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Pilot Decision Making: Modeling Choices in Go-Around Situations

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Pilot decision making is highly influenced by cockpit information displays. Decision quality could benefit from knowledge of temporal and individual influences on decision making under time pressure that suggests leverage points for cockpit or process design. In a recent flight simulator experiment, airline pilots were presented a realistic landing scenario. During the approach phase, instruments indicated weather conditions suggesting a go-around decision to be taken. The alternative decision consists of landing in spite of illegitimate strong tailwind. Gaze tracking analysis identified, whether relevant display information was picked up by the pilots. The time between checking the aircraft's wind indicator and the moment of decision was taken as predictor of choice to go-around. Modeling of pilots' choice behavior shows strong influences of the predictor analyzed. A comparison of long-haul captains and short-haul first officers shows dependency of decision-behavior on level of practice and training.

Introduction

One important aspect of good airmanship is pilots' decision making (FAA, 2004; DeMaria, 2006). A pilot's ability to soundly decide duly prevents hazardous situations. While several aspects of good airmanship like manual flying skills can be taught and exercised at flight school, long-term experience is needed to build up comprehensive knowledge for an aviator to find appropriate decisions in a certain situation. One potentially hazardous situation is the approach phase, representing more than one third of all fatal accidents (IATA, 2011; Boeing, 2012). Two typical accident categories defined by the International Air Transport Association are runway excursions (23% of IATA listed aircraft accidents in 2010) and hard landing (5%). In-depth analysis has shown, that in 35% of the runway excursions in 2010, meteorology has been a contributing factor. To complement this information, in one fourth of all cases, the flight crew has failed to go-around after an unstabilized approach (IATA, 2011). The safety reports of the years before have shown very similar numbers and evidence. One lesson to be learned from these reports is that a go-around can be a safe decision to master the high-risk situation of a hazardous approach.

Taxonomy of go-around behavior

The focus of this experiment is the pilots' behavior in an approach scenario, where a go-around has to be performed by the pilot flying (PF) because of an illegitimate high tailwind (Table 1). The PF should be aware of this wind situation and trigger the go-around by himself (type 1). If he is not aware of the tailwind, a cue by the pilot monitoring (PM) can lead the PF to trigger the go-around (type 2). In both cases it may happen that the PF does not trigger the go-around because of a decision to land in spite of the tailwind (type 3) or because of not being aware of the wind even when a cue is given (type 4).

Table 1.

Different types of pilots' behavior concerning the decision of a go-around.

	pilot is aware of wind situation	pilot is not aware of wind situation
pilot is going around (PGA)	Type 1	Type 2
pilot is not going around (PnGA)	Type 3	Type 4

For type 1 und 2 the time intervals between different wind checks can be calculated (Figure 1). If a pilot is aware of a wind potentially differing from the ATC information, he should early perform a first wind check (t_1) in the final approach (below 1,000 ft above ground level) and should repeat this check continuously until a final decision to (not) go around is made. The final wind check before the go-around is also measured (t_2). If only one wind check is performed first and last check time coincide (t_1=t_2).

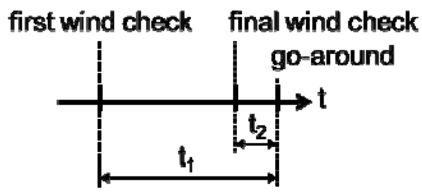

Figure 1. Times measured between different wind checks.

As third gaze indicator the time duration between first (t_1) and final (t_2) wind check (t_1-t_2) can be calculated.

Research Questions

One research question of this study is: Does the amount of experience influence pilots‘ decision making behavior? In a first analysis two groups of pilots that differ in their level of training are compared in regard of frequencies of go-around behavior as described in Table 1. In a second analysis, this behavior is further detailed independently from the two different groups in terms of related underlying mechanisms?

Dual-process influences on pilot decision making. To understand the mechanisms underlying these go-around decisions, we put them in context of established behavioral taxonomies and propose continuous usage of relevant information displays as an important predictor of decision making. Many process-models of pilot decision making in a first step assess the situation by observing information and data scanning (e.g. Jenkins et al., 2008; Orasanu, 1995) and branch out depending on the interpretation of this assessment. A central source of decision errors is thereby made explicit: the lack of consideration of important data displays; a perceptual step that also builds the foundational level of Endsley's conception of situation awareness (e. g. Endsley, 2006).

What are the driving forces for pilots to consider relevant information sources, i.e. important data displays? Rasmussen's classification of action identifying skill-based, rule-based, and knowledge-based behavior can help to localize relevant mechanisms (Rasmussen, 1983). As designers of man-machine interfaces we intend to facilitate behavior that is situated near the lower, skill-based part of the taxonomy. The reason for this is illuminated when put in context of dual-process theories of thinking and decision making (e. g. Evans, 2008; Kahneman & Fredricks, 2002; Kahneman, 2003, 2011). Skill-based behavior is a function of system 1 whose processes are automatic, opaque, and effortless (Kahneman, 2011). System 2 is a highly flexible regulatory entity with potential control of system 1 suggestions for action. Its processes are slow, self-aware, and effortful. Behavior on a skill-based level requires less effort and induces less workload than rule- or knowledge-based behavior that is in the domain of system 2. From an energetic self-regulatory perspective that leads to the tendency to invest not more effort than is required in a task. System 2 usually endorses system 1 suggestions and activities; especially in domains of skilled performance.

Recognizing these dependencies the importance of defaults in action selection has to be focused. Using defaults allows automatic behavior by reducing effort necessary for information acquisition and weighing different courses of action (Johnson & Goldstein, 2003). According to O'Hare (2003), "it will be easier to continue with an existing course of action than to change to a new one" (p. 223). So pilots will sometimes tend to stick to unsuitable skill- or rule-based behavior, where analytical knowledge-based strategies would be appropriate (O'Hare, 2003).

Based on these considerations of the interplay of system 1 and system 2 there is one central conjecture on pilot behavior: Variability is to be expected in the influence of system 1 and system 2 on decision making. This variability leads to different degrees of endorsement of less effortful behavioral or decision strategies. We suppose two possible consequences of these strategies: Variability in investing effort in data acquisition behavior and variability in sticking to default decision options. We suppose that these behavioral tendencies have clear influences on the decision to go around.

Hypotheses

Research Hypothesis 1: Pilots with a high level of expertise will come to 'better' decisions based upon good airmanship.

The consequences of potential effort reducing strategies described above might become manifest in different gaze strategies for pilots that finally take the decision to go around (PGA) versus those pilots that would presumably take the decision to land in spite of strong tailwind and a cue from the PM (PnGA). The difference between these two groups might stem from different information acquisition strategies or from different use of default decision options. According to this demarcation, two different, mutually exclusive gaze behaviors would result as a consequence:

Research Hypothesis 2: Pilots not intending to go around (PnGA) perceive relevant information too late or not at all. That is expressed by the following gaze profile: First wind check is later for PnGA than for PGA. There is no difference in final wind check between PnGA and PGA. There is a difference between first and final wind check between PnGA and PGA.

Research Hypothesis 3: Pilots intending to land (PnGA) stick to a default option; up to the point of deciding to choose the default of landing, information acquisition does not differ from PGA. That is expressed by the following gaze profile: First wind check is not differing between PnGA and PGA. There is a difference in final wind check between PnGA and PGA. There is a difference between first and final wind check between PnGA and PGA (Figure 2).

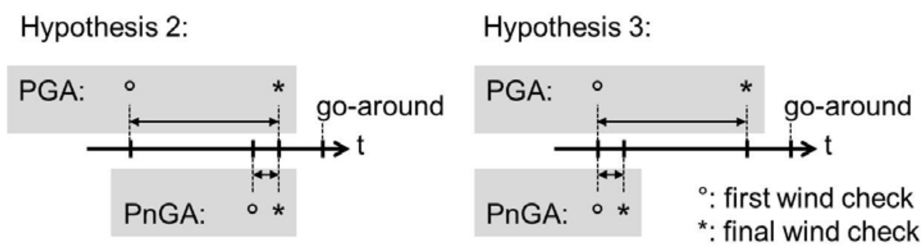

Figure 2. Time charts for wind checks concerning hypotheses 2 and 3.

Method

Participants

This study has been undertaken in cooperation with a major European airline. Pilots with different levels of practice and training were scheduled for a flight simulator experiment by their operations department; i. e. participation was not voluntary. Twenty-six long-haul captains (CPTs) flying Airbus A330/340 types participated the experiment in a full flight simulator (JAR-STD 1A Level D) with A340-600 configuration and twenty-seven first officers (FOs) scheduled on the A 320 short-haul fleet participated in an equivalent A320-200 full flight simulator. The CPTs had a lower level of practice and training, because of their flight school attendance was more way back and they had only few long-haul operations per month (mean value of own performed landings in the 30 days prior to the experiment = 3.4). As contrasting group, younger FOs coming recently from flight school face a high number of short-haul operations per month (mean value of own performed landings in the 30 days prior to the experiment = 16.6). Flight experience (total flight hours) is diametrically opposed to the level of practice and training. All participants had the role of the (PF). A confederate PM complemented the aircrew and was instructed to play a rather passive roll but to avoid errors. All pilots were scheduled on the airline's corresponding fleet, held an appropriate license (ATPL) and were asked to prepare themselves in a same way as for a real flight, to wear uniforms and to bring their own computer for the electronic flight bag system (Haslbeck et al., 2012).

Scenario

All participants were briefed on an uneventful flight from the east to Munich Airport in the early morning hours. The PF came back from his last rest about 25 minutes prior to the landing to perform the approach and landing. In the first phase of the approach, using the autopilot, foreign air traffic control (ATC) communication ('party line') between other approaching aircraft and the airport could be heard. Pilots' tasks were to plan, to monitor and to communicate. When approaching the instrument landing system, it was the PF's decision when to change from autopilot to manual control. To provoke a hazardous situation, at 1.000 ft. above ground level (AGL), a gentle wind turned into an illegitimate strong tailwind (16 knots) by a scripted event. The wind information given by ATC was constantly good over the whole scenario. For pilots, this information given by ATC is binding. Only the non-binding wind indicator located at the pilot's navigation display has shown the real wind strength and direction. Such a hazardous situation can occur when the wind turns, because the wind information given by ATC is averaged over several minutes. So the situation was inexplicit and uncertain for the participants to make the trade-off between a fuel-saving and economic landing with a noticeable higher risk or the abort of the approach for a safe second try (Haslbeck et al., 2012). The chance to go around was given to all participants until 70 ft. AGL. At this height, the PM was instructed to callout 'go-around' and abort the approach due to strong tailwind.

Measurement

Behavioral data were recorded by three complementary methods. All participants were equipped with a head-mounted eye-tracking system (DIKABLIS) to measure their visual behavior (Haslbeck, Schubert, Gontar, & Bengler; 2012); pilots' control inputs were recorded by the flight simulator's data recorder; finally, video and audio data in the cockpit were recorded. From these different sources, a comprehensive image of pilots' decision making can be drawn.

Results

Accomplishment of the go-around according to the different types described in Table 1 was analyzed; results are shown in Table 2. The distinction between type 1 and 2 is based upon the gaze data. It was not possible to distinguish between type 3 and 4, because these pilots could not be asked whether they were aware of the wind in that explicit situation. Pilots were asked about this in the debriefing session after the experiment, but not all could clearly recall this situation and thus type 3 and 4 are considered as one joint type here.

Table 2.

Accomplishment of the go-around.

	Type 1	Type 2	Type 3/4	Total
CPTs	10	4	12	26
FOs	14	11	2	27

In a statistical comparison between CPTs and FOs, significant differences between both groups were found using the chi-squared test: $\chi^2(2)=11.02$; $p = .004$. Because two cells contained less than five cases, Fisher Exact Probability Test was additionally used. This test also shows significant results ($p = .004$).

Comparison of gaze behavior of pilots who took the decision to go around (PGA) and pilots intending to land (PnGA) led to distinct results. Statistical analysis was carried out using Mann-Whitney-Wilcoxon test. Effect size is expressed in units of a bivariate correlation coefficient r, as suggested by Rosenthal and Rosnow (2007). The time of first wind check (t_1) was markedly earlier for PGA than for PnGA: $U = 89$; $z = 2.11$; $p = .035$; $r = .399$, indicating a medium to large effect. There was no significant difference in regard of the time of last wind check (t_2): $U = 137.5$; $z = 0.54$; $p = .597$; $r = .102$. The difference between the time of first and last wind check showed a considerable difference: $U = 49$; $z = 3.41$; $p < .001$; $r = .645$, indicating a very large effect.

Discussion

The results of this study show that long-haul captains with a lower level of practice and training but a high level of operational experience show significantly more willingness to land in a risky situation with strong tailwind than short-haul first officers do. Thus Hypothesis 1 is supported/not supported by the data. When thinking about this behavior, the question arises, how a 'better' decision can be characterized. Two different statements were given by PnGAs corresponding to type 3 and 4:

Type 3: The pilot was aware of the tailwind, but decided to land. In the concrete situation of Munich Airport (MUC) a tailwind landing may be an acceptable risk for someone. Both runways have a length of 4.000m each, which offer a certain safety margin (for comparison longest runway 15R at Boston 3.073m). In addition, some pilots are aware of the fact, that performing a missed approach is also a challenge after several hours of flight duty and so they tend to avoid the go-around.

Type 4: The pilot was not aware of the tailwind and thus the risk of this situation. Some reasons can be fatigue, high workload or a complacent behavior towards the wind situation because of safe wind information given by ATC. This case means insufficient airmanship and yields a higher risk in aviation, independently from the location of the airport.

Hypothesis 1 can neither be accepted nor rejected entirely. Under the assumption, the ‘better’ decision was to go around, the FOs with a higher level of practice and training but less experience more often made the ‘better’ decision to go around. Under the assumption that pilots who feel uncomfortable with a go-around under these circumstances (type 3), the results are not that clear. In this case, more CPTs came to a ‘better’ decision from their point of view. One limitation of this analysis is the fact, that type 3 and 4 couldn’t be clearly distinguished after the experiment.

Results of gaze behavior analysis support the general assumption that there is a difference in effort investment between pilots who took the decision to go around (PGA) and pilots intending to land (PnGA). Based on dual-process theory of cognition two distinct patterns of gaze behavior were derived. According to *Research Hypothesis 2* effort-preserving behavior leads PnGA to delayed information acquisition and so to different first but comparable final wind-checking times. According to *Research Hypthesis 3* reliance on a default option makes PnGA to comparable first but different final wind-checking times. Results provide evidence for the first of these two hypotheses. PnGA perceive relevant information markedly later than PGA, whereas there is no difference in time of the last check. Although not applicable to differentiate between the two explanatory approaches, the difference in time of first and last wind check between PGA and PnGA serves as strong support for the general assumption of effort preserving behavior; be it by way of strategic decision behavior in form of information acquisition or in form of sticking to a default alternative. There seems to be variability in the influence of system 1 and system 2 on decision making. This variability leads to different degrees of endorsement of less effortful behavioral or decision strategies, in turn leading to different information acquisition strategies for PGA and PnGA.

These results suggest two leverage points for supporting decision quality. Effort investment could be reduced by shifting the balance between system 1 and system 2 processes. Information acquisition is cognitively effortful in part because it is not fully automatized. Intensive gaze training procedures could improve theses information acquisition skills. Another approach is to use findings of the fields of human-computer interaction and human factors, to reduce acquisition effort by designing displays appropriately; e. g. by reducing the gaze angle necessary or making relevant information visually more distinct.

Interestingly only a small number of pilots (26 %) would have landed without the PM being instructed to trigger the go-around in any case. Instructor pilots normally report a higher tendency to go-around when being in the flight simulator in comparison to real flights. Pilots can show safety awareness in the flight simulator by frequently performing go-arounds without really making the trade-off between safe flight operation and economic constraints, while in reality the tendency to go around seems lower.

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