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Title	The data-driven pilot and the risk of personal sensitivity to a negative outcome
Authors	O'Driscoll, Michael;Kiely, Gaye L.;McAvoy, John
Publication date	2019-05-28
Original Citation	O'Driscoll, M., Kiely, G. and McAvoy, J. (2019) 'The data-driven pilot and the risk of personal sensitivity to a negative outcome', Journal of Decision Systems, 28(2), pp. 101-119. doi: 10.1080/12460125.2019.1620574
Type of publication	Article (peer-reviewed)
Link to publisher's version	https://www.tandfonline.com/doi/full/10.1080/12460125.2019.1620574 - 10.1080/12460125.2019.1620574
Rights	© 2019 Informa UK Limited, trading as Taylor & Francis Group. This is an Accepted Manuscript of an article published by Taylor & Francis in Journal of Decision Systems on 28 May 2019, available online: http://www.tandfonline.com/10.1080/12460125.2019.1620574
Download date	2026-11-15 17:35:04
Item downloaded from	https://hdl.handle.net/10468/8677



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THE DATA DRIVEN PILOT AND THE RISK OF PERSONAL SENSITIVITY TO A NEGATIVE OUTCOME

Corresponding Author/ Author 1:
Michael O'Driscoll
Cork University Business School
Address:
Room 3.69 O'Rahilly Building,
University College Cork,
College Road,
Cork,
Ireland
Telephone: +3532149043344
email: michael.odriscoll@ucc.ie

Co-author 2:
Dr Gaye Kiely
Cork University Business School,
University College Cork,
Cork,
Ireland.
Email: Gaye.Kiely@ucc.ie

Co-Author 3:
Dr John McAvoy
Cork University Business School,
University College Cork,
Cork,
Ireland.
Email: J.McAvoy@ucc.ie

Abstract

The past decade has seen a gradual mistrust of the human-centric decision-making approaches with both researchers and practitioners advocating an increased use of data-driven decision making to lower decision-making risk. This is seen as vital in the aviation field with one of the greatest risks to passenger safety being errors in pilot decision making. Data from the United Kingdom and the United States show that human decision-making failures contribute to 80% of aircraft crashes, and, analysis of ten years of fixed-wing air crash data from New Zealand showed outcomes with incorrect decision-making approaches resulted in over 60% of the fatal crashes. The Federal Aviation Authority (FAA) has cited a loss of control in a pilot's decision making as the number one cause of fatal accidents from 2016-2017. Although the introduction of information systems has attempted to lower the risk of fatal crashes, human decision-making is still required. This article *seeks to understand if a pilot will oscillate between human-centric decision-making approaches and information system based decision-making approaches. A case study approach was iteratively built to investigate this phenomenon. From this case study, the emergent theme of an individual's personal sensitivity to a negative outcome is presented and discussed. The implications of these themes for information systems and the associated risks in the aviation field are then presented.*

Keywords: Aviation, Risk, Cognitive Continuum Theory, Data Analytics, Decision Making, Aircraft Pilot.

1 Introduction

The nature and volume of information, and managers' behaviour in seeking and using information has undergone massive transformations in the past 50 years in which we have seen the emergence of electronics, the internet, and data analytics (Van Knippenberg, Dahlander et al. 2015). Mobile technology, internet of things, and traditional devices are now offering organisations the ability to support highly mobile, location-aware, person-centred, and context-relevant operations and transactions (Chen et Al, 2012). These data-driven operations and transactions have seen rapid growth in the amount of data being generated, with the total amount of data in the world 4.4 zettabytes in 2013 and due to rise to 44 zettabytes by 2020 (Pyne, Rao et al. 2016). Data is now available to organisations in structured, transactional and in unstructured, complex formats. (Phillips-Wren, 2015). The rapid growth in the nature and volume of data available to managers has transformed technology from a supportive tool into a strategic weapon (Davenport and Harris 2007). Organisational leaders now believe that utilising a data analytics decision-making approach can exploit growing data and computational power to improve decision making by lowering risk and innovate in ways not previously possible (LaValle, Lesser et al. 2011). The growing application of data analytics has seen a rise in employees being hired specifically for their expertise with numbers or trained to develop these skills for use with data analytics (Davenport 2006). In contrast to the data-driven decision making sought by organisations today, organisations have traditionally utilised high performing managers who relied on an intuitive decision-making approach. These decision makers have been observed in professions such as doctors, factory foremen, grand chess masters, and business managers (Simon 1987). Adopting an intuitive decision-making approach allows managers to cut through vast quantities of data (Gladwell 2012). Despite the noted advantages of an intuitive decision-making approach, organisations have moved away

from the traditional expert manager to lower risk, as the information system data-driven manager offers "fact-based comprehension to go beyond intuition when making decisions" (Davenport, 2013, pp.3).

The current consensus is that more data is required to improve decision making, but Simon's (1957) observation that the structures created by organisations are for "a world in which the scarce factor is information may be exactly the wrong one[s] for a world in which the scarce factor is attention" (pp.167) should strike a note of caution. This is especially true in dynamic environments which are characterised by high risk, complexity, instability, and time pressure (Driskell and Salas 1991, Khatri and Ng 2000). Dynamic environments have been shown to present challenges and increased risk in information processing and data analysis due to: (1) time constraint in collecting data/information; (2) the need to collect a large amount of data to deal with environmental instability; and (3) the lack of reliability of the data or information. (Khatri and Alvin Ng, 2000). Environmental features have major implications for all aspects of management and decision making (Goll and Rasheed, 1997). The balance between adopting an intuitive decision-making approach and an analytical viewpoint of a scenario has been described as the ultimate skill to possess in organisational management today (Hodgkinson and Sadler-Smith 2003). To that end, this article seeks to explore intuitive decision making and data-driven decision making through the lens of cognitive continuum theory in high risk, dynamic environments. The next section will review the theoretical and conceptual background of the study.

2 Theoretical and Conceptual Background

Intuitive Decision Making

Intuition is a decision-making approach which has been observed in decision makers such as those in the medical profession, grand chess masters, and business managers (Simon 1987). An intuitive decision-making approach is advantageous as it allows the manager to cut through vast quantities of data (Gladwell 2012). An intuitive decision-making approach is characterised as being associative in nature, rapid in speed, unconscious, and with the managers finding it difficult to retrace the steps taken to arrive at a decision (Dane and Pratt 2007). Intuitive decision making is described as recognising features or patterns in data rather than making connections through logical considerations (Iivari, Hirschheim et al. 1998). The associative nature of intuitive decision making allows for rapid decision making when utilised. Intuition has been found to be advantageous in situations of a crisis when time is of a premium (Eisenhardt 1990). It has also been shown that utilising an intuitive decision-making approach can reduce information "bottlenecks" to allow for a more rapid decision-making response (Kihlstrom 1987, Dane and Pratt 2007). Intuitive decision making has also been described as a form of expertise or distilled experience based on a deep knowledge of the problems that continually arise with a specific task or knowledge that is accumulated via experience of handling specific situations (Prietula and Simon 1989). This distilled experience accrued over time is organised into highly sophisticated schemas which enable experts to quickly highlight relevant information in a problem and process it quickly and accurately (Chi, Feltovich et al. 1981). Business executives have described that intuitive decision-making processes were in part, based on inputs from facts and experience gained over a number of years (Agor 1990). Despite the advantages outlined of utilising an intuitive decision-making approach human decision-making approaches have been shown to be error-prone and sub-optimal (Cohen 1987). In contrast to the historical view of the expert intuitive manager outlined here,

practitioners and academics today promote the utilisation of data-driven decision making to lower risk and improve organisational decision making.(Davenport 2013). Cognitive continuum theory also views intuition and analysis as two opposite poles on a spectrum of decision making. The next section will discuss a data-driven analytical approach to decision making.

Data Driven Decision Making

Historically, high performing managers have been described as having an in-depth sense of a particular situation before it becomes apparent and promptly putting their finger on any problems arising (Simon 1987). Despite this, human decision-making approaches have been shown to be sub-optimal and error-prone (Cohen 1987) with 50% of all human performance accidents decision-making related in the aviation field. Findings such as these have led to a mistrust of this style of decision making and the modern manager is required to follow systematic procedures within an organisation to reduce risk of errors occurring (Tsoukas 2005). This had led to a rise in the use of data analytics within organisations as a tool to aid decision making, transforming technology from a supporting tool into a strategic weapon (Davenport and Harris 2007). Research has shown that organisations now opt for an analytics approach to decision making over traditional human decision-making systems such as intuition, and organisations seek managers who use scenarios and simulations that provide immediate guidance on the best course of action to reduce risk when disruptions occur (LaValle, Lesser et al. 2011).

This is also seen in current day academic research with the focus on data-driven aspects of management compared to a focus on human-centric decision-making approaches in previous decades (Davenport 2013). This style of manager who predominately relies on analytics from information systems when making decisions is known as a data-driven manager (Tsoukas 2005). The data-driven manager is a trend which has seen organisations specifically look to hire more and more people with a high proficiency in the use of statistics and numbers (Davenport 2006) and the use of analytical information systems are now viewed as an important tool and key differentiator for organisations (Chen, Chiang et al. 2012). The high adoption of information systems has also been seen in the aviation field where pilots must continuously input and evaluate a number of diverse and dynamic data sets to maintain an accurate, complete, and up to date understanding of rapidly evolving scenarios (Endsley, Farley et al. 1998).

The mass introduction of information systems across all domains has been generally welcomed by academics who view the data-driven manager as a person who uses data to be more effective at real-time decision making, responding to change, and understanding customers (Cao, Duan et al. 2015). This type of decision making indicates a further shift away from the traditional intuitive manger with the data-driven manager being described as utilising “fact-based comprehension to go beyond intuition when making decisions” (Davenport, 2013, pp.3). There is a growing view that as the amount of data organisations collect increases, the importance placed on human decision-making approaches should be decreased (McAfee 2013). This approach has led to criticism with a situation developing that instead of having the statistics as a servant to expert choice, the expert becomes a servant of the statistical machine (Ayres 2007). Domains such as the medical profession have also raised concerns, with research in the medical field showing that surgeons should trust their intuition far more than the systems they use in the operating theatre as switching on a particular analytical information system can switch off the decision makers intuition whilst in the operating theatre (Sutton, Hornby et al. 2015). Simon

(1987) concurs believing that research into decision making has had "less impact on decision making that is loosely structured, intuitive, and qualitative; and they have had the least impact on face-to-face interactions between a manager and his or her co-workers, the give and take of everyday work" (pp.57).

Dynamic Environment

Environmental features have been shown to have major implications on all aspects of management (Goll and Rasheed 1997). Research has shown that the decisions people make are often susceptible to the demands exerted on them by the environment which can lead to stressful and difficult conditions for managers to operate in (Porcelli and Delgado 2009). Operating environments such as those that CEOs, aircraft pilots, medical professionals, emergency services, and air traffic controllers operate in require large amounts of complex information to be processed in a short period of time. Dynamic environments are characterised as having high time pressures, high complexity, high levels of instability, and overall higher levels of risk (Driskell and Salas 1991, Khatri and Ng 2000). These conditions caused by the dynamism of the environment have been found to negatively affect decision making (Khatri and Ng 2000). Whilst working under conditions of high time pressure, decision makers have been shown to rely most heavily upon negative information rather than the best information available (Wright 1974). Decision makers under time constraints have also been shown to either filter information that is used or omit certain information from consideration altogether (Miller 1960).

Dynamic environments may also alter the amount of information available to a decision maker with less dynamic environments allowing a decision maker more time to collect and analyse data, whereas more dynamic environments pose challenges such as time constraints in the collection of data, the need to collect a large amount of data due to environmental uncertainty, and the lack of reliability in the data collected (Khatri and Ng 2000). These factors increase the degree of risk resulting in an error in decision-making occurring. The need to collect large amounts of data to contend with the dynamism of the environment may also lead to information overload. This is a phenomenon identified by Simon (1957) who identified that managers at the time were beginning to work under conditions of information overload moving away from information scarcity which had impacted managerial decision making previously. The abundance of data available to individuals results in increasing competition for the attention of individuals, groups, and organisations and a key challenge of the information age is to manage the wealth of information available and channel it to a productive end (Van Knippenberg, 2015).

Cognitive Continuum Theory

In various decision-making domains, such as aircraft pilots, market trading, and management, there are many obstacles and challenges which can inhibit the use of pure analysis or pure intuition by a decision maker (Dhami and Thomson 2012). Alternative decision-making approaches are more applicable to specific scenarios and no one specific decision-making system is applicable to all scenarios (Dhami and Thomson 2012). Intuition has been shown to be best utilised by managers in unstructured environments, whilst, in contrast to this, analytical decision-making systems are more applicable to structured environments (Dane and Pratt 2007). The ability to utilise multiple decision-making approaches has been shown to be advantageous with Simon (1987) advising that successful managers utilise a combination of intuition and analysis**.** Cognitive continuum theory aims to improve decision making by

defining the characteristics of a task and assigning the optimum decision-making approach to a specific task (Hamm 1988). Cognitive continuum theory purposes that decision makers utilise an intuitive decision-making approach, an analytical decision-making approach, or a combination of both referred to as quasirationality (Dhami and Thomson 2012). The need to understand how decision makers approach problems and arrive at a particular decision can be of great importance, especially in domains of limited time, high pressure, and complexity such as the aviation field. The environments decision makers operate in are not always stable with managers required to solve both structured and unstructured problems. It has been proposed that the decision-making approach and psychological processes adapt to the environment in which they function (Dhami, Hertwig et al. 2004). If this is the case, further research in this area could lead to improved data-driven decision making, by focusing on the relationship between the decision-making approach and the operating environment. The risks of relying on one decision-making approach has been highlighted in professions such as medical diagnosis, process control management, and aircraft pilots.

Cognitive continuum theory seeks to avoid reliance on one decision-making approach, and looks to allow the manager to adopt the correct decision-making approach for a specific scenario. Cognitive continuum theory has been applied to management, the medical profession, and engineering (Hamm 1988) . Cognitive continuum theory has yet to be applied to the information systems domain but there have been calls to expand the theory to this domain (Dhami and Thomson 2012).

Aircraft Pilots & Information Systems

Pilots have been identified as being required to be adept at utilising both an intuitive decision-making approach and a data-driven approach to decision making. It has been shown that pilots will often intuitively focus on specific aspects of data and information (Layton and Mccoy 1989). Intuitively focusing on specific aspects of data and information means a pilot does not require detailed information of a specific task; for example it has been shown that pilots do not require detailed information of weather situations and will intuitively view the positives or negatives of salient points en-route (Simpson 2001). In addition to intuitive decision making, pilots have also been shown to rely on a data driven decision-making approach. Pilots are required to interact with highly complex, multi-faceted systems which offer the pilot a range of data points and detailed information as seen in **Figure 1**. Information systems, automated aides, and decision support tools have become commonplace in cockpits and of critical performance in these domains due to the increased complexity and data (Mosier, Skitka et al. 1998). Aircraft flight management systems are not only designed to keep the aircraft on course, but also to increase control of tasks previously managed cognitively by the aircraft pilot such as calculating fuel-efficient routes, navigating, or detecting and diagnosing system malfunctions and abnormalities. The introduction of these information systems to aircrafts has not been without its flaws and there have been several risks highlighted with these highly complex systems in the cockpit

- System misunderstandings,
- Pilot errors,
- Failures of understanding automation behaviour,
- Confusing or lack of awareness concerning what automated systems are doing and why,
- Difficulty tracing the functioning or reasoning processes of automated agents,
- Disorientation,
- (Nagel 1988, Sarter and Woods 1993, Billings 1996, Mosier, Skitka et al. 1998).

The complexity and various number of information systems a pilot needs to interact with can be seen in **Figure 1** which shows a Boeing 737-800 cockpit. The complexity of aircraft information systems has been highlighted by the Federal Aviation Authority of the United States, who concluded several aircraft accidents are as a result of "the highly integrated nature of current flight decks and additional add-on features have increased flight crew knowledge and introduced complexity that sometimes results in pilot confusion and errors during flight deck operation" (Stanton and Bucchianico 2014, pp. 376). The incorrect use of any one of these complex systems shown in **Figure 1** can produce errors and increase risk which can lead to catastrophic consequences for both the pilot and all passengers aboard.

Both the United Kingdom and the United States cite that human decision-making failures contribute to 80% of aircraft crashes, and analysis of ten years of fixed-wing air crash data from New Zealand, showed outcomes with incorrect decision-making activities accounting for over 60% of the fatal crashes (O'Hare and Smitheram 1995). In addition, it has also been shown that pilots are required to operate in highly dynamic environments under conditions of high risk, time pressure, and uncertainty (Sarter and Schroeder 2001). These risks are highlighted further by the Federal Aviation Authority (FAA) who state that from October 2016 to September 2017, 247 died in 209 general aviation accidents where the loss of control in pilot's decision making was the number one cause of those accidents (Federal Aviation Authority, 2018). The requirement for pilots to operate under high risk these conditions coupled with existing research, which shows pilots are required to utilise both an intuitive decision-making approach and a data-driven decision-making approach means that pilots are an exemplar unit of analysis for this study. The next section will further explore the application of cognitive continuum theory to the information systems domain and identify the research gap.

Oscillating Decision Making in Information Systems

Previous sections have identified intuitive, and data-driven decision making as being important decision-making approaches which are at opposite ends of a spectrum. The associative, rapid, and unconscious aspects of intuitive decision making contrast with the systematic and data driven nature of information systems based decision making. Although both of these decision-making approaches have been championed in existing literature, research has also shown that reliance on one singular decision-making approach can be detrimental to decision making success. The risks of relying on one decision-making approach have been highlighted in the aviation domain: (i) system misunderstandings; (ii) pilot errors (iii) failures of understanding automation behaviour; (iv) confusing or lack of awareness concerning what automated systems are doing and why; (v) difficulty tracing the functioning or reasoning processes of automated agents (Sarter and Woods 1993, Billings 1996, Mosier, Skitka et al. 1998). These risks have also been highlighted by managers who rely on analytical information systems with potential risks occurring at the analytical processing stage and at the application of the data which can lead to potential errors occurring at an individual level, and organisational level (Krasnow Waterman and Bruening 2014). The risks of relying on a singular decision-making approach is discussed by King (1985) who remarked:

> *"It is so easy to lose sight of reality – to believe that the computer models numerical forecasts are real and that they describe future outcomes that will, in fact, come to pass (...). The computer models forecasts are based solely on those predictions about the future that we are able to quantify. Those things that are not readily quantifiable are usually omitted, and in being omitted there is a danger that they may be ignored. (p. xi).*

As well as the concerns around relying on a singular decision-making approach, existing research in non-IS domains has shown that managers may move between decision-making approaches (Custers 2013). Cognitive continuum theory proposes that the modes of cognition a decision maker utilises are in fact temporal and decision makers will move between intuition, analysis and a hybrid of the two referred to as 'quasirationality'. Although intuition and the use of analysis have been discussed in existing information systems literature, quasirationality is a phenomenon which has yet to be explored from an information systems perspective.

When viewed through the lens of cognitive continuum theory decision makers in management (Simon 1987, Mahan 1994), engineering (Hammond, Hamm et al. 1987) and the medical domain (Custers 2013) have all been shown to oscillate between differing decision-making approaches. Despite existing research showing that decision makers oscillate between decision-making approaches in the above domains, cognitive continuum has yet to be applied to the information systems domain. To rectify this there have been calls from cognitive continuum theorists to research and further explore this theory from an information systems perspective. Dhami and Thomson (2012) highlighted this research gap by commenting that "cognitive continuum theory also needs to be expanded to include an understanding of the impact of information technology and support systems on the task and cognition (p. ix)".

This is an important topic for the information systems community as modern organisations are now seeking managers who use scenarios and simulations that provide immediate guidance on the best actions to take when disruptions occur, which contrasts with the intuitive decision making managers of previous generations (Simon 1987, LaValle, Lesser et al. 2011). This modern manager is referred to as a data driven manager who is now required to operate all entities within the organisation through the use of data analytics (Tsouka, 2005). The rise in popularity from both practitioners and the IS academic community to promote data driven decision making individuals contradicts research from other domains such as management and medicine which found that individuals who utilise a range of decision-making approaches perform to a higher standard than those who rely on a singular decision-making approach (Hamm 1988, Hodgkinson and Sadler-Smith 2003, Cader, Campbell et al. 2005). The concerns highlighted by the academic community outside of IS on relying on a singular decision-making approach in tandem with the promotion of data driven decision making within the IS community leads to the research question being formulated:

How do decision makers oscillate between differing decision-making systems when utilising information systems in a dynamic environment?

The subsequent sections will address this research question by first focusing on the research strategy, case study background, and data analysis before exploring the findings of this study.

3 Research Strategy

This section outlines both the key research decision and the methodological choices undertaken which have guided this study. A case study approach is suitable when the intent of the research is description, theory building, or theory testing which allows for cross-case analysis and extension of theory (Benbasat, Goldstein et al. 1987). The case study approach allowed the research to explore emergent themes across the four pilots who were observed and to peruse specific themes that arose.

Case Study Background

The correct methodology utilised needs to align with the phenomena the researcher is exploring rather than any personal preference the researcher may have for a particular approach (Cavaye 1996, Krauss 2005). By focusing and understanding the phenomenon that is under examination rather than having a predefined methodology, the researcher can select the correct research approach for the particular study (Falconer and Mackay 1999). Case study research is most applicable when the research is exploratory in nature (Marshall and Rossman 2014), and involves the collection of evidence from multiple sources in relation to a particular set of circumstances (Remenyi and Williams 1995). Actions undertaken by an individual in a specific case are described in detail; which include the reactions, responses, and effects on other participants which are then compared and contrasted in order to draw conclusions (Hair 2007). The use of a case study approach is applicable to this study as cognitive continuum theory is currently an under-researched phenomenon and has yet to be studied from an information systems perspective (Dhami and Thomson 2012).

The lack of research surrounding the application of cognitive continuum theory in the information systems domain is a gap in existing research. This article has shown that managers across a number of domains, notably pilots, are required to utilise both an intuitive decision-making approach and data-driven approach to decision making. In addition, failures by pilots to adopt the correct decision-making approach can result in catastrophic life threatening scenarios for both the pilot and all passengers aboard. This is an important research area to pursue from both the perspective of a theoretical gap in research but also to improve pilots' decision-making processes which may help to reduce the number of aircraft accidents related to decision making. Errors in pilots' decision-making approaches have accounted for 41.5% of casualties in general aviation (Causse et al 2013).

In circumstances where research and theory are at an early formative stage, such as the application of cognitive continuum theory to information systems, a qualitative approach is best suited (Yin 1994). Case studies allow for the collection of complex and rich evidence (Remenyi and Williams 1995). The case study was iteratively built over time beginning in October 2016 and ending in April 2017 and took place at an international flight training academy for pilots which is approved by the European Aviation Safety Agency (EASA). As aircraft pilots are required to operate under conditions of high risk, time pressure, and uncertainty they were seen as the ideal candidates for this study(Sarter and Schroeder 2001). Data was collected for this study via four separate pilots who were observed operating a Boeing 737-800 simulator and will be henceforth referred to as pilot A, B, C, D. The Boeing 737-800 simulator had 31 distinct systems with which the pilot needed to interact. These systems were comprised of 24 pictorial, 6 analogue, and 1 was a combination of both. The pilot also had a combination of over 100 buttons, levers, and switches which will alter specific settings of the aircraft. These buttons, lever, and switches in conjunction with the information systems can result in thousands of different potential system configurations for the aircraft. The Boeing 737-800 simulator utilised by the pilots can be seen in Figure 1. The pilot is required to be comfortable operating a range of information systems including:

- Automation
- Communications
- Emergency & Warning systems
- Flight controls & instruments
- Navigation



Figure 1 – Highly Complex Multi-Faceted Boeing 737-800 Simulator

The correct use of these information systems by the aircraft pilot will all have an impact on the success of the flight, lowers risk, and ensures the safety of all those aboard. As well as interacting with the information systems, each pilot worked alongside a co-pilot who would provide support and information relating to navigational data and specific weather patterns. Each pilot was also required to operate with an air traffic controller who would relay information to the pilot and request information about specific incidents from the pilot. All four pilots were experienced in the aviation field with each pilot having hundreds of hours' experience operating the Boeing 737-800 simulator, class room based aeronautical training, and live flying experience of a light aircraft. Whilst operating the Boeing 737-800 simulator the pilot was being observed and graded by an experienced flight instructor. The flight instructor would grade the students on: (i) verbal communication with their co-pilot and air traffic control; (ii) navigational ability; (iii) take-off and landing scenarios; (iv) interactions with the information systems; (iv) hazardous flying scenarios; and (vi) life threatening scenarios. The pilots were awarded a score from 1 -10 based on their performance levels in each category whilst operating the Boeing 737-800 simulator.

The grade awarded to the pilot by the flight instructor would determine whether the pilot would receive their pilot's license to fly a commercial aircraft or not. The pilot would be awarded their grade after the simulation and be presented with feedback by the experienced pilot instructor. Due to the examination of the pilot by the flight instructor the pilot was placed under a high level of pressure to secure a satisfactory grade in order to obtain their commercial pilot's license. As well as the personal investment of multiple hundreds of hours studying for these

examinations, the pilots' had invested heavily financially with fees to complete the course costing upwards of 100,000 euro. The high financial and personal cost resulted in these examinations being critical for the pilot's future, with either a pass or fail grade being awarded being of life changing importance.

Data Analysis

The data obtained from the pilots A, B, C, and D was coded and tabulated before a matrix of categories were developed and data placed within each matrix. The information matrix of categories allowed the researcher to compare and contrast different themes of data. Recurring themes were noted and then formed into clusters to aid the researcher in better understanding the phenomenon, which were then conceptualised to find similar patterns or characteristics (Miles and Huberman 1994). This method allowed the researcher to streamline the data by removing extraneous and irrelevant data from the study. The data was also validated by an experienced Boeing 737-800 commercial pilot and flight instructor to ensure what was being observed, recorded, and validated was correct. This post-validated data was subsequently filtered using content analysis which allowed the researcher to explore underlying meanings and ideas which were revealed from the analysed patterns of data (Yang and Miller 2008).

4 Findings

This section will present findings from a series of multiple observations of pilots conducting their commercial airline pilots' examination. The findings compared the multiple findings from the case study conducted of the aircraft pilots. Only findings which arose multiple times by more than one pilot were considered. This was to ensure that the findings would be both correct and consistent across the case study. This method provided an additional layer of validation for the researcher. These findings are presented and discussed in further detail in the subsequent sections.

Oscillating Decision-Making Approaches

It was noted that Pilots A, B, C, and D would all utilise differing decision-making approaches for different tasks whilst utilising the Boeing 737-800 simulator. Three differing decision-making systems were identified from the series of observations. These included (i) intuitive decision making; (ii) system aided judgement; and (iii) data driven decision making. Both intuitive decision making and data driven decision making had been identified in existing pilot and information systems literature, however this study also identifies system aided judgement as a quasirational and hybrid decision-making approach adopted by the aircraft pilots (Standing 2008). The data collected for this study examines pilots' decision-making behaviour whilst being examined by a flight instructor for their pilots' license. The successful completion of the simulation tasks the pilots were being examined under would result in the pilots being awarded their commercial airline pilots' license. These series of examinations would be of high importance to the pilots as they had invested many hours of simulation, theoretical, and live fight training as well as having a high financial investment of 100,000 euro in passing the examination. Although nobody would be injured if the pilot made an error in the simulation, the factors listed previously made successfully flying without errors of large personal importance to the pilot.

An intuitive decision-making approach was found to be utilised in multiple scenarios by pilots A, B, C, D. Each pilot was required to utilise an intuitive decision-making approach when performing routine tasks such as take-off requests, responding to routine status updates from

air traffic control, and requesting landing permission in clear weather conditions. It was found that for these tasks the pilots would all adopt an intuitive decision-making approach and that the pilots were able to make the correct decisions instantaneously. Pilots would feel comfortable performing these tasks when the environment remained static with low time pressure and stress for the pilot such as during calm weather. The pilots' experience of operating an aircraft was noticeable with each pilot remaining comfortable operating the information systems of the aircraft and interacting with air traffic control despite being graded in an exam by their flight instructor. All four pilots had a high level of experience operating the aircraft and were rapidly able to move through pre-flight functions. A high level of experience was evident when the pilots would utilise a system aided judgement approach to decision making.

A system aided judgement decision-making approach was also found to be utilised by each of the pilots when the environmental conditions were favourable even whilst being examined. Whilst the flying conditions were favourable, each of the pilots were able to remain calm and had additional time to respond to specific issues that might arise. In such an environment all four pilots were found to adopt a system aided judgement decision-making approach whilst operating the aircraft. The adoption of a system aided judgement approach was evident when pilot D was attempting to land the aircraft in clear conditions. In the build up to landing the aircraft, pilot D felt comfortable requesting clearance from air traffic control and amending system setup based on specific feedback from air traffic control regarding which runway to land on. Pilot D was also required to perform system tasks such as reducing the aircrafts speed, attaining the correct flight angle, lowering the aircraft gradually to the correct altitude, and amending the aircrafts flaps. Adopting a system aided judgement approach allowed pilot D to correctly amend the information system for variances which occurred in the operating environment whilst also being able to interact with their co-pilot and air traffic control if necessary. The instructor recommended to the pilots that they utilise "both their experience and the systems" or the "default approach". Although the instructor did not use the term, this decision-making approach is that of a system aided judgement approach. This decision-making approach was repeated in pilots A, B, and C.

As deteriorating weather conditions were introduced to the simulation it was found that each of the pilots would begin to oscillate their decision-making approach towards a data-driven approach. The deteriorating weather conditions would increase the time pressure, navigational difficulties, aircraft stability issues, and pilot stress. This shift towards a data-driven approach was seen with pilot B who had initially flown during fair weather conditions and adopted a system aided judgement approach. During this phase of the simulation, pilot B felt comfortable interacting with air traffic control and amending the on-board information system to keep the flight on course for its destination. However on final approach severe weather conditions of fog was introduced to the simulation and the pilot subsequently began to oscillate their decision making towards a data-driven decision-making approach. As the severe level of fog was introduced, pilot B began to become audibly and visibly nervous with a shaking voice and sweating whilst performing pre-landing checks. During this scenario pilot B was required to remain in contact with air traffic control and amend their information systems. The shift in their decision making towards a data-driven approach resulted in pilot error occurring. The pilot began to monitor their instruments too closely and stopped communicating with air traffic control. By adopting the incorrect decision-making approach and becoming overly fixated on the information system, pilot B took an incorrect flight path on the final approach and was unable to land the aircraft. This oscillation in decision-making approach and subsequent

altering of the pilot's behaviour resulted in the pilot failing the task. This surprised the pilot's flight instructor who remarked that he had previously seen the pilot complete this task "numerous times" in the past and asked if the pilot was "rusty". The instructor noted that pilot B oscillated their decision-making approach towards a data-driven approach due to changes in the operating environment caused by unfavourable weather conditions. The shift towards a data driven decision-making approach as flying conditions became unfavourable under examination was repeated by all the pilots. Each of the pilots would become visibly stressed and overly reliant on the information system as the environment became unfavourable despite having completed this task numerous times in the past. The correct decision-making approach as pointed out by the flight instructor would have been to rely on a combination of their intuition (past experience) and a data-driven approach (the information system). A combination of prior flight training and utilising the information system as the flight instructor recommended can be referred to as adopting a quasirational approach or system aided judgement decision-making approach.

Although the pilots were recorded by the flight instructor as having failed the task due to altering their decision making due to the environmental conditions, this article proposes an alternative explanation. All four pilots had completed the same tasks whilst operating under difficult weather conditions multiple times in the past. However when individuals are placed in a threatening situation an individual's well-learned or dominant response may be utilised, but this learned response may be incompatible with the task or the operating environment which may have altered to make the response inappropriate (Staw, Sandelands et al. 1981). Pilots are required to operate in dynamic environments often under situations of high risk, time pressure, and uncertainty (Sarter and Schroeder 2001). It has also been shown that anxiety or stress will negatively interfere with a pilot's decision-making process (Adams, 2000).

These symptoms were visible in all four pilots when attempting to successfully complete their pilot's examination despite having successfully completed these tasks in the past. It can therefore be proposed that all four pilots who had successfully completed this task in the past multiple times were unable to repeat these steps whilst under examination due to having a high personal sensitivity to a negative outcome (failing their commercial pilots' exam). All pilots had invested hundreds of hours of practise in these scenarios in the classroom, simulator, and in live flying environments and had previously displayed an expertise in comfortably completing the task. Despite this experience, the heightened personal sensitivity of failing the exam interfered with the pilot's perception of the scenario and resulted in the pilots becoming overly focused on the information system. A pilot who displays expertise at a task has been described as looking for patterns and combining information from multiple sources to correctly navigate the aircraft (Mosier, 1998). However, these findings indicate that a pilot can suddenly lose their expertise of a particular task due to a high level of personal sensitivity to a negative outcome.

This resulted in the pilot reverting to behaviour mimicking that of a novice pilot by relying solely on the information system to provide full guidance and being unable to retrieve and process information outside of what is displayed on the information system. These findings which are summarised in **Figure 2** show all four pilots adopting an intuitive decision-making approach whilst performing pre-flight checks, interacting with the co-pilot, and air traffic control prior to take off. All four pilots were found to be relaxed, confident, and rapidly able to perform these tasks intuitively.

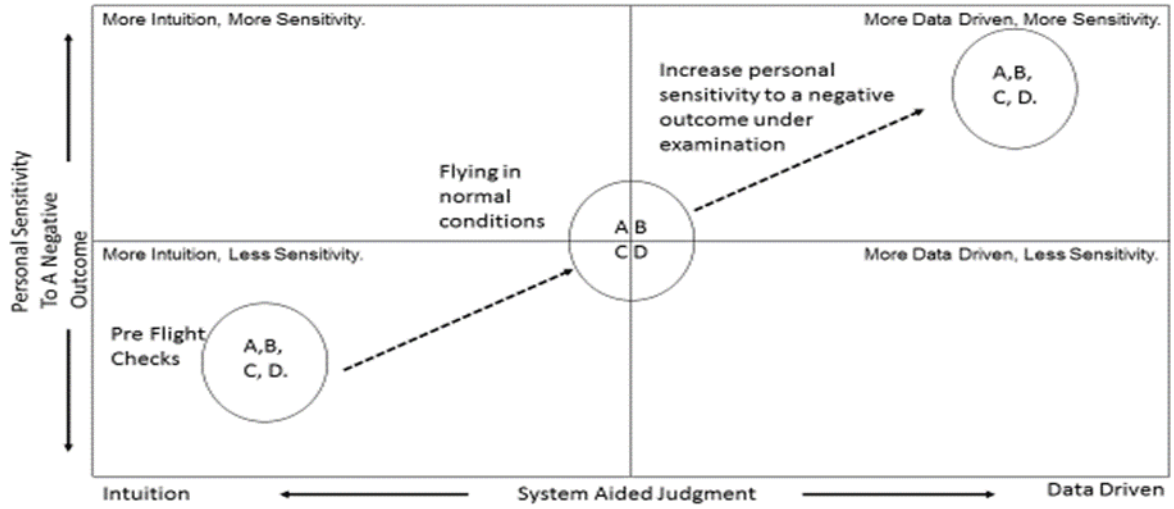


Figure 2 - Increased Personal Sensitivity to a Negative Outcome Alters Decision Making Approach

Whilst flying the aircraft in normal weather conditions under examination by their flight instructor the pilots were at ease utilising both their intuition and the information system, adopting a system aided judgement approach to their decision making. The pilots were successfully able to interpret data from the information system whilst also searching for information cues in the environment through the use of air traffic control or prior experience of the task. The pilots displayed real expertise in their ability to fly the aircraft, however this would change as shown in **Figure 2** when under examination by their pilot instructor and poor weather conditions were introduced. In such conditions the pilots were constricted in their decision-making approach, unable to search for information in the environment, and would become overly reliant on the information system reverting to novice behaviour. Overall **Figure 2** shows that the pilot's decision-making approach would oscillate towards a data driven decision-making approach when their personal sensitivity to a negative outcome was increased. These findings will be discussed in further detail in the next section.

5 Conclusions and Future Works

Current academic research has focused on the benefits of organisations and individuals adopting a data-driven approach to decision making, however this article identifies that decision makers may adopt multiple differing decision-making approaches when utilising an information system. It was found that all four pilots would oscillate between an intuitive decision-making approach, a data driven decision-making approach, and also a quasirational approach referred to as system aided judgement. All four pilots were experienced in their roles and felt at ease utilising all three different decision-making approaches depending on the task. Although movement between decision-making approaches has been found in domains such a medical, engineering, and management, this article presents the first findings of this phenomena from an information systems perspective. This is an important finding as it offers an alternative viewpoint to recent academic research which has highlighted the importance of decision makers moving towards a data driven decision-making approach to improve decision-making performance. Despite the multi-faceted and highly complex information systems

available to the pilots (shown in **Figure 1**), it was found that the pilot would often use the information system in conjunction with their own intuitive knowledge of a task.

These findings can be transferable to a number of industries and managers who have or will be introducing additional complex information systems to their environments. As even in a highly dynamic environment such as piloting a Boeing 737-800 with access to large scale and sophisticated information systems, the pilot would still utilise the more human centric decision-making approaches of intuition and system aided judgment. This finding should strike a note of caution for current academic and practitioner trends that advocate for an increased adoption of data-driven decision making by managers. As decision-making within organisations becomes increasingly automated and augmented by information systems, the interplay between a data-driven approach and a more human intuitive decision-making approach will become increasingly important.

This study has also found that a decision makers' personal level of sensitivity to a negative outcome will affect their selection of decision-making approach which will increase the risk of failure. Despite all four pilots being domain experts with hundreds of hours of experience and having previously completed requested tasks with ease, it was found that whilst under examination for a commercial pilot's license the pilots' decision-making approach would alter. The pilots' high level of personal and financial investment (100,000 euro) to passing or failing their commercials license exam oscillated the pilot's decision-making approach towards a data-driven approach to decision making. It was found that despite the previous expertise shown by the pilots in performing specific tasks, the high level of personal sensitivity to a negative outcome constricts the pilots' decision-making approach and reverts their behaviour to that of a novice. This constriction in information processing and over focus on the information system increases the risk of failing a specific task.

This is an important finding which indicates that despite the mass introduction of information systems to cockpits to reduce risk and reliance on human decision making, these information systems may increase the number of errors occurring if the pilot has a high level of personal sensitivity to a negative outcome. The incorrect adoption of a decision-making approach would increase the risk of an error occurring during flight and offers a stark warning for a domain which is attempting to move away from human centric decision making where studies have reported that 80% of all crashes were human decision-making failures (O'Hare and Smitheram 1995).The flight instructor commented that increased stressors which may affect a pilots decision-making approach include "personal problems, fatigue, or a high workload", and existing research has shown that plan continuation error (Causse, Dehais et al. 2013) and cockpit information system complexity (Chow, Yortsos et al. 2014) may adversely affect a pilots decision-making approach by increasing risk. The lowering or removal of a pilot's personal sensitivity to a negative outcome will remove one potential risk for aircraft pilots.

In addition, the findings presented in this study are relevant and transferable to all domains where managers need to utilise complex information systems and complete tasks were the threat of failure may result in harsh personal, and financial consequences. Industries where individuals operate in high risk and dynamic environments, such as the aviation industry, financial industry, and the medical industry should implement measures to lower an individual's personal sensitivity to a negative outcome. These industries often expose individuals to life threatening, high stakes, or crisis scenarios were the environmental propensity increases the probability of such scenarios occurring. This research shows that when an individual's personal sensitivity to a negative outcome is increased, it may alter their decision-making approach so it is no longer compatibility to the current task.

Organisations in dynamic environments were managers are required to complete high stakes or life threatening decision-making tasks should be further trained for such scenarios. Increased decision making based training for scenarios of high personal sensitivity to negative outcomes will allow individuals to have a well learned response mechanism if such a scenario presents itself in a live environment. Individuals who adopt the correct decision-making approach in high risk professions when their personal sensitivity to a negative outcome is heightened, will reduce the probability of errors and risks occurring which may lead to regulatory issues, financial issues, or even fatalities occurring. This is an important finding going forward as the utilisation of information systems in the aviation industry, and industries of similar characteristics will continue to grow over the coming years.

This research is also of importance to the design of future information systems in the aviation industry, and in industries were individuals will be required to make decisions which will increase the decision-maker's personal sensitivity to a negative outcome. As decision makers will oscillate their decision-making approach towards a data-driven decision-making approach when experiencing a heightened personal sensitivity to a negative outcome; information systems in dynamic environments should be designed to guide the decision maker towards the correct response for a given scenario. This may alleviate or lower human traits of stress and anxiety, which manifest when personal sensitivity to a negative outcome is heightened. This is of importance, as these findings reveal that although the aviation industry has introduced information systems en masse to cockpits to lower risk and human error, an individual experiencing a heightened personal sensitivity to a negative outcome may utilise the information system incorrectly, potentially leading to risks of catastrophic consequences. Future avenues of research for this topic should include managers who operate in similar conditions to pilots such as financial traders or healthcare professionals. Managers who operate in more static environments should also be investigated to find if these results are replicated. Future research should also focus on if training individuals with coping mechanisms will allow the individual to lower their personal sensitivity to a negative outcome when performing tasks and thus remove an error in decision making. The authors of this article are currently investigating the results of this study with air-traffic control managers, and national grid operation managers. In conclusion, this article finds that decision makers oscillate between a range of decision-making approaches when utilising information systems, however, a decision maker may be inclined to adopt a data-driven approach to decision-making approach due to having a high level of personality sensitivity to a negative outcome.

Disclosure statement

No potential conflict of interest was reported by the authors.

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