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# Hierarchy in the cockpit: How captains influence the decision-making of young and inexperienced first officers

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## ABSTRACT

The present study aimed at investigating the extent to which Captains' risky decisions influence young and inexperienced First Officers. Participants (i.e., student pilots who had almost completed their training) had to decide, alone or in a crew configuration, whether to continue or abort the landing according to four risk levels (safe, moderately risky, highly risky and extremely risky). In the lone pilot configuration, they made their decisions by themselves, while in the crew configuration they were paired with a Captain who acted as a risk taker and almost always chose to land (except in extremely risky situations). The Captain's mere presence led participants to increase their risk-taking in moderately risky situations (before they even knew the Captain's decision), supposedly in an attempt to look competent and impress their superior. In reaction to the Captain's decision to land, participants also increased their risk-taking in highly risky situations. This tendency was positively correlated to the perceived authority of the Captain. Surprisingly, some participants sometimes insisted on continuing the landing in extremely risky situations after the Captain asked for a go-around, suggesting that some pilot students may greatly overestimate their piloting skills (i.e., Dunning Kruger effect). Some applications of the present experimental protocol as training for student pilots are proposed.

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## 1. Introduction

### 1.1. Monitoring and challenging errors in the hierarchical context of the cockpit

Flight crews are composed of one Captain and one or two First Officers depending on the aircraft, with a designated leader and clear lines of authority and responsibility. Though all pilots have the necessary skills to operate the aircraft, only the Captain holds the authority to make crucial and strategic decisions. For instance, before take-off the Captain allocates the role of *pilot flying* – who flies the aircraft – and the role of *pilot monitoring* – who is responsible for the monitoring of instruments, checklists and air traffic control communications (e.g., FAA, 2015). While both the Captain and the First Officer should agree to allow the landing, the Captain is the only one allowed to abort take-off. The Captain as pilot in command is also ultimately responsible for the

operation of the aircraft and its safety during flight, normally being the primary individual liable for the infraction of any rule (e.g., ICAO, 2005). Differences in power, responsibilities, and almost always age and experience between the Captain and the First Officer result in a clearly defined hierarchical system within the cockpit (Palmer, et al., 1995).

Although such an asymmetric organization is highly effective in most cases, a strong difference in status can sometimes be detrimental to flight safety (Tarnow, 2000). Maintaining safety in an aircraft is highly dependent on the pilots' capacity to monitor each other's performance, challenge each other's errors, and intervene in the case they consider an action or a decision is unsafe (Fischer & Orasanu, 2000). The National Transportation Safety Board (NTSB) reported that the failure to monitor and challenge the other pilot's error was involved in 31 of the 37 major accidents attributed to crew errors that occurred between 1978 and 1990 (NTSB, 1994). In these accidents, the Captains were on average three to four times more experienced than the First Officers (i.e., median

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total flying time: 14000 versus 5100 h; experience on the aircraft: 3300 versus 880 h; Tarnow, 2000). Moreover, the Captains almost always committed the primary error and the First Officers failed to detect or correct it (NTSB, 1994). Later, Dismukes and colleagues (2007) found similar results regarding the major accidents that occurred between 1991 and 2000. Taken together, these results suggest that both flight experience and status asymmetries between the Captains and the First Officers can sometimes affect First Officers' capacity to efficiently monitor and correct Captains (e.g., Bienefeld, & Grote, 2012; 2014; Jentsch et al., 1997c; Orasanu et al., 1998).

### 1.2. The difficulty of speaking up to correct the Captain

In the first decades of commercial aviation, the idea that First Officers could challenge Captains was considered outrageous (Tarnow, 2000). In 1952, one major American airline even stated in its guidelines for proficiency that First Officers should not correct the errors made by the Captain (Helmreich & Foushee, 1993). The advent of Crew Resource Management (Helmreich, et al., 1999; Kanki et al., 2019) completely changed the functioning of crews. First Officers are now called to play a more prominent role. They are expected to monitor the Captains' actions and to actively challenge the errors and risky decisions they make. While several studies and safety reports highlighted that most dramatic accidents could have been prevented if First Officers had spoken up and challenged the Captains, First Officers (especially young and inexperienced ones) still struggle to adopt this behavior (Barshi, & Bienefeld, 2018; Dismukes et al., 2007; Jentsch et al., 1997c; NTSB, 1994).

Past research found that when asked about past events in which First Officers observed an error or a violation of procedures from the Captains' part, only 30% of the First Officers who were interviewed declared that they chose to speak up as they are expected to (Bienefeld & Grote, 2012). When asked the reasons why they chose to remain silent, 11% of First Officers declared that they did not speak up because they considered that compared to the Captain, they lacked experience in their current job position or on the aircraft they were operating (Bienefeld & Grote, 2012). Admittedly, the expertise of less experienced pilots is sometimes insufficient to form a judgement, assess levels of risk, maintain a good situation awareness, and manage multiple competing demands (Beveridge et al., 2018; Jentsch et al., 1997a). However, First Officers might also be likely to overestimate the skills of Captains compared to theirs (Milanovich et al., 1998). In the study of Milanovich and colleagues (1998) in which young and inexperienced pilots were asked to indicate their expectations regarding the skills of a Captain and a First Officer (after reading stories depicting a two-pilot crew in which both pilots were described in a similar way), participants reported that they expected the Captain to be more competent, better at situations, more intelligent and to have greater instrument check rating, greater verbal and leadership abilities than the First Officer. Therefore, First Officers, especially when young and inexperienced, may underestimate the likelihood that Captains make an error, partly explaining why they tend to pay too little attention to the Captains' actions and struggle to detect their errors (Orasanu et al., 1998). Even when First Officers detect an error, their unrealistic view of Captains' competence combined with their lack of self-confidence may stifle their willingness to challenge the Captains, fearing to err and worsen the situation – especially when there is an important gap in experience between the two pilots (Tarnow, 2000).

First Officers were also found to be reluctant to speak up by fear of the social consequences of such a behavior (Barshi, & Bienefeld, 2018). In the study of Bienefeld and Grote (2012), 43% of First Officers declared that they feared it would have damaged their relationship with the Captain, 29% reported that they feared being viewed negatively and 23% indicated that they feared retaliations from the Captain. Moreover, First Officers were found to be significantly less likely to challenge the Captains when the errors they made were associated with a high level than a low level of *face threat* (i.e., “the degree of challenge to the status

or integrity of the challenged person”; Orasanu et al., 1998). In brief, these results suggest that First Officers often avoid challenging the Captains' errors (when they are certain that they are making an error) in order to maintain a good relationship with them or by fear of retaliations.

Finally, First Officers' tendency to challenge Captains was found to be highly dependent on cultural norms (Helmreich et al., 2001; Merritt, 2000). First Officers who 1) work in airlines in which safety culture is low and/or 2) whose national culture is characterized by a high-power distance (i.e., acceptance by subordinates of unequal power relationships; Hofstede, 2011) – such as many Asian and Arabic cultures for instance – are way less likely to challenge the Captains' errors (Anca, 2019; Blajev & Curtis, 2017).

### 1.3. Deciding to land or not as a crew

Flight safety highly depends on pilots' effective decision-making (Drinkwater & Molesworth, 2010; Fischer et al., 2003). However, making good decisions can be extremely difficult when the situation is uncertain (i.e., incomplete, vague or conflicting information about current and futures states of the environment; Fischer et al., 2003; Orasanu et al., 2001) and rapidly changing, especially in the case pilots are stressed, overloaded and/or tired (Behrend & Dehais, 2020; Blajev & Curtis, 2017). One of the most important and risky decision pilots have to make during a flight is to decide whether to land the aircraft or make a go-around (e.g., Fischer et al., 2003; Fischer, 2008). Burin (2011) found that flight crews choose to continue the approach to landing 95 to 97 percent of the time during an unstable approach (i.e., unstable approaches representing 3.5 to 4.0 percent of all approaches; Blajev & Curtis, 2017). Unsurprisingly, in the last 20 years the vast majority of accidents occurred during the approach and the landing phases (Airbus, 2020; Boeing, 2020). While these accidents (mainly undershoots, hard landings and runway excursions) are generally not among the deadliest (yet they were responsible for 9% of the fatalities in the 2015–2019 period; IATA, 2020), they result in significant economic costs for airline companies – for instance, runway excursions alone are the primary cause of hull losses (Airbus, 2020). It is estimated that the greater majority of these accidents could have been prevented if pilot crews had made the decision to go-around (Burin, 2011).

Various studies have investigated the reasons why some airline pilots struggle to abort unstable approaches and initiate a go-around (e.g., Behrend & Dehais, 2020; Blajev & Curtis, 2017; Dehais et al., 2017; Fischer et al., 2003; Fischer, 2008). Interestingly, in the study of Blajev and Curtis (2017) airline pilots reported that they usually continue unstable approaches in part because they feel crew pressure to land, perceive a lack of crew support for a possible go-around decision, feel uncomfortable to challenge or being challenged by others, and inhibit their call for a go-around because of the authority structure in the cockpit. This last result is in line with Behrend and Dehais (2020) who found that compared to Captains, First Officers are less likely to call for a go-around. Blajev and Curtis (2017) concluded that while the crew relationship (i.e., crew roles, expectations and communication) should be used as a tool for safe decision making, it may sometimes have a deleterious effect on safety at the moment of landing.

It is long known that individuals tend to make riskier decisions as a group than individually, as a result of peer influence (i.e., risk shift; Dion et al., 1970). Human beings are sensitive to the influence of peers their entire lifetime, with a decline of peers' influence observed between adolescence and adulthood (e.g., Gardner & Steinberg, 2005; Knoll et al., 2015; Reniers et al., 2017; Steinberg & Monahan, 2007). Peers can influence one's decision-making in different ways (e.g., Tomova & Pessoa, 2018). First, the mere presence of another individual was found to be sufficient to modulate one's performance and decisions (e.g., Guerin, 1986; 1989; Qi et al., 2020). Many studies have shown that being observed by peers is likely to increase one's risk-taking (i.e., indirect influence), except when the observer is known to have an aversion

for risk (Gardner & Steinberg, 2005; Haddad et al., 2014; Kretsch & Harden, 2014; Reniers et al., 2017; Smith et al., 2014). Being observed by a peer, whose preference toward risk is either high or unknown, increases the focus on the anticipation of the desired outcome and the tendency to ignore negative consequences of a risky choice (Reniers et al., 2017). Second, receiving a risky advice from a peer, being notified that a peer behaved in a risky way or observing a peer making a risky choice was found to increase one's risk-taking (i.e., direct influence; Haddad et al., 2014; McCoy and Natsuaki, 2018; Suzuki et al., 2016; Tomova & Pessoa, 2018). Being informed that a peer made a specific choice appears to increase the subjective value of that choice (Chung et al., 2015; Tomova & Pessoa, 2018). In case of a risky choice, it nudges the individuals who are provided with the information about peers to behave in a riskier way. Peers can also modulate an individual's risk-perception. Knoll et al. (2015) found that participants scaled down their risk-rating of a risky situation, after knowing that a peer gave a lower risk-rating than theirs.

Individuals usually increase their risk-taking in reaction to peer influence (direct or indirect) aiming to achieve or maintain status, meet the expectations of peers and/or be accepted by a peer or a group of peers (Brown & Braun, 2013; McCoy and Natsuaki, 2018; Reniers et al., 2017; Rimal & Real, 2003). Therefore, the strength of peer influence is highly dependent of the social characteristics of this peer. For instance, peers who are perceived as trustworthy (Frost, & Moussavi, 1992; Hall, et al., 2004), experienced/expert (Meshi et al., 2012) and/or well-intentioned (Bonaccio & Dalal, 2010) are more likely to exert an influence on others. Moreover, high-status peers are usually more influential than neutral or low-status peers (e.g., Choukas-Bradley et al., 2015; Cohen & Prinstein, 2006; Knoll et al., 2015; Prinstein et al., 2011). While the impact of the peer influence on risk-taking has been thoroughly investigated in many fields, such as psychology, economics or law to name a few (see Tomova & Pessoa, 2018), this question has received little attention in aviation (Torrance, 1954). It remains unclear whether and to what extent Captains influence First Officers' landing decisions. The present study aims to contribute to fill this gap in the literature.

#### 1.4. The present study

The aim of the present study was twofold: investigating 1) the own tendency of young and inexperienced pilots to make risky landing decisions; and 2) the extent to which their landing decisions are influenced by a risk-taking Captain. Participants performed a computer task in which they had to decide whether to continue the landing or make a go-around in four types of landing situations that were either *safe*, *moderately risky*, *highly risky* or *extremely risky*. In the first part of the experiment, participants had to make their landing decisions alone (i.e., lone pilot configuration). Their tendency to land as lone pilots served as a risk-taking baseline. In the second part of the experiment, participants were informed that this time they would be paired with a Captain and would have to make their decision with him. In this crew configuration, participants first had to indicate whether they wanted to land or not (i.e., crew pre-decision); and second to make their final decision (i.e., crew final decision), after having been informed of the Captain's decision who always chose to land in safe and uncertain (i.e., moderately and highly risky) landing situations and to make a go-around in the extremely risky landing situations.

Regarding participants' behavior in the lone pilot setting, we predicted that participants' landing rates would be inversely proportional to the dangerousness of the landing situations (*hypothesis 1*). We also predicted that safe and extremely risky landing situations would be easy to categorize as such and that participants would decide quite automatically to continue the landing in safe situations and go-around in extremely risky situations (*hypothesis 2a*). As uncertain situations may trigger a conflict between participants' desire to land the aircraft and the fear of an accident, we predicted that participants would take more time to analyze and decide on uncertain situations (*hypothesis 2b*).

Regarding the impact of the Captain on participants' behavior, we predicted that the Captain's decisions would only influence participants' decisions in uncertain situations (*hypothesis 3*), as the latter were expected to already behave like the Captain in both safe and extremely risky situations (i.e., always choosing to land in safe situations and to make a go-around in extremely risky situations).

We predicted that the Captain's mere presence might influence participants' decisions immediately after the two have been paired (Gardner & Steinberg, 2005; Ginnett, 2019; Haddad et al., 2014), resulting in a difference in landing rates between the crew pre-decision and the lone pilot settings observed for uncertain situations, occurring as of the first trials (*hypothesis 4* on the impact of the Captain's mere presence).

We also made the hypothesis that participants might modify their landing decisions after being informed of the Captain's decisions, resulting in higher landing rates observed for uncertain landing situations in crew final decision setting than in the crew pre-decision setting (*hypothesis 5* on the influence of the Captain's decision; McCoy and Natsuaki, 2018; Suzuki et al., 2016; Tomova & Pessoa, 2018) – and also possibly in the lone pilot setting. Moreover, we predicted that participants would adapt their own risk-taking to the Captain's along the experiment, and progressively increase their landing rates in uncertain situations before knowing the Captain's decision. This would result in higher landing rates observed for the second half than for the first half of uncertain trials in the crew pre-decision setting (*hypothesis 6* on the risk adaptation effect). Finally, we predicted that it would be harder for participants to oppose than to go along with the Captain in crew final decision setting, resulting in participants taking longer to decide to oppose than to validate the Captain's decision to land in uncertain situations (*hypothesis 7*).

## 2. Methods

### 2.1. Participants

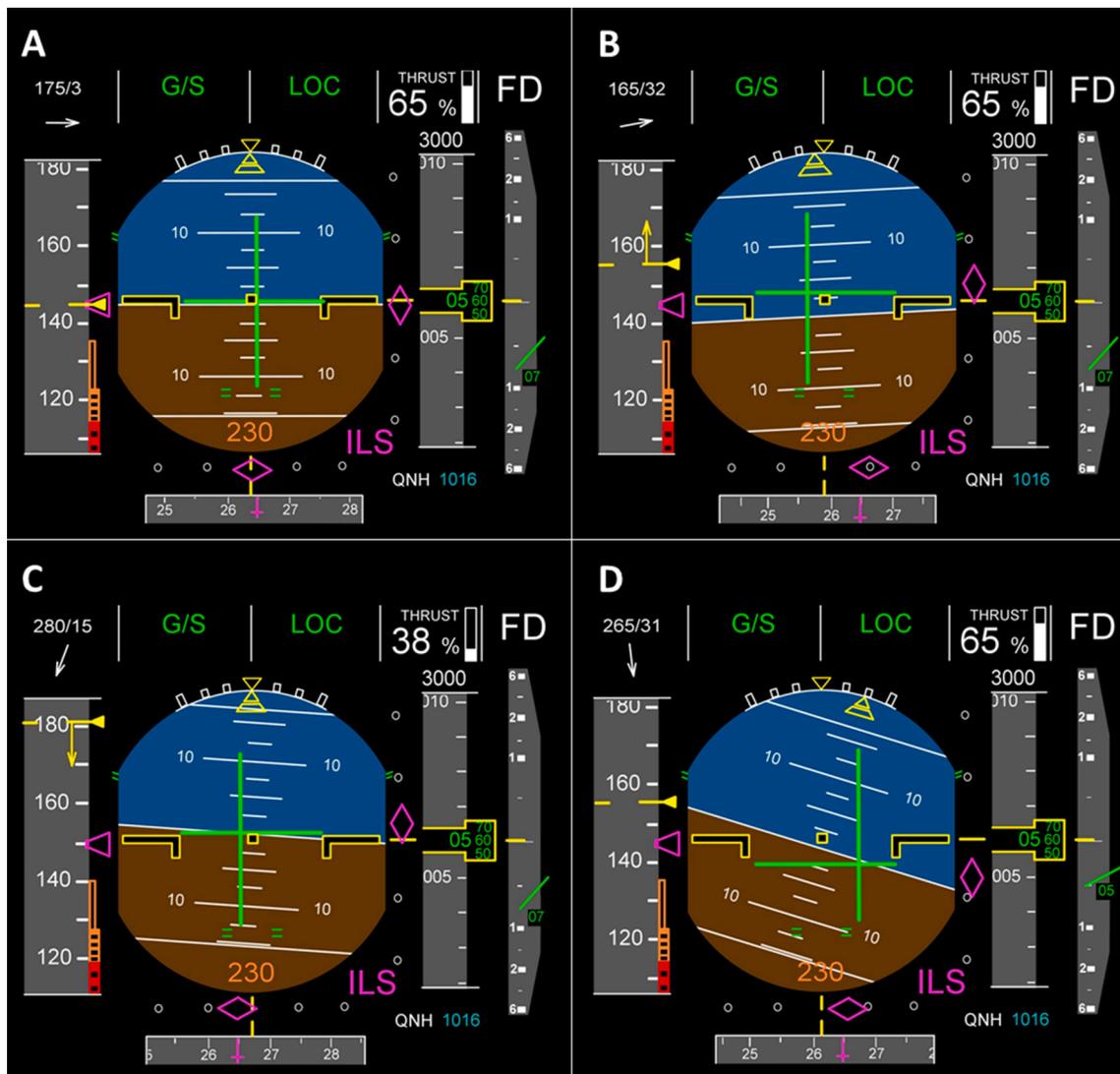
17 male student pilots at ENAC of Toulouse in France (Age:  $M = 23.25$  years old,  $SD = 1.84$ ; Flight hours:  $M = 232.25$  h,  $SD = 12.64$ ) took part in the present experiment. All had normal or corrected-to-normal vision and reported no history of neurological or psychiatric disorders. They received no financial compensation for their participation in the study. We chose student pilots on the verge of completing their training as our participants because 1) they had the knowledge necessary to make landing decisions, but 2) had never worked as airline pilots, which made them inexperienced and therefore supposedly highly susceptible to the influence of the Captain.

### 2.2. Ethics statement

The study was conducted in accordance with the Declaration of Helsinki (1973, revised in 1983) and was approved by the ethics committee of the Federal University of Toulouse in France (CERNI no. 2019-185). After being informed of their rights, all participants gave their written consent.

### 2.3. Material

50 pictures of the Primary Flight Display (PFD; see Fig. 1) representing 50 different landing situations were created by a A380 Air France pilot. The airspeed, the acceleration, the thrust, the wind (both crosswind and tailwind), the pitch and the attitude (Flight Director "FD"), the alignment with the runway (localizer "LOC"), the glide slope (G/S) and the thrust (which is normally displayed in the ECAM and had been appended to the PFD for a sake of simplicity) parameters were manipulated to create landing situations with different levels of risk. The altitude was set to 560 feet. A rating study was conducted in order to rate the level of risk associated with each of the 50 landing situations. 25 Air



**Fig. 1.** Illustration of (A) a safe landing situation, (B) a moderately risky landing situation, (C) a highly risky landing situation and (D) an extremely risky landing situation.

France pilots (Biological gender: 23 men and 2 women; Status: 14 First Officers and 11 Captains; Age:  $M = 45$  years old,  $SD = 9$ ; Flight hours:  $M = 10792$ ,  $SD = 5118$ ) took part in the rating study. Nine of them operated on Boeing aircraft (one on B737, seven on B777 and one on B787), while sixteen operated on Airbus aircraft (five on A320, eight on A330, two on A340 and one on A380). Participants were recruited via email and received no financial compensation for their participation in the rating study. They were given a link to an online questionnaire on LimeSurvey ©, which guaranteed the anonymity and the protection of participants' personal data. On the first page of the questionnaire, they were explained that the online study aimed at evaluating the risk level of different landing situations – each illustrated by a PFD picture – based on the values of the parameters (i.e., airspeed, thrust, wind, pitch, attitude, alignment with the runway, glide slope and thrust).

After they gave their consent to participate in this on-line study, their task consisted in rating the risk level of each of the 50 landing situations on a Likert scale ranging from 1 (*totally safe*) to 5 (*extremely risky*). They also had the possibility to make comments on the landing situations. After they rated the 50 landing situations, participants were informed that they had completed the questionnaire and were thanked for their participation. Based on the results of the rating study and a *meta*-evaluation of the landing situations by the ENAC Director of Training, the 50 landing situations were classified in the four different classes: 10 were

classified as safe situations (risk:  $M = 1.38$ ,  $SD = 0.21$ ), 14 were classified as moderately risky situations (risk:  $M = 3.05$ ,  $SD = 0.32$ ), 10 were classified as highly risky situations (risk:  $M = 3.64$ ,  $SD = 0.13$ ) and 16 were classified as extremely risky situations (risk:  $M = 4.11$ ,  $SD = 0.38$ ).

In the safe situations, landing was considered safe as all parameters were nominal. In extremely risky situations, a landing would inevitably lead to a deadly accident and was therefore far too risky (off-nominal parameters). In moderately and highly risky situations (i.e., uncertain situations), pilots could try to land but the non-nominal flight parameters made this decision uncertain and risky, especially for unexperienced First Officers.

#### 2.4. Procedure

Participants were comfortably seated in the experimental room. After they signed the informed consent, participants were explained that the experiment would be divided into two parts. In the first part of the experiment, participants had to imagine that they were operating the aircraft as a lone pilot. In each trial, a picture of a PFD was displayed on the computer screen and participants had to decide whether to continue or not the landing by pressing respectively the "A" and the "P" letters of the keyboard. Participants had to decide on 50 different landing situations based on the values of the parameters displayed on the PFD (i.e.,

airspeed, thrust, wind, pitch, attitude, alignment with the runway and glide slope).

After completing the first part of the experiment, participants were informed by the experimenter that an extremely skilled Air France A380 Captain had agreed to be part of the experiment and that they would have to make the landing decisions as a crew in the second part of the experiment. The experimenter then invited the Captain in the experimental room in order to introduce himself to the participants. The introduction was scripted in advance and served as an induction phase to create a strong hierarchical asymmetry between the participants and the Captain. The Captain entered the room dressed in his uniform saying “Hello, I am Captain [Surname], nice to meet you. How are you today?”. He then firmly shook the student pilot’s hand (i.e., gesture serving as a power induction; for instance see Dolcos et al., 2012). He continued saying “So you are a student pilot here at ENAC?”. The student pilot confirmed he was. Then the Captain said “Ok, so we are going to fly together today, and you will be the pilot flying. Landing decisions can be hard to make sometimes. I myself faced a difficult landing situation a few days ago, but I eventually succeeded in landing. Anyway, let’s go! I see you at the end of the experiment”. This sentence aimed at making explicit that the Captain was a risk-taker. After the Captain left the room, participants were asked to evaluate the extent to which they thought the Captain was authoritarian, trustworthy, skilled and kind on four distinct Likert scales

ranging from 1 (*not at all*) to 5 (*extremely*). We measured the participants’ perception of the Captain to ensure that the latter was perceived as having the attributes of a good leader who might have to capacity to influence them.

Afterwards, the second part of the experiment started. Participants still had to imagine that they were operating the aircraft as pilot flying and were explained that the Captain was in another experimental room and would be the pilot monitoring. Each trial unfolded as described hereinafter. First, a PFD picture was displayed on the screen and participants had to indicate whether they wanted to continue the landing or to make a go-around (i.e., crew pre-decision setting), as they did in the first part of the experiment. Participants were told that their “pre-decision” would not be communicated to the Captain. Then, the Captain’s decision was displayed on the screen, in the form of a landing icon or a take-off icon representing the Captain’s decision to respectively continue the landing or make a go-around (i.e., Captain’s decision; see Fig. 2). The Captain always decided to 1) continue the landing in safe, moderately risky and highly risky landing situations and to 2) make a go-around in the extremely risky landing situations. The airline pilot playing the Captain did not really make the decisions. The latter were pre-registered and automatically displayed by the E-Prime program. Finally, a “summary” of the situation was displayed, consisting of the PFD, the participant’s pre-decision and the Captain’s decision. The

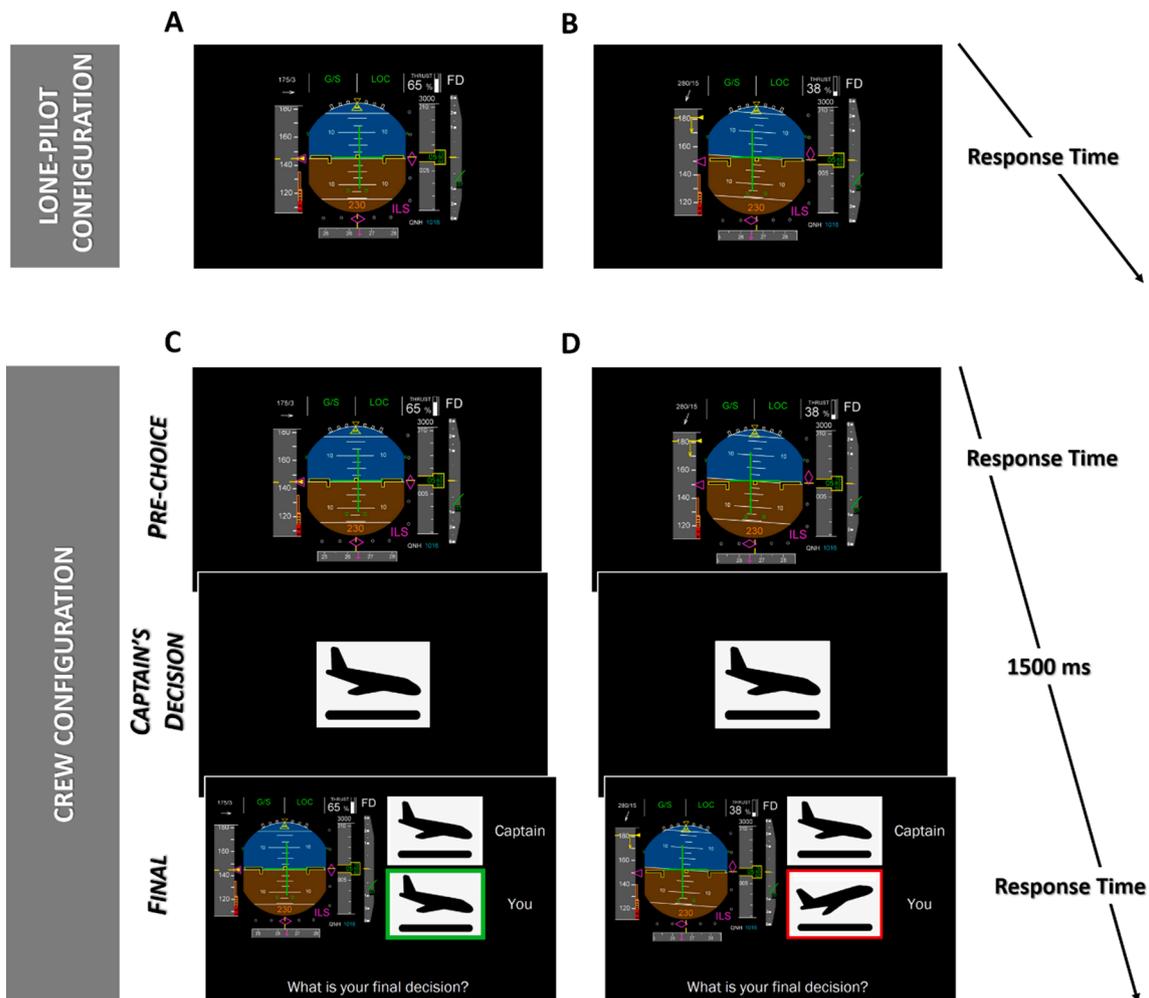


Fig. 2. Illustrations of a safe situation trial (left) in the lone pilot configuration (A), and the crew configuration (C) in which both the Captain and the participant chose to continue the landing (concordant decisions highlighted with a green frame encircling the participant’s pre-decision); and an highly risky situation trial (right) in the lone pilot configuration (B), and the crew configuration (D) in which the Captain chose to continue the landing and the participant made the pre-decision to go-around (discordant decisions highlighted with a red frame encircling the participant’s pre-decision). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

participants' pre-decision was surrounded by a green frame or a red frame, depending on whether the pilots' decisions were respectively concordant or discordant. Participants had to decide whether they wanted to continue the landing or make a go-around, but they knew that this time their decision would be communicated to the Captain (i.e., crew final decision setting). Participants had to imagine that in the case the Captain and themselves agreed, their decision would be applied (i.e., landing versus go-around), while when they disagreed the decision process would further continue. For a sake of simplicity, the trial stopped after the participants' final decision.

All participants started with the lone-pilot run. We made the unusual decision not to counterbalance the order of the runs between the participants to prevent potential experimental biases in this particular experimental paradigm. Most people tend to be strongly influenced by superiors. There was then an important risk for the participants who would have started with the crew run to continue to be influenced by the decisions made by the Captain in the lone-pilot run. It would have triggered a conflict between what they genuinely wanted to do and what they remembered the Captain chose to do, which may have affected their decisions.

At the end of the second part of the experiment, participants were debriefed by the main experimenter, a psychology professor at ENAC and the Air France airline pilot who played the Captain. The aim of the debrief session was to 1) explain the purpose of the experiment and why they had been deceived and to 2) ensure that the experiment would not increase their risk taking in the future. Participants were explained that the aim of the experiment was to investigate the influence of the Captain's risk taking on young pilots' landing decisions. They were explained that the asymmetry in status played a key role in many accidents and that it was crucial to study this phenomenon to prevent future accidents, even though it implies using deception. They were told that for the purpose of the experiment the Captain behaved in a very risky way and that he (or any other airline pilot) would not have made such risky decisions. They were explained that they should not be ashamed to have followed the Captain's decision to land and that they should rather see the present experiment as an opportunity to improve their self-awareness of their tendency to approve Captains' dangerous decisions. They were encouraged to ask all the questions they wanted and to feel free to share their feelings regarding the experiment. Afterwards, they spent 10 to 15 min talking with the Captain. He always started the interaction by confirming that he would never have taken such dangerous decisions. Before they left, participants were kindly asked not to reveal the aim of the experiment to future participants for obvious reasons and were thanked for their participation in the study.

## 2.5. Data acquisition

### Experimental apparatus.

The experimental paradigm was presented using E-Prime 3 (Psychology Software Tools Inc., Pittsburgh, PA, USA) on a computer screen in the laboratory.

## 3. Results

### 3.1. Participants' perception of the Captain

On average, participants reported that they perceived the Captain as being highly trustworthy ( $M = 4.35$ ,  $SD = 0.70$ ), experienced ( $M = 4.18$ ,  $SD = 0.73$ ), kind ( $M = 4.18$ ,  $SD = 0.81$ ) and quite authoritarian ( $M = 3.88$ ,  $SD = 0.70$ ).

### 3.2. Landing decision

#### 3.2.1. Landing rates

The landing rates were calculated for each type of landing situation

(i.e., safe, moderately risky, highly risky, extremely risky) by dividing the number of decisions to land observed for a type of landing situations by the number of trials of this specific type of landing situation (respectively 10, 14, 10 and 16 trials). A 4 [Risk Level (safe, moderately risky, highly risky, extremely risky)]  $\times$  3 Decision Setting (lone pilot decision, crew pre-decision, crew final decision) within-subject ANOVA was performed on the landing decision rates. Post-hoc analyses were performed using HSD corrections for multiple comparisons. For a sake of simplicity, the means and standard deviations of the landing rates are reported in [Table 1](#).

The analysis revealed a significant main effect of risk level [ $F(3, 48) = 175.38$ ,  $p < .001$ ,  $\eta^2 = .92$ ; see [Fig. 3](#)] with a higher landing rate: 1) in the safe situations than in uncertain situations and extremely risky situations ( $p_s < .001$ ); and 2) in the moderately risky situations than in both the highly risky and extremely risky situations ( $p_s < .001$ ); and 3) in the highly risky situations than in the extremely risky situations ( $p < .001$ ). The analysis also revealed a significant Risk Level  $\times$  Decision Setting interaction [ $F(6, 96) = 21.28$ ,  $p < .001$ ,  $\eta^2 = .57$ ]. The results of the Risk Level  $\times$  Decision Setting interaction were concordant with the results of the landing situation main effect ( $p_s < .001$ ), with the exception of the landing rates observed for the highly risky situations that were not significantly different from those observed in the extremely risky situations in both the lone pilot ( $p = .555$ ) and the crew final decision ( $p = .436$ ) settings. In the safe situations, no significant differences in landing rates were found as a function of the decision setting ( $p_s > .999$ ). In the moderately risky situations, significantly lower landing rates were found in the lone pilot setting than in both the crew pre-decision ( $p = .008$ ) and the crew final decision ( $p < .001$ ) settings, but no significant difference between the crew pre-decision and the crew final decision settings was found ( $p = .513$ ).

In the highly risky situations, higher landing rates were found in the crew final decision setting than in both the lone pilot setting ( $p < .001$ ) and the crew pre-decision setting ( $p = .049$ ), but the landing rates in the crew pre-decision setting were not significantly different from those found in the lone pilot setting ( $p = .826$ ). In the extremely risky situations, lower landing rates in the crew final decision setting ( $p_s < .001$ ) than in both the lone pilot and the crew pre-decision settings, while no significant difference in landing rates was found between the lone pilot and the crew pre-decision ( $p = .903$ ) settings. In crew final decision setting, five participants never insisted on continuing the landing, six insisted once, six insisted twice or three times (out of 16 extremely risky situations). The main effect of decision setting did not reach significance [ $F(2, 32) = 2.51$ ,  $p = .097$ ,  $\eta^2 = .14$ ].

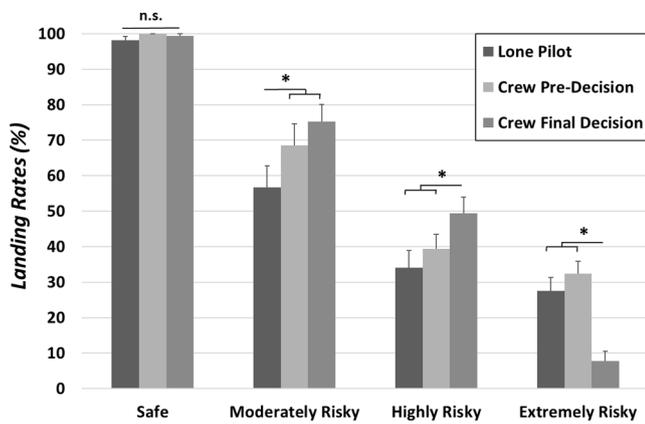
#### 3.2.2. Landing rates in the crew pre-decision setting as a function of the phase

To investigate the progressive influence of the Captain on the participants' decision-making in the crew pre-decision setting along the experiment, we conducted an analysis to compare the landing rates observed in the first half and the second half of the trials. A 3 [Risk Level (moderately risky, highly risky, extremely risky)]  $\times$  2 [Phase (first half, second half)] within-subject ANOVA was performed on the landing rates. Post-hoc analyses were performed using HSD corrections for multiple comparisons. For a sake of simplicity, the means and standard deviations of the landing rates in the crew pre-decision as a function of the phase are reported in [Table 1](#). The analysis revealed a significant main effect of risk level [ $F(2, 32) = 51.77$ ,  $p < .001$ ,  $\eta^2 = .76$ ], with higher landing rates observed in the crew pre-decision setting for moderately risky situations ( $p_s < .001$ ) than for both highly risky situations, and extremely risky situations, but no significant difference in landing rates between highly risky situations and extremely risky situations ( $p = .102$ ). The analysis also revealed a significant Risk Level  $\times$  Phase [ $F(2, 32) = 3.85$ ,  $p = .032$ ,  $\eta^2 = .19$ ]. In both experimental phases, the landing rates observed in the crew pre-decision setting for moderately risky situations than for both highly risky situations (phase 1:  $p < .001$ ; phase 2:  $p < .001$ ) and extremely risky situations (phase 1:  $p$

**Table 1**

Summary of 1) the landing rates (means and standard deviations) as a function of the setting and the phase of the experiment in the crew pre-decision setting and 2) the responses times (means and standard deviations) as a function of the setting, observed in response to the four types of landing situations.

Landing Rates (%)		Safe		Moderately risky		Highly risky		Extremely risky	
		M	SD	M	SD	M	SD	M	SD
<b>Total</b>									
	Lone Pilot	98.24	3.93	56.72	24.80	34.12	20.02	27.57	15.48
	Crew Pre-decision	100.00	.00	68.49	25.13	39.41	16.76	32.35	14.36
	Crew Final Decision	99.41	2.43	75.21	20.22	49.41	18.86	7.77	7.21
	Average	99.22	2.72	66.81	24.28	40.98	19.31	22.56	16.58
<b>Pre-decision by phase</b>									
	Phase 1	100.00	.00	77.31	28.15	39.12	23.00	24.26	20.48
	Phase 2	100.00	.00	59.66	26.36	36.47	23.70	34.12	20.95
<b>Response Times (s)</b>									
	Lone Pilot	6.09	5.04	8.44	6.71	8.13	5.51	7.14	5.35
	Crew Pre-decision	3.71	1.90	6.22	3.02	6.08	2.49	4.86	2.21
	Crew Final Decision	1.16	.42	2.09	1.18	3.64	3.31	2.71	2.49



**Fig. 3.** Landing rates observed in response to safe situations (dark grey), moderately risky situations (light grey), highly risky situations (medium grey) and extremely risky situations (black) in the lone pilot (left), the crew pre-decision (center) and the crew final decision (right) settings. Error bars represent standard errors.

= .026; phase 2:  $p = .011$ ), but no significant difference in landing rates between highly risky situations and extremely risky situations (phase 1:  $p = .979$ ; phase 2:  $p = .999$ ). No difference in landing rates was found between the first phase and the second phase for moderately risky situations ( $p = .150$ ), highly risky situations ( $p = .999$ ) or extremely risky situations ( $p = .724$ ). The main effect of phase failed to reach significance [ $F(1, 16) = 3.48, p = .080, \eta p^2 = .18$ ].

### 3.3. Response times

#### 3.3.1. Mean response times

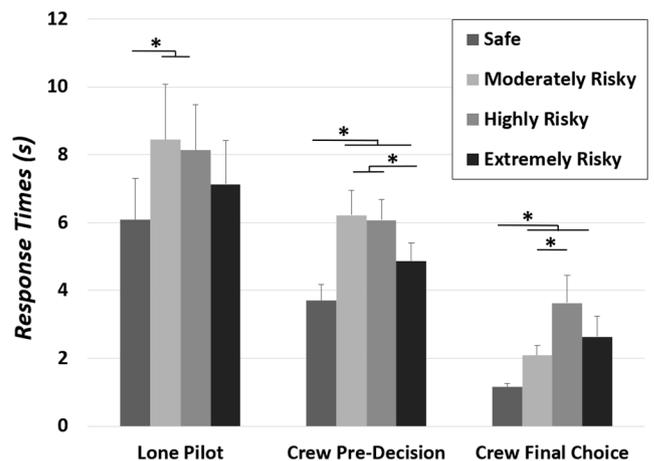
The mean response times were calculated for each type of landing situation (i.e., safe, moderately risky, highly risky, extremely risky). As the data were not normally distributed (Shapiro tests:  $p_s < .05$ ), we conducted a log-transformation to normalize the response times data. Since the landing situations were always presented first in the lone pilot run, we did not compare the response times as a function of the decision setting. Three separated 4 [Risk Level (safe, moderately risky, highly risky, extremely risky)] within-subject ANOVAs were performed (one per decision setting) on the log-transformed response times. Post-hoc analyses were performed using HSD corrections for multiple comparisons. For a sake of simplicity, the means and standard deviations of the response times are reported in Table 1. The analysis revealed a significant main effect of risk level in the lone pilot decision setting [ $F(3, 48)$

= 9.13,  $p < .001, \eta p^2 = .36$ ; Fig. 4], the crew pre-decision setting [ $F(3, 48) = 33.76, p < .001, \eta p^2 = .68$ ] and the crew final decision [ $F(3, 48) = 16.09, p < .001, \eta p^2 = .50$ ]. In the lone pilot setting, shorter decision times were observed for safe situations ( $p_s < .001$ ) than for uncertain situations. No difference in response times was found between moderately risky and highly risky situations ( $p = .993$ ). Response times to extremely risky situations were not significantly different from those observed for the three other landing situations ( $p_s > .060$ ).

In the pre-decision decision setting, shorter decision times were observed for 1) safe situations than for uncertain situations and extremely risky situations, and 2) for extremely risky situations than for uncertain situations ( $p_s < .001$ ). No difference in response times was found between moderately risky and highly risky situations ( $p = .999$ ). In the crew final decision setting, shorter decision times were observed for 1) safe situations than for uncertain situations and extremely risky situations ( $p_s < .001$ ); and for 2) moderately risky situations than for highly risky situations ( $p = .014$ ). Response times to extremely risky situations were not significantly different to those observed for uncertain situations (moderately risky:  $p = .511$ ; highly risky:  $p = .289$ ).

#### 3.3.2. Response times as a function of the decision

A 2 (Decision [land, go-around]) linear logistic regression was performed on the log-transformed response times for each of the nine



**Fig. 4.** Illustration of the response times to safe situations (dark grey), moderately risky situations (light grey), highly risky situations (medium grey) and extremely risky situations (black) in the lone pilot decision (left), the crew pre-decision (center) and the crew final decision (right) settings. Error bars represent standard errors.

combinations of landing situation/decision setting on the participants who showed both types of responses (the number of participants included in the analysis  $n$  is reported in Table 2). Safe situations were not analyzed as participants almost always chose to land in these situations. For a sake of simplicity, the means, standard deviations and statistical results are reported in Table 2.

In the lone pilot setting, the analyzes revealed a main effect of decision for both moderately risky ( $p = .037$ ) and extremely risky situations ( $p < .001$ ), with landing decision predicting for 1) shorter response times than go-around decision in moderately risky situations and 2) longer response times than go-around decision in extremely risky situations (see Fig. 5.A.). In the crew pre-decision setting, the analyzes revealed a main effect of decision for both highly risky situations ( $p < .001$ ) and extremely risky situations ( $p < .001$ ), with landing decision predicting for 1) longer response times than go-around decision in highly risky situations, and 2) longer response times than go-around decision in extremely risky situations (see Fig. 5.B.). In the crew final decision setting, the analyzes revealed a main effect of decision in the moderately risky situations ( $p = .017$ ), the highly risky situations ( $p = .013$ ) and the extremely risky situations ( $p = .048$ ), with landing decision predicting for shorter response times than go-around decision in uncertain situations, and the landing decision predicting for longer response times than go-around decision in the extremely risky situations (see Fig. 5.C.).

### 3.4. Correlation analyses

We investigated whether the mean landing rates observed for the 50 landing situations were correlated to the risk ratings of these landing situations measured in the rating study. As the data were not normally distributed, we conducted two-tailed Spearman correlation tests. Participants' landing rates were negatively correlated to risk ratings measured in the rating study in the lone pilot setting ( $r_s = -.752, p < .001$ ), the crew prechoice setting ( $r_s = -.743, p < .001$ ) and the crew final choice setting ( $r_s = -.889, p < .001$ ).

We also investigated whether the way participants perceived the Captain was correlated to their decision-making behavior. We predicted that the extent to which participants perceived the Captain as authoritarian and trustworthy would be positively correlated to participants' tendency to increase their risk-taking in both 1) medium-risk uncertain situation (lone pilot versus crew pre-decision) and 2) high-risk uncertain situations (crew pre-decision versus crew final decision). As the data were not normally distributed, we conducted two-tailed Spearman correlation tests. Participants' tendency to increase their risk-taking in response to the Captain's decision in high-risk uncertain situations (compared to the crew pre-decision setting) was positively correlated to the Captain authority rating ( $r_s = .521, p = .032$ ), but not his

trustworthiness rating ( $r_s = .109, p = .677$ ). No significant correlation was found between the increase in risk-taking in medium-risk uncertain situations (lone pilot versus crew pre-decision) and the authority ( $r_s = .123, p = .639$ ) and trustworthiness ( $r_s = .267, p = .300$ ) ratings.

## 4. Discussion

The aim of the present study was twofold: investigating 1) the tendency of young and inexperienced pilots to take risks on their own at the moment of landing and 2) the extent to which their landing decisions are influenced by a risk-taking Captain. Participants operating as pilot flying had to decide either alone or with an A380 Captain operating as pilot monitoring whether they wanted to continue the landing or abort it in four types of landing situations characterized by different levels of risk.

### 4.1. Deciding alone as a function of the landing situation risk level

In line with our predictions, in the lone pilot setting participants' landing rates decreased according to the risk level of the landing situations (i.e., safe, moderately risky, highly risky, extremely risky). Moreover, participants' landing rates were negatively correlated to the professional pilots' risk ratings of the landing situations (assessed in the rating study). Taken together, these results demonstrates that overall participants were able to discriminate fairly well the level of risk associated with the different landing situations, which validates *hypothesis 1* and serves as a manipulation check confirming that the landing situations were properly defined. Moreover, participants almost always chose to land in safe situations and were faster to make a decision in safe situations than in uncertain situations in general. These results show that participants easily categorized safe landing situations as such and quickly made the decision to land in these situations, while deciding on uncertain situations appears to have been more complex – partially confirming *hypothesis 2a*.

In contradiction with *hypothesis 2a*, participants decided to continue the landing about one third of the time in extremely risky situations. They also took significantly longer to decide to land than to make a go-around in these situations. Taken together, these results suggest that participants might have detected that landing in extremely risky situations was hazardous, but often struggled to abort the landing in these situations (in line with Causse et al., 2013; Cohen, 1993).

### 4.2. Influence of the Captain's risky behavior in uncertain situations

After meeting the Captain, participants indicated that they found him highly skilled, kind and trustworthy, and relatively authoritarian. This result indicates that the power induction was successful and that participants considered the Captain as a good leader (Helmreich, &

**Table 2**

Summary of 1) the response times (means and standard deviations) as a function of the decision and the risk level of the situations and 2) the statistical results of linear logistic regressions.

Response times (s)	Go-Around		Landing		n	B(SE)	CI (95%)		Wald $\chi^2$ (1)	p
	M	SD	M	SD			LL	UL		
<b>Lone Pilot Setting</b>										
Moderately risky	7.19	4.54	5.88	3.61	16	.100 (0.048)	.006	.194	4.329	.037*
Highly risky	5.80	3.53	6.64	3.98	17	-.841.87 (630.26)	-2077.2	393.41	1.784	.182
Extremely risky	4.28	2.89	6.15	3.84	14	-.166 (.038)	-.242	-.091	18.676	< .001*
<b>Crew Predecision Setting</b>										
Moderately risky	8.06	7.42	8.85	8.87	17	-.066 (.061)	-.186	.054	1.157	.282
Highly risky	7.47	7.19	10.01	7.39	15	-.162 (.043)	-.246	-.077	14.139	< .001*
Extremely risky	7.35	7.92	9.30	6.30	13	-.179 (.054)	-.284	-.074	11.104	< .001*
<b>Crew Final Decision Setting</b>										
Moderately risky	3.38	3.24	1.64	1.78	17	.228 (.095)	.042	.415	5.747	.017*
Highly risky	4.31	6.12	3.12	5.73	16	.205 (.082)	.044	.367	6.224	.013*
Extremely risky	2.86	5.38	4.71	4.96	9	-.312 (.158)	-.621	-.003	3.924	.048*

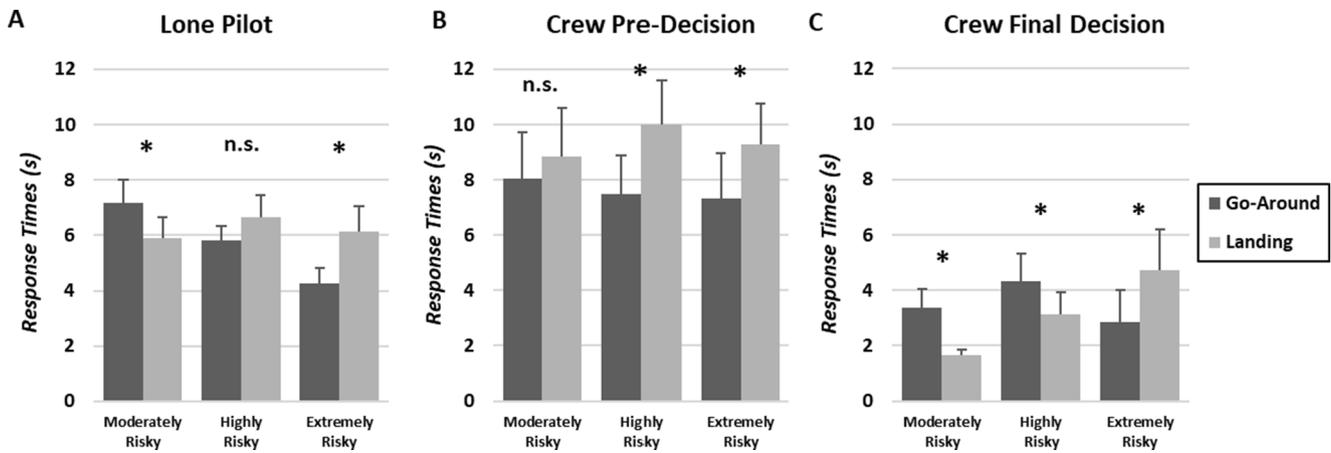


Fig. 5. Illustration of the response times as a function of the decisions: go-around (dark grey) and landing (light grey) observed for moderately risky situations (left), highly risky situations (center) and extremely risky situations in (A) the lone pilot setting, (B) the crew prechoice setting and (C) the crew final decision setting. The Captain chose the land in both types of uncertain situations and to go around in extremely risky ones. Error bars represent standard errors.

Foushee, 1993) characterized by attributes that were found to be predictive of peer influence (Bonaccio & Dalal, 2010; Choukas-Bradley et al., 2015; Hall, et al., 2004; Meshi et al., 2012).

In uncertain situations, participants were strongly influenced by the Captain, as they significantly increased their landing rates in the crew configuration compared to the lone pilot configuration. The results also suggest that the reasons why participants made more risky decisions in moderately risky situations and in highly risky situations may differ.

For moderately risky landing situations, greater landing rates were found in the crew pre-decision setting (i.e., before the Captain's decision was communicated) than in the lone pilot setting, and no significant difference in landing rates was found between the crew pre-decision setting and the crew final decision setting. These results show that First Officers increased their risk-taking in moderately risky situations once paired with the Captain, even before knowing whether the Captain wanted to continue the landing or not. To determine whether the increased risk-taking observed in moderately risky situations resulted from an adaptation to the Captain's risky behavior throughout the experiment or the mere presence of the Captain, we conducted a complementary analysis consisting in comparing the landing rates observed in the first half and the second half of trials in the crew pre-decision setting. No difference in landing rates between the first half and the second half of moderately risky trials in the crew pre-decision setting was found. This result suggests that the increased risk-taking observed in moderately risky situations – in the crew pre-decision setting compared to the lone pilot setting – is more likely to result from participants' reaction to the Captain's mere presence than from a progressive adaptation to the Captain's behavior throughout the experiment (in line with Gardner & Steinberg, 2005; Haddad et al., 2014; Kretsch & Harden, 2014; Reniers et al., 2017; Smith et al., 2014) – confirming hypothesis 4 on the impact of the Captain's mere presence.

Individuals can be aroused by the mere presence of another person, which may result in a greater motivation to perform and look competent (i.e., social facilitation; Bond & Titus, 1983; Triplett, 1898), that is usually combined with a greater tendency to take risks (Gardner & Steinberg, 2005; Haddad et al., 2014). Some previous studies showed that First Officers try hard to look competent (e.g., Ginnett, 2019; Jentsch et al., 1997b), and that this behavior can sometimes affect both their performance and flight safety (Beveridge et al., 2018). Taken together these results suggest that participants significantly increased their risk taking in moderately risky situations on their own and without any pressure from the Captain, supposedly in order to look competent, impress the latter and gain in status (Brown & Braun, 2013, Reniers et al., 2017).

For highly risky situations, greater landing rates were found in the

crew final decision setting (after participants knew the Captain's decision) than in both the lone-pilot and the crew pre-decision settings. However, no significant difference in landing rates was found between the lone-pilot and the crew pre-decision settings. These results demonstrate that participants increased their risk-taking in highly risky situations mostly in reaction to the Captain's decision (confirming hypothesis 5 on the influence of the Captain's decision). In the crew final decision setting, participants also took longer to decide on highly risky situations than on other landing situations, revealing the greater complexity of the decision in these landing situations attributable to the conflict between their eagerness to agree with the Captain and their concern for flight safety (confirming hypothesis 7). Moreover, in highly risky situations the more participants perceived the Captain as being authoritarian, the greater their tendency to adapt their decision to the Captain's. This last result suggest that participants might have increased their risk-taking in these landing situations in reaction to the Captain's decision by fear of the consequences of opposing the Captain (in line with Bienefeld & Grote, 2012). Participants chose to challenge the Captain's decision to land about one fourth of the time in moderately risky situations and half of the time in highly risky situations. Moreover, it took them significantly longer to decide to challenge the Captain and ask for a go-around than to go along with him in crew final decision setting (confirming hypothesis 7). These results suggest that opposing the Captain may have been more effortful for the participants than agreeing with him (in line with Bienefeld & Grote, 2012; Dismukes et al., 2007; Jentsch et al., 1997c).

#### 4.3. Extreme risk-taking and the Dunning-Kruger effect

While we predicted that participants would almost always make a go-around in the extremely risky situations, they continued the landing about one third of the time in both the lone-pilot and crew pre-decision settings. Learning that the Captain decided to abort the landing in these situations significantly lowered participants' risk-taking (i.e., from 32% in the pre-decision setting to ~8% in the final decision setting). This result is in line with previous studies that showed that knowing that a peer made a safe choice or receiving a safe advice from a peer significantly decreases one's risk taking (Braams et al., 2019; Chung et al., 2015; 2020). However, notifying participants that the Captain chose to make a go-around in the extremely risky situations was not sufficient to totally suppress their tendency to take risks in these landing situations, showing that participants sometimes resisted the Captain's safe advices (in line with Haddad et al., 2014). In the crew final decision setting, five participants never insisted on continuing the landing, six insisted once, six insisted twice or three times (out of 16 extremely risky situations).

Finally, one participant – who showed an important propensity to take risks in both the lone-pilot and the pre-decision settings (choosing to land ~ 45% of the time) – insisted on continuing the landing in extremely risky situations one time in four in the crew final decision setting. Complementary analysis conducted on the participants showing both types of responses in extremely risky situations (i.e., opposing versus going along with the Captain's decision) revealed that it took them longer to make the decision to insist on landing than to go along with the Captain and go-around. These results show that the decision to insist on landing in extremely risky situations may not be impulsive and result from a lack of reasoning, but that participants put some thought in this decision and made it willingly. Moreover, these participants decided to insist on continuing the landing, knowing that they were the pilot flying and would have had to land the aircraft themselves in these extremely critical conditions, with extremely limited flying experience. These young and inexperienced pilots appear to have had an unrealistic positive image of their piloting abilities – a judgement bias known as the Dunning-Kruger effect (Kruger & Dunning, 1999), which led them to insist on continuing landings doomed to failure (in line with Pavel et al., 2012).

#### 4.4. Limitations, future work and applications

In the present study, participants were operating as pilot flying. However, the *pilot flying* Captain / *pilot monitoring* First Officer configuration was previously found to be by far the most likely to trigger an accident (e.g., Jentsch et al., 1999; Milanovich et al., 1998; Mosier & Fischer, 2014; NTSB, 1994; Tarnow, 2000). First Officers are less likely to ask for a go-around, this effect being more pronounced when the Captain operates as pilot monitoring and the First Officer operates as pilot flying (Behrend & Dehais, 2020). While in the present study the level of opposition to landing in uncertain situations was quite low, we may have found even lower opposition rates if participants had performed the experiment as pilot monitoring. It would be interesting to conduct a second study similar to the present one, inverting the pilots' roles to confirm (or infirm) this assumption.

While the results of the present study are in line with literature, some limitations should nevertheless be acknowledged. First, we chose young and inexperienced pilots as participants and an extremely experienced Captain with one of the highest statuses in commercial aviation (i.e., Airbus 380 Captain in a major International Airline) in order to maximize the status gap between the First Officer and the Captain. We made this experimental choice both because 1) in most accidents attributed to crew errors, the Captain was way more experienced than the First Officer (Dismukes et al., 2007; Tarnow, 2000) and because 2) the Captain's influence was expected to be the highest in this particular crew configuration (Choukas-Bradley et al., 2015; Cohen & Prinstein, 2006; Knoll et al., 2015; Prinstein et al., 2011). We might have found a lower influence of the Captain on First Officers in crews characterized by lower status gaps (i.e., less experienced Captains and/or more experienced First Officers). Therefore, the results of the present study cannot be generalized (at least yet) to all types of crews. Conducting this same experiment on diverse types of crews would help understand how the Captain's influence varies depending on the crew (e.g., age gap; expertise gap). The personality of both Captains and First Officers might also modulate the strength of the Captain's influence. Various experiments in the field psychology have shown that some social characteristics of peers – such as being perceived as trustworthy (Frost, & Moussavi, 1992; Hall, et al., 2004), experienced (Meshi et al., 2012) and/or well-intentioned; Bonaccio & Dalal, 2010) – could make them more influential. However, in the present study only the extent to which participants perceived the Captain as authoritarian was correlated to the strength of his influence. Further work is necessary to better understand how inter-individual differences of both crew members might increase or decrease the Captain's influence on First Officers.

Second, the experiment was conducted on a computer screen (not in

a flight simulator) and the Captain's stood in an adjacent room. It would be interesting to conduct the same experiment in the flight simulator using a dynamic protocol and placing participants at the Captain's side to ensure that similar results can be observed in more ecological conditions.

The experimental protocol of the present study is easy to set up and could be used in the future to evaluate student pilots' skills along their training. First, it could be used to appraise their capacity to accurately discriminate landing situations according to their risk level. Second, it may be helpful to assess student pilots' tendency to be influenced by risk-taker Captains and heighten their awareness on this potential risk before they become airline pilots. Finally, First Officers biased by the Dunning-Kruger effect are likely to put flight safety in jeopardy (NTSB, 2007) – especially when they are paired with a Captain who lacks assertiveness (Orasanu, et al., 1999; Sumwalt, & Lemos, 2010). The present experimental protocol could also be used to detect pilots' tendency to overestimate their capacities. To tackle the Dunning-Kruger effect before they become active airline pilots, these individuals could be subdued to adapted trainings in the simulator, so that they could experience the consequences of their risky decisions by themselves and become competent decision makers (see Dunning, 2011). In conclusion, we think that subduing young and inexperienced pilots to such a training could improve their capacity to challenge the Captain and accept being challenged by the latter when safety is compromised.

#### CRedit authorship contribution statement

**Eve F. Fabre:** Conceptualization, Methodology, Investigation, Resources, Formal analysis, Writing - original draft, Writing - review & editing, Funding acquisition. **Nadine Matton:** Investigation, Resources, Writing - original draft, Writing - review & editing. **Frédéric Beltran:** Conceptualization, Methodology, Investigation. **Valeria Baragona:** Investigation. **Cerise Cuny:** Software. **Jean-Paul Imbert:** Software, Resources. **Stéphane Voivret:** Conceptualization, Resources. **Jean-Baptiste Van Der Henst:** Conceptualization, Methodology, Writing - original draft, Writing - review & editing. **Mickaël Causse:** Conceptualization, Methodology, Resources, Writing - original draft, Writing - review & editing.

#### Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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