Impulsivity modulates pilot decision making under uncertainty

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Abstract

Personality has an important influence on the variability in human decision making. Little is known whether intensive training and a highly-procedural environment can alleviate the influence of personality on decision making. Here, we address this issue by investigating the influence of impulsivity as personality factor on decision making among airline pilots. We showed that impulsivity modulated pilots' indecisiveness in uncertain decision scenarios as well as pilots' self-reported compliance to airline guidelines in real life. This result suggests that the personality factor impulsivity is a profound trait that continues to have an influence through intensive training and highly-procedural decision situations.

Introduction

There is a great variability of human behaviour in response to uncertainty. It is well documented that personality influences decision preferences and actions (Byrne, Silasi-Mansat & Worthy, 2015; Sutin & Costa, 2010; Hirsh, Morisano, & Petersen, 2008). In high-risk environments, such as in commercial aviation, individuals often have to make critical decisions under uncertainty and time pressure without compromising safety. For example, a pilot has to decide whether to continue a landing approach - keep action plan - or to discontinue an approach – change action plan. In order to decide, a flight crew, composed of a Captain and a First Officer, should integrate and respect a list of defined airline guidelines, the approach criteria. Approach criteria are technical values such as correct speed, wind, vertical glide path, etc. This particular decision moment is one of the most dynamic and incident-sensible flight phases in aviation (U.S. Department of Transportation, 2015). Here, pilots have to make rapid decisions under time pressure by proving their adaptation skills (Dehais, Behrend, Peysakhovich, Causse, & Wickens, 2017). When approach criteria exceed guidelines, pilots should discontinue the approach by changing the current action plan. Surprisingly, in more than 97% of this type of situation pilots kept their action plan and did not adapt it although it would have been required by airline guidelines (IATA, 2016). Due to the dynamic character and the operational consequences, this type of decision is complex. Much is known about contributing factors, such as financial incentives and emotions (Causse, Dehais, Péran, Sabatini, & Pastor, 2013), lack of airline policy and time pressure (IATA, 2016), overconfidence (Goh & Wiegmann, 2001), or safety implications due to the rarity of the event in real life (Dehais et al., 2015; BEA, 2013). However, the understanding of the psychology of non-compliance to airline guidelines lacks.

Pilots are a very homogenous population since they follow a complex selection process that requires a high level of executive functions (O'Hare, 1997) and a stable personality (Childester, Helmreich, Gregorich, & Geis, 2009). An individual's personality could be described as result of constant interactions between inherited genetic influence, epigenetic effects, and social environment (Montiglio, Ferrari, & Réale, 2013). However, flight crews do not compromise the same individuals. A consequence of the worst air disaster in history, the Tenerife airport crash of two airplanes in 1977, was to reduce subjective decisions of the part of pilots (McCreary, Pollard, Stevenson, & Wilson, 1998). This was also the birth of the earlier concept of crew resource management (CRM): a set of mandatory training procedures with a focus on interpersonal communication, leadership and decision-making in the cockpit (Helmreich, Merritt, & Wilhelm, 1999). In this accident, the KLM Captain released the brakes and the airplane crashed into another airplane, even though the First Officer was reading back the ATC clearance to the tower. The KLM Captain made a quick and autocratic decision, although he had seemed to be pace and non-autocratic before. Among other causes, human factors analyses argued that his personal leadership appeared to change – possibly due to his hierarchical status in the cockpit, his responsibility in the company, and the stressful environment under time pressure (McCreary et al., 1998). The question is, *do personality factors persist in highly-trained individuals and in highly-procedural situations, such as in airline pilot decision making?* One hypothesis could be that an intensive training and a highly-procedural environment reduce the influence of personality on decision making. Or alternatively, personality is a profound trait which influence cannot be reduced by intensive training and a highly-procedural environment. We addressed this issue among airline pilots making decisions during landing approach scenarios. The focus was on impulsivity as personality factor.

Impulsivity is a multi-dimensional personality construct that is frequently described as "a predisposition toward rapid, unplanned reactions to internal or external stimuli without regard to the negative consequences of these reactions to the impulsive individuals or to others" (Moeller, Barratt, Dougherty, Schmitz, & Swann, 2001). For example, impulsive individuals are more likely to choose immediate-smaller over larger-delayed rewards; demonstrated via decision preference (Bialaszek, Gaik, McGoun & Zielonka, 2015), physiological activity (Korponay, Dentico, Kral, et al. 2017), and brain activity (Garavan, Ross, Murphy, Roche, & Stein, 2002). One area of significant importance to the measurement of impulsivity is executive function and decision making (Stanford, Mathias, Dougherty, Lake, Anderson, & Patton, 2009). Executive control is characterized as the capacity to coordinate thoughts and to perform non-automatic actions for the purpose of adaptation to stimuli (Koechlin, 2016). Individuals with executive deficits, e.g. cognitive impairment, tend to score higher on impulsivity (Stanford et al., 2009). Garavan et al. (2002) found a positive correlation between cognitive impairment and anterior cingulate activation in the

"Go/noGo task"; which measures impulsive control behaviourally. Importantly, cingulate activation is crucial to inhibition tasks, where deliberative responses are more appropriate than automatic responses. The "Wisconsin Card Sorting Test" (WCST) assesses cognitive flexibility, which is part of executive functioning and can be described as the ability to switch between different task sets and to decide flexibly. Cheung, Mitsis, and Halperin (2004) used this test demonstrating that motor impulsivity explained significant parts of the performance variance of cognitive flexibility. Two studies among general aviation pilots showed that perseverative errors on the WCST (Causse, Dehais, Arexis, Pastor, 2011a) as well as flight experience, motor impulsivity, and updating capacity could predict landing decision relevance (Causse, Dehais, & Pastor, 2011b). Indeed, in the second study the pilot's ability to detect meteorology degradation during the decision making process was measured. It was found that general aviation pilots with a higher motor impulsivity score showed less adaptation skills by continuing the current action plan. Although impulsivity is often characterized as a negative and dysfunctional state, it has been shown that being impulsive can be positive and more adaptive in simple decision tasks (Dickmann, 1990). Importantly, the decision context plays a crucial role to an individual's response behaviour (Maule, Hockey, & Bdzola, 2000).

Analysing a pilot's individual decision in a questionnaire – a non-dynamic context - can be useful to improve the understanding of the decision-relevant information and the interpretation of airline guidelines. In this study, we investigated the influence of impulsivity along with other factors such as flight hours, hierarchy, and prior airline career on individual pilot decision-making in a questionnaire.

Material and methods

Participants and demographic information

Forty randomly-selected airline pilots (age-range 32-65 years) from the same airline participated in this study. The planning department of an airline randomly chose these pilots from the pilot pool. Afterwards, we contacted these pilots by e-mail in order to ask for their agreement. Nationalities represented in our sample included the following: France (n = 38), and Belgium (n = 2). French was their native language. Table 1 resumes the demographic characteristics of this sample size. Captains were significantly older ($t(38) = 4.46$, $p < 0.001$) and had more flight hours ($t(38) = 4.69$, $p < 0.001$) than First Officers in this sample size. Half of the airline pilots reported having worked for at least another airline prior to their current employment. The percentage of pilots with a military career was 10%. All participants were paid for their participation by their airline and gave written consent prior to the experiment. Confidentiality was guaranteed.

Table 1. Demographic characteristics of this sample size

Participants (n)	*Gender, Male % (n)*	*Age, years M (SD)*	*Flight experience, hours M (SD)*
All (40)	93 (37)	47.9 (7.4)	11613 (4142)
Captain (24)	96 (23)	51.4 (5.6)	13633 (3355)
First Officer (16)	88 (14)	42.7 (6.8)	8581 (3317)

Barratt Impulsiveness Scale (BIS-11)

The BIS-11 (Patton, Stanford, & Barratt, 1995) is a self-report measurement of impulsivity with three sub traits: attentional impulsivity (e.g. “I don’t pay attention”), motor impulsivity (e.g. “I act on the spur of the moment”) and non-planning impulsivity (e.g. “I say things without thinking”). The questionnaire’s instructions ask subjects to indicate how often description of impulsive behaviour pertain to themselves on a 4-point-Likert scale. Lower questionnaire scores indicate lower levels of impulsivity. The BIS has good internal consistency (Cronbach’s Alpha = .83) and test-retest reliability (Spearman’s rho = .83) (Stanford et al., 2009). In this sample size, internal consistency was computed and considered acceptable (Cronbach’s Alpha = .73).

Landing questionnaire

Participants considered eighteen decision scenarios. The order of these scenarios was randomized across participants. For each scenario, participants were asked: “Based on the following information, would you continue the approach?” They could reply “Yes”, “No” or “I don’t know”. We manipulated the presence of uncertainty in the landing decisions (uncertain vs. certain continue approach or discontinue approach). All decision scenarios were chosen from an airline’s real event database. Prior to the experiment, we asked five experts - all flight instructors - to evaluate the chosen landing scenarios. All flight instructors agreed on 12 certain (8 continue, 4 discontinue the approach). The remaining 6 scenarios were labelled as uncertain (at least two instructors chose the opposite of the three others). Information complexity was reduced to three main approach criteria (localizer deviation, glide slope deviation, and airspeed) and two additional decision criteria (wind, weather conditions). For each scenario, the type of approach and the airport were identical. The information relevant for landing decisions was either within the airline guidelines (certain/continue the approach), out of the airline guidelines (certain/discontinue the approach) or at thresholds of airline guidelines (uncertain/continue or discontinue the approach). Certain decisions to continue required all criteria to be within airline guidelines. Certain decisions to discontinue occurred when at least one criterion was out of airline guidelines. Uncertain decisions (to continue or discontinue) occurred when at least one criterion was at threshold. After the 18 landing decisions, pilots were asked in an open question if they had ever taken a decision that was not in line with airline procedures (non-compliance).

Experimental design

The experiment was performed within a period of 30 days. All participants replied to the questionnaires after a full-flight simulator training. Each participant was seated separately in a room with paper and pencil. Pilots were told that the experiment was part of a research project aiming to better understand their evaluation of approach criteria. Afterwards, they were asked to complete the paper-and-pencil version of the BIS-11. Finally, they gave demographic information (Figure 1). They had no time restriction to complete the questions. The experiment duration was between 30 and 80 minutes. Figure 1 shows the protocol timeline.

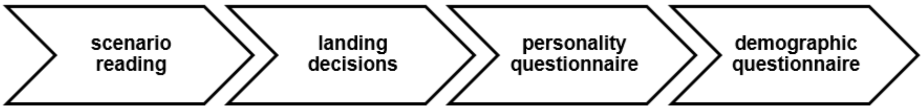

Figure 1. Protocol timeline.

Results

Statistical analysis

Normality of variables was evaluated using Kolmogorov-Smirnov-Test. Normally-distributed variables were: impulsivity and flight hours. Descriptive statistics summarized pilots' approach decisions of all 18 scenarios. If sample sizes were small, Fisher's exact test for categorical variables - instead of chi-square statistics – was used. T-tests compared the pilots' level of impulsivity to normative data of other studies. Linear regression was used to describe pilots' indecisiveness during uncertain approach scenarios. Logistic regression was performed in order to encode pilots' self-reported compliance to airline guidelines in real life. A p-value .05 was considered significant. Statistical tests were performed two-tailed.

Uncertainty rating in approach decisions

We first analysed whether pilots rated the approach scenarios in the same way as pilot experts. Table 2 shows that 93% of the participants agreed on the decision to continue the approach in the certain/continue scenario. In the certain/discontinue scenario, 90% of participants made the decision to discontinue the approach. In the uncertain scenarios, 54% of the participants decided to continue, whereas 35% decided to discontinue the approach. 11% of the participants expressed their indecisiveness. Fisher's exact test confirmed significant differences between both certain/continue scenarios and uncertain scenarios ($p < .001$), certain/discontinue scenarios and uncertain scenarios ($p < .001$) as well as certain/continue and certain/discontinue ($p < .001$).

Table 2. Mean of decision agreement with expert judgement for the three types of scenarios

Decision agreement in %	*Certain/continue*	*Certain/discontinue*	*Uncertain*
Continue	93	4	54
Discontinue	3	90	35
Indecisiveness	4	6	11

BIS-11 impulsivity scores

Next, the pilot's mean impulsivity score ($M = 51.9$, $SD = 5.4$) was compared to other studies. Therefore, we calculated the impulsivity t-value of different studies by comparing it to the impulsivity t-value of this experiment. Table 2 shows that pilots scored significantly lower on the BIS-11 than healthy controls of two studies (Patton et al., 1995; Spinella, 2007). There were no significant differences between the adult sample size of Stanford et al.'s study (2009) and this study.

Table 2. Comparison of BIS-11 impulsivity scores between the reference study and other studies

Study authors	*Reference study*	*Patton et al. 1995*	*Spinella . 2007*	*Stanford et al. 2009*
Sample type	Pilots	Male undergraduates	Adults	Adults
N	40	130	700	1577
M (SD)	51.9 (5.4)	64.9 (10.1)	64.2 (10.7)	62.3 (10.3)
|t|, p < .05	2.02	> 2.41 *	> 2.27 *	< 1.93

Linear regression: encoding indecisiveness during uncertain approach scenarios

More than half of the participants (52.5%) expressed at least once their indecisiveness during all 18 landing scenarios. They were named indecisive pilots in the analysis. Pilots, who never expressed their indecisiveness during all scenarios, were labelled decisive pilots. Chi-square test revealed that the percentage of expressed indecisiveness (indecisive vs. decisive pilots) did not significantly differ by hierarchy (Captain vs. First Officer) (χ^2 (2) = 0.1, p < .69, **φ** = .01, n = 40). An independent *t*-test was conducted to compare the level of impulsivity and the number of flight hours in decisive vs. indecisive pilots. There was a significant difference in the impulsivity scores between decisive pilots (*M* = 53.61, *SD* = 5.6) and indecisive pilots (*M* = 50.10, *SD* = 4.5); *t*(38) = -2.1, p < .03, Cohen's d = .69). There were no significant differences regarding the flight hours between the decisive (*M* = 11481, *SD* = 3644) and indecisive pilots *(M* = 11758, *SD* = 4730); *t*(38) = -.08, *p* = .83, Cohen's d = .06). In order to gain a more precise understanding of the level of indecisiveness, we then calculated an indecisiveness score that was defined as the number of times a pilot expressed indecisiveness during all uncertain approach scenarios. Next, a linear regression analysis was conducted to predict this indecisiveness score using flight hours, impulsivity, hierarchy and prior airline experience. Together, these measures explained 27 % of the variance in the individuals' indecisiveness score (*F*(4,35) = 3.2, *p* < .02). Individually, impulsivity (*t* = -2.02, p < .05) and flight hours (*t* = 2.00, *p* < .04) were significant (see Figure 1). These results suggest that the number of flight hours influenced positively (β = .40) the level of indecisiveness, whereas the level of impulsivity (β = - .31) influenced negatively the level of indecisiveness.

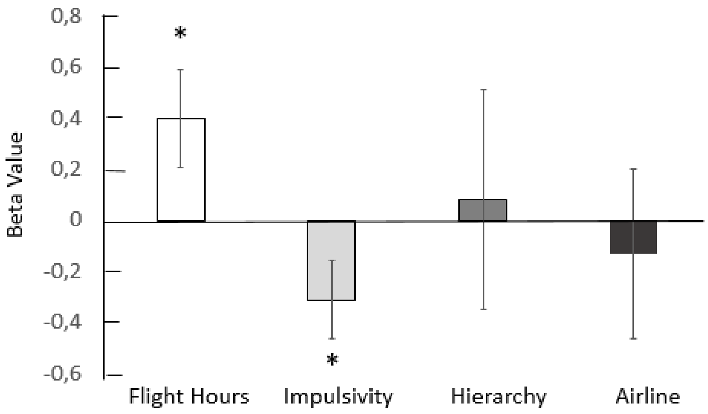

Figure 1. Standardized betas and standard errors for all factors of the model

Logistic regression: encoding self-reported compliance to airline guidelines in real life

A logistic regression was conducted to encode pilots' self-reported compliance to airline guidelines in real life (compliers vs. non-compliers) for 40 airline pilots using flight hours, impulsivity, hierarchy, and prior airline experience as predictors. A test of the full model against a constant only model was statistically significant, indicating that the predictors as a set reliably distinguished between compliers and non-compliers of airline procedures in real life (χ^2 (3) = 11.47, p < .001, n = 40). Nagelkerke' R square was .364. Prediction success was 64.9 %. The Wald criterion demonstrated that impulsivity (p < .02) made significant contributions to prediction (see Figure 2).

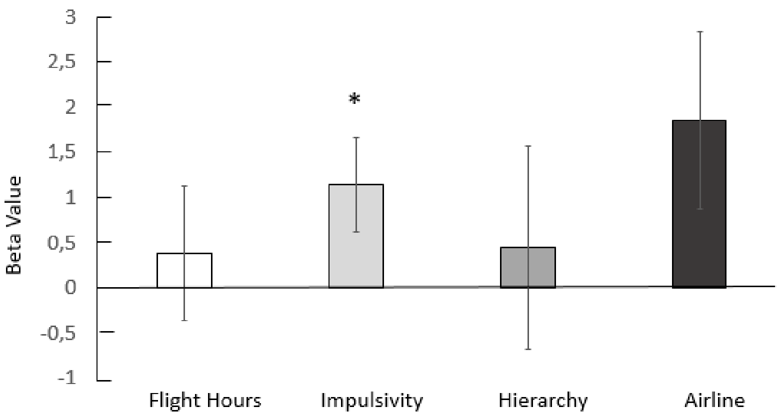

Figure 2. Standardized betas and standard errors for all factors of the model

Discussion

General discussion

The aim of this experiment was to investigate the influence of impulsivity among other factors - flight experience, hierarchy, and prior airline experience - on airline pilot decision making. In line with expert ratings, participants strongly agreed on decisions that were well-defined by airline guidelines. Nevertheless, we explored the existence of response uncertainty in the questionnaire when airline guidelines allowed interpretation: half of the pilots expressed at least once indecisiveness despite the existence of airline guidelines. Pilot experts reported that airline guidelines were theoretically applicable in the questionnaire scenarios. Indecision may be an indicator of (a) evaluation difficulty of the situation and decision complexity due to outcome uncertainty, (b) a lack of information or (c) non-familiarity with decisions (Anderson, 2003; Rassin, 2007). Further; pilot experts emphasized that indecisiveness in a dynamic situation could be described as momentary persistence in the current action plan.

It was pertinent to study the influence of impulsivity as personality factor on pilot decision making. Impulsivity predicted decisions in real life (self-reported compliance to airline guidelines) and decisions in this static questionnaire (uncertain approach scenarios).

Self-reported compliers of airline guidelines in real life were less impulsive than non-compliers. Previous research has shown a link between impulsivity, punishment and reinforcement sensitivity (Gray, 1987; Martin & Potts, 2004). Potts, George, Martin, and Barratt (2005) measured sensitivity to punishment among individuals with low and high impulsivity BIS-11 scores. They found reduced behavioural inhibition among participants with higher impulsivity scores. Martin and Potts (2009) demonstrated in a risky choice paradigm with electroencephalography that low impulsive individuals – in contrast to high impulsive individuals – were more sensitive (i.e. larger error-related negativity) to the consequences of high-risk choices. This is in line with the findings of this experiment. It is possible that self-reported non-compliers of airline guidelines in real life are less sensible to possible punishments of the airline. Qualitative data suggested that non-compliers of airline guidelines in real life reported having taken a decision that was not within guidelines for a positive reason, i.e. in order to avoid a worst-case scenario. The question arises if, in this case, a little bit more impulsivity may be functional. Dickmann (1990) describes functional impulsivity as behaving rapidly with positive outcomes.

The exploratory variables of indecisiveness in the approach scenarios were flight hours and impulsivity. Both factors are independent. This means that impulsivity persists despite intensive training and a highly-procedural environment, whereas flight hours can be acquired. More experienced pilots expressed more indecisiveness than less experienced pilots. Previous research has shown that experience improves performance in aviation studies (Harkey, 1996; Taylor, Kennedy, Noda, & Yesavage, 2007), especially when decision making is concerned (Wiegmann, Goh, & O'Hare, 2002). More experienced pilots recognize the uncertain character of the decision situation and its complexity by delaying their decision. They might aim to acquire more information in order to make a more appropriate decision. In addition, less impulsive pilots expressed more often their indecisiveness than decisive pilots. Delaying action options is the opposite of making rapid, unplanned decisions, which is positively correlated with self-reported motor impulsivity on the BIS-11 (Baumann & Odum, 2012).

The randomly-chosen airline pilots represent a low impulsive population in comparison to normative data. *Can training and environment modify the influence of personality on decisions?* In a literature review, Baumeister, Gailliot, DeWall, and Oaeten (2006) argue that ego depletion moderates the effect of personality traits on choice behaviour. If an individual's ability to self-regulate behaviour is depleted, desires may have a stronger impact on actions. Therefore, the ability of self-regulation may suppress individual differences in behaviour. Montiglio et al. (2013) emphasize the link between the social context and the prevalence of certain personality traits by the term behavioural flexibility.

Limitations and future research

One limitation is that participants were instructed to make their decisions in a non-dynamic environment. In real life, decision parameters are dynamic and may evolve over time since they depend on pilots' technical skills and actual weather conditions. Importantly, deviation detection of parameters (context updating) is therefore another challenge prior to the actual decision. Thus, pilots had no time restriction for responses and approach decisions were reversible, contrary to dynamic situations. Under time pressure in the real world, potential consequences of their actions may be valued differently as in a questionnaire. Next, this experiment focused on individual decision making under uncertainty. Although this type of decision has a low-procedural interdependence character, i.e. each pilot in the cockpit is allowed to make the decision; at least two pilots are physically present in a cockpit: Both pilots exchange information concerning the decision. Future field studies in a full-flight simulator might confirm the static results by investigating the influence of hierarchy and personality factors on uncertain and dynamic decisions.

Conclusion

Despite the existence of guidelines, the complex selection process of an airline pilot, the intensive training and the highly-procedural environment, a personality factor – impulsivity- mainly accounted for decision making differences among individuals. Impulsivity modulated pilots' indecisiveness in the questionnaire scenarios and pilots' self-reported compliance to airline guidelines in real life. Results emphasize that personality is a profound trait which influence on decision making cannot be removed by intensive training and a highly-procedural environment.

Acknowledgements

This paper originates from an interdisciplinary project that was supported by Air France. We thank Jérôme Rodriguez for technical support. We would also like to express our sincere gratitude to all airline pilots who participated in this research.

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