers' behavior it is relevant to include a section about previous research on this topic.

Driving speed is an important component in road safety. High speed not only raises the risk to be involved in a crash, but also affects the severity of a crash and consequences in terms of injuries and fatalities (Aarts & van Schagen, 2006; Ayuso, Guillén & Alcañiz, 2010; De Winter & Dodou, 2010).

Numerous attempts to explain drivers' behavior have been made within the framework of the theory of planned behavior where important antecedents of drivers speeding behavior have been found such as attitudes, subjective norm, perceived control, intention, anticipated regret, and past behavior (e.g. Cestac, Paran, & Delhomme, 2011; Conner et al., 2007; De Pelsmacker & Janssens, 2007; Elliot, Armitage & Baughan, 2003; Elliot & Thomson, 2010; Wallén Warner & Åberg, 2008).

Personal characteristics among people who speed include thrill seeking (Begg & Langley, 2001; McKenna & Horswill, 2006), sensation seeking (Jonah, 1997), masculinity (Schmid Mast, Sieverding, Esslen, Graber & Jäncke, 2008), internal locus of control (Wallén Warner, Özkan & Lajunen, 2010), high level of social deviance (West, Elander & French, 1993; West & Hall, 1997), and a disposition to overweight gains (Farah, Yechiam, Bekhor, Toledo & Polus, 2008; Lev, Hershkovitz & Yechiam, 2008).

Other factors influencing speeding include attitudes (Haglund & Åberg, 2000; West et al., 1993; West & Hall, 1997), habits (De Pelsmacker & Janssens, 2007), time-saving bias (Fuller et al., 2009; Peer, 2010; Svensson, 1970, 2008, 2009), other drivers' behavior (Haglund & Åberg, 2000), being in a hurry, the speed limit being set too low, inattention to speed, road and traffic conditions (Lahausse, van Nes, Fildes & Keall, 2010), arriving quicker, follow the traffic rhythm better, making it easier to overtake (Wallén Warner & Åberg, 2008), ego-gratification, risk-taking, time pressure, disdain of driving, inattention (Gabany, Plummer & Grigg, 1997), experience of speeding violations, crash involvement (Williams, Kyrychenko & Retting, 2006), and perceived credibility of the speed limit (Goldenbeld & van Schagen, 2007).

Affect may have an important role in drivers' behavior. Emotions such as anger are related to speeding (Mesken, Hagenzieker, Rothengatter & de Waard, 2007). Fuller (2005) argues that high speed induces feelings of risk that in turn may inform drivers' decision-making in order to control task difficulty. This is in line with the literature arguing that affect guide and influence peoples' actions (e.g. Loewenstein, Weber, Hsee & Welch, 2001; Peters, 2006; Pfister & Böhm, 2008; Slovic, Finucane, Peters & MacGregor, 2002, 2004; Wilson & Arvai, 2006).

Judgment and decision-making (JDM)

Background

The history of decision-making is closely connected to the concepts of rationality and probability. Through the history philosophers, psychologists, economists and other scientists have discussed if the human is rational or not when making decisions, what rationality really is. They have also discussed how and if decision-makers utilize probabilities in their judgments. The ancient Greeks defined the human being as the rational animal. Rationality is a normative concept and rational is something people ought to be. The Greek philosopher Parmenides (520-450 B.C.E) concluded that, because the senses deceive, they should not be trusted, and one should rely on logic instead. Heraclitus (535-475 B.C.E), that maintained that the way to truth is through the senses, not logic, represented an opposite view. Following Parmenides and Heraclitus, Plato (427-347 B.C.E) and Aristotle (384-322 B.C.E), argued that humans are both rational and irrational at the same time. In addition, Aristotle described how humans, after repeated experience with different types of the same stimuli gradually form an impression or an image about the world. This was later adopted by the associationism represented by David Hume (1711-1776) who added probability to describe how humans infer the probability of future events from past experiences. Another philosophical area, utilitarianism proposed a simple and potentially quantifiable theory of human motivation, hedonism. First advanced by the Greeks, hedonism proposes that people are motivated by the pursuit of pleasure and the avoidance of pain. Jeremy Bentham (1748-1832) attempted to measure units of pleasure and pain so that they might be entered into equations that would predict behavior or could be used by decision-makers to make correct, that is, the most happiness-maximizing, choices Utilitarianism was the basis for expected utility theory, developed by the two cousins Nicolas (1687-1759) and Daniel Bernoulli (1700-1782). They were both Swiss mathematicians who discovered that people often violated expected value theory. Expected value was a mathematical estimation of the value assigned to money in proportion to its quantity. This relationship is linear in expected value theory. Instead the Bernoulli cousin's described a non-linear relationship, people value money in the proportion to the usage that they may make of it. The value of money has a diminishing effect. The idea was that the same amount of additional money was less useful to an already-wealthy person than it would be to a poor person (Leahey, 2003).

Contemporary research on judgment and decision-making

John von Neumann (1903-1957) and Oskar Morgenstern (1902-1977) later developed expected utility theory, and showed that the principles of normative and rational behavior were often violated. The expected utility hypothesis predicts that the preferences of people with regard to uncertain outcomes in gambles can be described by a mathematical relation, which takes into account the size of a payoff, the probability of occurrence, risk aversion, and the utility of the payoff (von Neumann & Morgenstern, 1947). In 1954, Ward Edwards (1928-2005), introduced psychologist to the field of decision-making in an extensive review of the economic literature on choice (Edwards, 1954). In the psychological research that followed the notion of utility maximization became central where it was often assumed that the decision maker act rational and carefully select an option considering all available options and consequences, trying to maximize some subjective measure of value or welfare, e.g. subjective expected utility (Savage, 1954).

Herbert Simon (1916-2001) criticized the assumption of maximization in utility theory and the rational decision-maker. He points out that most people are only partly rational, and are in fact emotional or irrational in the remaining part of their actions. Simon (1957) suggested that individual judgment is bounded in its rationality. The idea about bounded rationality is that a bounded rational decision maker attempts to attain some satisfactory, although not necessarily maximal, level of achievement. The bounded rationality framework acknowledges that decision-makers often lack the information needed to make an accurate decision. Although the concept of bounded rationality is important in showing that judgment deviates from rationality, it does not tell us how judgment will be biased, which was further described by Amos Tversky (1937-1996) and Daniel Kahneman (1934 -), who described a range of specific systematic biases that influence judgment. Specifically, they found that people rely on a number of simplifying strategies, or rule of thumb, in making decisions. These simplifying strategies are called heuristics. These heuristics have an adaptive function in the sense that they help us coping with the complex environment surrounding our decisions. In general, heuristics are helpful, but their use can sometimes lead to severe error (Tversky & Kahneman, 1974). However, heuristics often outperforms traditional normative rational decision-making models (Gigerenzer, Czerlinski & Martignon, 2002; Gigerenzer & Goldstein, 1996).

Expected utility theory has difficulties explaining why people sometimes are risk aversive and sometimes risk seeking. Furthermore, expected utility theory does not account for the possibility that people structure and simplify the decision problem before a decision is made. Prospect theory (Kahneman & Tversky, 1979) extends the expected utility theory further. Prospect theory is a two-stage model for decision-making. The first stage is an editing phase and the second is a judgment phase. In the editing phase the decision maker analyzes and structures the decision-problem at hand. The judgment phase consists of two functions, the value function and then the weighting function. The value function is similar to expected utility theory. The difference is that prospect theory distinguish between gains and losses. In addition, prospect theory states the importance of a variable reference point from which the decision maker defines gains and losses, which is important to explain framing effects. People have been found to be risk averse when gambles are presented as possible gains and risk seeking when gambles are defined in terms of losses. In addition, the affective consequences are different between gains and losses such that the negative feeling experienced when losing an amount of money is experienced as worse than the positive feeling when winning the same amount. Losses loom larger than gains.

In addition to the value function, the weighting function of prospect theory describes how people tend to overweight small probabilities and underweight large probabilities. People make a subjective weighting of the probability for an outcome that is not linear. Instead the weighting curve has an inversed s-shape that is steeper for small and large probabilities and more flat for intermediate probabilities. The weighting function can be seen in Figure 4.

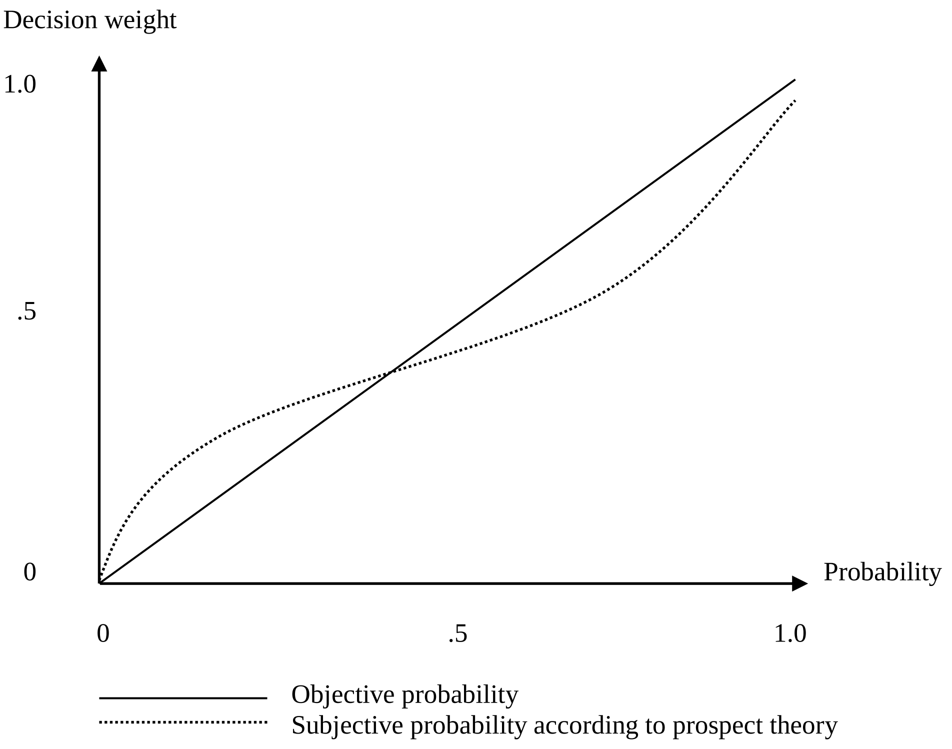

Figure 4. The weighting functions of prospect theory. The shape of the subjective probability curve is approximate.

Together, the value and the weighting function describe a fourfold pattern of judgment where people are risk averse for gains and risk seeking for losses for intermediate probabilities while the reverse is found for small and large probabilities.

The description-experience gap

Experimental research on decision making under risk and uncertainty has been heavily influenced by the lottery paradigm where people choose between gambles after receiving explicit probabilities about outcomes (Weber, Shafir & Blais 2004). However, in real life situations, decisions are rarely accompanied with explicit probabilities. Instead, decisions are made based on personal experience with previous outcomes. A number of studies have found that decision behavior in gambling cannot be generalized to non-gambling decision tasks (e.g. Huber, Beutter, Montoya & Huber, 2001; Huber & Huber, 2003; Huber, Wider & Huber, 1997; Klein, 1993; Zsambok, 1997).

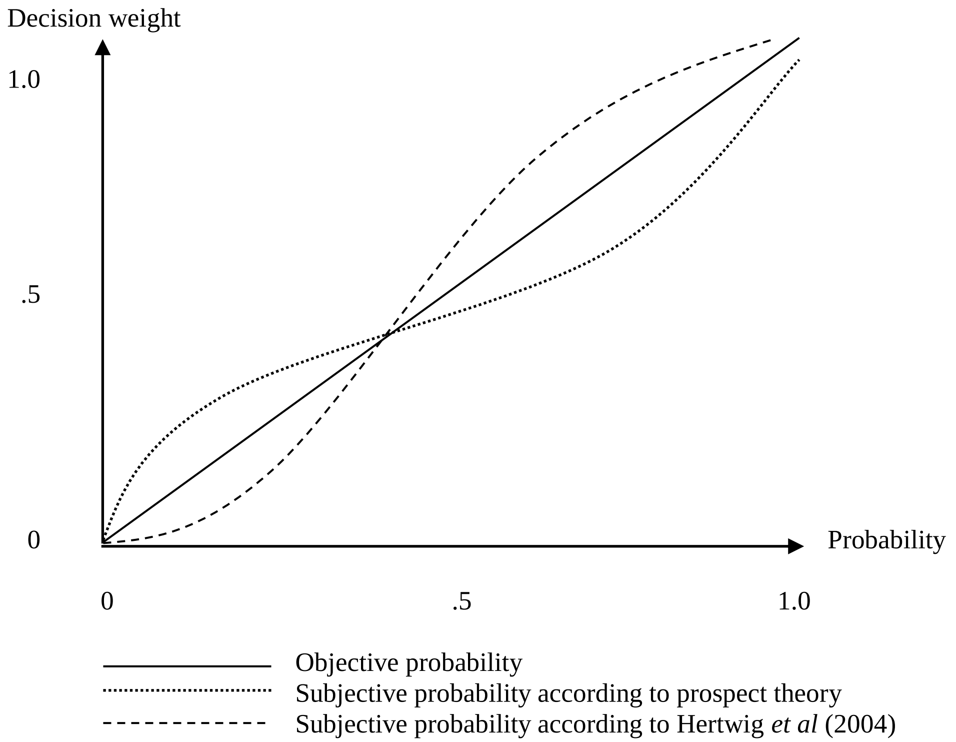

Figure 5. The weighting functions of prospect theory and Hertwig et al. (2004). The shapes of the subjective probability curves are approximate.

The weighting function of prospect theory (Kahnemann & Tversky, 1979) states that people overweight rare events and underweight events with high probability. Hertwig, Baron, Weber and Erev (2004) argue that this only holds true if people get explicit descriptions of probabilities, a case they call decisions from description (DFD).

In DFD people are provided with explicit descriptions of each outcome and corresponding probability. To get explicit information about probabilities is rare in reality when people typically base judgments and make decisions based on experience with similar situations, what Hertwig et al. (2004) call decisions from experience (DFE). Contrary to what prospect theory prescribes; Hertwig et al. found that when people make choices based on experienced probability distributions they seem to underestimate rare events. That is, people choose as if small-probability events receive less weight than they deserve according to their objective probabilities of occurrence. The weighting functions of prospect theory and Hertwig et al. can be seen in Figure 5.

Although Hertwig et al. called the phenomenon they encountered underweighting, others have found the weighting function to be close to linear (Hau, Plescac, Kiefer & Hertwig, 2008). However, a difference between the weighting functions of DFD and DFE still persists. This has been termed the description-experience gap (Hau et al., 2008).

Several explanations for the description-experience gap have been offered. Fox and Hadar (2006) argue that the sampling procedure is biased in the sense that people stop sampling too early and hence never experience the rare event. However, Ungemach, Chater and Stewart (2009) found evidence for the gap even when the frequencies of outcomes precisely matched the underlying probabilities thus reducing this concern. Another explanation for the gap is a working memory limitation, recency. When people observe the rare event late in a sequence it has more impact than if it is experienced early (Hertwig et al., 2004; Rakow, Demes & Newell, 2008). Lack of matching between the presentations formats, percentages versus frequencies, may also contribute to the description-experience gap (Hau, Pleskac & Hertwig, 2010). It has been argued that presenting probabilities as frequencies versus percentages may create different estimates (Visschers, Meertens, Passchier & de Vries, 2009) promote better statistical reasoning and enhance imaginability and affect of low probability events (Newell, Mitchell & Hayes, 2008; Slovic et al., 2002) and encourage risk avoidance (Siegrist, 1997). Furthermore, perceived risk is judged to be higher when communicated as relative frequency compared to percentage (Slovic, Monahan & MacGregor, 2000). In studies of the decision-experience gap probability are typically presented as percentages to represent the rare event in the description condition, while the experience conditions typically involves frequency formats.

Decision-making and affect

Affect has traditionally not been recognized as an important component in research and theory in judgment and decision-making (Finucane, Peters and Slovic 2003). Affect is largely ignored or at best seen as a consequence of decision-making. Most theories of choice under risk or uncertainty are cognitive and consequential (Loewenstein et al. 2001). Instead Loewnnstein et al. (2001) propose an alternative theoretical approach, the risk-as-feelings hypothesis that might help to explain some divergences from the cognitive-consequentialist predictions. The risk-as-feelings hypotheses stress the importance of affect experienced at the moment of decision-making. Loewnnstein et al. argue that cognitive and emotional processes are two different systems that interplay to determine behavior. When cognitive and emotional reactions to risky situations occur the latter often drive behavior. This is also in line with

Wilson and Arvai (2006) who found that affective responses to a stimulus might overwhelm analytical computations during decision-making.

Slovic et al. (2002, 2004) describe how human-decision-making is guided by affect by what they call the affect heuristic. When people make judgments they refer to mental representations of objects and events. These representations are, consciously or unconsciously, associated with some degree of affect. The affect is used as a cue to guide the decision-maker and enable mental shortcuts, hence the affect heuristic.

Peters (2006) argue that affect has four separate functions important to judgment and decision-making: 1. Affect can act as information to guide the judgment and decision processes. The feelings felt at the moment of judgment or choice is consulted to determine what feels right. These feelings are often based on prior experience. 2. Affect work as a common currency, allowing people to compare the values of very different decision options or information. This allows people to simplify a complex decision task by relying on feelings about what is good or bad rather than making sense of multiple, conflicting logical reasons. 3. Affect may work as a spotlight. This happens in a two-step process. First, the extent, or type of affective feelings (e.g. weak-strong, or anger-fear) focuses the decision maker on new information. Second, the new information, rather than the initial feelings themselves, is used to guide the judgment or decision. 4. Affect appears to function as a motivator of information processing and behavior. Similarly, Pfister and Böhm (2008), describe the functions of emotions in decision-making; to provide information about pleasure and pain, to enable rapid choices under time pressure, to focus attention to relevant aspects and finally, to generate commitment. Therefore, to understand human behavior it is important to understand the role of emotional processes in decision-making.

The term affect is often used to describe a state that is primarily differentiated on valence and arousal. Valence refers to a state dimension that ranges from positive to negative. Arousal refers to a general state of activation ranging from low to high. The term emotion is often used to describe a relatively brief state that can be qualitatively differentiated with specific wording such as anger, fear or sadness. Emotions are connected to affect such that emotions can differ in both valence and arousal. Affective influence on decision-making has typically been described as an emotional process involving a sequence of events starting with an emotional stimulus, through some underlying affective state, and terminating with behavior (Winkielman et al. 2007). Slovic et al. (2004) define affect as “the specific quality of 'goodness' or 'badness' (1) experienced as a feeling state (with or without consciousness) and (2) demarcating a positive or negative quality of a stimulus” (p. 312).

Rottenstreich and Hsee (2001) describe how affect-richness influences probability weighting. Their result suggests that affect-poor prospects show a relatively linear function while affect-rich prospects are more sensitive to high and low probabilities as can be seen in Figure 2. In Figure 2 it can be seen that affect-rich prospects cause people to overestimate small probabilities relative affect-poor prospects. Furthermore, Hsee and Rottenstreich (2004) investigated the relationship between scope sensitivity and subjective value of an object. They compared two psychological processes that people might use to construct preferences: valuation by calculation and valuation by feelings. They found that people showed scope insensitivity for affect-rich objects and scope sensitivity for affect-poor objects. When feelings predominate, value is almost a step function. When calculation predominates, value shows a steeper, close to linear, function as can be seen in Figure 6.

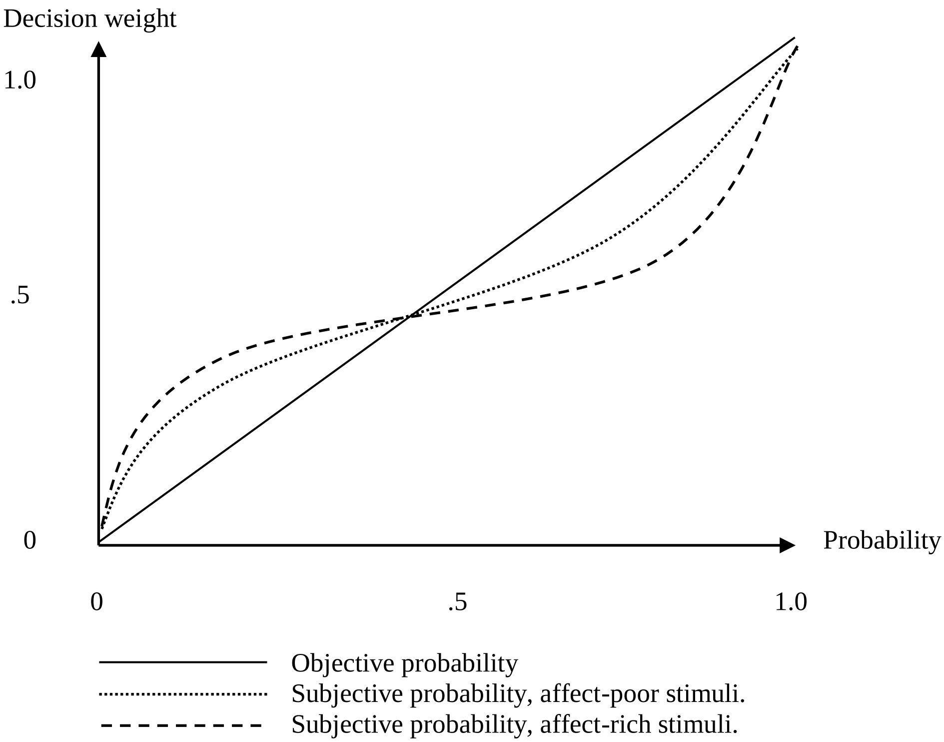

Figure 6. The weighting functions for affect-poor and affect-rich stimuli. The shapes of the subjective probability curves are approximate.

Dual process theory

Affect and the idea of two parallel systems influencing human thinking and decision-making are central in what has become known as dual-process theories (e.g. Chaiken & Trope 1999; Kahneman, 2003; Sloman, 1996; Stanovich & West, 2000). Dual process theory depicts human cognition as controlled by two separate systems, system 1 and system 2. These two systems operate separately and in parallel. System 1 is typically affective, intuitive, fast, and effortless. It relies on images and associations, linked by experience to emotion and affect. System 1 operates automatically and unconsciously, acts on things such as emotions, spontaneity and drives, and often utilizes mental shortcuts or heuristics. System 2 is slower, serial, effortful, systematic, and often conscious and controlled. System 2 monitors and controls the operation of system 1. The monitoring and controlling functions of System 2 relates to the quality of both mental operations and overt behavior. Likewise, analytical system 2 thinking cannot be effective unless it is guided by emotion and affect. Therefore, both system 1 and 2 seems to be dependent on each other for effective decision-making.

Decision-making style

Research on individual differences in decision-making style has identified several differences between individuals (Harren, 1979; Scott & Bruce, 1995; Thunholm, 2004). Differences in decision-making styles imply that different individuals may perceive the same objective decision problem in different ways, and react from their own experience. Thus, identical decision problems can result in different decisions for different individuals (Svenson, 1979).

Several definitions of decision-making style have been suggested. Harren (1979) defined decision-making style as: "…the individual's characteristic mode of perceiving and responding to decision-making tasks, or the manner in which the person goes about making decisions" (pp.124-125). Characteristics is defined by Harren as: "…relatively stable personality traits which determine the person's perception of the tasks and conditions and which influence the person's progress in the process" (pp. 120 and 122). Scott and Bruce (1995) defined decision-making style as: "…the learned, habitual response pattern exhibited by an individual when confronted with a decision situation. It is not a personality trait, but a habit-based propensity to react in a certain way in a specific decision-context" (pp. 820). Similar to Harren (1979), Thunholm (2004) argues that the decision-making styles are more than just a habit and conclude that decision-making styles should not only be viewed as a habit-based propensity but as a stable characteristic of the decision maker, since it is also dependent on basic and stable cognitive abilities. Thunholm defines decision-making style as: "The response pattern exhibited by an individual in a decision-making situation. This response pattern is determined by the decision-making situation, the decision-making task and by the individual decision maker. Individual differences between decision makers include differences in habits but also differences in basic cognitive abilities such as information processing, self-evaluation and self-regulation, which have a consistent impact on the response pattern across different decision-making tasks and situations" (pp. 941).

Harren (1979) defines three decision-making styles: Rational, intuitive and dependent. Scott and Bruce (1995) add two more styles and identify five different decision-making styles: rational, intuitive, dependent, avoidant and spontaneous. The rational decision-making style is characterized by a comprehensive search for information, and logical evaluation of alternatives. Prominent feature of the rational style is to make decisions in a logical and systematic way, and consider various options in terms of a specific goal. It also involves factors like planning important decisions carefully and double check information sources to be sure to have the right facts before making decisions (Thunholm, 2004). Non-expert people higher in rational decision-making style make decisions closer to the traditional normative linear models. In, addition they feel more positive about the process and make decisions more in line with their overall goals and values. Furthermore, they use less intuition (Galotti, 2007). Typical for the intuitive style is a tendency to rely on instincts, inner feelings and reactions. It is characterized by making decisions based on what feels right, rather than to have a rational reason for it. Attention is given to details in the flow of information, rather than systematic search for and processing of information. Intuitive decision-making is usually a strategy used by people with extensive experience in a given field or environment (Thunholm, 2004). Non-expert people higher in intuitive style make decisions more in line with their overall goals and values (Galotti, 2007). The dependent style is characterized by a search for guidance and support from other people when making important decisions. Typical for the dependent style is to rarely make important decisions without consulting other people, and to often use the advice of others in decision-making situations (Thunholm, 2004). Non-expert people higher in dependent decision-making style feel more negative about the process (Galotti, 2007). The avoidant style is characterized by a tendency to postpone decision-making whenever possible and to make last minute decisions. To avoid making important decisions until the pressure is on is typical for the avoidant style, possibly because thinking about them leads to feelings of uneasiness (Thunholm, 2004). Non-expert people higher in avoidant decision-making style consider fewer options and used fewer criteria when making important real life decisions. In addition, they tend to not consider their overall goals and values when making the decisions, and feel more negative feelings towards the decision-making process. Furthermore, people with an avoidant decision-making style do not make decisions in line with the traditional normative linear models (Galotti, 2007). Thunholm (2008) found that avoidant style was related to negative stress in military decision-making scenarios. The spontaneous style is characterized by feelings of immediacy and a desire to get through the decision-making process as quickly as possible. Quick and impulsive decisions are usually made, and the spontaneous decision-maker bases decisions on what seems natural at the moment. The spontaneous style could be seen as a kind of high-speed intuitive style, perhaps used in decision situations with time-pressure (Thunholm, 2004).

The five decision-making styles identified by Scott and Bruce (1995) are independent but not mutually exclusive, and even though one style is often dominant individuals seem to use a combination of styles when making important decisions (Scott & Bruce, 1995; Thunholm, 2004). Chermack and Nimon (2008) found that participants in a scenario planning training task changed their decision-making style from rational to intuitive in a before and after design. Scenario planning is a task that requires participants to utilize experience, a factor found to be relevant in intuitive decision-making.

Naturalistic decision-making (NDM)

Overview

Rational standards and models of traditional decision theories suggest that people generate probability and utility estimates for different options, and make a systematic comparison among alternatives when making decisions (Klein, 2008). Traditional decision theories, such as expected utility theory, have primarily focused on identifying optimal ways of making decisions, in well-structured and carefully controlled settings (Klein, 2008). This type of research studied people without specific experience, in laboratory settings, where the contextual factors play a limited role. Traditional rational theories has limited ability to explain how people react and make decisions in real-world settings, because they do not take into account the effects of contextual and situational factors and the adaptive characteristics of real-world behavior (Zsambok, 1997).

In reality people seem not to be rational from a mathematical decision theory perspective and not to make decisions according to normative decision models. Most decisions are made without a complete search for information (Svenson, 1979), and in situations involving uncertainty in terms of lack of information there is normally no plausible models of decision-making, which may lead to the use of intuitive judgment (Tversky & Kahnemann, 1983). Intuitive decisions have been proposed to be automatic, fast, and emotional and made without structured reasoning, calculations and analytical models (Kahnemann & Tversky, 1982).

Traditional decision research has invested most of its energy in only one part of decision-making, the decision event. In this view, the crucial part of decision-making occurs when the decision maker surveys a known and fixed set of alternatives, weighs the likely consequences of choosing each, and makes a choice. The decision maker evaluates the options in terms of a set of goals, purposes, or values that are stable over time, and that he or she knows quite clearly. Research on decision events tends to focus on the ways in which decision-makers pull together all available information into their choice of a best alternative (Orasanu & Connolly, 1995).

The field of naturalistic decision-making (NDM) developed as a reaction to traditional decision research and proposes that in real world decision-making people are not rational in a mathematical sense, and not utility maximizing. NDM research seeks to understand and describe how people actually make decisions in real-world environment, in contrast to how optimal decisions are made according to rational standards in laboratory settings (Zsambok, 1997).

NDM differs from traditional decision-making in several perspectives. For example, in NDM, the focus of the decision event is more front-loaded, so that decision-makers are more concerned about sizing up the situation and refreshing their situation awareness through feedback, rather than developing multiple options to compare to one another. Traditional decision-making research focuses on studying people in laboratories and therefore they do not take into account effects of most contextual factors that accompany decision-making in real world settings. In addition the traditional paradigm use inexperienced participants and therefore they do not account for the effect of expertise. NDM research studies how people are able to make tough decisions under difficult conditions such as uncertainty, time pressure, unstable conditions and high stakes (Orasanu & Connolly, 1995) and suggests that people use their experience when making situational judgments (Klein, 2008). A short definition of NDM: “NDM is the way people use their experience to make decisions in field settings” (Zsambok, 1997, pp. 4).

Orasanu and Connoly (1995) describe how NDM identifies a number of key contextual factors that affect the way real-world decision-making occurs such as: 1. Ill-structured problems, not artificial, well-structured problems. 2. Uncertain, dynamic environments, not static, simulated situations. 3. Shifting, ill-defined, or competing goals. Not clear and stable goals. 4. Action/feedback loops instead of one-shot decisions. 5. Time stress, as opposed to ample time for the task. 6. High stakes, not situations devoid of true consequences for the decision-maker. 7. Multiple players, as opposed to individual decision-making. 8. Organizational goals and norms influence decisions, as opposed to decision-making in vacuum. Taking the above factors in consideration a new and longer definition emerges: “The study of NDM asks how experienced people, working as individuals or groups in dynamic, uncertain, and often fast-paced environments, identify and assess their situation, make decisions and take actions whose consequences are meaningful to them and to the larger organization in which they operate” (Zsambok, 1997, pp. 5).

The processes and strategies used in naturalistic decision-making differs from those used in traditional decision-making, in the sense that in naturalistic decision-making people are more interested in understanding the situation and refresh the situation awareness, than developing several different options to compare (Zsambok, 1997). The decision-maker is generally not unfamiliar with the situation, and despite the fact that details in situations may differ, the decision maker normally has experience which can be used when evaluating the situation and making decisions (Thunholm, 2005). A sampling of the types of decision-makers studied in the domain of NDM includes fire fighters, cockpit crews, corporate executives, computer software designers, military commanders, and physicians (Flin, Strub, Salas & Martin, 1997; Zsambok, 1997). NDM is usually studied in operative environments, though field studies are not considered the only feasible methodology. Other methodologies can be used, if the factors present in real-world decision-making are replicated to the extent that participants consider the tasks almost as serious as in real life (Zsambok, 1997). In addition to looking at naturalistic task conditions, it is also important to understand how people use their knowledge and experience in coping with complex decision tasks. This does not necessarily mean that the decision makers are experts on decision-making, they are instead experts and highly knowledgeable within their specific domain. When the task requires problem-structuring, interpretation of ambiguous cues within the expert's domain, and reliance on underlying causal models, experts surpass novices who lack the knowledge base to guide their performance. Experience enables a person to seek information that will be helpful in coping with the situation, and to generate a limited set of plausible diagnoses, options, or hypotheses, rather than wasting precious time and energy on low-payoff leads (Orasanu & Connolly, 1995).

NDM is not a theory; rather it is a field of research where several models may be classified as NDM models. See Table 2 for an overview. Lipschitz (1993a) has identified six themes that are common to the NDM models seen in Table 2. The six themes, which represent the core of a naturalistic decision theory, are: 1. Diversity of form; the models suggest that real world decisions are made in a variety of ways. The diversity of form among these models indicates that they agree on the difficulty of trying to understand and improve real world decisions in terms of a single concept such as maximizing expected utility. 2. Situation assessment; making decisions in realistic settings is a process of constructing a mental picture of the situation at hand to understand what is going on. 3. Use of mental imagery; NDM models put less emphasize on calculative cognitive processes. Instead the NDM models emphasize different cognitive processes that are related to creating images of the situation. 4. Context dependence; context familiarity and the nature of the context determine decision strategy. 5. Dynamic processes; reject the notion that decisions are made as discrete isolated events. Decision makers switch between intuitive and analytic decision-making as a function of changing task requirements. 6. Description-based prescriptions; one cannot separate prescription from description. The development of description-based prescriptions begins by studying how experts make decisions in their areas of expertise and then developing methods for improving decision quality either by imitating these experts, or by designing decision support systems which are compatible with human information-processing.

Table 2

NDM models, author and summary of the basic concept.

Model	Author	Basic concept
Recognition primed decisions	Klein (1993, 1997)	People use their experience to identify situations
Recognition/ metacognition model	Cohen, Freeman & Thompson (1997)	Metacognitive skills supplement recognition
Situational assessment	Endsley (1997)	Pattern matching between critical cues in the environment and elements in a mental model
Explanation-based decisions	Pennington & Hastie (1993)	Three-stage process: constructing a causal model; organize available facts; create a set of potential solutions
Search for dominance structure	Montgomery (1993)	People search for the dominant alternative among a set
Image theory	Beach (1993)	Cognitive structures organizes values and principles, and guide peoples' decisions
The cognitive control of decision processes	Rasmussen (1986, 1993)	Behavior is controlled on three levels: skill, rule, and knowledge
Task characteristics human cognition	Hammond (1993)	Decisions processes and change as a function of changes in the task or environment
Decision cycles	Connolly & Wagner (1993)	Cyclical interplay between situation assessment, evaluation of alternatives, and action
Decision-making as argument-driven action	Lipshitz (1993b)	People visualize the future and plan accordingly.

Perhaps the most commonly known model within the NDM field is the Recognition Primed Decision (RPD)-model. The RPD-model describes how people can use their experience to make decisions. The model differs from traditional decision theory in the sense that it hypothesis that people can generate a good option as the first one considered, without comparing alternatives (Klein, 1993). The decision maker uses knowledge about the field and experience of similar situations to understand and make judgments about the current situation. The RPD-model fits in real-world settings where it is important to make rapid decisions, and there is not enough time to generate several options and evaluate strengths and weaknesses of these options in parallel (Klein, 1993). In these situations comparing options and evaluates their strengths and weaknesses do not lead to better decisions than the first one considered based on experience (Klein, 2008). Instead of comparing options, the decision maker strives to rapidly find the first possible alternative, and not necessarily the optimal one. Thus, the RPD-model hypothesizes that the decision maker is satisfying rather than optimizing (Klein, 1993).

The RPD-model consists of three levels, or functions: 1. Simple match. 2. Diagnose the situation, and 3. Evaluate a course of action. In the simple match case a decision-maker search for patterns that describes the most casual factors of the situation. The decision maker matches the patterns of the current situation to patterns learned from previous situations, and if a match is found a typical course of action can be carried out. Through the pattern matching a plausible option is generated. The decision-maker identifies a situation in a straightforward manner, meaning that the goals are obvious, the critical cues are being attended to, expectations about future states are formed, and a typical course of action is recognized. The decision-maker reacts accordingly and a course of action is implemented. Diagnose of the situation is initiated when the situation is more complex and ambiguous, and when no readymade solution can be found. Diagnosis is an attempt to link the observed events to causal factors, and is important since the nature of the situation can largely determine the course of action adopted. Often, decision makers spend more time assessing the situation; determine what is happening, and attempt to find explanations, rather than comparing different courses of actions. Two common diagnostic strategies are feature matching and story building. Feature matching consists of identifying the relevant features of a situation in order to categorize it. Story building involves mental simulation in order to find plausible causal explanations. Mental simulation can be used to project a course of action forward in time, and it can also be used to look backwards in time as a way of making sense of events and observations. Here, the decision-maker is trying to find the most plausible story, or sequence of events, to understand what is going on and to implement a course of action. Evaluate a course of action represents a more complex case when the decision maker has to evaluate a course of action by deliberate assessment utilizing a mental simulation to see if the course of action runs into any difficulties and whether these can be remedied, or whether a new course of action is needed. If it does work it will be implemented, and if it does not, it will be modified, until a satisfying one is found. The process of mental simulation is intended to result in situation awareness (Klein, 1993, 1997).

The function of the RPD model is to describe how people can use their experience to reach good decisions without comparing strengths and weaknesses of alternative courses of actions (Klein, 1997). The RPD-model contains both intuition and analysis, where the pattern matching is the intuitive part, and the mental simulation is the deliberate and analytic part (Klein, 2008). Evidence that the RPD-model may be applicable only on people with domain specific experience in a time constrained environment has been put forward by Galotti (2007), who found that non-experts making important real-life decisions, without time constraints rarely consider one option at the time.

NDM and aviation

Many decisions in the aviation domain are procedural in nature. Much thought have gone into developing checklists and procedures for situations that have occurred or can be expected to occur. Because these checklists prescribe the appropriate course of action for specified situations, in many cases the task of the decision-maker is not to generate and evaluate courses of action. It is to accurately assess the situation. Once the decision-maker recognizes the situation, the course of action becomes obvious. The source of information about this action may be previous experience, a procedure, or a checklist. Often, decisions made in the cockpit have potential serious consequences, and are made with ambiguous information, under great risk, and with very little time. It is known that a critical component of pilot proficiency is the ability to make good decisions and that decision skills can be trained. Decision training has become commonplace in the aviation industry, which have had a positive impact on pilot performance. Training programs are often based on the traditional paradigm of decision-making. NDM may offer a more attractive alternative for understanding how pilots make decisions and for designing interventions that will help them make these decisions (Kaempf & Orasanu, 1997). Many of the concepts and findings within the field of NDM research have been found to be considerably more useful as a basis for training aircrews than earlier normative notions of decision-making (Flin et. al, 1997).

Aeronautical decision-making (ADM)

Overview

Aeronautical decision-making, ADM, is both a research field and a topic for training. The primary objective of the field of ADM has been to improve pilots' decision-making performance through training. A second application of ADM is in the design and implementation of better information displays (Kaempf & Klein, 1994).

Through the history people have believed that good judgment and decision-making skills are learned by experience, and that pilots are motivated to always select the safest course of action. Of course pilots have always made decisions and therefore ADM is nothing new. However, the idea that decision-making skills could be trained was a new thought that emerged with the field of ADM (Kaempf & Klein, 1994; Robertson, 2004).

Aeronautical decision making, ADM, has been defined as: "…a systematic approach to the mental process used by aircraft pilots to consistently determine the best course of action in response to a given set of circumstances" (FAA, 1991, pp. ii). This definition includes both process and outcome. However it does not include the actual choice. Jensen (1982) offers another definition of ADM. Jensen define ADM in two parts. The first part describes the more cognitive part of ADM as: "…the ability to search for and establish the relevance of all available information regarding a situation, to specify alternative courses of action, and to determine expected outcomes from each alternative" (pp.64). The second part is on a behavioral level and describes ADM as: "…the motivation to choose and authoritatively execute a suitable course of action within the time frame permitted by the situation" (pp. 64). The cognitive part pictures the pilot as a rational and probabilistic human. The behavioral part describes the pilot as motivated to always choose the safest option.

ADM has traditionally borrowed the concept of the rational decision-maker from the normative judgment and decision-making (JDM) paradigm, where the decision-maker generates several alternatives, evaluates and weights probabilities and outcomes, and then choose the optimum alternative (Kaempf & Klein, 1994). Studies made with the rational and probabilistic decision-maker in mind have found that pilots sometimes consider multiple options and use decision strategies found in traditional JDM research (Orasanu, 1990). Pilots have been found to be risk averse when receiving information in a positive frame and risk seeking when receiving information in a negative frame (O'Hare & Smitheram, 1995), in accordance with the principles of prospect theory (Kaneman & Tversky, 1979). Heuristic processes have been found to highly influence peoples' judgment under uncertainty (e.g. Gilovich, Griffin & Kahneman, 2002). The heuristics and bias approach has been highly influential in research about judgment and decision-making. However, with a few exceptions (e.g. Raby & Wickens, 1994; Sulistyawati, Wickens & Ping Chui, 2011; Wickens & Flasch, 1988; Wiggins & Bollwerk, 2006), this has not been the case within ADM (O'Hare, 2003). Studies conducted with the pilot as a rational decision-maker in mind has shown that the judgment process of calculating a value or worth of an option is highly complex and the presence of interaction effects indicates that pilots use compensatory decision strategies in which levels on one attribute of an object can be traded off against levels of attributes for another object (Hunter, Martinussen & Wiggins, 2003; O'Hare, 2003). However, a compensatory strategy may not always be safe in aviation. Therefore, the aviation industry has established procedures that are non-compensatory and are supposed to inhibit actions that fall under certain criteria such as minimum descent altitudes. This simplifies a complex decision by reducing the cognitive effort required (O'Hare, 2003).

Pilots do not always follow the rules of the rational decision-maker (Kaempf & Klein, 1994). Instead, pilots tend to adapt decision-strategies according to the situation (Orasanu, 1993), which is in line with the idea of the adaptive decision-maker (Payne, Bettman & Johnson, 1993). According to Payne, Betman and Johnson people adapt their decision strategies according to the features of the decision situation based on a desire to trade off accuracy and cognitive effort. The use of simple heuristics might be perfectly satisfactory for resolving inconsequential decision problems, whereas complex, analytical strategies might be preferred for dealing major decisions that involve high levels of personal accountability.

Orasanu (1993) describe a taxonomy of decision types that consider how the nature of the process involved in a decision in the cockpit depends on the nature of the task and the context. The decision taxonomy is defined by two dimensions, cue clarity and response options available. Cues can be unambiguous or ambiguous, in which case additional effort is required in diagnosis. Response options can be divided into three categories, a single prescribed response, a choice from several response options, or no prescribed response. Examples of each of the six combinations of cue clarity X response options are shown in Table 3. These six types of decisions fall on a continuum ranging from simple to complex, requiring little cognitive work to considerable effort. The simplest situation (unambiguous cue/ single prescribed response) is on the upper left, with the most complex (ambiguous cues/no prescribed responses) on the lower right.

Table 3

Orasanu's (1993) taxonomy of decision types.

	Retrieve response	Select or schedule response	Create response
Clear cues	Simple Go/No-Go	Choice	Procedural management
Ambiguous cues	Condition-action	Scheduling	Creative problem solving

The NDM approach emphasizes the ability of knowledgeable experts to retrieve ready-made solutions to problems from memory (Zsambok, 1997). Similarly, the bias and heuristic tradition (Tversky & Kahneman, 1974) describe how people associate cues in the environment with memories. In terms of Orasanu's (1993) taxonomy, experience in a domain should have the effect of increasing clarity of the critical cues and strengthening the association between critical cues and prepared responses in memory. The effect is to simplify the decision task by moving away from the lower right of the matrix in Table 3 towards the upper left.

O'Hare (1992, 2003) outlines a model for ADM where goal setting is central with reciprocal connections to the processes of situational awareness and planning. Linking these two is a process of risk assessment. The risk associated with the current goal is continually assessed. If the level of risk rises or appears to be becoming unacceptable, the decision-maker determines how much time is available to generate new goals. Actions will then be dependent on time available. Thus the two key dimensions in ADM is the amount of risk associated with the decision and, second, the time available to make the decision. Jensen (1995) describes a similar model describing eight processes involved in ADM: problem vigilance, problem recognition, problem diagnosis, alternative identification, risk assessment, motivation, decision, and action.

The models described by O'Hare (1992, 2003) and Orasanu (1993) both suggest that it will be easier to continue with an existing course of action than to change to a new one, as this requires continual monitoring, planning, and risk assessment. As such, the models predict that errors due to continuing on with an unprofitable course of action will be more prevalent than errors due to prematurely switching to other courses of action.

One of the most widely known approaches to pilot decision-making, particularly in the field of general aviation, GA, has involved an analysis of the underlying attitudinal bases of decisions (O'Hare, 2003). Hazardous attitudes, or thought patterns, have been proposed as a reason to why pilots not always follow the rules of good decision making (Kaempf & Klein, 1994; Wetmore & Lu, 2006). The five attitudes can be described as follows: 1. Anti-authority. This attitude is found among people who do not like to be told what to do. This includes being obliged by persons, rules or procedures. 2. External control. People believe that events and outcomes are unrelated to their own behavior and that what is happening is driven by factors such as fate, chance, or someone else's actions. 3. Impulsivity. Impulsivity is found among people who do the first thing that comes to their mind without careful thought to various alternatives. 4. Invulnerability. Accidents happen to other people. Feelings of invulnerability may also lead to taking chances and increased exposure to risk. 5. Macho. Found in pilots who continually try to prove themselves better than others and takes risks to impress others. These pilots also tend to be overconfident.

Pilots receiving training to avoid hazardous thought patterns have been found to make better judgments (Buch & Diehl, 1984). However, research on the psychometric properties of the hazardous attitude scales has shown limited validity with high intercorrelations between the five scales. Furthermore, no relationship has been found between impulsivity and other impulsivity measures found in standard personality questionnaires (O'Hare, 2003). In addition, no relationship has been found between hazardous attitudes and accident involvement (Lester & Bombaci, 1984; O'Hare, 2003; Platenius & Wilde, 1989).

Previous research in various domains has found that individual differences in decision-making style are related to behavior (e.g. Harren, 1979; Scott & Bruce, 1995; Thunholm, 2004). In the aviation domain, Lubner, Hunter, and Struening (2001) have developed self-report measures of decision-making styles (DMS) and risk profile (the PIRIP). The measures have been found to have sound psychometric properties, and to be related to involvement in occurrences.

Several studies of expert-novice differences have been reported in aviation. Expert pilots seem to utilize a long-term memory strategy based on the identification of situational relevant cues. Their performance appears to be more resistant to stress effects. They are more likely to generate an appropriate action as the first alternative considered than are novices. Furthermore, experts decide more quickly, require less information, and are more confident in their decisions. (Bellenkes, Wickens & Kramer, 1997; Schvaneveldt, Beringer & Lamonica, 2001; Stokes, Kemper & Kite, 1997; Wiggins & O'Hare, 1995). The key differences between expert and the merely competent, are to be found in the domain of cognitive (e.g. attention management, judgment, and decision-making), rather than stick-and-rudder skills. Most competent pilots possess the necessary skills to control the maneuver an aircraft, but fewer reliably exhibit the cognitive qualities outlined (Jensen, Chubb, Adrion-Kochan, Kirkbride & Fisher, 1995). Expertise contributes to rapid situation assessment, retrieval of workable solutions, and guidance based on past experience. However, expertise does not hinder crews from making poor decisions. Expertise may lead to rigid expectations, biases, overconfidence, and greater risk taking (Orasanu, 1993). Jensen (1997) defines five main components of expertise in aeronautical decision-making: experience, risk management, dynamic problem solving, crew resource management, and attention control.

The overall conclusion to be drawn from studies regarding expertise in aviation is that expertise is related to specific experience with a task rather than overall global experience in terms of total flight time (O'Hare, 2003). This is consistent with the emphasis in NDM on domain specific experience rather than with general characteristics or problem-solving skills.

Previously discussed topics, within ADM, focus on purely internal shortcomings, either in character or in information processing, that might lead to inadequate decision-making. Other work in the decision-making literature such as that on adaptive decision-making (Payne et al. 1993) or NDM (Zsambok, 1997) has emphasized the interrelationship between decision-maker and the context of the decision.

It has been a movement in the field of aviation safety away from individualistic explanations of human performance towards more complex sociotechnical theories that consider different levels within a system. The combination of work context and individual performance defines the possible outcomes. The organizational view emphasizes the organizational constraints that determine what is possible in a given situation. The individual decision-making process consists of deciding whether there is an accepted procedure for the situation and then deciding whether, and how, to follow that procedure (Reason, 1997).

According to Orasanu (1993), good decisions in the cockpit support effective task performance. Factors contributing to good cockpit decision-making include: 1. Situation awareness. Crews are identifying developing situations by being attentive to cues in the environment. 2. Planfulness. Crews work out plans and strategies for reaching their goals, prepare for contingencies, figure out what information they need, and evaluate their progress. 3. Shared mental models. Crews communicate efficiently to create a shared big picture. Through shared mental models crews utilize all available resources, make sure that they are all solving the same problem, and assure coordination. Good decision-making in the cockpit includes cognitive economy since the context is often constrained by time limits. Traditional normative decision models do not always fit well in the cockpit since the nature of the environment is different from the laboratory such that the cockpit environment is dynamic, reactive, action oriented, and time-pressured. Furthermore, cockpit decisions are heuristic, based on expert knowledge and experience that work most of the time. Cockpit decisions are often shortcuts that reduce mental workload and yield decisions that are good enough rather than optimal.

Both naturalistic studies of real-world decision-making and controlled experimentation can be useful in developing and refining the theoretical basis of decision-making (6Cialdini, Cacioppio, Bassett & Miller, 1978). Furthermore, most pilots do not act only as individuals. They are part of a flight crew. Thus ADM must take the social context into consideration (Kaempf & Klein, 1994). Crew decisions are managed decisions. They are made by individuals but with support from others. Crews may perform both better and worse than individuals (Orasanu, 1993). Research on group decision-making has found that individuals do as well, or better than groups on tasks for which there is a best or right answer, or those for which an effective strategy will lead to a good answer. However, teams often perform better in situations where the solution depends on contributions from multiple sources and where coordination is required (Brown, 2000). One attempt to improve decision-making skills is through mnemonic techniques. A number of decision-making acronyms have been developed (e.g. Hörman, 1995; Murray, 1997). The aim of these techniques is to foster a systematic approach to decision-making that should be less affected by the heuristics and biases described earlier. However, with a few exceptions (see Li & Harris, 2001) these methods suffer from a lack of empirical validation. Furthermore, previous research has shown that slow, analytical decision-making is a characteristic of novice, rather than expert, decision-makers (O'Hare, 1993; Wiggins & O'Hare, 1995). Therefore, the applicability of mnemonic techniques in the aviation domain is questionable (O'Hare, 2003).

NOTECHS

In addition to technical skills and knowledge, non-technical skills like cognitive and social abilities, are essential for effective and safe flight operations. Pilots are trained to use systematic, analytic and normatively correct non-technical skills in cockpit decision-making situations through courses in Crew Resource Management (CRM). CRM training has been found to successfully transfer desired behavior to the flight deck (Salas, Burke, Bowers & Wilson, 2001). To assess pilots' non-technical skills the NOTECHS system was developed (Flin et al. 2005). The European Joint Aviation Authorities (JAA) initiated the NOTECHS system project. The project had two design requirements. First, the system was to be used to assess the skills of an individual pilot, rather than a crew. Second, it had to be suitable for use across Europe, by both large and small operators. The development process consisted of three phases. First, a review of existing systems was performed to identify common features and themes. Second, a literature search for research identifying relevant aspects of the existing systems was performed. Finally, extended discussions with subject experts were performed. A set of design principles was established to guide the final choice of components. First, the basic categories and elements should be formulated with the maximum possible mutual exclusivity. Second, the system should be parsimonious, that is containing the minimum number of categories and elements possible. Third, the terminology used should reflect everyday language. Lastly, the skills listed at the behavioral level should be directly observable or inferred from communication. The final NOTECHS system consists of four categories: Co-operation, Leadership and Management Skills, Situation Awareness, and Decision-Making. Each category consists of elements with associated example behaviors. The latter are examples of effective and ineffective behaviors. The primary focus of the present thesis is on the decision-making category. Decision-making is defined by Flin et al. as: "The process of reaching a judgment or choosing an option" (pp.145). Pilots make different types of decisions at different times. Therefore, pilots' decision making typically do not involve just one strategy. Instead various cognitive processes are called upon depending on the situation. The elements and related behavioral markers of the NOTECHS decision-making category can be seen in Table 4, and described as follows. *Problem definition and diagnosis*: gathering information and determining the nature of the situation, and considering alternative explanations for observed conditions. *Option generation*: formulating alternative approaches to dealing with the situation. The opportunity for this will depend on available time and information. *Risk assessment and option selection*: making a judgment or evaluation of the level of risk/hazard in the alternative approaches and choosing a preferred approach. *Outcome review*: considering the effectiveness/suitability of the selected option against the current plan, once the course of action has been implemented.

As decision-making is a cognitive process it has to be inferred from behavior and communication, since it is not directly observable. A five-point scale was selected for ratings on both the category and element levels. The five-point scale consisted of: *very good*, *good*, *acceptable*, *poor*, and *very poor.* As a final stage in the project a test of the system was performed as an experimental study utilizing video scenarios filmed in a flight simulator with pilots as actors. Experienced flight instructors rated the video scenarios according to the NOTECHS rating system. The system was found to have good internal consistency, inter rater agreement, and user acceptability (Flin et al., 2005). This has been replicated in other research (O'Connor, Hörmann, Flin, Lodge & Goeters, 2002). Subsequent operational trials with airlines have been performed confirming the applicability and feasibility of the system and the NOTECHS system has been adopted, and customized by several airlines (Flin et al.).

Table 4

Elements and behavioral markers of the decision-making category (Flin et al., 2005).

Element	Good practice	Poor practice
Problem definition and diagnosis	Gathers information to identify problem	Nature of problem not stated or failure to diagnose
	Reviews casual factors with other crew members	No discussion of probable causes
Option generation	States alternative options	Does not search for information
	Asks crew members for options	Does not ask crew f for alternatives
Risk assessment and option selection	Considers and shares estimated risks of alternative options	Inadequate discussion of limiting factors with crew
	Talks about possible risks for action in terms of crew limits	No consideration of limiting factors
	Confirms and states selected option/agreed action	Does not inform crew of decision path being taken
Outcome review	Checks outcome against plan	Fails to check selected outcome against goal

Even though the NOTECHS system was primarily intended as an evaluation tool of individual pilots, and not a research tool, it can still be used for research purposes (Flin et al., 2005). The NOTECHS system has been used in practice to evaluate the impact of CRM (crew resource management) training on pilots' non-technical skills (Goeters, 2004), and error management (Thomas, 2004).

Summary of empirical studies

Overview

The overall aim of the present thesis was to explore pilots' judgment and decision-making. More precisely why do pilots sometimes decide to violate rules, or standard operating procedures? There might be many reasons for violating a procedure;

therefore a broad approach was taken in the present thesis. As a common theme in the four empirical studies is the idea that to understand why people sometimes decide to violate procedures it is necessary to take both an individual and systemic viewpoint, and to acknowledge that these viewpoints may interact. To do this it is argued that it might be fruitful to look at all stages of decision-making: the process leading up to the final choice, the actual choice, and finally the outcome and consequences.

The system approach argue that the reasons behind peoples' unsafe acts and causes of accidents cannot be found only by studying the individual events or behaviors leading to an event that in hindsight was inevitable. Instead one must take a holistic standpoint and look at the system as a whole (Leveson, 2011; Pew & Mavor, 2007; Sheridan, 2008). To understand why humans behaved as they did, as a given event unfolded, one must first take an inside perspective from the operators point of view (Dekker et al., 2011). To understand why a certain behavior made sense and was perfectly logical and safe for the operator at the time, given the psychological, operational, environmental, and organizational constraints present one has to look at both external and internal factors influencing the individual (Leveson, 2011; Pew & Mavor, 2007). A proposed framework for aeronautical decision-making in context can be seen in Figure 7.

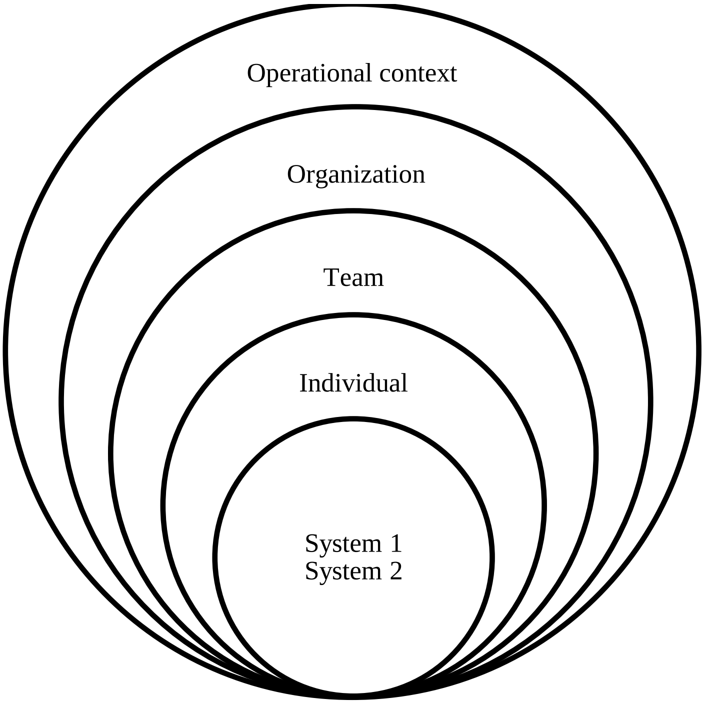

Figure 7. A proposed framework for aeronautical decision-making in context.

An airline organization is operating in an operational context including factors such as societal norms and values, national culture, and geographic characteristics. Society and national culture have been found to influence people working in organizations (Hofstede, 1980, 1991). This has also been found among pilots (Helmreich et al., 2001). In addition, national culture has been found to influence risk perception (Douglas & Wildavsky, 1982; Kim & Park, 2010). However, since national culture and the larger operational context are outside the scope of the present dissertation, this will not be elaborated further here.

At an organizational level people are influenced by the organizational culture (Cooper & Phillips, 2004; Garavan & O'Brien, 2001; Johnson, 2007; Keren et al., 2009; Reason, 1993; Zohar, 1980). In addition, pilots are influenced by their professional culture as pilots. Positive aspects of pilots' professional include factors such as; pride in their profession, and strong commitment and liking for their job. On the negative side, unrealistic self-perception of invulnerability can be found (Helmreich & Merritt, 1998; Helmreich et al., 2001).

At the team level it can be said that people in complex systems such as aviation, rarely operate solely as individuals. Pilots are part of a crew that forms a team. Therefore, the social context must be taken into consideration (Kaempf & Klein, 1994; Orasanu, 1993). Pilots' performance in teams has been specifically addressed and found to be influenced both positively and negatively (Orasanu, 1993; Merket, Bergondy & Salas, 1999; Sasou & Reason, 1999).

At the individual level, differences in decision-making style, has been observed (Harren, 1979; Scott & Bruce, 1995; Thunholm, 2004). Differences in decision-making styles imply that different individuals may perceive the same objective decision problem in different ways, and react from their own experience. Thus, identical decision problems can result in different decisions for different individuals (Svenson, 1979). In addition to technical skills and knowledge, non-technical skills like cognitive and social abilities, are essential for effective and safe flight operations. To assess pilots' non-technical skills the NOTECHS system was developed (Flin et al., 2005). Furthermore, it has been argued that risk perception mediate risky behavior (Haisly et al., 2010; Sitkin & Pablo, 1992; Sitkin & Weingart, 1995). Therefore, decision-making style, non-technical skills, and risk perception might be influential in pilots' performance.

In the core of the framework it can now be seen that the cognitive and affective processes have been replaced with the terms system 1 and 2, a dual-process theory. The underlying idea with such a dual-process theory is that two parallel systems influence human thinking and decision-making. Dual-process theory depicts human cognition as controlled by two separate systems, system 1 and system 2. These two systems operate separately and in parallel. System 1 is typically affective, intuitive, fast, effortless, and associative. System 1 operates automatically and unconsciously, acts on things such as emotions, spontaneity and drives, and often utilizes mental shortcuts or heuristics. System 2 is slower, serial, effortful, systematic, and often conscious and controlled. System 2 monitors and controls the operation of system 1. The monitoring and controlling functions of System 2 relates to the quality of both mental operations and overt behavior (e.g. Chaiken & Trope 1999; Kahneman, 2003; Sloman, 1996, 2001; Stanovich & West, 2000).

A particular situation to study was chosen as a starting point in the present thesis: the unstabilized approach situation. One of the reasons for this choice was that this situation to a large degree resembles the gamble paradigm of traditional judgment and decision-making research where people typically make choices between two alternatives. Four empirical studies were performed. In Study I and II, cognitive and affective processes were studied in experimental designs. One idea that was pursued was the possibility that pilots underestimate the risk, or underweight the probability for a rare event. Underweighting of small probabilities when making decisions based on experience is a topic that is currently under discussion among scientists within the traditional judgment and decision-making field. This is largely due to that this underweighting is contrary to what Kahneman and Tversky's (1979) Prospect Theory prescribes. One further idea that was explored was the possible role of affect in decision-making. In Study I, a replication of previous research using non-pilots as subjects was carried out. In addition to previous research affect was added. This was to closer mimic decisions in real life that often have some degree of affective consequence attached to the outcome, especially in situations with possible serious consequences. In Study II, underweighting was again investigated, this time by using car drivers and professional airline pilots as subjects. In Study I, some support was found for the roles of underweighting, and affect. However, no support was found in Study II. In Study III and IV, focus was shifted away from probability weighting towards other possible reasons for violating. In Study III, affect was still a theme and other possible reasons for violating procedures were added, such as organizational, social, and individual factors. These variables were created based on previous research, comments from experienced pilots and my own personal experience as an airline pilot, and aimed at capturing both individual and organizational factors. In Study IV focused turned towards individual differences in decision-making style, non-technical skills, and overconfidence as possible antecedents to violations. Example quotations from the studies that express pilots' views about the stabilized concept can be seen in Table 5.

Table 5

Quotations from pilots

- *"Runway 22L is a long runway and even slightly wet, stopping is no problem"*
- *"The risk for not performing a missed approach is very low if having just a few knots too high speed at 1000 ft."*
- *"More risk with a missed approach then continue"*
- *"I use my experience to take the decision to land or not"*
- *"I would judge if we will be stabilized at 500 ft., if yes I would continue"*
- *"The criteria for stabilized approach do not account for rwy length/conditions, wx conditions at the airport or crew experience"*
- *"The mandatory G/A should be 500 ft. for both VMC and IMC"*
- *"It depends partly on whether the condition will be logged in the system or not"*
- *"A missed approach is not normal for us as pilots. We will try to avoid it not only because it means increased workload for us but also that we will lose face in front of our peers"*
- *"I am a first officer, and as long as the commander has not called for a missed approach my option would have been to continue"*
- *"At this time I cannot come up with a good explanation on why we violated the Stabilized approach criteria. There is most likely an element of complacency, and also possibly an element of 'misunderstood' loyalty between colleagues preventing the call: Not stabilized, GO Around"*
- *"Provided that landing flaps have been set at this point, I would never go around from 1000 ft."*

Study I

The aim of Study I was to find out if people that make decisions based on their experience, which is common in naturalistic settings, tend to underweight rare events (Hertwig et al. 2004). In addition, one more aim was to study if and how peoples weighting tendencies were influenced by affect (Hsee & Rottenstreich, 2004; Rottenstreich & Hsee, 2001). The main purpose of Study I was to replicate and extend previous research on probability weighting among a sample from the general population. More specifically, the purpose of Study I was to extend previous research on the description-experience gap by controlling for biased sampling, recency, and presentation format. In addition, the affect-richness of the judged alternatives was varied. Furthermore, ratings of subjective experience of risk, and how difficult it was to judge the probability was also investigated.

In Study I (n = 176) participants chose between a sure or uncertain loss, either after reading a description of probabilities (decision from description, DFD) or after experiencing the probability distribution (decision from experience, DFE). The DFE condition utilized a sampling procedure. Participants were randomly assigned to either one out of two conditions. The conditions were either affect-poor (money) or affect-rich (saving pandas). Ratings of affect, subjective experience of risk, and how difficult it was to judge the probability was also investigated.

In a sampling procedure Ungemach et al. (2009) let participants sample 40 outcomes from each option where the frequencies of outcomes precisely matched the underlying probabilities. In Study I a variation of this paradigm was used by letting the participants sample 10, 20 or 30 times from each option. An attempt to control for recency effects was made by counterbalancing where in the sequence the rare event occurs (early, middle, late). To eliminate the problem of different presentations formats in previous studies (percentages for DFD versus frequencies for DFE), frequencies were used in both presentation modes.

An attempt to manipulate and measure affect (Rottenstreich & Hsee, 2001) was made. Affect was measured as the intensity of good-bad feelings to an object. Interestingly, previous research on affect and probability weighting has used a description paradigm (Rottenstreich & Hsee, 2001; Hsee & Rottenstreich, 2004), therefore Study I extended previous research to include an experience paradigm. McGraw, Shafir and Todorov (2010) found that when nonmonetary outcomes were converted to their corresponding monetary value the choice pattern was again similar to what is found for monetary affect poor outcomes. To allow mapping of probabilities to outcomes and to extend the study by McGraw et al. (2010) a nonmonetary, affect rich outcomes that were numeric but not converted into a monetary value was used.

Since probability weighting is not directly observable it was inferred from choice. The options to choose between were all in the negative, loss domain with similar but not equal expected value. We expected that people would underweight rare events when making decisions based on experience, compared to when they made decisions based on description, according to Hertwig et al. (2004). Therefore, compared to people in the DFD condition, people in the DFE condition were expected to underweight the small probability of a loss rendering the following hypothesis:

Hypothesis 1: People in the DFE condition will choose the option with the rare event more often compared to people in the DFD condition.

In the DFD affect-rich condition it was expected that people would overweight rare events more compared to the affect-poor conditions in accordance with Rottenstreich and Hsee (2001). Furthermore, if affect has an amplifying effect on the weighting function it was expected that people in the DFE affect rich condition would underweight small probabilities even more than in the corresponding affect poor condition. Therefore, an interaction between DFD versus DFE and affect rich versus affect poor was expected rendering the following two hypothesizes:

Hypothesis 2: People in the DFD affect rich condition will choose the rare event less often compared to the corresponding affect poor condition.

Hypothesis 3: People in the DFE affect-rich condition will choose the rare event more often compared to the corresponding affect poor condition.

In addition, Hsee and Rottenstreich (2004) found that people showed scope insensitivity for affect-rich objects and scope sensitivity for affect-poor objects rendering the following hypothesizes:

Hypothesis 4: People in the affect rich condition will rate their affective reaction to the stimuli equally regardless of magnitude of the stimuli.

Hypothesis 5: People in the affect poor condition will rate a small magnitude of the stimuli to be less affective compared to a large magnitude.

As expected, participants in the affect-poor condition overweighted rare events by description and underweighted when experiencing, replicating Hertwig et al. (2004). However, this was only found in one of the sampling conditions, 20 draws. In the affect-rich condition no difference between experience and description was found. Overall, the affect rich condition produced more random choices compared to the affect poor condition. Differences in ratings of affect were also found. In general, pandas elicited more affect than money. In addition, as expected and consistent with previous research (Hsee & Rottenstreich, 2004; Slovic, 2007), participants showed scope insensitivity for pandas and scope sensitivity for money. However, no significant effect of subjective experience of risk or probability judgment difficulty was found, which is in line with previous research (Yang, Coble & Hudson, 2009).

Study II

Previous research in laboratory settings has found evidence for the description-experience gap (e.g. Hertwig & Pleskac, 2010; Hau et al., 2010; Hau et al., 2008; Rakow et al., 2008; Ungemach et al., 2009). Evidence has also been found in naturalistic settings (Yechiam, Erev, & Barron, 2006). In addition, affect has been found to influence decision weights (Rottenstreich & Hsee, 2001). The main purpose of Study II was to extend Study I on the description-experience gap by applying the paradigm in a naturalistic setting. Like in Study I, the affect-richness of the judged alternatives was varied, and a measure of perceived risk was included.

To apply the description-experience decision-making paradigm to naturalistic settings two environments were chosen, driver behavior and aviation. The paradigm was examined in three experiments. Experiment 1 used a web based scenario design to investigate peoples' choice to exceed the law-enforced speed limit on a rural road. Experiment 2 and 3 used airline pilots as participants. Experiment 2 took place as a part of an airline's mandatory training in a Boeing 737 full motion flight simulator. The flight crews were put in a situation where they were forced to make a choice between two alternatives, either to violate or comply with the standard operating procedure. Experiment 3 utilized a web based scenario design. Again, pilots were forced to make a choice between violating and complying with the standard operating procedure.

To examine the prediction that affect-richness would cause people to overweight rare events more than affect-poorness, Study II, like Study I, attempted to manipulate and measure affect (Rottenstreich & Hsee, 2001), and measure perceived risk (Haisly et al., 2010; Sitkin & Pablo, 1992; Sitkin & Weingart, 1995).

One purpose of Study II was to extend Study I by including a new sampling paradigm, sampling from own experience, that is decisions made without any form of probability manipulation. Therefore, one aim of Study II was to explore the relation between affect and, sampling from description, experience and, own experience in terms of both choice certainty and subjective risk ratings. In Study II, decisions from description was referred to as DFD, decisions from experience was referred to as DFE1, and decisions from own experience was referred to as DFE2. All conditions were either affect rich or affect poor. Instead of the dichotomous choice used in Study I, experiment 1 and 3 in Study II used a continuous scale were participants were asked to make a choice, and at the same time rate how certain they were about their choice. This scale was developed in order to capture that choices are often more than a clear and simple choice between two alternatives.

Experiment 1. Participants (n = 139) with a driving license were recruited from a general population sample and randomly assigned experimental conditions. Each participant chose between two alternatives, either after reading a description of probabilities, or after experiencing the probability distribution, or after no description or experience. The conditions were either affect-poor or affect-rich. The experiment was set up using a scenario based web survey. The scenario described a driving situation were the participants were late to an important meeting. After the scenario participants were asked to make choice between two alternatives, either to comply with the current speed limit or to violate and increase the speed. Participants in the affect rich condition were shown a picture of a car accident before making a choice. Participants in the description, DFD, condition received explicit information about the probability for an incident or accident in connection with the two alternatives. In addition to the DFD condition two experience conditions were set up, DFE 1 and DFE 2. The scenario and description of the two alternatives were identical to the DFD condition. However, no explicit information about probabilities was given in the DFE conditions. In the DFE 1 condition the participants had to experience the probability of the outcomes by clicking through pages each showing a possible outcome. As in the DFD condition the DFE 1 condition was either affect rich or affect poor. In the DFE 2 condition participants received neither description nor experience sampling. Instead participants were expected to make a risk judgment based on their personal experience. As in the DFD condition, the two DFE conditions were either affect rich or affect poor.

Hypotheses. We expected that people would underweight rare events when making decisions based on experience, compared to when they made decisions based on description, according to Hertwig et al. (2004). Therefore, compared to people in the

DFD condition, people in the DFE1 condition were expected to underweight the small probability of an accident rendering the following hypothesis:

Hypothesis 1: People in the DFE1 condition will be surer about their choice in the direction of violating compared with people in the DFD condition.

In the DFD affect-rich condition it was expected that people would overweight rare events more compared to the affect-poor condition in accordance with Rottenstreich and Hsee (2001). Furthermore, if affect has an amplifying effect on the weighting function it was expected that people in the DFE1 affect rich condition would underweight small probabilities even more than in the corresponding affect poor condition. Therefore, an interaction between DFD versus DFE1 and affect rich versus affect poor was expected rendering the following two hypothesizes:

Hypothesis 2: People in the DFD affect rich condition will be surer of their choice in direction of complying compared with the corresponding affect poor condition.

Hypothesis 3: People in the DFE1 affect-rich conditions will be surer of their choice in direction of violating compared with the corresponding affect poor condition.

The result showed that the number of participants that would choose to violate the speed limit was 101. The number choosing to comply was 38. However, no effects of probability information or affect, on peoples' decision-making or subjective probability ratings were found.

Experiment 2. Experiment 1 used a scenario involving a traffic situation with expectedly nonprofessional participants. In order to extend experiment 1 a second experiment was set up using highly skilled experts in an aviation domain as participants. A total of 48 commercial aviation pilots participated. The experiment took place as a part of an airline's mandatory training in a Boeing 737 full motion flight simulator. The flight crews were put in a situation where they were forced to make a choice between two alternatives, either perform a missed approach or continue the approach to land. The situation was one in which the crews found the approach to be unstabilized. The correct action in this situation according to the standard operating procedure is to abort the approach.

Before the simulator session, half of the participating crews received explicit information about the probability for an incident after an unstabilized approach. Therefore, they were assumed to make a decision based on description, the DFD condition. Half of the crews did not receive any specific probability information and hence assumed to make a decision based on experience, the DFE condition.

The main aim of experiment 2 was to find out if participants would choose to comply or violate the standard operating procedure, depending on probability information. Additional aims were to explore possible differences in subjective probability ratings and probability awareness between violators and compliers and, between the conditions, DFD and DFE in a naturalistic setting.

Hypothesis: *Participants receiving explicit probability information will overestimate the risk for an incident and be more likely to perform a missed approach compared with participants in the DFE condition.*

The simulator instructors noted if participants had chosen to violate or comply with the procedure. After the simulator session, participants were asked to complete a questionnaire with a set of questions and statements meant to capture subjective probability and probability awareness. Probability awareness refers to what degree participants thought of probabilities when making the decision to either comply or violate the standard operating procedure.

The result showed that, out of the 48 participants, 8 chose to violate and 40 chose to comply with the procedure. The hypothesis stated that participants receiving explicit probability information would overestimate the risk and be more likely to perform a missed approach. However, this was not found. Additional aims were to explore possible differences in subjective probability ratings and probability awareness between violators and compliers and, between the conditions, DFD and DFE. However, no significant result was found.

Experiment 3. To extend experiment 2 and add affect a third experiment was set up using a scenario based web survey, and airline pilots as participants (n = 193). The study was based on a scenario familiar to the participants and it described a decision situation where an unstabilized approach occurs and the mandatory action according to the standard operating procedure is to perform a missed approach. Before reading the scenario half of the participants read a description of the probability for an incident in connection with landing after an unstabilized approach. Therefore, they were assumed to make a decision based on description, the DFD condition. Half of the crews did not receive any specific probability information and hence assumed to make a decision based on experience, the DFE condition. In addition, half of the participants were presented with a picture of an aircraft accident before making their choice. This was to induce affect and an affect manipulation check was included. Furthermore, in experiment 2, participants made a dichotomous choice between two alternatives. Experiment 3 extended this by also asking participants to rate how certain they were about their choice at the same time as they were making the choice.

Hypotheses. We expected that people would underweight rare events when making decisions based on experience, compared to when they make decisions based on description, according to Hertwig et al. (2004). Therefore, compared with people in the DFD condition, people in the DFE condition were expected to underweight the small probability of an accident rendering the following hypothesis:

Hypothesis 1: People in the DFE condition will be surer about their choice in the direction of violating compared with people in the DFD condition.

In the DFD affect-rich condition it was expected that people would overweight rare events more compared to the affect-poor condition in accordance with Rottenstreich and Hsee (2001). Furthermore, if affect has an amplifying effect on the weighting function it was expected that people in the DFE affect rich condition would underweight small probabilities even more than in the corresponding affect poor condition. Therefore, an interaction between DFD versus DFE and affect rich versus affect poor was expected rendering the following two hypothesizes:

Hypothesis 2: People in the DFD affect rich condition will be surer of their choice in direction of complying compared with the corresponding affect poor condition.

Hypothesis 3: People in the DFE affect-rich conditions will be surer of their choice in direction of violating compared with the corresponding affect poor condition.

As in experiment 2, additional aims of experiment 3 were to explore possible differences in subjective probability ratings and probability awareness between violators and compliers depending on probability presentation. In addition, a measure of affect was included. Like in experiment 1, participants were given the choice between two alternatives and at the same time they were asked to rate how certain they were about their choice.

The result showed that, out of 193 participants, the number of violators was 124 and compliers 69. Hypothesis 1 stated that people in the DFE condition would be surer about their choice in the direction of violating compared with people in the DFD condition. Hypothesis 2 stated that people in the DFD affect rich condition would be surer of their choice in direction of complying compared with the corresponding affect poor condition. Finally, hypothesis 3 stated that people in the DFE affect-rich conditions would be surer of their choice in direction of violating compared with the corresponding affect poor condition. However, no significant result was found. Furthermore, no significant effect on subjective probability ratings was found either.

Study III

Study II did not show any significant result for underweighting of probabilities as a possible reason for violating the stabilized approach procedure. The aim of study III was therefore to explore other possible reasons why pilots violate the stabilized approach procedure. Specifically, why do people not perform a missed approach when the approach is not stabilized?

Data for Study III was collected in connection with Study II, during two experiments. A full motion flight simulator was used in experiment 1 while a scenario based web survey was used in experiment 2. After the simulator session, participants were asked to complete a questionnaire. First, the participants were asked to judge the risk for an incident if continuing to land or performing a missed approach. An eleven-step scale was used. Next, the participants were asked to answer a questionnaire with statements. The scales used in the questionnaire were meant to tap the following dimensions: regret, probability use, situation recognition, use of experience, decision difficulty, feelings of psychological pressure, decision stress, decision support and willingness to land. In addition a set of questions were asked meant to capture various attitude and personal dimensions such as attitudes about the strictness of the stabilized approach criteria, importance for flight safety and if the criteria are difficult to follow. Personal and organizational dimensions were captured with questions about if it is a personal failure to be unstabilized, pressure from company management, thoughts about consequences in terms of fuel costs in case of a missed approach or missed flight schedules.

Experiment 1. Data from 48 pilots acting as pilot flying were used. The number of violators was 8 and compliers 40. The result from the statistical analysis showed that compared to compliers, violators used less experience based decision-making, felt more pressure to land and felt less support from their colleague in the decision process. In addition, the statistical analysis showed a relationship to actual behavior indicating that pilots that felt pressure to land and felt less support from their colleague were more likely to violate.

Experiment 2. Experiment 1 had a limited number of participants. In addition the number of violators did not match what was expected from real life statistics (Directorate Generale of Civil Aviation, 2008). Therefore experiment 2 was set up using a scenario based web survey. Participants were 193 commercial aviation pilots that read a scenario describing a decision situation where an unstabilized approach occurs. After reading the scenario, participants were asked to make a choice and at the same time rate how certain they were about their choice. Next the participants were asked to complete the same questionnaire used in experiment 1 except for one item found to be almost identical as another item.

The number of violators was 124 and compliers 69. The result from the statistical analysis showed that compared to compliers, violators rated the risk for an incident if continuing the approach to be lower, used more experience based decision-making and, felt less stress. Furthermore, violators believe that the rule is too strict and less important for flight safety compared to compliers. However, further statistical analyses showed that these attitude measures were not related to actual behavior of procedure violation. Instead, lower experienced risk if continuing to land, more experience based decision-making, feeling less stress and a need to land, were related to actual behavior. In addition, the statistical analysis showed that violators judged the risk if continuing to land to be lower compared to compliers. Furthermore, compliers rated the probability for an incident if continuing to land to be higher than if performing a missed approach. However, no significant difference was found between subjective probability rating if continuing to land and performing a missed approach among violators.

Study IV

The result of Study III showed that a number of both personal and organizational factors influence pilots' decision to violate the stabilized approach procedure. Study IV extended Study III by including individual differences in non-technical skills and general decision-making style. Individual differences in non-technical skills were measured with the NOTECHS system (Flin et al., 2005), and general decision-making styles were measured with the GDMS inventory (Scott & Bruce, 1995). One aim of Study IV was to examine the NOTECHS system and the possible relationship to GDMS and to overt behavior in the form of procedure violations. An additional aim of Study IV was to explore a new concept, overconfidence regarding own non-technical skills and the relation to procedure violation.

Previous research used ratings at the element and category levels of the NOTECHS system only (O'Connor et al., 2002; Thomas, 2004). Study IV extended previous research by using ratings of the individual example behaviors of the NOTECHS elements. One reason for this was that this was the normal procedure at the airline where the study was conducted. The second reason was that extracting data from a lower level would allow a more detailed analysis. Data for Study IV was collected in connection with Study II and III, during two experiments. A full motion flight simulator was used in experiment 1 while a scenario based web survey was used in experiment 2.

Experiment 1. The instructors rated participants' (n = 48) non-technical skills during the simulator session in experiment 1. The following example behavior from the

NOTECHS decision making category were selected: reviews causal factors with other crew member, asks crew members to develop options, considers and shares risks of alternative course of action and checks outcome against plan. The reason for choosing these four example behaviors was that they were the ones used by the airline where the study was conducted. NOTECHS were judged on a five-step scale describing to what degree the participant fulfilled the criteria. After the simulator session, participants were asked to complete the General Decision-Making Style inventory (Scott & Bruce, 1995) measuring each of the general decision-making styles: Rational, Intuitive, Dependent, Avoidant and Spontaneous.

The statistical analysis showed that the rational decision-making style is most dominant among pilots. However, no relation between NOTECHS and GDMS was found. The number of violators was 8 and compliers 40. To investigate possible differences between violators and compliers regarding NOTECHS and, GDMS, a statistical test were performed that showed that compared to violators, compliers asked crew member to develop options to a larger extent, and have a more rational decision-making style. Further statistical analyses, aiming at testing the relation between NOTECHS, GDMS, and actual behavior, showed that pilots that were more prone to ask the colleague to develop options were more likely to comply with the procedure.

Experiment 2. Experiment 1 had a limited number of participants. In addition the number of violators did not match what was expected from real life statistics (Directorate Generale of Civil Aviation, 2008). Therefore experiment 2 was set up using a scenario based web survey. The aims of experiment 2 remained the same as of experiment 1: to evaluate the NOTECHS and the GDMS scales and, to examine the possible relationship between NOTECHS, GDMS, and procedure violations. An additional aim was to explore the possible effect of confidence levels, regarding subjective NOTECHS, on choice.

After reading the description of the scenario participants (n = 193) made a choice and at the same time rated how sure they were about their choice. Next, participants were asked to complete the same questionnaire used in experiment 1 regarding GDMS. Two self-rating scales replaced the objective rating of NOTECHS used in experiment 1. Subjective non-technical skills were measured with a self-rating scale with eight items based on the example behaviors of the decision-making category of the NOTECHS-system. The participants were asked to consider statements regarding their own decision-making at work as a pilot. In addition, the same items and answering alternatives were used to capture how the participants would like to be as decision-makers. The participants were asked to assess how well the statements describe how they would like to act in a decision situation in the cockpit.

As in experiment 1, the statistical analysis showed that pilots mainly have a rational decision-making style. Furthermore, all NOTECHS items were related to all decision-making styles. The total number of violators was 124 and compliers 69. Additional statistical analyses showed that compared to compliers, violators gather information to identify problems to higher extent and, have a more spontaneous decision-making style. Furthermore, the analysis showed that participants that gather information to identify problems to higher extent, talk less about possible risks for action and, have a more spontaneous decision-making style were more certain about their choice to violate.

The differences between how pilots rated actual NOTECHS and how they would like to behave regarding NOTECHS were analyzed. As a first step the actual behavior measure was subtracted from the “would like” measure. The result showed that participants would in general like to be better on all NOTECHS items than they actually are. To further analyze the data the actual behavior scores for each individual on each NOTECHS item were subtracted from the “would like” score. The resulting number was taken as an indirect measure of confidence about own non-technical skills. A positive number represented being underconfident, zero meant being well calibrated and, a negative number being overconfident. Participants were found to have different confidence levels and were grouped accordingly. The result from a statistical analysis showed that participants that were overconfident regarding their ability to gather information to identify problems were more prone to violate compared to underconfident participants. The result also showed that participants with a more rational decision-making style were more likely to be overconfident regarding their ability to gather information and review causal factors (one of the NOTEHS items). In addition, more avoidant decision-making style meant that participants were more likely to be underconfident in their ability to confirm and state selected option (one of the NOTEHS items).

Discussion

Interpretation of the results

In Study I, a replication of previous research on probability weighting was carried out. Some support was found for the description-experience gap. However, the gap only occurred in the affect-poor condition when participants sampled 20 times in the experience condition. The reason that it was only found when making 20 draws and not 10 or 30, may be that the gap is not a stable effect and that it is dependent on the interaction between the properties of the underlying probability (small, large, certain, uncertain) and the number of draws. In studies replicating decision problems and sampling method mixed results have been found. Sometimes the description-experience gap exists and sometimes it does not for the same decision problem and sampling method (Hau et al., 2010; Hau et al. 2008; Hertwig et al., 2004; Hertwig & Pleskac, 2010; Rakow et al., 2008; Ungemach et al., 2009). Furthermore, in Study I, the affect rich condition produced more random choices compared to the affect poor condition. The more random pattern of choices in the affect-rich condition is not easy to explain. However, one possible explanation is that people in this condition, since it was framed in negative terms, focused on the negative consequences and was therefore confronted with a negative emotion laden decision involving a difficult tradeoff (Luce, Bettman & Payne, 1997; Schneider, 1992). People therefore likely made a “random” choice between two alternatives considered equally bad, hence explaining the 50/50 choice pattern.

The main purposes of Study I were to extend previous research on how people weight probabilities depending on presentation mode, described or experienced, and to include affect. A number of factors previously found to account for the description-experience gap were taken into consideration, such as recency, biased sampling, size of the distribution and probability presentation format. However, this did not totally eliminate the gap. Overall, the result of Study I show that the description-experience gap might still exist and that affect cannot be ignored.

In Study II, underweighting was again investigated, this time by using car drivers and professional airline pilots as subjects. However, no effects of probability information or affect on peoples' decision-making or subjective probability ratings were found. One explanation for the lack of significant results in Study II is that people do not utilize probabilities when making decisions in naturalistic settings (Huber et al., 2001; Huber & Huber, 2003; Huber et al., 1997; Jeske & Werner, 2008; March & Shapira, 1987; Tyszka & Zaleskiewicz, 2006). Instead people might be more concerned with the magnitude of the outcomes when making decisions in naturalistic settings (Tyszka & Zaleskiewicz, 2006). Participants had to retrieve probability information from memory when making the actual decision, a process that may have failed (Slovic, 1972). It might also be that the contexts in the present experiments were not rich enough, and some of the probabilities might have been too small to be meaningful (Slovic, Fischhoff & Lichtenstein, 1978; Stone, Yates & Parker, 1994; Weinstein, Kolb & Goldstein, 1996). The probability information may not have come to mind because the actual decision situation was stressful and dispersed in time from the actual presentation of the probability (Hsee, 1996; Hsee, Loewenstein, Blount & Bazerman, 1999: Kunreuther, Novemsky & Kahneman, 2001). Furthermore, both car drivers and pilots in the present study may have felt in control, and found themselves to be competent and knowledgeable within their respective area of operation and therefore they tended to disregard probabilities (Camerer & Weber, 1992; Heath & Tversky, 1991; Ranyard & Charlton, 2006). It is also possible that the probability information given was not salient enough to be utilized (Rottenstreich & Kivetz, 2006), and that the content domains of the present study did not facilitate probabilistic approaches (Rettinger & Hastie, 2001). In addition, affect did not have any effect on decision-making or risk perception. It might be so that the pictures used to evoke affect did not activate the certain affective reactions necessary to affect risk perception (Kobbeltved, Brun, Johnsen & Eid, 2005; Rundmo, 2002), or that affect may not have an influence on decision weights (McGraw et al., 2010). When people make decisions in naturalistic settings they may not use decision strategies that involve the use of probabilities or affect. Instead people may rely on more simple heuristics, experience or other factors in the environment (Cokely & Kelley, 2009).

In Study III, focus was shifted away from probability weighting towards other possible reasons for violating. Study III aimed at investigating various variables that possibly could affect the decision to violate. The result showed differences between violators and compliers in terms of subjective risk judgment, attitudes and, reasons for violation. Compared to compliers, violators rated the risk for an incident if continuing the approach to land to be lower. However, caution must be taken when making conclusions about causality since the ratings were made after the decision was taken. Therefore participants may have search for support for the prior decision (Svensson, 2003; Svensson, Salo & Lindholm, 2009). Furthermore, violators felt less stress, felt a strong need to land, felt pressure to land, and felt less support from their colleague when they made their decision. Cockpit decision-making is a teamwork were active involvement of the colleague is encouraged (Flin et al., 2005). Crew decisions are managed decisions. They are made by individuals but with support from others. Crews may perform both better and worse than individuals (Orasanu, 1993). The result of Study III that violators felt a strong need to land, felt pressure to land, and felt less support from their colleague when they made their decision suggests that a supportive climate in the cockpit may be beneficial for good decision-making.

Furthermore, violators believe that the procedure criteria are too strict and less important for flight safety compared to compliers. However, there was no relation between these attitude measures and overt behavior. The relation between attitudes and overt behavior has generally been found to be weak. The relation strengthens somewhat if the mediating effect of the concept of intention is taken into consideration (Eagly & Chaiken, 1993). However, evidence for the idea about intentionality as antecedent to violations in an aviation environment has been found to be week (Busby & Bennett, 2008). Furthermore, the lack of relation between attitudes and overt behavior in Study III may partly be contributed to the use of explicit measurement of attitudes (Eagly & Chaiken, 1993). More implicit measures have been found to predict pilot behavior better than explicit measures (Molesworth & Chang, 2009).

No direct relation between choice and measures related to productivity was found in Study III. The reason for this might be that it has been found that very little emphasize is put on productivity during the information acquisition in a decision-making task (Keren et al., 2009). However, violators stated that they felt pressure to land, which may stem from organizational pressure. This is only a speculation however, since it is not possible to determine the cause of this pressure in the present study. It might stem from internal, social or organizational sources.

Two experiments were carried out in Study III. Experiment 1 showed that compliers used more experience-based decision-making. Experiment 2 showed the opposite. One reason for this might be that the situations in the two experiments were not identical. When the majority decision was compared to the minority decision across the studies regardless whether the decision was to violate or to comply it was found that the majority used more experience-based decision-making. Experience has been found to be an important factor in pilots' decision-making (Byrne & Kirlik, 2005; Klein, 2008; O'Hare & Wiggins, 2004; Orasanu & Connolly, 1995; Schriver et al., 2008; Wiggins & Bollwerk, 2006; Wiggins & O'Hare, 1995), and one possibility is that pilots, even though they are trained to use rational and normatively correct decision-making (Flin et al., 2005), revert to experienced based decision-making when the situation calls for it. Pilots adapt their decision-making strategy according to the situation (Payne et al., 1993). It is important to understand how people use their knowledge and experience in coping with complex decision tasks. The recognition primed decision model (the RPD-model) fits in naturalistic settings where it is important to make rapid decisions, and there is not enough time to generate several options and evaluate strengths and weaknesses of these options in parallel (Klein, 1997). In these situations comparing options and evaluating their strengths and weaknesses do not lead to better decisions than the first one considered based on experience (Klein, 2008). Instead of comparing options, the decision maker strives to rapidly find the first possible alternative, and not necessarily the optimal one. Thus, the RPD-model hypothesizes that the decision maker is satisfying rather than optimizing (Klein, 1993). Similarly, Gigerenzer and Goldstein (1996) stress the recognition principle when people make fast decisions, which they describe in their fast and frugal heuristic. People either recognize cues in the environment or they do not. If cues are recognized, people choose the alternative with the best cues. Fast and frugal heuristic often outperforms traditional normative rational decision-making models (Gigerenzer et al., 2002; Gigerenzer & Goldstein, 1996). The result from Study III that participants tended to use their experience, in addition with the result that they were not consciously thinking about probabilities when making the decision, supports the naturalistic view.

Study IV turned the focus more towards individual differences in decision-making style, non-technical skills, and overconfidence as possible antecedents to violations. The result showed that pilots have a predominantly rational decision-making style. This was expected since pilots are trained and evaluated according to rational and normative criteria (Flin et al., 2005). Furthermore, there was a relation between decision-making style and procedure violation/compliance where violators are less rational and more spontaneous compared to compliers. In relation to subjective NOTECHS ratings, positive correlations were found to rational, intuitive, and dependent decision-making styles, and negative correlations with avoidant and spontaneous styles. The NOTECHS system should reflect systematic, analytic and normatively correct decision-making (Flin et al.). The NOTECHS system may therefore be seen as a model reflecting rational decision-making, and a positive correlation between the NOTECHS items and the rational decision-making style and a negative correlation to the other styles were expected. However, no significant correlations were found between objective NOTECHS ratings and decision-making style in experiment 1 of Study IV. In experiment 2 of Study IV a positive correlation were found between rational decision-making style and all of the subjective NOTECHS ratings. In addition, a negative correlation with avoidant and spontaneous style were found. However, contrary to the expectation, a positive correlation was found between subjective NOTECHS items, and intuitive and dependent style, respectively. One explanation might be that the NOTECHS system does not reflect a totally systematic and analytic approach to pilots' decision-making. However, the NOTECHS system might still be reflecting normatively correct decision-making acknowledging that intuition is not necessarily bad since intuition as decision-making style may be related to organizational effectiveness (Andersen, 2000). The reason for the positive correlation between NOTECHS and dependent style might reflect the dependent nature of the work environment in an aircraft cockpit since cockpit decision-making is a teamwork were active involvement of the colleague is encouraged (Flin et al.). Therefore a certain degree of dependence might be expected. Likewise, when rated objectively on the NOTECHS scale, as in experiment 1, compliers asked crewmember to develop options to a larger extent than violators. This might also be a reflection of that effective teamwork by including the colleague in the decision-making process might enhance decision performance (Flin et al.).

One somewhat surprising finding in the present study was that some individuals showed something that can be characterized as overconfidence in their own non-technical skills. In addition, this was related to procedure violation and rational decision-making style. Pilots have been found to be more overconfident in their own ability compared to the general population (Stewart, 2008). Pilots with high self-confidence, believing they are very competent, judged situations to be less risky than other pilots and were also willing to accept greater risk as part of a flight (Hunter, 2005). Overconfidence in personal skill and judgment ability are related to risk taking among pilots (Goh & Wiegmann, 2001).

To summarize the result of Study IV; it is assumed that the NOTECHS system should reflect systematic, analytic and normatively correct decision-making (Flin et al., 2005). However, the result indicate that this is not always the case. None of the objective measures of NOTECHS correlated with rationality as measured with the decision-making style inventory (Scott & Bruce, 1995). In addition, not all of the subjective NOTECHS items correlated with the decision-making styles in the expected direction. Also, the subjective rating on one of the NOTECHS items and overconfidence in ability about the same item were related to procedure violation. Taken together, the result from Study IV showed that there might be reason to further develop the NOTECHS system.

Conclusions

Three major categories of safety violations may be distinguished: routine, optimizing and situational violations. In each case, the decision not to abide by safe operating procedures is shaped by both organizational and individual factors. Routine violations typically involve corner cutting, taking the path of least effort. Eventually, these short cuts can become a habitual part of the person's behavioral repertoire (Reason et al., 1998). In addition, it may be easier to continue with an existing course of action than to change to a new one, as this requires continual monitoring, planning, and risk assessment (O'Hare, 1992, 2003; Orasanu, 1995). Optimizing violations reflect the fact that human actions serve a variety of goals, and that some of these are quite unrelated to the functional aspect of the task. Optimizing violations may be a result of divergent goals of the individual and the organization. Situational violations have their primary origins in particular work situations. Here, non-compliance is seen as essential in order to get the job done (Reason et al., 1998). The result from the present thesis suggests that the decision to violate the stabilized approach concept may be seen as routine, optimizing, and situational violations. Reason (1993) further distinguishes two additional types of violations: exceptional violations, which are one-off violations mostly dictated by unusual circumstances, and sabotage, were the individual intends both the deviation and a bad outcome. However, violating the stabilized approach procedure are rarely exceptional or the result of sabotage.

Reason (1990) argues that errors and violations are mediated by different cognitive mechanisms. Reason (1993) therefore suggests that the actions necessary to combat errors and violations are different. Reason (1993) states that errors arise as a result of information processing problems, violations have a motivational basis. Errors may be understood in relation to a cognitive function, and may be minimized by retraining, redesign of the workplace and memory aids. Violations are a social phenomenon and can only be understood in an organizational context. Violations must be dealt with by changing attitudes, beliefs and norms and by improving morale and the safety culture. The result from the present thesis suggests that violations are indeed a social phenomenon. However, contrary to Reason, it is argued here that violations may also stem from cognitive and affective processes. For example, differences between compliers and violators in terms of subjective risk perception may be a result of a cognitive, analytical system 2 process. Furthermore, even though the explicit affect manipulations failed it may be argued that affective processes might still be involved. Inferring indirect affective influence, since differences were found between compliers and violators in terms of stress, feelings of a need to land, pressure to land, and use of experience can make such an argument. These effects may stem from a less analytical and more affective system 1 process. This, together with the other results from the present thesis makes it reasonable to argue that violations can only be understood in a contextual, organizational, social, individual, and cognitive/affective perspective.

The finding that violators had a more spontaneous decision-making style may be related to the concept of intentionality in the human error literature (Reason, 1990;

Serale, 1980). One distinction can be made between behavior with "prior intentions" and "intentions without prior intentions". The latter may still be intentional actions in the sense that there is an intention in the action in itself. Intentional actions without prior intention can be either spontaneous or subsidiary actions. Spontaneous actions are when the intention resides only in the action itself, the action and the intention is inseparable. Subsidiary actions involve well-practiced action sequences were only the overall action is specified in the prior intention such as "I will drive to the office". We are then not likely to specify a prior intention of every single action on the way (Searle, 1980). Since the action of violating a procedure may be either spontaneous or subsidiary, the action may be more likely among individuals with a spontaneous decision-making style. Furthermore, assuming that most pilots do not have a prior intention to violate the stabilized approach procedure but that there is intention in action it follows from the previous reasoning that this particular violation must be involuntary, spontaneous or subsidiary. However, this reasoning is not compatible with the definition of violations as intentional and errors as unintentional (Reason, 1990). Reason defines intentional violations as: "Deliberate – but not necessarily reprehensible – deviations from those practices deemed necessary (by designers, managers, and regulatory agencies) to maintain the safe operation of a potential hazardous system" (pp. 195). While it may certainly be true that some violations are intentional, it cannot be assumed that all violations are necessarily intentional. Therefore, the distinction between violations and errors is not as clear as one might first think. However, numerous definitions of a violation exist in the literature, and if a more parsimonious definition is used it will be less problematic, such the definition offered by Alper and Karsh (2009): "…an action that is contrary to a rule" (pp. 740). However, this definition may be too general. In addition, the relation between intentions and actual behavior is modest (Eagly & Chaiken, 1993) making it possible to argue that the role of intention in violations is also modest, although intentionality was not directly tested in the present thesis. Therefore, an alternative definition is proposed: "A violation is an action, not necessarily intentional, that deviates from those practices deemed necessary (by designers, managers, and regulatory agencies) to maintain the safe operation of a potential hazardous system, taking contextual, organizational, social, and individual factors into consideration".

Limitations

The present thesis attempted to transfer a relatively robust finding from laboratory experiments, the description-experience gap (e.g. Hau et al., 2008; Hertwig et al., 2004), into a more naturalistic environment. In addition, affect was introduced to closer mimic decisions with real consequences. Even though some support was found for the gap, and the role of affect, in the laboratory setting of Study I, this did not transfer to a more naturalistic setting. This does not mean that the gap or affective influence do not exist outside the laboratory. Instead it might have been that the probability and affect stimuli were too week and not salient enough in the naturalistic settings. Future research should attempt to increase the salience of these stimuli.

In Study I the description-experience gap was only found in one of the conditions. One explanation might be that the design of the experience and affect-rich conditions were quite complex. Although pilot studies were performed in the development process to assure that it was possible to understand the instructions and perform the experiment adequately, the possibility that it might have been difficult to understand what to do for some individuals cannot be excluded. If an individual do not clearly understand how to answer it is reasonable to think that they answer randomly, thus explaining the limited result in Study I. The study was performed over the Internet. This gave limited possibilities to answer questions from participants. Even though an email address was provided if they had any questions it is not the same as asking a question directly and getting immediate feedback. Future research should therefore consider a setting allowing an instructor to be present to answer questions.

In experiment 2 of Study II, the simulator study, participants were presented with a probability just before the simulator session. However, since the session was a mandatory training, the experiment was only one part embedded in a set of other activities. Therefore, the probability information had to be retrieved from memory in an environment with a lot of other stressful activities, a process that might have failed. Future research should therefore consider performing a similar experiment in isolation. This was not possible in the present research due to high costs and limited availability of full motion airliner simulators.

The set of probabilities used in Study I and II were also limited. Future research should consider expanding the probability information by including more variations. In addition, the probability used with the pilots of Study II might have been too small to be effective. This probability was much smaller than what is found in traditional experiments. However, this was a tradeoff judged to be necessary to keep the experiment reasonably realistic. Future research should try to establish exactly when a probability becomes too small.

The affect manipulation in Study II was not successful. The pictures used to induce affect did not cause any affective reaction, as measured in the affect manipulation check. This might help explain the lack of result for the affect-rich conditions. Future research should consider either a more affective stimuli or a better affect manipulation check.

In Study III it was found that violators rated the risk for an incident if continuing the approach to land to be lower, compared to compliers. However, a limitation to this result is that the ratings were only performed after the decision was taken. It can therefore not be excluded that participants tried to justify their decision in hindsight. Future research should therefore apply a counterbalancing strategy.

The simulator study used to collect data for Study II, III and IV had a limited number of participants. Future research should include more participants. However, professional participants, such as airline pilots, that are available to study in their natural working environment are not easily found. Therefore, data from a small sample can still be valuable considering the limited availability of participants.

The number of situations used in the experiments was limited. The car-driving situation in Study II was only one out of many possible. The situations used for the simulator and scenario experiments with airline pilots were also only examples of what might be in real life. It cannot be excluded that other environments and situational factors might alter the results, in any direction. Factors such as road conditions, different speed limits, and reasons for being late might play a role in drivers' behavior. Likewise, factors such as different airports, weather and airport conditions, and aircraft types and performance capabilities may also influence pilots' behavior. Future research should try to vary the contextual factors.

This thesis involved a limited number of rule violation situations, the speeding and stabilized approach situations. The generalizability of the result to other rules and procedures may therefore be limited. Rule violations have been found to be selective such that different rules may be followed and different rules may be violated at different times. Furthermore, different organizations and individuals may violate different rules (Lehman & Ramanujam, 2009). However, in aviation it has been found that the stabilized approach concept is violated universally across organizations (Directorate Generale of Civil Aviation, 2008). The results from the present thesis showed that the rule was violated sometimes and sometimes it was not. Further research is needed to determine under what circumstances the rule is violated. In addition, future research should focus on varying the rules and procedures under investigation.

The experimental manipulations in the naturalistic settings (Study II, III, and IV) were not successful which means that no causal links may be drawn. The significant results that were found in these settings were all correlational making it impossible to make causal inferences. This, however, does not necessarily make the findings uninteresting. Instead the result may inspire future research and work as a resource when designing future experiments.

Some statistical limitations may also be found. From a strict statistical point of view it is reasonable to argue that the familywise error rate was not adequately controlled for in some of the studies. For example, many *t*-tests, regression analyses, and ANOVAs might have rendered a significant result by chance alone. Instead it might have been more appropriate to use some overall test, such as MANOVA in some cases. However, especially in Study III and IV where the purpose was exploratory and not strict hypothesis testing, it is argued that a strict statistical testing approach would have been too conservative. Especially since the results might be of practical importance. Instead, the results of the present thesis may be seen as an inspiration for future research to set up experiments with the purpose of strict hypothesis testing.

Considering that some interesting findings were made despite these limitations it might be reasonable to conclude that the use of simulated environments and scenarios are fruitful methods to apply when attempting to bridge the gap between internal and ecological validity.

Applications

Simply providing and enforcing prescriptive rules and procedures are not sufficient to foster safe behavior in the workplace (Reason et al., 1998). The results from the present thesis and other research (Thomas, 2004) suggest that pilots sometimes violate standard operating procedures. In order for an organization to achieve correct compliance it needs to encourage behavior that satisfies the goals of both the organization and the individual and the interaction between these goals (Reason et al., 1998). To create rule-compliance management needs to acknowledge that procedures are always a work in progress that needs to be actively managed by being sensitive to workers inputs (Hopkins, 2011). The present thesis contributes to previous research by further identify both individual and organizational factors that are related to violations. When people make decisions in naturalistic settings they may not use decision strategies that involve the use of probabilities. Instead people may rely on more simple heuristics, experience or other factors in the environment. The results of the present thesis showed that there were differences between violators of standard operating procedures and compliers in terms of risk perception, psychological pressure, attitudes, social support, decision-making style, and overconfidence. In order to further improve safety, an organization may benefit from emphasizing areas such as safety climate, norms, and risk awareness. An organization needs to create a safety climate that fosters norms allowing pilots to feel less pressure to land, and as the qualitative data suggest, prevent loss of face feelings. Risk awareness should be targeted in order for pilots to have a realistic picture of the risks involved with certain behaviors. Furthermore, both the qualitative and quantitative data suggests that violators believe that the criteria for a stabilized approach are too strict and less important for flight safety compared to compliers. However, these attitude measures were poor predictors of actual behavior. Attitudes may be a necessary, but not sufficient, concept to work with when creating a safe system. However, since attitudes might not be sufficient, it is necessary to take a broader approach to violations. The content of procedures and/or training together with feedback from the operators should be examined to learn from violations. Rule violations are not necessarily a bad thing. Sometimes rule violations might lead to a better outcome compared to following the rules (Dekker, 2003a). Organizations can learn from violations if they trigger a search for new ways of organizing activities (Desai, 2010). In addition, individuals need to ask themselves how to be a more supportive colleague in order to facilitate decision-making. Not all items in the NOTECHS system were positively related to a desirable behavior, assuming that procedure compliance is desirable. Therefore, there might be reason to further develop the NOTECHS system to determine what constitutes desirable behavior and how it should be measured. Finally, organizations need to acknowledge that pilots are not always rational even if they are trained to be rational. Instead they convert to experience based decision-making when the situation calls for it, which gives further support for the use of realistic simulator training already in use in the aviation industry (Skybrary, 2010b).

Final remarks

Research within the field of human error and violations has made a major contribution to the understanding, and knowledge of reasons for violating procedures by highlighting that these reasons may stem from both organizational and individual sources. The field of JDM has contributed with insight in how cognitive and affective processes affect decision-making. Finally, the field of NDM has contributed with the knowledge that decisions are made in a variety of ways. Making decisions in realistic settings is a process of constructing a mental picture of the situation at hand to understand what is going on. The models put less emphasize on calculative cognitive processes. Context familiarity and the nature of the context determine decision strategy. Decisions are not made as discrete isolated events. Instead decision makers switch between intuitive and analytic decision-making as a function of changing task requirements. The results from the present thesis have showed that it might be fruitful to consider themes and ideas from all three fields when trying to understand decision-making in an aviation context.

In the present thesis an attempt was made to look at procedure violations from both a holistic systems perspective and a from the individual operators point of view. The conclusion to be made is that both system and individual factors interact to determine pilots’ behavior. The system cannot be separated from its parts, the internal processes of the individuals. At the same time, to just analyze the individual processes without taking the context into consideration is not satisfying. The different parts of Figure 8 are interacting to create the whole. The challenge for the future is to determine exactly how a resilient system can be created in practice, and to show that all the measures that are taken produce actual safety and resilience. For this, behavioral changes could be measured in a before and after training design were both safe and unsafe acts are analyzed in either simulated environments or scenarios. Understanding of how the different parts in Figure 8 are interacting might be a key factor when attempting to create, not only a safe system, but also to take safety a step further and create a resilient system.

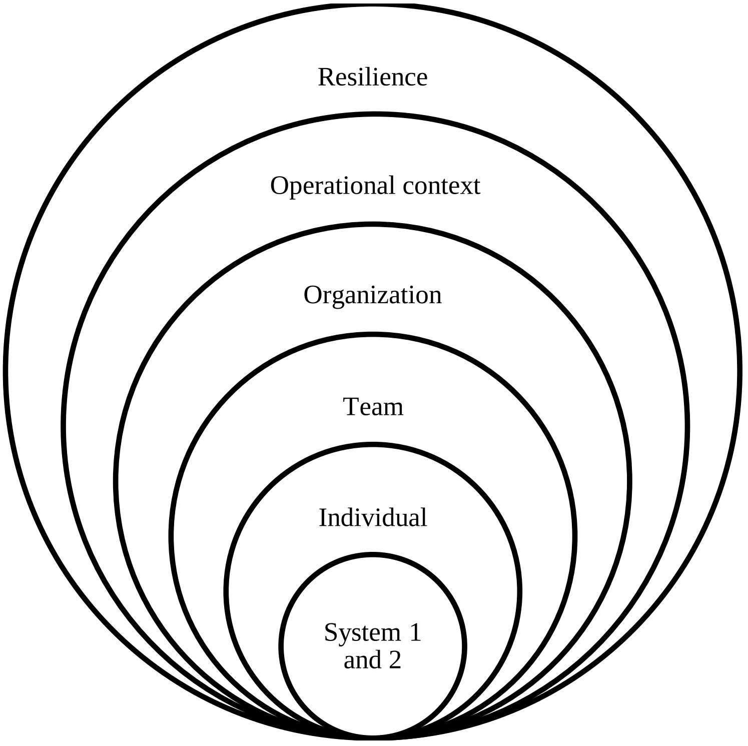

Figure 8. A framework for operational resilience in aviation organizations.

References

Aarts, L., & van Schagen, I. (2006). Driving speed and the risk of road crashes: A review. *Accident Analysis and Prevention, 38*, 215-224. doi:10.1016/j.aap.2005.07.004

Alper, S. J., & Karsh, B-T. (2009). A systematic review of safety violations in industry. *Accident Analysis and Prevention, 41*, 739-754. doi:10.1016/j.aap.2009.03.013

Amalberti, R. (2001). The paradoxes of almost totally safe transportation systems. *Safety Science, 37*, 109-126.

Andersen, J. A. (2000). Intuition in managers: are intuitive managers more effective? *Journal of Managerial Psychology, 15*, 46-67.

Atak, A. & Kingma, S. (2011). Safety culture in an aircraft maintenance organization: A view from the inside. *Safety Science, 49*, 268-278. doi:10.1016/j.ssci.2010.08.007

Ayuso, M., Guillén, M., & Alcañiz, M. (2010). The impact of traffic violations on the estimated cost of traffic accidents with victims. *Accident Analysis and Prevention, 42*, 709-717. doi:10.1016/j.aap.2009.10.020

Baker, D. P., & Krokos, K. J. (2007). Development and validation of aviation causal contributors for error reporting systems (ACCERS). *Human Factors, 49*, 185-199. doi:10.1518/001872007X312432

Barling, J., Loughlin, C., & Kelloway, E. K. (2002). Development and test of a model linking safety-specific transformational leadership and occupational safety. *Journal of Applied Psychology, 87*, 488-496. doi:10.1037//0021-9010.87.3.488

Beach, L. R. (1993). Image theory: personal and organizational decisions. In G. Klein, J. Orasanu, R. Calderwood & C. E. Zsambok, (Eds.), *Decision making in action: Models and methods* (pp. 148-157). Norwood, New Jersey: Ablex.

Begg, D., & Langley, J. (2001). Changes in risky driving behaviour from age 21 to 26 years. *Journal of Safety Research, 32*, 491-499.

Bellenkes, A. H., Wickens, C. D. & Kramer, A. F. (1997). Visual scanning and pilot expertise: The role of attentional flexibility and mental model development. *Aviation, Space, and Environmental Medicine, 68,* 569-579.

Block, E. E., Sabin, E. J., & Patankar, M. S. (2007). The structure of safety climate for accident free flight crews. *International Journal of Applied Aviation Studies, 7*, 46-59.

Brown, R. (2000). *Group Processes. Dynamics within and between groups.* Malden, MA: Blackwell Publishing.

Buch, G., & Diehl, A. (1984). An investigation of the effectiveness of pilot judgment training. *Human Factors, 26*, 557-564.

Busby, J. S., & Bennett, S. A. (2008). Analysing the risk of individual and collective intentionality. *Journal of Risk Research, 11*, 797-819. doi:10.1080/13669870802056896

Byrne, M. D., & Kirlik, A. (2005). Using computational cognitive modeling to diagnose possible sources of aviation error. *The International Journal of Aviation Psychology,15*, 135-155. doi:10.1207/s15327108ijap1502_2

Cacciabue, P. C., & Cojazzi, G. (1995). An integrated simulation approach for the analysis of pilot-aeroplane interaction. *Control Engineering Practice, 3*, 257-266.

Camerer, C., & Weber, M. (1992). Recent development in modeling preferences: Uncertainty and ambiguity. *Journal of Risk and Uncertainty, 5*, 325-370.

Cestac, J., Paran, F., & Delhomme, P. (2011). Young drivers' sensation seeking, subjective norms, and perceived behavioral control and their roles in predicting speeding intention: How risk-taking motivations evolve with gender and driving experience. *Safety Science*, *49*, 424-432. doi:10.1016/j.ssci.2010.10.007

Chaiken, S., & Trope, Y. (Eds.). (1999). *Dual-process theories in social psychology*. New York: The Guilford Press.

Chermack, T. J., & Nimon, K. (2008). The effect of scenario planning on participatant decision-making style. *Human Resource Development Quarterly*, *19*, 351-372. doi:10.1002/hrdq.1245

Cialdini, R. B., Cacioppo, J. T., Bassett, B., & Miller, J. A. (1978). Low-ball procedure for producing compliance: Commitment then cost. *Journal of Personality and Social Psychology*, *36*, 463-476.

Cohen, M. S., Freeman, J. T., & Thompson, B. B. (1997). Training the naturalistic decision maker. In C. E. Zsambok & G. Klein (Eds.), *Naturalistic Decision Making* (pp. 257-268). Mahwah, NJ: Lawrence Erlbaum Associates.

Cokely, E. T., & Kelley, C. M. (2009). Cognitive abilities and superior decision making under risk: A protocol analysis and process model evaluation. *Judgment and Decision Making*, *4*, 20-33.

Conchie, S. M., & Burns, C. (2009). Improving occupational safety: Using a trusted information source to communicate about risk. *Journal of Risk Research*, *12*, 13-25. doi:10.1080/13669870802433749

Conner, M., Lawton, R., Parker, D., Chorlton, K., Manstead, A. S. R., & Straddling, S. (2007). Application of the theory of planned behavior to the prediction of objectively assessed breaking of posted speed limits. *British Journal of Psychology*, *98*, 429-453. doi:10.1348/000712606X133597

Connolly, T., & Wagner, W. G. (1988). Decision cycles. In R. L. Cardy, S. M. Puffer & M. M. Newman (Eds.), *Advances in information processing in organization* (pp. 183-205). Greenwich, CT: JAI Press.

Cooper, M. D., & Phillips, R. A. (2004). Exploratory analysis of the safety climate and safety behaviour relationship. *Journal of Safety Research*, *35*, 497-512. doi:10.1016/j.jsr.2004.08.004

Dekker, S. (2002). Reconstructing human contribution to accidents: the new view on error and performance. *Journal of Safety Research, 33*, 371-385.

Dekker, S. (2003a). Failure to adapt or adaptations that fail: contrasting models on procedures and safety. *Applied Ergonomics*, *34*, 233-238. doi:10.1016/S0003-6870(03)00031-0

Dekker, S. (2003b). Illusions of explanation: a critical essay on error classification. *International Journal of Aviation Psychology*, *13*, 95-106. doi:10.1207/S15327108IJAP1302_01

Dekker, S. (2005). Why we need new accident models. In D. Harris & H. C. Muir (Eds.), *Contemporary issues in human factors and aviation safety* (pp. 181-198). Aldershot, UK: Ashgate Publishing.

Dekker, S. (2007). Doctors are more dangerous than gun owners: a rejoinder to error counting. *Human Factors*, *49*, 177-184. doi:10.1518/001872007X312423

Dekker, S., Cilliers, P., & Hofmeyr, J-H. (2011). The complexity of failure: implications of complexity theory for safety investigations. *Safety Science, 49*, 939-945. doi:10.1016/j.ssci.2011.01.008

De Pelsmacker, P., & Janssens, W. (2007). The effect of norms, attitudes and habits on speeding behavior: Scale development and model building and estimation. *Accident Analysis and Prevention, 39*, 6-15. doi:10.1016/j.aap.2006.05.011

Desai, V. M. (2010). Rule violations and organizational search: A review and extension. *International Journal of Management reviews, 10*, 184-200. doi:10.1111/j.1468-2370.2008.00245.x

De Winter, J. C. F., & Dodou, D. (2010). The driver behavior questionnaire as a predictor of accidents: A meta-analysis. *Journal of Safety Research, 41*, 463-470. doi:10.1016/j.jsr.2010.10.007

Directorate General of Civil Aviation (2008). *DGAC – Unstabilized approaches* [Electronic version]. French Department of Safety Management. Retrieved May, 20, 2010, from: http://www.skybrary.aero/bookshelf/books/535.pdf

Douglas, M., & Wildavsky, A. (1982). *Risk and culture: An essay on the selection of technological and environmental dangers.* Berkeley : University of California Press.

Drinkwater, J. L., & Molesworth, B. R. C. (2010). Pilot see, pilot do: Examining the predictors of pilots' risk management behavior. *Safety Science, 48*, 1445-1451. doi:10.1016/j.ssci.2010.07.001

Eagly, A. H., & Chaiken, S. (1993). *The psychology of attitudes.* Belmont, CA: Wadsworth Group/Thomson Learning.

Edwards, W. (1954). The theory of decision making. *Psychological Bulletin, 51*,380-417.

Elliot, M. A., Armitage, C. J., & Baughan, C. J. (2003). Drivers' compliance with speed limits: An application of the theory of planned behavior. *Journal of Applied Psychology, 88*, 964-972. doi:10.1037/0021-9010.88.5.964

Elliot, M. A., & Thomson, J. A. (2010). The social cognitive determinants of offending drivers' speeding behaviour. *Accident Analysis and Prevention, 42*, 1595-1605. doi:10.1016/j.aap.2010.03.018

Endsley, M. R. (1997). The role of situation awareness in naturalistic decision making. In C. E. Zsambok & G. Klein (Eds.), *Naturalistic Decision Making* (pp. 269-284). Mahwah, NJ: Lawrence Erlbaum Associates.

Evans, B., Glendon, A. I., & Creed, P. A. (2007). Development and initial validation of an aviation safety climate scale. *Journal of Safety Research, 38*, 675-682. doi:10.1016/j.jsr.2007.09.005

Farah, H., Yechiam, E., Bekhor, S., Toledo, T., & Polus, A. (2008). Association of risk proneness in overtaking maneuvers with impaired decision making. *Transportation Research Part F, 11*, 313-323. doi:10.1016/j.trf.2008.01.005

Federal Aviation Administration, FAA. (1991). *Aeronautical decision making* (Advisory Circular No. 60-22). Washington, DC: U.S. Department of Transportation.

Finucane, M. L., Peters, E., & Slovic, P. (2003). Judgment and decision making: The dance of affect and reason. In S. L. Schneider, & J. Shanteau (eds.), *Emerging Perspectives on Judgment and decision Research*, (pp. 327-364). New York: Cambridge University Press.

Flin, R., Martin, L., Goeters, K-M., Hörmann, H-J., Amalberti, R., Valot, C., et al. (2005). Development of the NOTECHS (non-technical skills) system for assessing pilots' CRM skills. In D. Harris & H. C. Muir (Eds.), *Contemporary Issues in Human Factors and Aviation Safety* (pp. 133-154). Aldershot, UK: Ashgate.

Flin, R., Strub, M., Salas, E., & Martin, L. (eds.). (1997). *Decision making under stress. Emerging themes and applications.* Aldershot: Ashgate.

Fogarty, G. J., & Buikstra, E. (2008). A test of direct and indirect pathways linking safety climate, psychological health, and unsafe behaviours. *International Journal of Applied Aviation Studies, 8*, 199-209.

Fox, C. R., & Hadar, L. (2006). "Decisions from experience" = sampling error + prospect theory: Reconsidering Hertwig, Barron, Weber & Erev (2004). *Judgment and decision Making, 1*, 159-166.

Fuller, R. (2005). Towards a general theory of driver behaviour. *Accident Analysis and Prevention, 37*, 461-472. doi:10.1016/j.aap.2004.11.003

Fuller, R., Gormley, M., Stradling, S., Broughton, P., Kinnear, N. & O'Dolan, C., et al. (2009). Impact of speed change on estimated journey time: Failure of drivers to appreciate relevance of initial speed. *Accident Analysis and Prevention, 41*, 10-14. doi:10.1016/j.aap.2008.07.013

Gabany, S. G., Plummer, P., & Grigg, P. (1997). Why drivers speed: The speeding perception inventory. *Journal of Safety Research, 28*, 29-36.

Gaël, M., Amalberti, R., & Chauvin, C. (2008). Articulating the differences between safety and resilience: the decision-making process of professional sea-fishing skippers. *Human Factors, 50*, 1-16. doi:10.1518/001872008X250683

Galotti, K. M. (2007). Decision structuring in important real-life choices. *Psychological Science, 18*, 320-325.

Garavan,T. N., & O'Brien, F. (2001). An investigation into the relationship between safety climate and safety behaviours in Irish organizations. *Irish Journal of Management, 22*, 141-170.

Gibbons, A. M., von Thaden, T. L., & Wiegmann, D. A. (2006). Development and initial validation of a survey for assessing safety culture within commercial flight operations. *The International Journal of Aviation Psychology, 16*, 215-238. doi:10.1207/s15327108ijap1602_6

Gigerenzer, G., Czerlinski, J., & Martignon, L. (2002). How good are fast and frugal heuristics? In T. Gilovich, D. Griffin & D. Kahneman (Eds.), *Heuristics and biases: The psychology of intuitive judgment* (pp. 397-420). New York: Cambridge University Press.

Gigerenzer, G., & Goldstein, D. G. (1996). Reasoning the fast and frugal way: Models of bounded rationality. *Psychological review, 103*, 650-669.

Gilbert, C., Amalberti, R., & Paries, J. (2007). Errors and failures: towards a new safety paradigm. *Journal of Risk Research, 10*, 959-975. doi:10.1080/13669870701504764

Gilovich, T., Griffin, D., & Kahneman, D. (Eds.). (2002). *Heuristics and biases: The psychology of intuitive judgment.* New York: Cambridge University Press.

Goeters, K-M. (2004). Validation of CRM training by NOTECHS: Results of the PHARE ASI project. In K-M. Goeters (Ed.), *Aviation Psychology: Practice and Research* (pp. 291-297). Aldershot, UK: Ashgate.

Goldenbeld, C., & van Schagen, I. (2007). The credibility of speed limits on 80 km/h rural roads: The effect of road and person(ality) characteristics. *Accident Analysis and Prevention, 39*, 1121-1130. doi:10.1016/j.aap.2007.02.012

Goh, J., & Wiegmann, D. A. (2001). Visual flight rules flight into instrumental meteorological conditions: An empirical investigation of the possible causes. *The International Journal of Aviation Psychology, 11*, 359-379. doi:10.1207/S15327108IJAP1104_3

Haglund, M., & Åberg, L. (2000). Speed choice in relation to speed limit and influences from other drivers. *Transportation Research Part F, 3*, 39-51.

Haisley, E. C., Kaufmann, C., & Weber, M. (2010). How much risk can I handle? The role of experience sampling and graphical displays on one's investment risk appetite and comprehension. *SSRN eLibrary*. Retrieved January 28, 2011, from http://papers.ssrn.com/sol3/papers.cfm?abstract_id=1616186

Hammond, K. R. (1993). Naturalistic decision making from a Brunswikian viewpoint: its past, present, future. In G. Klein, J. Orasanu, R. Calderwood & C. E. Zsambok, (Eds.), *Decision making in action: Models and methods* (pp. 205-227). Norwood, New Jersey: Ablex.

Harren, V. A. (1979). A model of career decision making for college students. *Journal of Vocational Behavior, 14*, 119-133.

Hau, R., Pleskac, T. J., & Hertwig, R. (2010). Decisions from experience and statistical probabilities: Why they trigger different choices than a priori probabilities. *Journal of Behavioral Decision Making*, *23*(1), 48-68. doi:10.1002/bdm.665

Hau, R., Plescac, T. J., Kiefer, J., & Hertwig, R. (2008). The description-experience gap in risky choice: The role of sample size and experienced probabilities. *Journal of Behavioral Decision Making, 21*, 493-518. doi:10.1002/bdm.598

Heath, C., & Tversky, A. (1991). Preference and belief: Ambiguity and competence in choice under uncertainty. *Journal of Risk and Uncertainty, 4*, 5-28.

Helmreich, R. L., Klinect, J. R., & Wilhelm, J. A. (1999). Models of threat, error, and CRM in flight operations. In *Proceedings of the Tenth International Symposium on Aviation Psychology (pp. 677-682)*. Columbus, OH: The Ohio State University.

Helmreich, R. L., & Merritt, A. C. (1998). *Culture at work in aviation and medicine: national, organizational, and professional influences.* Aldershot, UK: Ashgate.

Helmreich, R. L., Merritt, A. C., & Wilhelm, J. A. (1999). The Evolution of Crew Resource Management Training in Commercial Aviation. *International Journal of Aviation Psychology, 9*, 19-32. doi:10.1207/s15327108ijap0901_2

Helmreich, R. L., Wilhelm, J. A., Klinect, J. R., & Merritt, A. C. (2001). Culture, error, and crew resource management. In E. salas, C. A. Bowers, & E. Edens (Eds.), *Improving Teamwork in Organizations* (pp. 305-331). Hillsdale, NJ: Erlbaum.

Hertwig, R., Barron, G., Weber, E. U., & Erev, I. (2004). Decisions from experience and the effect of rare events in risky choice. *Psychological Science, 15*, 534-539.

Hertwig, R., & Plescac, T. J. (2010). Decisions from experience: Why small samples? *Cognition, 115*, 225-237. doi:10.1016/j.cognition.2009.12.009

Hofmann, D. A., & Stetzer, A. (1996). A cross-level investigation of factors influencing unsafe behaviors and accidents. *Personnel Psychology, 49*, 307-339.

Hofmann, D. A., & Stetzer, A. (1998). The role of safety climate and communication in accident interpretation: Implications for learning from negative events. *Academy of Management Journal, 41*, 644-657.

Hofmann, D. A., Jacobs, R., & Landy, F. (1995). High reliability process industries: Individual, micro, and macro organizational influences on safety performance. *Journal of Safety Research, 26*, 131-149.

Hofstede, G. (1980). *Culture's consequences: international differences in work related values.* Beverly Hills, CA: Sage.

Hofstede, G. (1991). *Cultures and organizationssoftware of the mind.* Maidenhead, UK: McGraw-Hill.

Hollnagel, E. (2008). Risk + barrier = safety? *Safety Science, 46*, 221-229. doi:10.1016/j.ssci.2007.06.028

Hooey, B. L., & Foyle, D. C. (2006). Pilot navigation errors on the airport surface: identifying contributing factors and mitigating solutions. *International Journal of Aviation Psychology, 16*, 51-76. doi:10.1207/s15327108ijap1601_3

Hopkins, A. (2011). Risk-management and rule-compliance: Decision-making in hazardous industries. *Safety Science, 49*, 110-120.

Hsee, C. K. (1996). The evaluability hypothesis: An explanation for preference reversals between joint and separate evaluations of alternatives. *Organizational Behavior and Human Decision Processes, 67*, 247-257.

Hsee, C. K., Loewenstein, G. F., Blount, S., & Bazerman, M. H. (1999). Preference reversals between joint and separate evaluations of options: A review and theoretical analysis. *Psychological Bulletin, 125*, 576-590.

Hsee, C. K., & Rottenstreich, Y. (2004). Music, pandas, and muggers: On the affective psychology of value. *Journal of Experimental Psychology, 133*, 23-30. doi:10.1037/0096-3445.133.1.23

Huber, O., Beutter, C., Montoya, J., & Huber, O. W. (2001). Risk-defusing behaviour: Towards an understanding of risky decision making. *European Journal of Cognitive Psychology, 13*, 409-426. doi:10.1080/09541440125915

Huber, O., & Huber, O. W. (2003). Detectability of the negative event: Effect on the acceptance of pre- or post-event risk-defusing actions. *Acta Psychologica, 113*, 1-21. doi:10.1016/S0001-6918(02)00148-8

Huber, O., Wider, R., & Huber, O. W. (1997). Active information search and complete information presentation in naturalistic risky decision tasks. *Acta Psychologica, 95*, 15-29.

Hunter, D. R. (2003). Measuring general aviation pilot judgment using a situational judgment technique. *The International Journal of Aviation Psychology,13*, 373-386. doi:10.1207/S15327108IJAP1304_03

Hunter, D. R. (2005). Measurement of hazardous attitudes among pilots. *The International Journal of Aviation Psychology, 15*, 23-43. doi:10.1207/s15327108ijap1501_2

Hunter, D. R., Martinussen, M., & Wiggins, M. (2003). Understanding how pilots make weather-related decisions. *International Journal of Aviation Psychology, 13*, 73-87. doi:10.1207/S15327108IJAP1301_5

Hunter, D. R., Martinussen, M., Wiggins, M., & O'Hare, D. (2011). Situational and personal characteristics associated with adverse weather encounters by pilots. *Accident Analysis and Prevention, 43*, 176-186. doi:10.1016/j.aap.2010.08.007

Hörmann, H. J. (1995). FOR-DEC: a prescriptive model for aeronautical decision making. In R. Fuller, R. Johnston & N. McDonald (Eds.), *Human factors in aviation operations* pp. 17-23). Aldershot, UK: Ashgate.

Jensen, R. S. (1982). Pilot judgment: training and evaluation. *Human Factors, 24*, 61-73.

Jensen, R. S. (1995). *Pilot judgment and crew resource management.* Aldershot, UK: Avebury Aviation.

Jensen, R. S. (1997). The boundaries of aviation psychology, human factors, aeronautical decision making, situation awareness, and crew resource management. *International Journal of Aviation Psychology, 7*, 259-267.

Jensen, R. S., Chubb, G. P., Adrion-Kochan, J., Kirkbride, L. A., & Fisher, J. (1995). Aeronautical decision making in general aviation: New intervention strategies. In R. Fuller, N. Johnston & N. McDonald (Eds.). *Human factors in aviation operations: Proceedings of the 21st conference of the European association for aviation psychology (EAAP).* Aldershot, UK: Avebury Aviation.

Jeske, K-J., & Werner, U. (2008). Impacts on decision making of executives: Probabilities versus outcomes. *Journal of Neuroscience, Psychology and Economics, 1*, 49-65.

Johansson, B., & Lundberg, J. (2010). Engineering safe aviation systems: balancing resilience and stability. In J. A. Wise, V. D. Hopkin & D. J. Garland (Eds.), *Handbook of Aviation human Factors* (pp. 6-1 – 6-8). Boca Raton, FL: Taylor and Francis Group.

Johnson, S. E. (2007). The predictive validity of safety climate. *Journal of Safety Research, 38*, 511-521. doi:10.1016/j.jsr.2007.07.001

Jonah, B. A. (1997). Sensation seeking and risky driving: a review and synthesis of the literature. *Accident Analysis and Prevention, 29*, 651-665.

Kaempf, G. L., & Klein, G. (1994). Aeronautical decision making: the next generation. In N. Johnson, N. McDonald & R. Fuller (Eds.), *Aviation psychology in practice* (pp. 223-254). Burlington, VT: Ashgate.

Kaempf, G. L., & Orasanu, J. (1997). Current and future applications of naturalistic decision making in aviation. In C. E. Zsambok & G. Klein (Eds.), *Naturalistic Decision Making* (pp. 81-90). Mahwah, NJ: Lawrence Erlbaum Associates.

Kahneman, D. (2003). A perspective on judgement and choice. *American Psychologist*. *58*, 697-720. doi:10.1037/0003-066X.58.9.697

Kahneman, D., & Tversky, A. (1979). Prospect Theory: An analysis of decision under risk. *Econometrica, 47*, 263-291.

Kahneman, D., & Tversky, A. (1982). On the study of statistical intuitions. *Cognition, 11*, 123-141.

Kecklund, L. J., Edland, A., & Svensson, O. (1996). Safety barrier function analysis in a process industry: a nuclear power application. *International Journal of Industrial Ergonomics, 17*, 275-284.

Keren, N., Mills, T. R., Freeman, S. A., & Shelley, M. C. (2009). Can level of safety climate predict level of orientation toward safety in a decision making task? *Safety Science, 47*, 1312-1323. doi:10.1016/j.ssci.2009.01.009

Kim, D-Y., & Park, J. (2010). Cultural differences in risk: the group facilitation effect. *Judgment and Decision Making, 5*, 380-390.

Klein, G. (1993). A recognition-primed decision (RPD) model of rapid decision making. In G. Klein, J. Orasanu, R. Calderwood & C. E. Zsambok, (Eds.), *Decision making in action: Models and methods* (pp. 138-147). Norwood, New Jersey: Ablex.

Klein, G. (1997). The recognition-primed decision (RPD) model: Looking back, looking forward. In C. E. Zsambok & G. Klein (Eds.), *Naturalistic Decision Making* (pp. 285-292). Mahwah, NJ: Lawrence Erlbaum Associates.

Klein, G. (2008). Naturalistic decision making. *Human Factors, 50*, 456-460. doi:10.1518/001872008X288385

Kobbeltved, T., Brun, W., Johnsen, B. H., & Eid, J. (2005). Risk as feelings or risk and feelings? A cross lagged panel analysis. *Journal of Risk Research*, *8*, 417-437. doi:10.1080/1366987042000315519

Kontogiannis, T. & Malakis, S. (2009). A proactive approach to human error detection and identification in aviation and air traffic control. *Safety Science*, *47*, 693-706. doi:10.1016/j.ssci.2008.09.007

Kunreuther, H., Novemsky, N., & Kahneman, D. (2001). Making low probabilities useful. *Journal of Risk and Uncertainty, 23*, 103-120.

Lahausse, J. A., van Nes, N., Fildes, B. N., & Keall, M. D. (2010). Attitudes towards current and lowered speed limits in Australia. *Accident Analysis and Prevention*, *42*, 2108-2116. doi:10.1016/j.aap.2010.06.024

Leahey, T. H. (2003). *A history of psychology: main currents in psychological thought*. New Jersey: Prentice Hall.

Lehman, D. W., & Ramanujam, R. (2009). Selectivity in organizational rule violations. *Academy of Management Review, 34*, 643-657.

Lester, L. F., & Bombaci, D. H. (1984). The relationship between personality and irrational judgment in civil pilots. *Human Factors*, *26*, 565-572.

Lev, D., Hershkovitz, E., & Yechiam, E. (2008). Decision making and personality in traffic offenders: A study of Israeli drivers. *Accident Analysis and Prevention, 40*, 223-230. doi:10.1016/j.aap.2007.05.009

Leveson, N. G. (2011). Applying systems thinking to analyse and learn from events. *Safety Science*, *49*, 55-64. doi:10.1016/j.ssci.2009.12.021

Li, W-C., & Harris, D. (2001). The evaluation of the effect of a short aeronautical decision-making training program for military pilots. *International Journal of Aviation Psychology*, *18*, 135-152. doi:10.1080/10508410801926715

Lipshitz, R. (1993a). Converging themes in the study of decision making in realistic settings. In G. Klein, J. Orasanu, R. Calderwood & C. E. Zsambok, (Eds.), *Decision making in action: Models and methods* (pp. 103-137). Norwood, New Jersey: Ablex.

Lipshitz, R. (1993b). Decision making as argument-driven action. In G. Klein, J. Orasanu, R. Calderwood & C. E. Zsambok, (Eds.), *Decision making in action: Models and methods* (pp. 103-137). Norwood, New Jersey: Ablex.

Lipshitz, R. (1997). Naturalistic decision making perspectives on decision making errors. In C. E. Zsambok & G. Klein (Eds.), *Naturalistic Decision Making* (pp. 151-160). Mahwah, NJ: Lawrence Erlbaum Associates.

Loewenstein, G. F., Weber, E. U., Hsee, C. K., & Welch, N. (2001). Risk as feelings. *Psychological Bulletin, 2*, 267-286. doi:10.1037//0033-2909.127.2.267

Lubner, M. E., Hunter, D., & Struening, E. (2001). Reliability and validity of decision making styles self-test. Paper presented at the Eleventh International Symposium on Aviation Psychology, Columbus, Ohio, March 2001.

Luce, M. F., Bettman, J. R., & Payne, J. W. (1997). Choice processing in emotionally difficult decisions. *Journal of Experimental Psychology: Learning Memory, and Cognition, 2,* 384-405.

Mach, E. (1905/1976). Knowledge and error: sketches on the psychology of enquiry (B. McGuinness, Ed., T. J. McCormack & P. Foulkes, Trans.). Dordrecht, Holland: Reidel Publishing Company.

March, J. G., & Shapira, Z. (1987). Managerial perspectives on risk and risk taking. *Management Science*, *33*, 1404-1418.

McGraw, A. P., Shafir, E., & Todorov, A. (2010). Valuing money and things: Why a $20 item can be worth more and less than $20. *Management Science, 56,* 816-830. doi10.1287/mnsc.1100.1147

McKenna, F. P., & Horswill, M. S. (2006). Risk taking from the participant's perspective: The case of driving and accident risk. *Health Psychology, 25*, 163-170. doi:10.1037/0278-6133.25.2.163

McLain, D. L., & Jarrell, K. A. (2007). The perceived compability of safety and production expectations in hazardous occupations. *Journal of Safety Research, 38*, 299-309. doi:10.1016/j.jsr.2006.10.011

Merket, D. C., Bergondy, M. L., & Salas, E. (1999). Making sence out of team performance errors in military aviation environments. *Transportation Human Factors, 1*, 231-242.

Mesken, J., Hagenzieker, M. P., Rothengatter, T., & De Waard, D. (2007). Frequency, determinants, and consequences of different drivers' emotions: An on-the-road study using self-reports, (observed) behaviour, and physiology. *Transportation Research Part F, 10*, 458-475. doi:10.1016/j.trf.2007.05.001

Molesworth, B. R. C., & Chang, B. (2009). Predicting pilots' risk-taking behavior through an implicit association test. *Human Factors*, *51*, 845-857. doi:10.1177/0018720809357756

Montgomery, H. (1993). The search for a dominance structure in decision making: examining the evidence. In G. Klein, J. Orasanu, R. Calderwood & C. E. Zsambok, (Eds.), *Decision making in action: Models and methods* (pp. 182-187). Norwood, New Jersey: Ablex.

Mullen, J. (2004). Investigating factors that influence individual safety behavior at work. *Journal of Safety Research*, *35*, 275-285. doi:10.1016/j.jsr.2004.03.011

Murray, S. R. (1997). Deliberate decision making by aircraft pilots: a simple reminder to avoid decision making under panic. *International Journal of Aviation Psychology, 7*, 83-100. doi:10.1207/s15327108ijap0701_5

Murray, S. R. (1999). FACE: Fear of loss of face and the five hazardous attitudes concept. *The International Journal of Aviation Psychology, 9,* 403-411. doi: 10.1207/s15327108ijap0904_6

Nagel, D. C. (1988). Human error in aviation operations. In E. L. Wiener & D. C. Nagel (Eds.), *Human Factors in Aviation* (pp. 263-303). San Diego, CA: Academic Press.

Neitzel, R. L., Seixas, N. S., Harris, M. J., & Camp, J. 2008. Exposure to fall hazards and safety climate in the aircraft maintenance industry. *Journal of safety Research, 39*, 391-402. doi:10.1016/j.jsr.2008.02.033

Newell, B. R., Mitchell, C. J., & Hayes, B. K. (2008). Getting scarred and winning lotteries: Effects of exemplar cuing and statistical format in imagining low-probability events. *Journal of Behavioral Decision Making, 21*, 317-335. doi:10.1002/bdm.584

O'Connor, P., Hörmann, H-J., Flin, R., Lodge, M., & Goeters, K-M. (2002). Developing a method for evaluating crew resource management skills: A European perspective. *The International Journal of Aviation Psychology, 12*, 263-285. doi:10.1207/S15327108IJAP1203_5

O'Connor, P., O'Dea, A., Kennedy, Q., & Buttrey, S. E. (2011). Measuring safety climate in aviation: A review and recommendations for the future. *Safety Science, 49*, 128-138. doi:10.1016/j.ssci.2010.10.001

O'Hare, D. (1992). The "artful" decision maker: A framework model for aeronautical decision making. *International Journal of Aviation Psychology, 2*, 175-191.

O'Hare, D. (2000). The "wheel of misfortune": a taxonomic approach to human factors in accident investigation and analysis in aviation and other complex systems. *Ergonomics, 43*, 2001-2019. doi:10.1080/00140130050201445

O'Hare, D. (2003). Aeronautical decision making: metaphors, models, and methods. In P. S. Tsang, & M. A. Vidulich (Eds.), *Principles and practice of aviation psychology* (pp. 201-237). Mahwah, NJ: Lawrence Erlbaum.

O'Hare, D., & Smitheram, T. (1995). "Pressing on" into deteriorating conditions: an application of behavioral decision theory to pilot decision-making. *International Journal of Aviation Psychology, 5*, 351-370.

O'Hare, D., & Wiggins, M. (2004). Remembrance of cases past: Who remembers what, when confronting critical events? *Human Factors, 46*, 277-287.

Orasanu, J. M. (1990). *Shared mental models and crew decision making.* Princeton, NJ: Princeton University.

Orasanu, J. M. (1993). Decision-making in the cockpit. In E. L. Wiener, B. G. Kanki & R. L. Helmreich (Eds.), *Cockpit resource management* (pp137-172). San Diego, CA: Academic Press.

Orasanu, J. M, & Connolly, T. (1995). The reinvention of decision making. In G. Klein, J. Orasanu, R. Calderwood & C. E. Zsambok (Eds.), *Decision making in action: Models and methods* (pp. 3-20). Norwood, New Jersey: Ablex.

Öz, B., Özkan, T., & Lajunen, T. (2010). An investigation of the relationship between organizational climate and professional drivers' driver behaviours. *Safety Science, 48*, 1484-1489. doi:10.1016/j.ssci.2010.07.009

Paletz, S. B. F. (2009). Socializing the human factors analysis and classification system: incorporating social psychological phenomena into a human factors error classification system. *Human Factors, 51*, 435-445. doi:10.1177/0018720809343588

Park, J., & Jung, W. (2003). The operators' non-compliance behavior to conduct emergency operating procedures – comparing with the work experience and complexity of procedural steps. *Reliability Engineering and System safety,* 82, 115-131. doi:10.1016/S0951-8320(03)00123-6

Patankar, M. S. (2003). A study of safety culture at an aviation organization. *International Journal of Applied Aviation Studies, 3*, 243-258.

Pauly, K. A., O'Hare, D., Mullen, N. W., & Wiggins, M. (2008). Implicit perceptions of risk and anxiety and pilot involvement in hazardous events. *Human Factors, 50*, 723-733. doi:10.1518/001872008X312350

Pauly, K. A., O'Hare, D., & Wiggins, M. (2008). Risk tolerance and pilot involvement in hazardous events and flight into adverse weather. *Journal of Safety Research, 39*, 403-411. doi:10.1016/j.jsr.2008.05.009

Payne, J. W., Bettman, J. R., & Johnson, E. J. (1993). *The adaptive decision maker*. Cambridge, England: Cambridge University Press.

Peer, E. (2010). Speeding and the time-saving bias: How drivers' estimation of time saved in higher speed affects their choice of speed. *Accident Analysis and Prevention, 42*, 1978-1982. doi:10.1016/j.aap.2010.06.003

Pennington, N., & Hastie, R. (1993). A theory of explanation-based decision making. In G. Klein, J. Orasanu, R. Calderwood & C. E. Zsambok, (Eds.), *Decision making in action: Models and methods* (pp. 188-204). Norwood, New Jersey: Ablex.

Perrow, C. (1984). *Normal accidents.* New York: Basic Books.

Peters, E. (2006). The functions of affect in the construction of preferences. In S. Lichtenstein & P. Slovic (Eds.), *The construction of preference*. (pp. 454-463). New York: Cambridge University Press.

Pew, R. W., & Mavor, A. S. (Eds.). (2007). *Human-system integration in the development process: a new look.* Washington, DC: National Academy Press.

Pidgeon, N., & O'Leary, M. (1994). Organizational safety culture: Implications for aviation practice. In N. Johnson, N. McDonald & R. Fuller (Eds.), *Aviation psychology in practice* (pp. 21-43). Burlington, VT: Ashgate.

Platenius, P. H., & Wilde, G. J. S. (1989). Personal characteristics related to accident histories of Canadian pilots. *Aviation, Space, and Environmental Medicine, 60*, 42-45.

Pfister, H.R., & Böhm, G. (2008). The multiplicity of emotions: A framework of emotional functions in decision making. *Judgment and Decision Making, 3*, 5-17.

Raby, M., & Wickens, C. D. (1994). Strategic workload management and decision biases in aviation. *International Journal of Aviation Psychology, 4*, 211-240.

Rakow, T., Demes, K. A., & Newell, B. R. (2008). Biased samples not mode of presentation: Re-examining the apparent underweighting of rare events in experience-based choice. *Organizational Behavior and Human Decision Processes, 106*, 168-179. doi:10.1016/j.obhdp.2008.02.001

Ranyard, R., & Charlton, J. P. (2006). Cognitive processes underlying lottery and sports gambling decisions: The role of stated probabilities and background knowledge. *European Journal of Cognitive Psychology, 18*, 234-254. doi:10.1080/09541440540000149

Rasmussen, J. (1986). *Information processing and human-machine interaction: An approach to cognitive engineering.* Amsterdam: Elsevier.

Rasmussen, J. (1993). Deciding and doing: decision making in natural contexts. In G. Klein, J. Orasanu, R. Calderwood & C. E. Zsambok, (Eds.), *Decision making in action: Models and methods* (pp. 158-171). Norwood, New Jersey: Ablex.

Reason, J. (1990). *Human error.* Cambridge, UK: Cambridge University Press.

Reason, J. (1993). The identification of latent organizational failures in complex systems. In J. A. Wise, V. D. Hopkin & P. Stager (Eds.), *Verification and validation of complex systems: Human factors issues* (pp. 223-237). Berlin, Germany: Springer-Verlag.

Reason, J. (1997). *Managing the risks of organizational accidents.* Aldershot, UK: Ashgate.

Reason, J., Parker, D., & Lawton, R. (1998). Organizational controls and safety: the varieties of rule-related behaviour. *Journal of Occupational and Organizational Psychology, 71*, 289-304.

Rebok, G. W., Qiang, Y., Baker, S .P., McCarthy, M. L., & Li, G. (2005). Age, flight experience, and violation risk in mature commuter and taxi pilots. *The International Journal of Aviation Psychology, 15*, 363-374. doi:10.1207/s15327108ijap1504_4

Rettinger, D. A., & Hastie, R. (2001). Content effects on decision making. *Organizational Behavior and Human Decision Processes, 85*, 336-359. doi:10.1006/obhd.2000.2948

Robertson, C. L. (2004). Teaching pilots judgment, decision-making, and critical thinking. *International Journal of Applied Aviation Studies, 4*, 203-220.

Rottenstreich, Y., & Hsee, C. K. (2001). Money, kisses and electric shocks: On the affective psychology of risk. *Psychological Science, 12*, 185-190. doi:10.1111/1467-9280.00334

Rottenstreich, Y., & Kivetz, R. (2006). On decision making without likelihood judgment. *Organizational Behavior and Human Decision Processes, 101*, 74-88. doi:10.1016/j.obhdp.2006.06.004

Rundmo, T. (2002). Associations between affect and risk perception. *Journal of Risk Research, 5*, 119-135.

Salas, E., Burke, C. S., Bowers, C. A., & Wilson, K. A. (2001). Team training in the skies: does crew resource management (CRM) training work? *Human Factors, 43*, 641–674.

Sasou, K., & Reason, J. (1999). Team error: definition and taxonomy. *Reliability Engineering and System Safety, 65*, 1-9.

Savage, L. J. (1954). *The foundations of statistics.* New York: Wiley Press.

Schmid Mast, M., Sieverding, M., Esslen, M., Graber, K., & Jäncke, L. (2008). Masculinity causes speeding in young men. *Accident Analysis and Prevention, 40*, 840-842. doi:10.1016/j.aap.2007.09.028

Schneider, S. L. (1992). Framing and conflict: Aspiration level contingency, the status quo, and current theories of risky choice. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 18*, 1040-1057.

Schriver, A. T., Morrow, D. G., Wickens, C. D., & Talleur, D. A. (2008). Expertise differences in attentional strategies related to pilot decision making. *Human Factors 50*, 864-878. doi:10.1518/001872008X374974

Schvaneveldt, R. W., Beringer, D. B., & Lamonica, J. A. (2001). Priority and organization of information accessed by pilots in various phases of flight. *International Journal of Aviation Psychology, 11*, 253-280. doi:10.1207/S15327108IJAP1103_02

Scott, S. G., & Bruce, R. A. (1995). Decision-making style: The development and assessment of a new measure. *Educational and Psychological Measurement, 55*, 818-831.

Searle, J. R. (1980). The intentionality of intention and action. *Cognitive Science, 4*, 47-70.

Shappell, S., Detwiler, C., Holcomb, K., Hackworth, C., Boquet, A., & Wiegmann, D. (2007). Human error and commercial aviation accidents: An analysis using the human factors analysis and classification system. *Human Factors, 49,* 227–242. doi:10.1518/001872007X312469

Shappell, S. A., & Wiegmann, D. A. (1997). A human error approach to accident investigation: the taxonomy of unsafe operations. *International Journal of Aviation Psychology, 7,* 269-291.

Sheridan, T. B. (2008). Risk, human error, and system resilience: fundamental ideas. *Human Factors, 50,* 418-426. doi:10.1518/001872008X250773

Siegrist, M. (1997). Communicating low risk magnitudes: Incidence rates expressed as frequencies versus rates expressed as probabilities. *Risk Analysis, 17,* 507-510.

Simon, H. A. (1957). *Models of man, social and rational: mathematical essays on rational human behavior in a social setting.* New York: Wiley.

Sitkin, S. B., & Pablo, A. L. (1992). Reconceptualizing the determinants of risk behavior. *Academy of Management Review, 17,* 9-38.

Sitkin, S. B., & Weingart, L. R. (1995). Determinants of risky decision-making behavior: A test of the mediating role of risk perceptions and propensity. *Academy of Management Journal, 38,* 1573-1592.

Skinner, B. F. (1965). *Science and human behavior.* New York: Free Press.

Skybrary, the single point of reference for aviation safety (2010a). *Line oriented flight training.* Retreived June 14, 2010, from http://www.skybrary.aero/index.php/Line_Oriented_Flight_Training

Skybrary, the single point of reference for aviation safety (2010b). *Stabilized approach.* Retrieved May 19, 2010, from http://www.skybrary.aero/index.php/Stabilised_Approach

Slappendal, C., Laird, I., Kawachi, I, Marshall, S., & Cryer, C. (1993). Factors affecting work-related injury among forestry workers: A review. *Journal of Safety Research, 24*, 19-32.

Sloman, S. A. (1996). The empirical case for two systems of reasoning. *Psychological Bulletin*, *119*, 3-22.

Slovic, P. (1972). From Shakespeare to Simon: Speculation and some evidence about man's ability to process information. *Oregon Research Institute Research Monograph*, *12,* 1-19.

Slovic, P. (2007). "If I look at the mass I will never act": Psychic numbing and genocide. *Judgment and Decision Making Journal, 2*, 79-95.

Slovic, P., Finucane, M. L., Peters, E., & MacGregor, D. G. (2002). The affect heuristic. In T. Gilovich, D. Griffin & D. Kahneman (Eds.), *Heuristics and biases: The psychology of intuitive judgment* (pp. 397-420). New York: Cambridge University Press.

Slovic, P., Finucane, M. L., Peters, E., & MacGregor, D. G. (2004). Risk as analysis and risk as feelings: Some thoughts about affect, reason, risk and rationality. *Risk Analysis,24*, 311-321.

Slovic, P., Fischhoff, B., & Lichtenstein, S. (1978). Accident probabilities and seat belt usage: A psychological perspective. *Accident Analysis and Prevention, 10*, 281-285.

Slovic, P., Monahan, J., & MacGregor, D. G. (2000). Violence risk assessment and risk communication: The effects of using actual cases, providing instruction, and employing probability versus frequency formats. *Law and Human Behavior, 24*, 271-295.

Stanovich, K. E., & West, R. F. (2000). Individual differences in reasoning: Implications for the rationality debate? *Behavioral and Brain Sciences, 23,* 645-726.

Stewart, J. E. (2008). Locus of control and self-attribution as mediators of hazardous attitudes among aviators: A review and suggested applications. *International Journal of Applied Aviation Studies, 8*, 263-279.

Stokes, A. F., Kemper, K., & Kite, K. (1997). Aeronautical decision making, cue recognition, and expertise under time pressure. In C. E. Zsambok & G. Klein (Eds.), *Naturalistic Decision Making* (pp. 183-196). Mahwah, NJ: Lawrence Erlbaum Associates.

Stone, E. R., Yates, J. F., & Parker, A. M. (1994). Risk communication: Absolute versus relative expressions of low-probability risks. *Organizational Behavior and Human Decision Processes, 60*, 387-408.

Sulistyawati, K., Wickens, C. D., & Ping Chui, Y. (2011). Prediction in situation awareness: Confidence bias and underlying cognitive abilities. *International Journal of Aviation Psychology, 21*, 153-174. doi:10.1080/10508414.2011.556492

Svensson, O. (1970). A functional measurement approach to intuitive estimation as exemplified by estimated time savings. *Journal of Experimental Psychology, 86*, 204-210.

Svenson, O. (1979). Process descriptions of decision making. *Organizational Behaviour and Human Performance, 23,* 86-112.

Svensson, O. (2003). Values, affect and process in human decision making: A differentiation and consolidation theory perspective. In S. L. Schneider & J. Shanteau (Eds.), *Emerging Perspectives on Judgment and Decision Research* (pp. 287-326). Cambridge, UK: Cambridge University Press.

Svensson, O. (2008). Decisions among time saving options: When intuition is strong and wrong. *Acta Psychologica, 127*, 501-509. doi:10.1016/j.actpsy.2007.09.003

Svensson, O. (2009). Driving speed changes and subjective estimates of time savings, accident risks and braking. *Applied Cognitive Psychology, 23*, 543-560. doi:10.1002/acp.1471

Svensson, O., Salo, I., & Lindholm, T. (2009). Post-decision consolidation and distortion of facts. *Judgment and Decision Making, 4*, 397-407.

Thomas, M. J. W. (2004). Predictors of threat and error management: Identification of core nontechnical skills and implications for training systems design. *The International Journal of Aviation Psychology, 14*, 207-231. doi:10.1207/s15327108ijap1402_6

Thunholm, P. (2004). Decision-making style: habit, style or both? *Personality and Individual Differences, 36,* 931-944. doi:10.1016/S0191-8869(03)00162-4

Thunholm, P. (2005). Planning under time-pressure: An attempt toward a prescriptive model of military tactical decision making. In, H. Montgomery, R. Lipshitz & B. Brehmer (Eds.), *How Experts Make Decisions*. New Jersey: Lawrence Erlbaum.

Thunholm, P. (2008). Decision-making styles and psychological correlates of negative stress: Is there a relation? *Scandinavian Journal of Psychology, 49*, 213-219. doi:10.1111/j.1467-9450.2008.00640.x

Tversky, A., & Kahneman, D. (1974) Judgment under Uncertainty: Heuristics and Biases. *Science,* 185, 1124-1131.

Tversky, A., & Kahneman, D. (1983) Extensional versus intuitive reasoning: The conjunction fallacy in probability judgment. *Psychological Rewiew, 90*, 293-315.

Tyszka, T., & Zaleskiewicz, T. (2006). When does information about probability count in choices under risk? *Risk Analysis, 26*, 1623-1636. doi:10.1111/j.1539-6924.2006.00847.x

Ungemach, C., Chater, N., & Stewart, N. (2009). Are probabilities overweighted or underweighted when rare outcomes are experienced (rarely)? *Psychological Science, 20*(4), 473 -479. doi:10.1111/j.1467-9280.2009.02319.x

Vaughan, E. (1993). Chronic exposure to an environmental hazard: risk perception and self-protective behavior. *Health Psychology, 12*, 74-85.

Visschers, V. H. M., Meertens, R. M., Passchier, W. W. F., & de Vries, N. N. K. (2009). Probability information in risk communications: A review of the research literature. *Risk Analysis, 29*, 267-287. doi:10.1111/j.1539-6924.2008.01137.x

von Neumann, J., & Morgenstern, O. (1947). *Theory of games* and *economic behavior*. Princeton, N.J: Princeton University Press.

Wallén Warner, H., & Åberg, L. (2008). Drivers' beliefs about exceeding the speed limits. *Transportation Research Part F, 11*, 376-389. doi:10.1016/j.trf.2008.03.002

Wallén Warner, H., Özkan, T., & Lajunen, T. (2010). Can the traffic locus of control (T-LOC) scale be successfully used to predict Swedish drivers' speeding behavior? *Accident Analysis and Prevention, 42*, 1113-1117. doi:10.1016/j.aap.2009.12.025

Weber, E. U., Shafir, S., & Blais, A-R. (2004). Predicting risk sensitivity in humans and lower animals: Risk as variance or coefficient of variation. *Psychological Review, 111*, 430-445. doi:10.1037/0033-295X.111.2.430

Weinstein, N. D. (1998). The precaution adoption process. *Health Psychology, 7*, 355-386.

Weinstein, N. D., Kolb, K., & Goldstein, B. D. (1996). Using time intervals between expected events to communicate risk magnitudes. *Risk Analysis, 16*, 305-308.

Weinstein, N. D., Sandman, P. M., & Roberts, N. E. (1991). Perceived susceptibility and self-protective behavior: A field experiment to encourage home radon testing. *Health Psychology, 10*, 25-33.

West, R., Elander, J., & French, D. (1993). Mild social deviance, Type-A behaviour pattern and decision-making style as predictors of self-reported driving style and traffic accident risk. *British Journal of Psychology, 84*, 207-219.

West, R., & Hall, J. (1997). The role of personality and attitudes in traffic accident risk. *Applied Psychology: An International Review, 46*, 253-264.

Westrum, R., & Adamski, A. J. (2010). Organizational factors associated with safety and mission success in aviation environments. In J. A. Wise, V. D. Hopkin & D. J. Garland (Eds.), *Handbook of Aviation human Factors* (pp. 5-1 – 5-37). Boca Raton, FL: Taylor and Francis Group.

Wetmore, M., & Lu, C-T. (2006). The effect of hazardous attitudes on crew resource management skills. *International Journal of Applied Aviation Studies*, *6*, 165-182.

Wickens, C. D., & Flash, J. M. (1988). Information processing. In E. L. Wiener & D. C. Nagel (Eds.), *Human Factors in Aviation* (pp. 111-155). San Diego, CA: Academic Press.

Wiegmann, D. A., Goh, J., & O'Hare, D. (2002). The role of situation assessment and flight experience in pilots' decisions to continue visual flight rules flight into adverse weather. *Human Factors*, *44*, 189-197. doi:10.1518/0018720024497871

Wiegmann, D. A., & Shappell, S. A. (2001). Human error perspectives in aviation. *International Journal of Aviation Psychology*, *11*, 341-357. doi:10.1207/S15327108IJAP1104_2

Wiegmann, D. A., & Shappell, S. A. (2006). Organizational factors in commercial aviation accidents. *International Journal of Aviation Psychology*, *16*, 239-261. doi:10.1207/s15327108ijap1603_1

Wiegmann, D. A., Zhang, H., von Thaden, T.L., Sharma, G., & Gibbons, A. M. (2004). Safety culture: An integrative review. *The International Journal of Aviation Psychology*, *14*, 117-134. doi:10.1207/s15327108ijap1402_1

Wiggins, M., & Bollwerk, S. (2006). Heuristic-based information acquisition and decision making among pilots. *Human Factors*, *48*, 734-746. doi:10.1518/001872006779166325

Wiggins, M., & O´Hare, D. (1995). Expertise in aeronautical weather-related decision making: A cross-sectional analysis of general aviation pilots. *Journal of Experimental Psychology: Applied*, *1*, 305-320.

Williams, A. F., Kyrychenko, S. Y., & Retting, R. A. (2006). Characteristics of speeders. *Journal of Safety Research*, *37*, 227-232. doi:10.1016/j.jsr.2006.04.001

Wilson, R.S., & Arvai, J. L. (2006). When less is more: How affect influences preferences when comparing low and high-risk options. *Journal of Risk Research*, *9*, 165-178. doi:10.1080/13669870500419503

Winkielman, P., Knutson, B., Paulus, M., & Trujillo, J. L. (2007). Affective influence on judgments and decisions: Moving towards core mechanisms. *Review of General Psychology*, *2*, 179-192. doi:10.1037/1089-2680.11.2.179

Yang, Z., Coble, K. H., & Hudson, M. D. (2009). The role of individual personality type in subjective risk elicitation outcomes. *Journal of Risk Research*, *12*, 209-222. doi:10.1080/13669870802488990

Yechiam, E., Erev, I., & Barron, G. (2006). The effect of experience on using a safety device. *Safety Science*, *44*, 515-522. doi:10.1016/j.ssci.2005.11.006

Zeckhauser, R. J., & Viscusi, W. K. (1990). Risk within reason. *Science*, *248*, 559-564.

Zohar, D. (1980). Safety climate in industrial organizations: Theoretical and applied implications. *Journal of applied Psychology*, *65*, 96-102.

Zohar, D. (2002). The effects of leadership dimensions, safety climate, and assigned priorities on minor injuries in work groups. *Journal of Organizational Behavior*, *23*, 75-92. doi:10.1002/job. 130

Zohar, D., & Luria, G. (2003). The use of supervisory practices as leverage to improve safety behavior: A cross-level intervention model. *Journal of Safety Research*, *34*, 567-577. doi:10.1016/j.jsr.2003.05.006

Zsambok, C. E. (1997). Naturalistic decision making: Where are we now? In C. E. Zsambok & G. Klein (Eds.), *Naturalistic decision making* (pp. 3-17). Mahwah, NJ: Lawrence Erlbaum Associates.