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Surprise and Unexpectedness in Flying: Factors and Features

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This database analysis was conducted to determine which factors, or combination of factors, play a part in creating an unwanted outcome due to surprising or unexpected events encountered by pilots. The purpose of this study was to identify likely precursors to perceived surprising and unexpected events and, to advance our understanding of the overt behaviors and misbehaviors found in response to these events. This study also sought to determine if there were any significant differences between commercial air carrier and general aviation flight operations in regard to surprising and unexpected events. The results of this study indicated that the involvement of surprise or unexpectedness can indeed have a detrimental effect on the outcome of the flight. We also found indicators of the processes and mechanisms leading from surprise to an unwanted outcome.

Introduction

It is widely accepted that aircraft accidents, incidents, and events can result from novel and catastrophic unexpected situations. One need only look back at recent history for examples of fatal accidents that resulted from highly unusual situations such as US Airway's Flight 427 near Pittsburgh (National Transportation Safety Board, 1999), Alaska Airlines Flight 261 off the coast of Southern California (National Transportation Safety Board, 2000), and American Airlines Flight 587 in New York (National Transportation Safety Board, 2001). However, Kochan, Breiter, and Jentsch (2004) found surprising and unexpected events need not be rare, unusual, or catastrophic. Quite the opposite, pilots often describe normal, everyday occurrences as surprising or unexpected. They concluded that typical or normal events that occur daily (or nightly) in flight operations can also be surprising or unexpected to pilots.

This study builds upon previous research (Kochan, Breiter, & Jentsch, 2004) that identified what factors, conditions, and situations pilots and other users of the National Airspace System regard as surprising or unexpected. With this database analysis, we sought to deepen our understanding of surprise and unexpectedness by determining what underlying factors are present in situations that pilots deem surprising or unexpected. We asked: Are there certain factors, or a combination of factors, that are more likely to be present in situations where an unexpected event has a harmful effect on the outcome of the flight? Can seemingly trivial, everyday events, if surprising or unexpected to the pilot, produce an unwanted outcome?

Background

Research suggests that a person becomes surprised when their expectations are inconsistent with reality by an amount higher than could reasonably have been expected from the cues available and utilized by the individual (Kochan, Breiter, & Jentsch, 2004; Reisenzein, 1999). Expert pilots are normally able to process large amounts of information quickly and accurately, while continually and seamlessly modifying their situation awareness (Endsley, 2001; Wickens, 2002; Orasanu & Martin, 1998). However, decision making performance might be impaired, when pilots are confronted with events that do not adhere to expected schemata (Wickens, 2002; Endsley, 2001). Unexpected or surprising events may cause a disruption in cognitive processes (Reisenzein, 1999) leading to a decision making delay. This decision making delay lasts until the inconsistency, between what was expected and reality, is analyzed and integrated into the pilot's situation awareness (Meyer, Reisenzein, & Schützwohl, 1997). Reisenzein (1999) found that the more unexpected an event, the more significant this disruption in cognitive processes. The extent to which this potential interruption of cognitive processes occurs in the task of flying may influence the outcome of a particular maneuver or even the entire flight. It was with this assumption that the following database analyses were performed.

Purpose of Study

The purpose of this study was to determine (a) what factors or combination of factors are present in unexpected and surprising events; (b) find out to what extent these factors influence the surprising or

unexpected event; (c) discover if there is a relationship between types of factors and severity of outcomes ranging from merely an event to a fatal accident; and (d) determine if there are any significant differences between commercial air carrier and general aviation flight operations, in regard to surprising and unexpected events.

Method

Search Procedure and Databases

Four databases (Table 1) were electronically keyword searched for the words "surprise" and "unexpected." Reports not relevant to this study were discarded. For example, if a reporter stated that, "it was not unexpected that…" or, if the reporter communicating the surprise or unexpectedness was not involved in the reported event (e.g. they were not a user of the National Airspace System) then the report was discarded. Also, reports submitted more than once were not included in the analysis. This study analyzed 638 reports.

Table 1. *Databases Reviewed for this Study.*

Database	Report Dates	*N*
National Transportation Safety Board (NTSB) Accident Database	1/1/1999 to 12/31/2003	131
National Aeronautics & Space Administration (NASA) Aviation Safety Reporting System (ASRS)	1/1/1999 to 1/1/2004	424
Federal Aviation Administration Accident and Incident Database (AIDS)	1/1/1999 to 12/31/2003	30
Major Air Carrier Aviation Safety Action Program (ASAP)	12/3/2002 to 10/19/2004	53

NTSB and AIDS reports are created as a result of an accident or incident investigation. ASRS and ASAP reports are compiled through voluntary reporting programs.

Report Analysis Procedure

Two aviation psychology researchers holding civilian flight instructor certificates reviewed the reports. Each report was examined for 71 variables. The variables selected for investigation were chosen to ascertain the location and environmental conditions surrounding the reported event, the demographics and experience level of the reporter, the type of aircraft, type of flight operation and purpose of flight, the factors surrounding the surprising or unexpected event, and the effect of the surprising or unexpected event on the outcome of the flight. The results from each report were coded and recorded into the Statistical Package for the Social Sciences (SPSS) v. 11.5.

Factors Surrounding "Surprise" and "Unexpectedness"

In addition to collecting data regarding the background and conditions of each surprising or unexpected event, each report was also reviewed for the presence of 35 factors (Table 2) believed to be involved with surprising and unexpected events.

Table 2. *Factors Associated with Unexpected or Surprising Events.*

Other's Surprise at Pilot's Actions	Go-Around
Surprise at Own Actions	Holding
Other Crewmember Actions	Delays
Maintenance Actions	Wind Takeoff
Loadmaster Actions	Wind Enroute
Passenger Actions	Wind Landing
Air Traffic Control	Wake Turbulence
Illusion or Disorientation	In-flight Turbulence
Aircraft State	Low Visibility
Automation	Icing
System Status	Bugs or Birds
Fuel State	Other Aircraft – Taxi
Landing Gear Position	Other Aircraft – Departure
Aircraft Position	Other Aircraft – Enroute
Aircraft Alerting Device	Other Aircraft – Landing
Airport Construction	NOTAMs
Runway Change	Temporary Flight Restrictions
	Fatigue

These contextual factors were selected for analysis because past research found them to be associated with surprising and unexpected events (Kochan, Breiter, & Jentsch, 2004). They were also selected because of their historical and reoccurring involvement in aviation events, incidents, and accidents. The task of this study was to determine if relationship exists between these factors, or a combination of these factors, and the manifestation of surprise and unexpectedness.

The Effect of Surprise and Unexpectedness

An important aspect of this study was to determine *to what extent* surprise and unexpectedness contributes to aviation events, incidents, and accidents. In this regard, each report was analyzed to discover what relationship existed between the involvement of surprise or unexpectedness and the outcome of the resulting event, incident, or accident. Following Helmreich, Klinect, & Wilhelm's (2001) model of threat and error management, if the report of surprise or unexpectedness had *no effect* on the outcome, then the surprise or unexpectedness was deemed *inconsequential*. If the report of surprise or unexpectedness *had an impact* on the outcome, then the surprise or unexpectedness was determined to be *consequential*. If the report of surprise or unexpectedness had a worsening effect on the outcome, then the surprise or unexpectedness was recorded as having *exacerbated* the situation.

The surprise or unexpected occurrences were then evaluated for their impact on the *outcome* of the flight; normal, reportable event (no damage or injuries), incident (damage and/or injuries less than accident threshold), or accident (substantial damage and/or significant injuries).

Results

A thorough look at these data indicated that the factors did not correlate adequately to perform a factor analysis. The factors and their frequency and percent occurrence in the reports are listed in Table 3.

Table 3. *Factors Most Frequently Involved with Surprising and Unexpected Events by Frequency and Percentage of Reviewed Reports (n=638).*

Factor	Frequency Present	Percent Present
Aircraft Position	420	65.8
Air Traffic Control	326	51.1
Other Crewmember Actions	270	42.3
Aircraft State	202	31.7
System Status	123	19.3
Automation	95	14.9
Inflight Turbulence	74	11.6
Low Visibility	64	10.0
Delays	62	9.7
Airport Contstruction	60	9.4
Other Aircraft - Enroute	60	9.4

Chi-Square tests for independence were conducted to evaluate the differences between the results of the unexpected or surprising event and the outcome of flight as displayed in Table 4.

Table 4. *Event Outcome vs. Flight Outcome by Percent within Outcome of Flight (n=638).*

Result of Event	Outcome of Flight			
	Normal	Event	Incident	Accident
Inconsequential	8.2	10.5	21.5	9.2
Consequential	21.3	34.0	18.5	18.4
Exacerbated	70.5	55.5	60.0	72.4

Chi-Square tests for independence were also conducted to find which factors involved in unexpected and surprising events were significantly different between events, incidents, and accidents, displayed in Table 5.

Table 5. *Relationship between Factors and Severity of Outcome Ranked by Strength of Association.*

Factor	Flight Outcome Severity Percent Present		
	Event	Incident	Accident
Air Traffic Control $X^2(3, 634=159.38)$, $p < .001$ (Φ=.501)	53.8	15.4	5.7
Wind Landing $X^2(3, 634=107.80)$, $p < .001$ (Φ =.412)	1.3	29.2	26.4
Other Crewmember Actions $X^2(3, 634=53.64)$, $p < .001$ (Φ =.291)	37.8	49.2	12.6
Automation $X^2(3, 634=36.01)$, $p < .001$ (Φ =.238)	15.1	3.1	0.0
Inflight Turbulence $X^2(3, 634=32.59)$, $p < .001$ (Φ =.227)	6.7	32.3	11.5
Aircraft Position $X^2(3, 633=19.48)$, $p < .001$ (Φ =.175)	62.9	56.9	54.0
Aircraft Alerting Device $X^2(3, 634=16.48)$, $p = .001$ (Φ =.161)	12.6	13.8	0.0
Other's Surprise at Pilot's Actions $X^2(3, 633=15.61)$, $p = .001$ (Φ =.157)	6.3	10.8	18.4
Maintenance Actions $X^2(3, 634=14.29)$, $p = .003$ (Φ =.150)	10.9	16.9	6.9
Other Aircraft – Enroute $X^2(3, 634=13.45)$, $p = .004$ (Φ =.146)	12.6	1.5	2.3
Illusion or Disorientation $X^2(3, 634=13.09)$, $p = .004$ (Φ =.144)	5.5	3.1	4.6

A Chi-Square two-way contingency table analysis was conducted to evaluate which factors involved in unexpected and surprising events were significantly different between air carrier and general aviation. The results of these analyses are displayed in Table 6.

Table 6. *Differences in Factors in General Aviation vs. Air Carrier Operations.*

Factor	Percent Present	
	Air Carrier	General Aviation
Wind Landing $X^2(1, 631=30.0), p < .001$	2.4	14.2
Aircraft Position $X^2(1, 630=19.34), p < .001$	57.9	74.6
Temporary Flight Restrictions $X^2(1, 631=13.11), p < .001$	0.6	5.4
Wind Takeoff $X^2(1, 631=9.84), p = .002$	0.3	3.7
Wind Enroute $X^2(1, 631=11.54), p = .001$	1.2	6.1
Other's Surprise at Pilot's Actions $X^2(1, 630=7.04), p = .006$	5.4	11.5
Illusion or Disorientation $X^2(1, 631=7.95), p = .005$	5.1	11.1
Landing Gear Position $X^2(1, 631=5.64), p = .018$	1.5	4.7
Airport Construction $X^2(1, 631=5.80), p = .016$	6.9	12.5
Other Aircraft – Departure $X^2(1, 629=3.99), p = .046$	3.3	6.8
Holding $X^2(1, 630=4.51), p = .034$	3.0	0.7
Aircraft State $X^2(1, 631=5.18), p = .023$	35.8	27.4
Aircraft Alerting Device $X^2(1, 631=8.04), p = .005$	11.3	5.1
Inflight Turbulence $X^2(1, 631=11.56), p = .001$	15.8	7.1
Automation $X^2(1, 631=16.44), p < .001$	20.3	8.8
Other Crewmember Actions $X^2(1, 631=91.52), p < .001$	60.0	22.3

Discussion

This study revealed that there is a relationship between the involvement of a surprising or unexpected event and the severity of the outcome of the flight (Table 4). In 72.4% of the accidents reviewed for this study, the involvement of surprise or unexpectedness did exacerbate the situation. On the other hand, the surprising or unexpected event was found to be inconsequential in only 9.2% of the accidents. We can see from Table 4 that in all 'outcome of flight' categories the surprising event was more likely to exacerbate the situation than not. Therefore, regardless of the ultimate outcome of the flight, surprise very often has a worsening effect on the situation. Interestingly, Table 4 shows that in 70.5% of the surprising or unexpected events that resulted in a *normal* outcome, the surprise or unexpectedness also exacerbated the situation. This category represents situations where surprise worsened the situation, but the flight continued normally never having crossed the event, incident, or accident threshold. This suggests that the occurrence of surprising or unexpected events might be a more nominal part of flight operations than previously thought. It is likely that the vast majority of surprising or unexpected events that end in normal outcomes go unreported.

This study found several factors which tend to be involved in more severe (incident or accident) flight outcomes (Table 5). It is interesting that the factor 'other crewmembers actions' is strongly associated with more severe flight outcomes. As would be expected, further analysis of this factor revealed it is more strongly associated with air carrier than general aviation operations. Further study into this area is needed to determine the nature, extent, and implications of the problem.

Results of this study also indicated that there are many types of surprising events in aviation. The fact that there are no consistent patterns of these events occurring suggests that potentially any event or combination of events can produce a situation which can end in an unwanted outcome as exhibited in the following examples.

Aircraft Position and Confounding Events. Findings from this study support research by Hoeft, Kochan, and Jentsch (2005) which revealed the flawed nature of the current NOTAM system. In this study, pilots repeatedly described the NOTAM system, which disseminates Temporary Flight Restriction (TFR) information, as unclear and difficult to use. This study found that TFRs are more of a general aviation problem than an air carrier problem (Table 6). In the example below, the pilot was conscience of nearby restricted airspace. However, an unexpected system malfunction contributed to the pilot's loss of awareness of the aircraft position and inadvertent penetration of a TFR. Aircraft Position was the most frequently (65.8%) occurring factor in all of the reports (Table 3).

They [ATC] were extremely busy and, I believe, were working another plane with a call sign of X, but I thought I heard a clearance. Near this time I experienced an ***unexpected*** *overload on my electrical system and had to flip the battery switch to correct it. This required me to reprogram my GPS which contains the communications I was using. I was unable to reach Orlando approach again and called Kissimmee tower. I had veered west and was attempting to circle south of the Disney World TFR and come back to the approach on runway 15, the runway in use; I was in contact with Kissimmee tower as I joined the approach. If I violated the TFR it must have been at this point. I was cleared to land*

by Kissimmee tower and landed on runway 15. I was advised that I had violated the Disney World TFR. (ASRS Report Number 578835 – Event)

Air Traffic Control Actions and Landing Traffic. ATC instructions or actions were found to be a factor in 326 or 51.1% of the reports reviewed for this study (Table 3). ATC instructions were more likely to be involved in events than incidents or accidents (Table 5). The following is an excerpt from an ASRS report submitted by a corporate jet pilot describing a hurried departure in marginal weather at a busy airport. Note that the controller advised the crew to be ready for takeoff. A takeoff clearance while holding for departure usually would not be regarded as surprising. However, after analyzing their situation this crew was convinced that an immediate takeoff was unlikely and therefore were "surprised" and rushed into a potentially dangerous departure.

The controller advised us to be ready to go. We acknowledged ok. And then, there was about a 3 minute break in the arriving traffic. Nothing happened. No takeoff clearance. We were spring loaded to go and then nothing happened. Finally, out of the clouds pops another aircraft on final. As I watched him get closer, I realized that we weren't going to be released. I relaxed, my copilot relaxed. Big mistake. Tower cleared us for an immediate takeoff. You can't even begin to imagine our total ***surprise****. Both crew and engines weren't spooled up to go. As we were turning the corner for a rolling takeoff, tower comes back and asked if we were rolling! As soon as we replied affirmative, the controller sent the arriving aircraft around. The controller wasn't happy, the arrival wasn't happy and I wasn't happy. (ASRS Report Number 598909 – Event)*

Going-Around the Automation. The go-around is a maneuver intended to be used when an approach or landing needs to be discontinued. By its very nature, a go-around is not generally a pre-planned maneuver. However, pilots should be prepared for a go-around at any point during an approach (Federal Aviation Administration, 1999). Go-around was found to be a factor in 52 or 8.2% of the reports. Automation issues found in 14.9% of the cases (95) combined with the go-around maneuver increases the surprise factor. The following ASRS excerpt reveals that flight crews are not always ready to perform a go-around and an unexpected go-around can result in potentially dangerous situations.

The aircraft was stabilized on approach and spacing with other traffic appeared to be comfortably spaced on TCAS II. Crossing the FAF at 2800 feet, the tower controller issued a clearance to climb to 4000 feet and to turn left to 360 degrees. I did not hear clearly the call sign on the clearance. I looked to the FO and asked him to verify the clearance being for us. My hands were on the flight controls as I was 'following' the autopilot on the approach. As the FO verified the clearance, I selected 'TOGA' mode of flight automation and proceeded with the normal GAR [go-around] callouts. Selecting TOGA automatically disconnected the autopilot and established nearly full power on both engines. As I was not looking directly at the flight instruments when selecting TOGA, the very rapid increase of power caused the aircraft pitch to increase past the desired attitude of 15 degrees to an attitude of 20 degrees, or possibly slightly higher. Although I instinctively placed forward pressure on the flight controls to counter the rapid change in pitch, the pressure was insufficient to stop the pitch at the desired attitude. In an attempt to smoothly lower the nose in the interest of passenger comfort, the aircraft experienced a 1 or 2 second stick shaker warning as we leveled at 4000 feet. Contributing factors: 1) An ***unexpected*** *condition: an* ***unexpected*** *GAR at an* ***unexpected*** *phase of flight, 2) automation which contributes to large* ***surprise*** *factor: large and rapid power change in engines well below the wing creating an instant pitch change, and then disconnecting the autopilot. 3) The selection of TOGA at a time when concentration was not firmly established on flight instruments. (ASRS Report Number 575644 – Event)*

Sixteen factors were found to have significantly different rates of occurrence in general aviation and air carrier operations (see Table 6). Wind on landing was the most influential, significant factor between general aviation and air carrier operations (x^2 (1,631) = 30.0 p, <.001). This finding supports a recent study by the FAA which reported that wind accounted for 46.3 percent of all the FAR Part 91 weather related accidents between 1991 and 2001 (Federal Aviation Administration, 2001). In addition, wind on landing was strongly associated with more severe flight outcomes (Table 5).

Other Aircraft. Pilots often cited the sudden presence of other aircraft as surprising or unexpected. Other aircraft were a factor in 168 or 27.6% of the reports. Often poor traffic scanning on the part of the pilot contributes to situations where other aircraft appear suddenly. Interestingly, the presence of other aircraft enroute was a factor in 60 or 9.9% of the reports, more than any other phase of flight. In the ASRS report below the pilot was busy configuring his aircraft for departure and not focusing his attention outside the aircraft while taxiing for takeoff.

While completing the [before takeoff] checklist, I heard the aircraft calling ground stating that they were clearing runway 19 onto taxiway D, which was ideal for him since taxiway D leads into the airline terminal ramp. As I looked up in ***surprise*** *and shock (at that moment I realized I didn't check the runway for traffic), the ERJ was turning off with all exterior lights still on, which caused temporary blindness. (ASRS Report Number 598235 – Event)*

Conclusions

This study established that surprising and unexpected events can and do have a negative effect on the outcome of flight. We found several factors that are consistently involved in surprising and unexpected events. We also determined what flight outcome each factor is likely to be involved with. However, a simple formula explaining what combination of factors, are more likely to cause a surprising or unexpected event resulting in an unwanted outcome remains allusive. Perhaps the most important finding from this study is that potentially any factor or combination of factors can create a surprising or unexpected event that leads to an unwanted outcome.

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