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Evaluating Startle, Surprise, and Distraction: an Analysis of Aircraft Incident and Accident Reports

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EVALUATING STARTLE, SURPRISE, AND DISTRACTION: AN ANALYSIS OF AIRCRAFT INCIDENT AND ACCIDENT REPORTS

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Over the years, startle, surprise, and distraction have been frequently cited as potentially having negative effects on aircraft flightcrew performance. This paper aims to build upon and extend our prior research (Rivera, Talone, Boesser, Jentsch, & Yeh, 2014) in which we found evidence that (a) startle may be less problematic to flight deck performance than surprise, and (b) negative flight deck performance following startle is most likely due to concurrent distraction or surprise. The current research examined the theoretical foundations underlying these concepts and analyzed two accident/incident databases to identify potential trends and assess the prevalence of startle, surprise, and distraction on the flight deck. Results indicated that across the entire 20-year period, distraction was the most prevalent, followed by surprise and startle.

In a recent analysis from 2004-2013, the Boeing Company's Statistical Summary of Commercial Jet Airplane Accidents identified loss of control in-flight (LOC-I) as one of the leading categories of fatal accidents (16 fatal accidents) and total number of fatalities (Boeing, 2014). LOC-I accidents have been found to be influenced by physiological and psychological factors such as startle, surprise, and distraction, which have been frequently cited as potentially having negative effects on aircraft flightcrew performance. As such, it is important to understand the psychological and behavioral similarities and differences between these concepts, and investigate their prevalence, especially considering changes in flight deck systems.

This effort aims to build upon and extend our prior research (Rivera, Talone, Boesser, Jentsch, & Yeh, 2014) in which we found evidence that (a) startle may be less problematic to flight deck performance than surprise, and (b) negative flight deck performance following startle is most likely due to concurrent distraction or surprise. Therefore, the current study examined the theoretical foundations underlying these concepts and analyzed records from two accident/incident databases (the Aviation Safety Reporting System [ASRS] database and the National Transportation Safety Board [NTSB] aviation accident database) to identify potential trends and assess the prevalence of startle, surprise, and distraction. Based on the results of this analysis, we discuss the benefits of incorporating these factors into flightcrew training programs, such as line-oriented flight training (LOFT), to improve crew resource management (CRM). Then, we present potential approaches to mitigate the negative effects of startle, surprise, and distraction.

Background

Startle

Startle is an involuntary physiological reflex elicited by sudden exposure to intense stimulation (Koch, 1999). Startle consists of two components: an involuntary, immediate *startle reflex* and a conditioned, behavioral *startle response.* The startle reflex typically consists of physiological responses such as eyes blink, head ducks, and shoulders crouched up to protect the body against adverse situations (Grillon & Baas, 2003). In addition, the startle reflex can have substantial, negative effects on immediate, gross motor performance, but these effects are typically brief (no longer than 1 to 3 s) (Ekman, Friesen, & Simons, 1985; Landis & Hunt, 1939). The conditioned startle response involves a pattern of behavioral and physiological responses, which can result in (a) task interruption and (b) substantial cognitive impairments (i.e., deficiencies in information processing) that can last significantly longer than the startle reflex (up to 15 s to 1 min) (Thackray & Touchstone, 1970; Vlasak, 1969).

During flight, the flightcrew may encounter a variety of situations that could elicit startle. For instance, the impact of laser illuminations, especially during final approach, has been found to have the potential to disorient and startle flightcrew (Nakagawara, Montgomery, Dillard, McLin, & Connor, 2004). However, based on our review and analyses, we believe that it is unlikely that the immediate psychomotor impact of the startle reflex typically results in control inputs that have a catastrophic influence on flight maneuvers (with the exception, perhaps, of startle during critical flight phases close to the ground/terrain, such as during takeoff or final approach/landing).

Surprise

In contrast to the startle reflex and the startle response, which manifest themselves primarily physiologically and behaviorally, surprise is a cognitive-emotional response to mismatches between mental expectations and perceptual representations of the actual environment (Meyer, Niepel, Rudolph, & Schützwohl, 1991; Schützwohl & Borgstedt, 2005). As has been stated before (Kochan, Breiter, & Jentsch, 2004; Rivera et al., 2014), surprise can occur at the onset/appearance of an unexpected stimulus, but also by the absence of an expected stimulus. The main concern regarding surprises in any task environment is that the feeling of surprise is generally strong and noticeable, and thus it interrupts the execution of an ongoing task. For example, Horstmann (2006) found that the inclusion of a surprising event during the execution of a continuous motor task caused 78% of the study's participants to interrupt the task. Horstmann also found that, on average, the interruption to the execution of the motor task lasted about 1 second. The length of an interruption from surprise, however, can vary based on the magnitude of the expectation mismatch. That is, a surprising event that vastly differs from what was expected can produce longer interruption durations.

Surprises occurring on the flight deck during line operations can affect a range of the flightcrew's responses, including their physiological, cognitive, and behavioral responses, manifesting themselves, for example, in increased heart rate, increased blood pressure, the feeling of being unable to comprehend/analyze the situation or to remember appropriate operating standards (Rivera et al., 2014). In extreme cases, behavioral "freezing" and loss of situation awareness have been reported (Bürki-Cohen, 2010). Additionally, surprise has been found to play a role in LOC-I accidents such as Air France Flight 447, in which the flightcrew seemed to be confused about multiple failure indications and a disconnection of the automated systems (Bureau d'Enquêtes et d'Analyses [BEA], 2012). Automation surprises, specifically, have been investigated extensively through the years to better understand the impact of flight deck designs on flightcrew performance (Sarter & Woods, 1995; Sarter, Woods, & Billings, 1997).

In a previous study exploring the impact of surprise in aviation, Kochan et al. (2004) analyzed incident and accident reports from the NTSB's aviation accident database, the National Aeronautics and Space Administration's (NASA's) ASRS database, and the National Aviation Safety Data Analysis Center (NASDAC) database. From their analysis, Kochan et al. concluded that factors eliciting surprise could be grouped into clusters, which included the aircraft's state (e.g., automation, system alerts), environmental conditions (e.g., turbulence, low visibility), instructions or actions from others (e.g., air traffic control [ATC] directing holding), and the sudden appearance of other aircraft. In addition, Kochan et al. stated that surprises did not need to be unusual or rare to be unexpected or surprising, given that most of the reports they reviewed involved a relatively routine flight procedure that became a surprising event by occurring, however, in an unusual situation or context (e.g., temporary runway closure due to debris on the runway, or wildlife in the vicinity of the runway).

Distraction

Distraction refers to the diversion of attention away from activities that are required for the accomplishment of a primary goal to other competing sensory (e.g., visual, auditory, biomechanical) and cognitive activities. Airbus (2004) and Dismukes, Young, and Sumwalt (1998) found that factors such as communication, heads-down work, responding to an non-normal/unexpected event, searching for traffic out-the-window, flight deck ergonomics, flight deck noise level, language proficiency (from both the pilots and controllers), airport infrastructure, and flightcrew fatigue can have an impact on flightcrew performance. In flight, distraction can contribute to the development of dangerous situations, such as runway incursions/excursions, late responses to ATC instructions, late retraction of the landing gear, altitude deviations, inadequate energy management, and controlled flight into terrain.

Method

To better understand the prevalence of startle, surprise, and distraction on the flight deck, we reviewed accident/incidents reports from two databases: the ASRS database and the NTSB's aviation accident database. Below, we describe the procedure used to search each database for reports in which startle, surprise, and distraction were involved. For both of these databases, our searches focused on (a) the terms *startle*, *surprise*, or *distraction* (and their derivatives), (b) the time period January 1994 to December 2013, and (c) Part 121 and 135 operations (i.e., air carriers and commuters). In addition to qualitative (narrative/content) analyses (which we will report in the future), we focused on identifying numerical trends. We asked, for example, whether the two decades (1994-2003 vs. 2004-2013) yielded comparable numbers of reports; whether there were changes in the number of reports across the three phenomena, etc.

Aviation Safety Reporting System (ASRS) Database

The ASRS database allows one to use a wildcard (%) to yield derivations of searched terms. For example, using the search term *distract%* will yield reports containing *distract*, *distraction*, *distractin*g, etc. This wildcard was used with all three constructs to ensure our search captured all reports in which the phenomena were discussed. Therefore, three separate searches were conducted: *startl%, surprise%*, and *distract%*.

NTSB Aviation Accident Database

The NTSB aviation accident database does not have a wildcard option, therefore, separate searches were conducted for each derivative of a particular term (e.g., *distraction* and *distracted* have to be used within their own search). The database also does not allow one to search more than one type of flight operation at the same time (e.g., Part 121 and Part 135). Therefore, six searches were completed for startle (*startle*, *startling*, *startled* for each type of operation), six for surprise (*surprise, surprised*, *surprising* for each type of operation), and eight for distraction (*distract, distraction*, *distracting*, *distracted* for each type of operation). After each search was completed, the resulting raw number of reports were analyzed to identify those in which more than one derivative of a word was used (e.g., *distraction* and *distracted*). This was done to prevent counting a report more than once when adding the number of reports across searches. After this process was completed, all of the unique reports were added up to yield the total number of reports in which each construct was mentioned.

Results

Taken together, our searches yielded an initial total of 4,781 reports in which the words *distract%*, *startl%*, or *surpris%* were used (here we used % to imply all derivatives of these words). After removing duplicate NTSB reports, our total was reduced to 4,773 reports. Our prior investigation (Rivera et al., 2014) had thoroughly examined the terminological usage of the terms startle and surprise within the reviewed ASRS reports. In the study reported here, in contrast, we were interested in establishing how often these three factors have been used to describe an incident or accident within aviation operations over the past 20 years. Table 1 displays the total numbers of reports in which *distract%, startl%*, or *surpris%* were used to describe an incident or accident. From the results of our investigation, it appears that distraction was much more prevalent than both surprise and startle across the 20-year period investigated. Furthermore, this trend was prevalent across both databases.

Table 1.
Number of ASRS and NTSB Reports Returned.

Factor	ASRS	NTSB	Total
Startl%	181	4	185
Surpri%	1,736	26	1,762
Distract%	2,770	56	2,826
Total	4,687	86	4,773

Note. The total number of ASRS and NTSB reports identified in which a derivative of *startl%*, *surpris%*, or *distract%* was mentioned in the incident/accident description.

Besides comparing the prevalence rates across constructs, we were also interested in assessing whether the prevalence of each construct had changed over time. As indicated in Tables 2 and 3, the total number of reports involving startle decreased during the second decade (Jan. 2004 – Dec. 2013). This trend was also found for surprise. In contrast, distraction increased during the second decade. These trends were prevalent across both databases.

Table 2.
Decade Comparison for the ASRS Reports.

Factor	Jan. 1994 – Dec 2003	Jan. 2004 – Dec. 2013	Difference
Startl%	110	71	-39
Surpri%	956	780	-176
Distract%	1,365	1,405	+40

Note. A comparison is provided between the total number of ASRS reports identified during the period Jan. 1994 – Dec. 2003 and Jan. 2004 – Dec. 2013.

Table 3.
Decade Comparison for the NTSB Reports.

Factor	Jan. 1994 – Dec 2003	Jan. 2004 – Dec. 2013	Difference
Startl%	3	1	-2
Surpri%	16	10	-6
Distract%	22	34	+12

Note. A comparison is provided between the total number of NTSB reports identified during the period Jan. 1994 – Dec. 2003 and Jan. 2004 – Dec. 2013.

Discussion

In this investigation, we found evidence that, across the entire 20-year period and consistently in both decades we investigated, distraction was the most prevalent phenomenon cited in accident and incident reports, followed by surprise and (far-distant) startle. In fact, our findings further supported our prior contention (cf. Rivera et al., 2014) that true startle events, in which the physiological and behavioral responses of flightcrew result in negative consequences to the safety of flight, are actually very, very rare. Instead, we believe that startle, to the degree that it is caused by events such as bird strikes, compressor stalls, and laser illuminations, mostly results in surprise and distraction – which, in turn, may cause incidents and accidents.

We also noticed that the preponderance of distraction as a causal or contributing element in safety events was consistent across both databases, despite each one serving different purposes. The ASRS database consists of voluntarily reported incidents, whereas the NTSB database consists of governmentally mandated reports of major accidents/incidents. Another interesting finding was the fact that, while the number of both startle and surprise reports had decreased from the first to the second decade, reports of distraction not only failed to decrease, but actually increased. This finding was also consistent across the two different databases. One possible explanation for the increased prevalence of distraction may be the introduction of electronic information management devices, such as portable electronic devices (PEDs) and electronic flight bags (EFBs), onto the flight deck; the narratives of the more recent reports certainly seemed to support this. Additionally, this mirrors a finding by Chase and Hiltunen (2014), who, in their own accident/incident database investigation, found evidence that pilots report that they are sometimes distracted by a PED or EFB. Another possible explanation is that increased airport and airspace congestion has placed higher attentional demands on flightcrew; especially during high workload periods (see also Loukopoulos, Dismukes, & Barshi, 2009). Taken together, these findings indicate that, while all three of these constructs are still prevalent on the flight deck, distraction may be the issue that is both most concerning but also most likely to be ameliorated through design of systems and procedures, as well as through training.

Despite the fact that distraction was found to be the most prevalent, our results showcase the fact that all three of these psychological phenomenon are still prevalent within flight deck operations. Given this, we believe that it is important to improve pilot training so that the negative impact of these psychological constructs on flightcrew performance can be mitigated. To this end, we suggest that these factors should be included within LOFT scenarios conducted during CRM training. This suggestion falls in line with a Notice of Proposed Amendment published by the European Aviation Safety Agency (EASA; 2014) in which it was proposed that startle and surprise should be incorporated into CRM training. In regards to startle, the EASA recommended that CRM training cover the acquisition and maintenance of adequate automatic behavioral responses during crisis to be used during unexpected, unusual, and/or stressful situations. In regards to surprise, the EASA recommended that CRM training should encourage the development of pilot resilience (e.g., mental flexibility and the ability to adapt performance to address current conditions). Other recommendations for addressing surprise include using in-flight discussions of "what if" scenarios (Martin, Murray, & Bates, 2011) and mental simulation (Roth & Andre, 2004) to promote better decision-making. As for distraction mitigation strategies, these include establishing distinctive roles (e.g., pilot flying, pilot not flying), scheduling/rescheduling activities to minimize distraction due to less important activities, avoiding task-irrelevant conversations during high workload phases of flight (e.g., takeoff, approach, and landing), and incorporating scenarios that require pilots to manage distractions into simulator training (Australian Transportation Safety Bureau [ATSB], 2005; Dismukes et al, 1998).

It is, however, important to note several limitations of our investigation. For one, the numbers reported here should be taken as conservative estimates of the true prevalence of distraction, startle, and surprise on the flight deck. This can be attributed to the voluntary aspect of ASRS reports. It is likely that there have been startle, surprise, or distraction occurrences that simply were not reported. Another limitation of this investigation is that we did not include other terms that arguably mean the same thing (e.g., *surprise* and *confuse*). Finally, there may have been reports in which the aforementioned constructs impacted other aviation professionals and not pilots on the flight deck. For example, reports describing distracted air traffic controllers, ground control personnel, or flight attendants may have been included in the numbers reported here. Despite these limitations, this investigation still provides initial insight into the frequency with which these constructs have been, and are currently, occurring on the flight deck. Furthermore, it makes evident the need for training interventions and strategies targeted at mitigating the negative impact of startle, surprise, and distraction on flightcrew performance.

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