Experience-based decision-making, non-technical skills and general decision-making styles among aviation pilots

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Aviation pilots are trained to base cockpit decisions on strategic and analytic reasoning, while naturalistic decision-making theory suggests that experts in naturalistic settings, like pilots, make decisions based on experience. In the present study, a scenario-based questionnaire was used, to explore the effects of aviation pilots’ non-technical skills and experience-based decision-making in a cockpit decision-making situation. Also, a negative relation between non-technical skills and decisions from experience was predicted. In addition, the relation between general decision-making styles, non-technical skills and experience-based decision-making, was explored. The results indicate that pilots’ non-technical skills can be predicted by a rational general decision-making style. However, the choice of action in a cockpit decision-making situation could not be predicted by high non-technical skills or high experience-based decision-making, and the expected relation failed to appear. The results are discussed in relation to existing theory.

Commercial aviation industry contains highly complex systems, and the occurrence of accidents can have catastrophic consequences for individuals, society and the environment. The commercial aviation sector is currently exposed to pressure of various kinds, in terms of the environmental debate, the financial crisis, and air fair reductions. Competition among airlines has increased as a result of the advent of low-price airlines on the market (Allwin, 2006), and increased profit demands have been suggested to lead to improved efficiency in terms of more flights (McFadden & Towell, 1999). In the year 2009, the number of passengers at Swedish airports was over 28 million, and more than 390 000 landings were performed (Swedish Transport Agency, 2009). The European air territory is today one of the busiest, and the commercial aviation sector is facing new challenges as the air traffic is expected to double during the next ten years (Swedish Aviation Department (LFV), 2010a).

Cost savings have been proposed to result in inadequately trained staff and poor equipment of some start-up airlines. On the other hand, the increased competition could lead to safety improvements, because of airlines’ reputation being at stake in case of an accident (McFadden & Towell, 1999). The aviation safety is nowadays highly prioritized and constantly evaluated and improved (Shappell et al., 2007). In the last decades aviation safety has improved to such an extent that commercial aviation today is one of the safest way to travel (Bove & Andersen, 2002). There are extensive international rules and regulations for the air traffic service and safety. The international regulations of civil aviation is worldwide and held together by a UN organization, called the International Civil Aviation Organization. In Sweden,

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the Swedish Aviation Department (LFV) controls the air traffic and is responsible for the civil aviation safety and security. To continuously improve flight safety, they work systematically to identify and exclude all potential risks of accidents, so that an increase in air traffic does not lead to more incidents (Swedish Aviation Department (LFV), 2010b). Despite this, there may be a difference in how airlines deal with safety issues, and security levels may also differ between countries (McFadden & Towell, 1999).

The safety perspective in high-risk industries is multifaceted and dependent of many factors, like technology, organization, context, individuals and activities in themselves, while all the different factors are connected and interacting with each other (Svenson, 2006). Managing complex technological systems requires understanding of the fact that technical shortcomings as well as human error or environmental factors may affect safety (Glendon, Clarke & McKenna, 2006). Research on aviation safety focuses largely on situational factors that may contribute to the occurrence of accidents, rather than the underlying factors to human error, even though aviation accidents are often somehow preceded by human error (Shappell et al., 2007). In order to understand more about the reasons for aviation-accidents, it can be considered relevant to explore psychological factors that are possibly related to human error, like pilot decision-making.

Pilot decision-making
There is an interest from society in studying situations where the public is likely to suffer severe damage (Svenson, 1975), and an example of this could be the occurrence of a plane crash. Accidents are often the result of a chain of events in which the pilot is the last link, and the pilots´ ability to handle an emergency situation can determine whether an incident will result in an accident or not (McFadden & Towell, 1999). Therefore, 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 largely influenced by multiple factors that act simultaneously on the psychological processes of the pilot (Madhavan & Lacson, 2006), and developing good decision-making skills is suggested to be far more difficult than developing good flying skills (Federal Aviation Administration, 1991).

Pilots need to possess certain abilities in order to handle the advanced and highly developed technology used in the aviation industry. Therefore, pilots are regularly tested in simulators in order to be prepared for unusual situations. 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). In such situations, individual factors may affect decision-making, although the pilots undergo similar training and have the same procedures to follow. There are a number of rules, models, standard procedures and policies for decision-making that pilots can adhere to when making decisions (Federal Aviation Administration, 1991). Although there are rules and models 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 one third of the accidents in commercial aviation (Shappell et al., 2007).

Unstabilized approach: A typical decision-making situation where violations occur
One reason why accidents may occur is because people sometimes decide to violate existing rules and regulations. Numerous reasons for rule-violations in organizations
operating in hazardous environments have been suggested, like psychological, situational and organizational factors influencing the behaviour of the individual (Reason, Parker & Lawton, 1998). One typical example of a situation when pilots are prone to violate standard operating procedures, is when the plane is nearing landing and the pilot find the approach being unstabilized (Directorate Generale of Civil Aviation, 2008). Being unstabilized means that certain criteria regarding speed, aircraft configuration and checklist completion are not fulfilled when the aircraft and crew are at an altitude of 1000 feet above the ground (Skybrary, 2009b). If the approach is unstabilized the pilot has to make a choice whether to continue the approach with the intention to land, or to abort the landing and perform a so-called missed approach. Performing a missed approach means to abort the approach to land, and return for a new approach. According to standard operating procedure the correct behaviour is to perform a missed approach. However, when this situation occurs in reality, pilots often choose to continue the approach with the intention to land, despite that it means a rule violation (Directorate Generale of Civil Aviation, 2008).

Continuing the approach when being unstabilized may cause the aircraft to arrive at the runway to high or to fast, or to be unprepared for landing in other ways. This can result for example in a so-called runway excursion, meaning that the aircraft is unable to stop before the end of the runway is reached (Skybrary, 2009b). Unstabilized approaches are rather common in reality, but for pilots to choose to perform a missed approach is not, and it has been suggested that in a thousand approaches only a few missed approaches are carried out (Directorate Generale of Civil Aviation, 2008).

There are a number of possible reasons for choosing to violate the standard operating procedure and not perform a missed approach when being unstabilized. For example, the procedure places special demands on the pilot, since it means a deviation from the normal work routine (Skybrary, 2009a). It involves extra amount of work, because it includes aborting the landing and redoing the approach. Besides, being unstabilized is sometimes considered a minor problem that can be managed, and does not necessarily require a missed approach (J. Lindvall, personal communication, April, 6, 2010). Most importantly, since the missed approach procedure is not common in reality the pilots may lack experience of it, and it may therefore be perceived as difficult and stressful. In addition, the pilots may have previous experience from continuing the approach with the intention to land, despite being unstabilized. Therefore, the perceived risk of going around and redoing the approach might be higher than continuing the approach with the intention to land (Directorate Generale of Civil Aviation, 2008). Still, when the criteria for being stabilized are not fulfilled, a missed approach is considered the safest option (Skybrary, 2009b).

Pilots non-technical skills, NOTECHS
In addition to technical skills and knowledge, non-technical skills like cognitive and social abilities, are essential for effective and safe flight operations (Flin, et al. 2005). With the aim of improving pilots’ non-technical skills, the concept of Crew Resource Management (CRM) was introduced. The pilots undergo CRM-training with the objectives to enhance cognitive and interpersonal skills, in order to decrease the number of incidents and accidents caused by human error (UK Civil Aviation Authority, 2006).
Good CRM skills includes good decision-making skills, and decision-making has been defined as the process of reaching a judgement or choosing an option (Flin et al., 2005, p. 145). Pilot decision-making does not involve any specific strategy, since different types of decisions are made in different situations. Decision situations vary for example in what options and support existing in standard procedures and policies for decision-making, in what they demand of the crew, and in which characteristics that are making the situation complex (Flin et al., 2005). Pilots are trained to act in accordance with certain guidelines in decision-making situations (UK Civil Aviation Authority, 2006). The guidelines help the pilots to make as systematic and normatively correct decisions as possible, in order to minimize the risk for unconsidered actions.

To assess pilots’ non-technical CRM skills, and to what extent the pilots adhere to the guidelines for good decision-making, Flin et al. (2005) developed the NOTECHS-system, on request by the European Joint Aviation Authorities. According to the standards of the NOTECHS-system, good decision-making involves problem definition and diagnosis, meaning that the pilot systematically gathers and evaluates information to identify problems and determine the nature of the situation. Good decision-making also involves generating and comparing options and alternative approaches that solves the situation. The risks and hazards in the alternative courses of action should also be considered and evaluated. In addition, good decision-making includes consulting other crewmembers, and after choosing and implementing a preferred approach, outcome review should be performed.

The evaluation procedure of the non-technical skills is executed in a flight simulator. One session in the simulator usually lasts for approximately four hours, and a number of scenarios and different exercises are carried out. In every session two pilots fly together as a team, and one certified flight instructor is present. During the session the instructor evaluates and judges the pilots’ non-technical skills, based on how they reason, behave and work together through the scenarios and exercises. Their non-technical skills are rated on a scale, and high ratings indicate that the pilots to a great extent adhere to the guidelines for ideal decision-making. This means that they have a systematic, analytic and normatively correct behaviour when making decisions in the professional role as a pilot.

The purpose of the assessment is to provide feedback and give indications for retraining, if this is required. The NOTECHS-system, or airlines own version of it, is used by a number of airline companies in Europe and beyond (Flin et al., 2005).

Naturalistic decision-making (NDM)
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, like the Expected utility theory and the Prospect theory, has 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 a 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 behaviour (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 (Svenson, 1975). 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. This may lead to the use of intuitive judgement (Tversky & Kahnemann, 1983). Intuitive decisions have been proposed to be automatic, fast, emotional and made without structured reasoning, calculations or analytical models (Kahnemann & Tversky, 1982).

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 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, 1993) and suggests that people use their experience when making situational judgements (Klein, 2008). In an attempt to define NDM it has been suggested that 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, p. 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 refreshing 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, 2003). NDM is usually studied in operative environments, for example among military commanders, pilots and fire-fighters, 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).

**Experience-based decision-making and the Recognition Primed Decision (RPD)-model**

One model describing how people can use experience to make decisions is the Recognition Primed Decision (RPD)-model, which is a model within the field of NDM. The model differs from traditional decision theory in the sense that it hypothesizes 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 judgements about the current situation. The model was generated to explain how people make decisions in difficult situations, where factors like time pressure and uncertainty are involved. It is based on studies of experts’ decision-making in real-world settings, like fire commanders (Klein, 2009). Literature on experts’ decision-
making proposes that they make better decisions than others, partly due to effective strategies for focus of attention. An expert refers to an individual with expertise in a specific area, evolved during a long period of time (Schriever et al., 2008), e.g. experienced aviation pilots. Experts are considered to be able to take more aspects in consideration, but their experience allows them to base decisions on fewer and more critical aspects (Klein, 2009; Svenson & Salo, 2003).

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 the strengths and weaknesses of these options in parallel (Klein, 1993). 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, 2009). 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 two parts – pattern matching and mental simulation. The decision-maker uses pattern matching to generate a possible course of action and then uses mental simulation to evaluate the chosen course of action (Klein, 1993). Pattern matching involves a search for patterns that describes the most typical 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 then conducts a mental simulation of the chosen alternative to see if it will work. If it does work it will be implemented, and if it does not, it will be modified, until a satisfying one is found (Klein, 1993). 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, 2009).

**Individual differences in decision-making and general decision-making styles (GDMS)**

Traditional decision theories, like the Expected utility theory and the Prospect theory, do not take into consideration the possibility of individual differences in decision-making styles. Nevertheless, the existence of individual differences in decision-making styles have been suggested in other research (Scott & Bruce, 1995; Thunholm, 2004).

Research on decision-making styles derives partly from research on cognitive styles (Thunholm, 2004). Understanding of why people might have different decision-making styles requires understanding of the fact that their cognitive styles might differ. People may perform the activities of perceiving, remembering, processing information and solving problems in different ways, indicating differences in cognitive styles (Messick, 1976). Cognitive styles have been suggested to be a stable part of the personality, since it is referring to the stable and habitual manner in which people perform cognitive activities (Messick, 1984). It cuts across domains of ability and interpersonal behavior and is not easily changed. Cognitive style reflects ‘how’, and not ‘how well’, people perceive and judge information, and focuses on individual traits rather than cognitive ability (Messick, 1976). Differences in cognitive 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).
As mentioned, research on decision-making styles derives partly from research on cognitive styles. Scott and Bruce (1995) identified five different decision-making styles; rational, intuitive, dependent, avoidant and spontaneous. Scott and Bruce 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 (Scott & Bruce, 1995, p 820). Thunholm (2004, p. 941) suggested a wider definition of the term after concluding 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 (2004) takes the whole individual into consideration and 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. The five decision-making styles identified by Scott and Bruce (1995) are independent but not mutually exclusive, and individuals seem to use a combination of styles when making important decisions (Scott & Bruce, 1995; Thunholm, 2004). The general decision-making styles have been explored among other categories of experts operating in naturalistic environments, like military forces (Thunholm, 2004; Thunholm, 2009), but never among aviation pilots. The five different general decision-making styles identified by Scott and Bruce (1995) are presented in the following sections.

The rational decision-making style is characterized by a comprehensive search for information, and logical evaluation of alternatives. A prominent feature of the rational style is to make decisions in a logical and systematic way, and to consider various options in terms of a specific goal. It also involves factors like planning important decisions carefully and double-checking information sources to be sure to have the right facts before making decisions.

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.

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 advise of others in decision-making situations.

The avoidant style is characterised 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.

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).

Present study
Since incorrect decision-making among pilots has proved to be contributing to numerous air-traffic incidents and accidents (Shappell et al., 2007), it may be considered relevant to study pilots’ decision-making. Pilots are trained to use systematic, analytic and normatively correct non-technical skills in cockpit decision-making situations (Flin et al., 2005). On the other hand, naturalistic decision-making theory suggests that experts in naturalistic settings, like aviation pilots, tend not to act systematic and analytic in decision situations, but make decisions based on experience (Klein, 1993). The primary purpose of the present study was to explore the relation between systematic and analytic non-technical skills and experience-based decision-making among aviation pilots. A second purpose of the present study was to explore whether non-technical skills and experience-based decision-making could predict whether to choose to perform a missed approach or continue the approach with the intention to land, when being unstabilized. In addition, the study aimed to explore the relations between general decision-making styles, and non-technical skills and experience-based decision-making.

It has been proposed that naturalistic decision-making can be studied with other than qualitative methods (Zsambok, 1997), and quantitative methods have been used in previous studies to measure use of experience-based decision-making (Fallesen, 2000; Klein, 1993; Pascual & Henderson, 1997). Therefore, it was considered relevant to try to capture experience-based decision-making with a quantitative method, though naturalistic decision-making traditionally has been studied in naturalistic settings. After having introduced the features of pilots’ non-technical skills, the missed approach procedure, and the fields of naturalistic- and experience-based decision-making, as well as general decision-making styles, some hypotheses underlying the present study will be presented in the following section.

Hypothesis 1: A negative relation between non-technical skills, and experience-based decision-making.

Hypothesis 2: Being sure of choosing to perform a missed approach when being unstabilized, can be predicted by high non-technical skills.

Hypothesis 3: Being sure of choosing to continue the approach with the intention to land when being unstabilized, can be predicted by high experience-based decision-making.

Hypothesis 4: High non-technical skills can be predicted by rational general decision-making style, but not by any of the other styles.

In addition, the study aimed to explore the relations between the five general decision-making styles, non-technical skills and experience-based decision-making.
Method

Participants and procedure
Sixty commercial aviation pilots participated in the questionnaire study. The average level of working experience as a pilot was 25.0 years, SD = 6.6. The average number of flight hours was 10725.0, SD = 3402.6. The participants who failed to fill out some of the questions were excluded from the analyses where appropriate.

In the present study a web-based questionnaire was used. The questionnaire was posted on a web-page and the participants were invited to participate via e-mail. The questionnaire contained information about the general purpose of the study, which was to explore decision-making in aviation. The participants were informed that the answers were anonymous and would only be treated statistically, and that their answers should reflected their real behavior and not how they would like or should behave. It was declared that the experience and opinion of the individual was of importance, no matter what manuals, authorities, the company, colleagues or others prescribed or believed.

Instrument
To replicate the factors present in real-world decision-making to the highest possible extent, the experiment was based on a scenario familiar to the participants. The scenario described a cockpit decision situation where an unstabilized approach occurs. When the described problem occurs in real life, the pilot should abort the approach and perform a missed approach, according to existing rules. In reality, pilots often choose to continue the approach with the intention to land when in this situation, despite that it means violation of the standard operating procedure (Directorate Generale of Civil Aviation, 2008).

The following scenario was presented: Imagine you are flying into Copenhagen on a normal working day. It is the end of May, the time is 11.30 and you are on time. The day has been uneventful with no delays or other problems so far. Now you are flying a radar vectored approach into rwy 22L in IMC conditions. The ATIS reports wind calm, visibility 4 km in drizzle, overcast at 700 feet. You are PF. ATC take you in rather tight and you are slightly high. You manage to compensate for this by increasing speed and rate of descend. When you are back on the ILS-profile you find that the speed is slightly high and slowly decreasing. Due to high speed you find yourself being not stabilized at 1000 ft. PNF calls: "1000 ft, not stabilized".

After the scenario the participants were instructed to try to imagine how they would act if it was a real situation. The pilots had two main alternatives to choose between: A, continuing the approach with the intention to land, or B, perform a missed approach. The pilots were asked the following question: Sometimes when people make choices they know for sure what they will choose, sometimes they are uncertain. If you had to choose one of the above options, A or B, what would you choose to do, and how certain are you about your choice? The choice and how certain they were about their choice was measured with a six grade scale: 1: A, for sure; 2: A, quite certain; 3: A, uncertain; 4: B, uncertain; 5: B, quite certain; and 6: B, for sure. The variable was considered a continuing variable with low value representing being sure of landing, and high value representing being sure of performing a missed approach. This scale
was developed in order to capture that choices are often more than a clear and simple choice between two alternatives.

Non-technical skills were measured with the NOTECHS-inventory. Traditionally the non-technical skills are objectively judged by certified flight instructors. For the purpose of the present study a self-rating scale with eight items was developed, based on the elements of the decision-making category of the NOTECHS-system, created by Flin et al (2005). The participants were asked to consider eight statements regarding their own decision-making at work as a pilot. They were instructed to assess how well the statements described their behavior in cockpit decision-making situations in general. The NOTECHS-inventory is included in an appendix.

For the purpose of the present study, one item was developed to capture experience-based decision-making. The item was: I used my experience to determine the best course of action. A five step Likert-scale with the answering-alternatives Strongly disagree, mostly disagree, partly disagree and partly agree, mostly agree, and strongly agree was used.

General decision-making styles were measured with the General Decision-Making Style- (GDMS) inventory, by Scott & Bruce (1995). The participants were asked to consider statements regarding how they go about making important decisions in general, both at work and in private. They were instructed to assess how well the statements describe how they actually act when they make important decisions in general. If they believe that they act differently in different situations they were asked to indicate how they would act most of the time. The inventory contained a total of 25 items, with five items measuring each of the general decision-making styles; Rational, Intuitive, Dependent, Avoidant and Spontaneous. A five step Likert-scale with the answering-alternatives Strongly disagree, mostly disagree, partly disagree and partly agree, mostly agree, and strongly agree was used. Example-items: Rational: I make decisions in a logical and systematic way. Intuitive: When making decisions, I rely upon my instincts. Dependent: I often need the assistance of other people when making important decisions. Avoidant: I postpone decision-making whenever possible. Spontaneous: I often make impulsive decisions.

In addition, some open-ended questions were asked, in order to get more information about the participants thoughts regarding the missed-approach procedure, and reasons for their behaviour.

Results

To test hypothesis 1, that there would be a negative relation between non-technical skills and experience-based decision-making, a correlation analysis was conducted. No significant correlation was found \((r = -.107; p > .05; N = 56)\), indicating no relationship between using non-technical skills and experience in decision-making.

To test hypothesis 2 and 3 a multiple regression was performed with the choice of action in the unstabilized approach-situation as the dependent variable. Non-technical skills and experience-based decision-making was independent variables. No significant effect for non-technical skills or experience was found. The result showed
no support for hypothesis 2, stating that being sure of choosing to perform a missed approach when being unstabilized, can be predicted by high non-technical skills. Also, the results showed no support for hypothesis 3, stating that being sure of choosing to continue the approach with the intention to land when being unstabilized, can be predicted by high experience-based decision-making. The model was not significant: $F(2,55) = 0.86, p > .05$. The overall explained variance was $R^2_{adj} = -.005$.

To test hypothesis 4, that high non-technical skills can be predicted by rational general decision-making style, but not by any of the other styles, a multiple regression was performed. Non-technical skills was dependent variable, and the general decision-making styles were independent variables. The results showed a significant effect for the rational general decision-making style, but not for the others, supporting hypothesis 4, and the results can be seen in Table 1. The model was significant: $F(5,55) = 3.37, p < .05$. The overall explained variance was $R^2_{adj} = .177$.

Table 1. Multiple regression analysis with non-technical skills as the dependent variable, and the general decision-making styles as independent variables

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<th>Variable</th>
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<th>SE B</th>
<th>β</th>
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<tr>
<td>Rational</td>
<td>0.78</td>
<td>0.20</td>
<td>0.51*</td>
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<tr>
<td>Intuitive</td>
<td>0.24</td>
<td>0.20</td>
<td>0.18</td>
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<td>Dependent</td>
<td>-0.10</td>
<td>0.17</td>
<td>-0.08</td>
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<tr>
<td>Avoidant</td>
<td>0.08</td>
<td>0.15</td>
<td>0.07</td>
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<tr>
<td>Spontaneous</td>
<td>-0.12</td>
<td>0.20</td>
<td>-0.09</td>
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* $p < .05$. $N = 55$.

The final aim of the present study was to explore the relations between the five general decision-making styles, non-technical skills and experience-based decision-making. A correlation analysis measuring the relations between the general decision-making styles, non-technical skills and experience-based decision-making showed a significant correlation between the intuitive and the spontaneous styles, as can be seen in Table 2. In Table 2 it can also be seen that the correlation between the rational style and non-technical skills, as well as between the intuitive style and experience-based decision-making, was significant.

Table 2. Correlations between the general decision-making styles, and non-technical skills and experience-based decision-making

<table>
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<td>2 Intuitive</td>
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<td>3 Dependent</td>
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<td>-.108</td>
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<td>4 Avoidant</td>
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<td>.210</td>
<td>.248</td>
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<tr>
<td>5 Spontaneous</td>
<td>-.115</td>
<td>.504**</td>
<td>-.056</td>
<td>.236</td>
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<td></td>
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<tr>
<td>6 Non-technical skills</td>
<td>.467**</td>
<td>.057</td>
<td>-.045</td>
<td>-.040</td>
<td>-.038</td>
<td></td>
</tr>
<tr>
<td>7 Experience</td>
<td>-.107</td>
<td>-.315*</td>
<td>-.195</td>
<td>-.138</td>
<td>.074</td>
<td>-.107</td>
</tr>
</tbody>
</table>

* $p < .05$; ** $p < .01$
In addition, descriptive statistics were calculated for the included variables and is presented in Table 3. All the variables were normally distributed with skewness and kurtosis less than +/- 2, except for the experience-variable, with kurtosis 2.3.

Table 3. Mean, standard deviation, and reliability measures where appropriate, for non-technical skills, experience-based decision-making, and the general decision-making styles

<table>
<thead>
<tr>
<th></th>
<th>Mean</th>
<th>SD</th>
<th>Alpha</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Non-technical skills</td>
<td>31.95</td>
<td>3.49</td>
<td>0.72</td>
<td>56</td>
</tr>
<tr>
<td>Experience</td>
<td>4.21</td>
<td>1.14</td>
<td></td>
<td>58</td>
</tr>
<tr>
<td>Rational</td>
<td>19.00</td>
<td>2.22</td>
<td>0.59</td>
<td>56</td>
</tr>
<tr>
<td>Intuitive</td>
<td>16.04</td>
<td>2.59</td>
<td>0.66</td>
<td>56</td>
</tr>
<tr>
<td>Dependent</td>
<td>15.73</td>
<td>2.63</td>
<td>0.61</td>
<td>56</td>
</tr>
<tr>
<td>Avoidant</td>
<td>10.09</td>
<td>3.10</td>
<td>0.84</td>
<td>56</td>
</tr>
<tr>
<td>Spontaneous</td>
<td>12.41</td>
<td>2.56</td>
<td>0.72</td>
<td>56</td>
</tr>
</tbody>
</table>

Note. Maximum score for non-technical skills = 40, experience-based decision-making = 5, and the general decision-making styles = 25.

Discussion

The primary purpose of the present study was to explore the relation between non-technical skills and experience-based decision-making among aviation pilots. A second purpose was to explore whether non-technical skills and experience-based decision-making could predict whether to perform a missed approach or continue the approach with the intention to land, when being unstabilized. In addition, the study aimed to explore the relations between general decision-making styles, and non-technical skills and experience-based decision-making.

To summarize the results, no relationship between using non-technical skills and experience in decision-making was found. Choosing to perform a missed approach when being unstabilized cannot be predicted by high non-technical skills. Also, choosing to land when being unstabilized cannot be predicted by high experience-based decision-making. However, high non-technical skills can be predicted by rational general decision-making style. In the following sections the results obtained from the present study will be further elaborated and discussed.

No relationship between using non-technical skills and experience in decision-making

High non-technical skills indicate systematic, analytic and normatively correct behaviour for pilots in a cockpit decision-making situation. It involves factors such as performing a systematic search for information to identify problems, to generate and compare different options, and consider and evaluate risks of alternative courses of action (Flin et al., 2005). Experience-based decision-making indicates that the decision maker uses knowledge about the field and experience of similar situations to understand and make judgements about the current situation, without making systematic and analytic evaluations. The theory suggests that people rapidly can generate a good option as the first one considered, without comparing alternatives, and that the decision maker is satisfying rather than optimizing (Klein, 1993). Hence, high
non-technical skills were assumed to be associated with a tendency not to make decisions based on experience, though the results from the present study did not confirm this.

One possible explanation for the results might be that the NOTECHS-inventory measures non-technical skills in general, and the answers reflect how the participants generally behave in cockpit decision-making situations. The experience-based decision-making variable on the other hand, refers to use of experience in the specific decision situation described in the scenario presented in the questionnaire. High mean for both non-technical skills (M=31.95; max=40) and experience-based decision-making (M=4.21; max=5) indicates that the pilots may generally be rational when making decisions in the professional role as a pilot, while they in the specific situation of choosing whether to land or perform a missed approach when unstabilized, use experience to determine the best course of action.

Choosing to perform a missed approach when being unstabilized, cannot be predicted by high non-technical skills

High non-technical skills suggest a tendency to act structured, analytical and normatively correct in a cockpit decision-making situation. Since performing a missed approach is the normatively correct behavior in the described scenario, it was expected that non-technical skills could predict choosing to perform a missed approach. However, the results from the present study failed to support this, why the hypothesis was rejected. In this case as well, the results might be explained by the design of the NOTECHS-inventory, measuring non-technical skills in decision-making situations in general.

Choosing to continue the approach with the intention to land when being unstabilized, cannot be predicted by high experience-based decision-making

The RPD-model hypothesise that decision-makers in naturalistic settings are satisfying rather than optimizing, meaning that they satisfy with the first possible alternative, if a mental simulation indicates that the option will work (Klein, 1993). It cannot be excluded that pilots to some extent act in line with the RPD-model and satisfy with the first possible option, when choosing whether to land or perform a missed approach, although the results from the present study failed to demonstrate this. Since the situation of continuing the approach with the intention to land when being unstabilized is rather common in reality (Directorate Generale of Civil Aviation, 2008), it is possible that pilots may have previous experience from the described situation. Also, since landing in general is a much more common procedure than performing a missed approach, being something the pilots do and practice in every flight, it might be the first option that comes to mind when nearing landing, even if the approach is unstabilized. According to the RPD-model, the decision-maker matches the pattern of the current situation to patterns learned from previous situations, and then conducts a mental simulation of the chosen alternative to see if it will work (Klein, 1993). If patterns match and the mental simulation suggests that landing is a possible course of action, pilots might be satisfied with this option and choose to land, despite that the optimal choice might be to perform a missed approach.

Various reasons for choosing not to perform a missed approach when being unstabilized was presented earlier in the present paper, and the answers to the open-ended questions in the questionnaire are in line with previous suggested theory. It was
expressed that to continue the approach with the intention to land, in the situation presented in the scenario, was not necessarily perceived as dangerous. It was also expressed that the missed approach procedure was associated with risk, due to lack of experience, since the missed approach procedure is a seldom executed manoeuvre. Therefore, performing a missed approach might just as well be connected to risk, and possibly not always the safest option after all. Still, the stabilized approach concept was described as being one of the most important tools there is for pilots, in order to avoid landing-related accidents.

*High non-technical skills can be predicted by rational general decision-making style*

The findings in the present study indicate that a rational general decision-making style can predict high non-technical skills, that is, systematic, analytical and normatively correct behaviour in a cockpit decision-making situation. Since the general decision-making style has been suggested to be a stable part of personality (Thunholm, 2004), it might be reasonable to believe that individuals with a rational style acts in accordance with the suggested characteristics of the style, in private as well as in the work role. This would imply that pilots with a rational general decision-making style would make a comprehensive search for information, evaluate and compare options, double-check information and so on, also when in the work context.

*Positive relation found between intuitive and spontaneous general decision-making style*

The intuitive general decision-making style is characterized by a tendency to rely on instincts, inner feelings and inner reactions. Individuals with an intuitive style has been suggested not to perform a systematic search for information, and to make decisions based on what feels right, rather than to have a rational reason for it (Scott & Bruce, 1995). The spontaneous style is characterized by feelings of immediacy and a desire to get through the decision-making process as quickly as possible, and by making decisions based on what seems natural at the moment (Scott & Bruce, 1995). The results from the present study suggest a positive relation between the intuitive and the spontaneous style. This might be due to possible similarities in the characteristics of the two related styles, since it has been proposed that 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 results from the present study are also in line with previous research, since a positive relation between the intuitive and the spontaneous style has been suggested before (Scott & Bruce, 1995; Thunholm, 2004; Thunholm, 2009).

*Negative relation found between intuitive general decision-making style and experience-based decision-making*

The negative relation found between the intuitive style and experience-based decision-making indicates that the more a person makes decisions based on intuition and feelings, the less the person makes decisions based on experience. The negative relation can also be interpreted the other way around, indicating that the less intuitive a person is in decision-making style, the more the person uses experience in decision-making.

*The scales used in the present study*

The scales of the GDMS-inventory have shown to be reliable with military officers, students, engineers and technicians with a Cronbachs alpha ranging from 0.65 to 0.85
for the rational scale; 0.72 to 0.84 for the intuitive scale; 0.62 to 0.86 for the dependent scale; 0.84 to 0.94 for the avoidant scale, and 0.77 to 0.87 for the spontaneous scale (Loo, 2000; Scott & Bruce, 1995; Spicer & Sadler-Smith, 2005; Thunholm, 2004). In
the present study, the reliability for some of the scales in the GDMS-inventory might be considered low, with a Cronbachs alpha of 0.59 for the rational scale and 0.61 for the dependent scale. This might obstruct high correlations and possibly result in underestimated relations between variables. However, the results from the present study suggest that the rational general decision-making style can predict high non-technical skills, and the correlation between the two variables was significant. The results also indicate that the NOTECHS-inventory and the rational decision-making style scale both measure what they intend to measure, that is, systematic and analytical decision-making, giving rise to the conclusion that both of the scales can be considered valid. The usability and psychometric properties of the NOTECHS-system used in flight-simulators has been tested by several aviation research centres and aviation business centres, as well as a number of airlines (see Flin et al., 2005, for review). The present study contributes with the use of the NOTECHS-inventory, measuring pilots’ non-technical skills by subjective ratings. The NOTECHS-inventory proved to be reliable, with a Cronbachs alpha of 0.72 suggesting that it can be used to successfully capture pilots’ subjective ratings of non-technical skills in decision-making situations. The item that was used to measure experience-based decision-making was designed based on informal interviews with airline pilots and validated in a pilot-study.

Further research
The NOTECHS-system was originally developed to measure pilots’ general non-technical skills, with the basis that general skills are used in specific situations. Therefore it was considered reasonable to believe that the skills would show in the specific decision-making situation presented in the present study. Still, it cannot be excluded that different results might have been obtained if the non-technical skills would have been measured differently. Therefore, one suggestion for further research would be to measure non-technical skills in a specific cockpit decision-making situation, instead of assuming that the general non-technical skills would show in a particular situation.

It might be reasonable to believe that other factors, besides non-technical skills and experience, can have an effect on the pilots’ choice of action when the approach is unstabilized. In order to understand more about the underlying factors influencing the decision, more research on the missed approach procedure is suggested. For example, it might be of interest to explore attitudes towards the missed approach procedure, among pilots as well as organizations as a whole.

The decision-making situation in the present study should be seen as an example of one situation where pilots might choose to violate standard operating procedures. Since the results show that the participants did to some extent chose to violate existing rules in the unstabilized approach situation described, it might be reasonable to believe that rule-violations occur in other decision-making situations as well. Therefore, the relation between experience-based decision-making and additional rule-violation behaviours in the aviation context would be interesting to investigate further.
Concluding remarks

One last remark is that it should be considered that every cockpit decision-making situation is unique. Despite the fact that different situations may be similar to each other, details will differ. It should also be kept in mind that all people are individuals, who perceive and understand situations in different ways depending on individual factors. Hence, they might behave in different ways, despite the existence of rules, policies and standard operating procedures. This means that whenever humans are involved, and processes are depending on human judgement and actions, the human factor cannot be ignored. Therefore, it can be considered relevant to further explore the underlying factors to human error, and their effect on safety in hazardous environments, like the aviation industry.

References


Thunholm, P. (2003). *Decision making under time pressure: To evaluate or not to evaluate three options before the decision is made?* Manuscript submitted for publication.


Appendix

The NOTECHS-inventory

I always gather information to identify problems
I always review casual factors with other crew members
I always state alternative options
I always ask other crew members to develop options
I always consider and share risks of alternative course of action
I always talk about possible risks for action in terms of crew limits
I always confirm and state selected option/agreed action
I always check outcome against plan

Answering-alternatives for all items:
Strongly disagree
Mostly disagree
Partly disagree and partly agree
Mostly agree
Strongly agree