Startle and Surprise on the Flight Deck: Similarities, Differences, and Prevalence

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Startle and surprise are often cited as potentially contributing factors to aircraft incidents due to their possible negative effects on flightcrew performance. In this paper, we provide definitions of startle and surprise with the goal of delineating their differences. In the past, these terms have often been used interchangeably; however, there are distinctive conceptual, behavioral, and physiological differences between the startle reflex and the surprise emotion. Furthermore, we investigated the prevalence of startle and surprise on the flight deck by examining voluntary incident reports in the Aviation Safety Reporting System (ASRS) and found surprise to be more prevalent than startle. Implications of these findings and limitations of our initial exploratory analysis are discussed.

INTRODUCTION

On December 28, 2013, two pilots on board a Cessna 210 took off from Brookeridge Airpark in Downers Grove, IL, and unexpectedly and inadvertently collided with a goose shortly after takeoff (Traut, 2014). The sudden impact shattered the windshield as the two pilots reflexively attempted to protect themselves from the strike, while still maintaining proper control of the aircraft – nobody was injured, and the aircraft landed safely. This incident can be categorized as a startle reaction to an unexpected event, although cognitive and emotional factors may have also played a role.

Pilot reactions to unexpected situations have been explored in regards to startle (Thackray & Touchstone, 1969) and surprise (Martin, Murray, & Bates, 2011; Wickens et al., 2009) on the flight deck. Startle, on the one hand, was studied extensively over the 1970s and 1980s to understand physical response times and the recovery of mental functions after high-intensity acoustic (sudden loud) signals (Thackray, 1965, 1988; Thackray & Touchstone, 1970, 1983), such as sonic booms. Surprise, on the other hand, has been examined more recently given the prevalence of flight deck automation surprises induced by mode confusions and unexpected events (Kochan, Breiter, & Jentsch, 2004, 2005; Rushby, 2002; Sarter, 2008; Sarter & Woods, 1995; Sarter, Woods, & Billings, 1997). Both startle and surprise have been deemed to play a role in aircraft upsets, and the Federal Aviation Administration recently issued Advisory Circular (AC) 120-109, *Stall and Stick Pusher Training*, which recommends implementing startling and surprising situations during pilot training for upset recoveries (Federal Aviation Administration [FAA], 2012). Over the years, the terms "startle" and "surprise" have often been used interchangeably by pilots when describing unexpected situations. This disparity has led to an only partial understanding of the role that startle and surprise may play during unexpected events on the flight deck. Therefore, there is a need to comprehensively review and compare these two phenomena to provide the aviation community with a clearer understanding of their particular implications on pilot behavior and aircraft safety.

The purpose of this practice-oriented paper is to provide clarity regarding the conceptual, behavioral, and physiological differences between startle and surprise by reviewing the literature. Additionally, implications of each term in aviation are presented to provide a better understanding of the impact these constructs may have on flight deck operations. Subsequently, an exploratory analysis of reports from the Aviation Safety Reporting System (ASRS) is detailed. Lastly, the results of this analysis and potential approaches for mitigating the negative effects of startle and surprise on the flight deck are discussed.

Startle

Startle is typically elicited by sudden exposure to *intense stimulation* that generates: (a) an involuntary physiological reflex, similar to a flight/fight reaction, with an emotional response component, and (b) a conditioned, behavioral startle response (Blumenthal et al., 2005; Bradley, Cuthbert, & Lang, 1993; Koch, 1999). The involuntary *startle reflex* is fast and involves the contraction of muscles (e.g., eye-blinks, head ducks, shoulders crouched up) to prepare the body for protection against adverse situations (Grillon & Baas, 2003; Koch, 1999). The *startle response* includes the involuntary muscle contractions typical of the startle reflex, but also other physiological, emotional, and cognitive responses (e.g., stress-related enervation of the sympathetic nervous system, orientation of attention to the startling stimulus).

The startle reflex can be elicited through auditory, visual, or tactile stimuli, and has been found to have a fixed and short latency (i.e., time delay between a stimulation and a response), which always begins within 100 milliseconds (ms) of a stimulus being sensed (Carlsen, Chua, Inglis, Sanderson, & Franks, 2008; Davis, Gendelman, Tischler, & Gendelman, 1982; Yeomans, Li, Scott, & Frankland, 2002). In terms of duration, the reflex lasts less than one second for a mild response (duration of 0.3 seconds [s]), and in the range of 1 s to 1.5 s for a high-intensity response (Ekman, Friesen, & Simons, 1985; Landis & Hunt, 1939). Additionally, the startle reflex is increased in situations where the individual's arousal or stress level is at the extremes; that is, both when an individual is highly aroused (e.g., when stressed, anxious, threatened, or intensely operating) *and* when an individual has a very low arousal level (e.g., when resting, drowsy, or about to fall asleep) (Barnett, Wong, Westley, Adderley, & Smith, 2012; Martin et al., 2011; Simons, 1996).

Performance and recovery after startle. In addition to an increase in blood pressure and heart rate following a high intensity stimulus, studies have determined that motor response performance following a startling stimulus is disrupted for approximately 0.1 s to 3 s for simple tasks (May & Rice, 1971; Sternbach, 1960; Thackray, 1965). For instance, Sternbach (1960) found that an unexpected loud stimulus (a pistol shot) disrupted performance on a simple motor task (key presses) and increased response times. Participants who responded the fastest after the loud stimulus had an average reaction time of 200 ms, while participants who responded the slowest had an average reaction time of 1,695 ms (note that this disruption duration also encompasses the physiological reflex duration). In more complex motor tasks, such as a continuous tracking task, startle may impact performance for up to 10 s following a loud intensity signal (Thackray & Touchstone, 1970).

One must also consider the time to cognitively recover after a startling stimulus. Here, startle has been found to impair information processing performance on mundane tasks, such as continuous arithmetic subtractions, for 30 s to 60 s after a startling stimulus (Vlasak, 1969; Woodhead, 1969). Additionally, Thackray and Touchstone (1983) determined that participants who were exposed to a sudden high-intensity aural alarm signal had more incorrect responses on an information-processing task when compared to participants who received a low-intensity alarm signal. Thus, "startle" disrupts cognitive processing and can negatively influence an individual's decision making and problem solving abilities.

Implications of startle on the flight deck. On the flight deck, pilots may be exposed to a variety of stimuli that have the potential to elicit the startle reflex and response. Visual stimuli, such as sudden illumination by lasers, have resulted in incidents where pilots have been startled or even disoriented, especially during the final approach phase (Nakagawara, Montgomery, Dillard, McLin, & Connor, 2004). The evidence suggests that in aviation, the immediate psychomotor impact of the *startle reflex* may induce brief disorientation and short-term psychomotor impairments which are likely to lead to task interruptions, or brief confusion. For instance, these interruptions may be associated with losing one's place in a checklist or a multi-step procedure, requiring time for re-orientation and task resumption.

A greater concern is that performance after startle can be substantially affected by the type and situational appropriateness of the flightcrew's decision choice and execution after the initial startle reflex (i.e., what they do during the conditioned *startle response*). Here, decision making can be significantly impaired, especially higher-order functions necessary for making judgments about complex flight tasks. Next, we explore the emotion of surprise and how it may affect flightcrew performance on the flight deck.

Surprise

Surprise is defined as a cognitive-emotional response to something unexpected, which results from a mismatch between one's mental expectations and perceptions of one's environment (Horstmann, 2006; Meyer, Niepel, Rudolph, & Schützwohl, 1991; Schützwohl & Borgstedt, 2005). In contrast to startle, which always occurs as a response to the presence of a sudden, high-intensity stimulus, surprise can be elicited by an unexpected stimulus or by the unexpected absence of a stimulus. Surprise can be described as a combination of physiological, cognitive, and behavioral responses, including increased heart rate, increased blood pressure, an inability to comprehend/analyze, not remembering appropriate operating standards, "freezing," and loss of situation awareness (Bürki-Cohen, 2010). Although humans may experience startle and surprise together in certain situations, a surprise response can be experienced in the total absence of a startle reflex. The element of surprise can also disappear in anticipation of a stimulus. For example, Ekman et al. (1985) found that when participants anticipated the exact moment in which an unexpected stimulus (i.e., blank pistol shot) would transpire, the element of surprise was eliminated. However, the startle reflex was still present, although response intensity was lower.

Much of the research described in the surprise literature focuses on schemas, which are defined as knowledge structures that play a role in comprehending events (Meyer et al., 1991). Typically, after an unexpected event, a cognitive response is produced in which the individual performs an appraisal of an unexpected situation; upon completing the appraisal, the individual can revise, correct, and extend a current schema in order to anticipate similar future deviating events, and react effectively (Horstmann, 2006; Meyer, Reisenzein, & Schützwohl, 1997; Schützwohl, 1998).

The primary concern with surprises is that they generally interrupt an ongoing task. For example, in a study investigating the effects of surprise on action interruption, Horstmann (2006) found that a surprising event interrupted the continuous action of 78% of the participants. In that study, on average, the duration of the interruption lasted 995 ms, thus about 1 s. Note that the length of an interruption can vary based on the magnitude of the schema-discrepant event. That is, a surprising event that differs substantially from what was expected can impact the duration of the analysis of the event and produce a longer interruption duration than a startle reflex.

Implications of surprise on the flight deck. Surprise has been considered to be factor in LOC accidents. On June 1, 2009, Air France flight 447 en route to Paris encountered turbulence and other environmental issues such as ice crystals obstructing the aircraft's speed probes (Bureau d'Enquêtes et d'Analyses [BEA], 2012). Given the inconsistencies in speed depicted in the speed indicator, the flightcrew did not keep the aircraft within the normal flight envelope. As a result, the aircraft stalled and the flightcrew was unable to recover before impact. The accident report cites that "surprise" was one of the main factors that contributed to LOC in this accident. Evidence suggests that the flightcrew could not make sense of multiple failure indications in combination with a disconnection of the automated systems, causing surprise and unexpectedness in an already stressful environment in which avoidance maneuvers were being executed to handle the inclement weather (BEA, 2012). In fact, automation has been identified as one of the major culprits in eliciting flight deck surprises (Kochan et al., 2004). Specifically, automation surprises have been extensively studied as a function of mode awareness (Sarter & Woods, 1995; Sarter et al., 1997; Sherry, Feary, Polson, & Palmer, 2001). These studies have focused on either (a) re-designing the automation to fit the mental models of the flightcrew or (b) the design of technologies that can help the flightcrew maintain mode awareness.

To determine what types of events pilots consider to be surprising, Kochan et al. (2004) analyzed incident and accident reports from the National Transportation Safety Board, National Aeronautics and Space Administration's (NASA's) ASRS, and the National Aviation Safety Data Analysis Center (NASDAC) databases that included the terms "surprise" and "unexpected." Results indicated that factors eliciting surprise 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. From their analysis, Kochan et al. concluded that unexpected events or surprises do not need to be unusual or novel to be perceived as unexpected or surprising. In fact, the majority of the reviewed reports involved a routine flight occurrence or procedure that turned into an unexpected event. For instance, the specific procedure of entering and executing a holding pattern is relatively ordinary. However, if ATC directs an aircraft to hold in an area of good weather, the procedure may be regarded as unexpected precisely because holding is rare during good weather.

PRACTICE INNOVATION

We conducted an exploratory review and analysis of the ASRS safety database in 2013/14 to further understand the impact of startle and surprise on the flight deck. This was not intended to be a comprehensive search of incidents related to startle and/or surprise. Rather, our goal in performing this analysis was to identify the prevalence of incidents involving startle or surprise, as well as analyze the instances in which the terms may have been used interchangeably. As such, we present a set of results from these analyses.

We focused on reports submitted for the time period from January 1994 to December 2013 for Part 121 and 135 (i.e., air carriers and commuters) operations. We selected this time period to retrieve two decades of data that could provide a clear picture of the prevalence of these events. We conducted text searches by entering a wildcard (%) to yield derivations of each searched term and thus produce a more thorough search (e.g., "startl%" and "surpri%"). Our search resulted in 1,917 reports (181 "startle" reports, 1736 "surprise" reports). From this, reports were coded and included in the analysis if the search terms were used to describe the flightcrew's behavior during flight (e.g., taxiing, takeoff, cruise, descent). Thus, reports in which the search term was used to describe equipment, flight attendants, passengers, mechanics, maintenance issues, etc. were excluded from coding and analysis. For instance, "…I could see the *startled* expressions on the faces of the *passengers* in front of me…" (ACN# 515946). This report involved a flight attendant describing passenger reactions and thus did not involve pilot reaction to startle and surprise. Report exclusion resulted in 134 total reports referencing the term "startle" and 902 referencing the term "surprise." Subsequently, reports were coded to assess if the terms were used with our definition according to the reviewed literature.

FINDINGS

From the 134 coded reports referencing "startle," 49 (37%) addressed incidents involved high intensity stimuli to which pilots described a protective reaction or the ongoing task being interrupted. This is consistent with our definition of "startle." Note that incident reports referencing "startle" that did not describe a reflexive reaction but indicated the presence of a high-intensity stimulus disrupting performance were coded as a startle event. An example of a "startle"-related report is:

> *Example 1*: "The balloon appeared to be about 4 to 5 FT in diameter and equally as long, it passed about 50 FT off the nose...***I heard the Captain yell and saw him duck. It startled me quite a bit as did it him***" (ACN# 1004144)

In contrast, in 85 (63%) of the startle reports, pilots may have used the term with the intent to say "surprise." This is because there was no evidence of the occurrence of a high intensity stimulus that caused the pilot to move reflexively. For instance,

> *Example 2*: "…***the Captain was pulling the L PWR lever to FLT idle and turning the aircraft back to Atlanta without my input. This startled me***" (ACN# 337756)

The term "surprise" was referenced in 902 coded reports; all of these reports used the term in a way that was consistent with our definition of surprise. It is worth noting that a few of these reports included an event in which there was an unexpected high-intensity stimulus. That is, some of these events may have induced a startle reflex experienced with the surprise. Thus, these reports were considered to be used in accordance with the "surprise" definition. The majority of the incidents usually involved an unexpected event which deviated from current schemas or incidents in which there was an absence of an expected stimulus:

> *Example 3*: "My attention immediately focused on the TCASII display. ***To my surprise, it showed no targets***" (ACN# 619250)

DISCUSSION

Not surprisingly, the findings of our exploratory ASRS analysis suggest that the term "startle" is often not used to refer to the actual occurrence of startle (i.e., the involuntary reflex and response), because this is more of a scientific – rather than operational – view of the term. That is, in the reviewed reports, "startle" was frequently used even in instances in which high-intensity stimuli did not occur. Additionally, when coding the reports we noticed that pilots seldom described a reflexive reaction to an event when using the term "startle", which made it difficult to determine if the event was startling or surprising. Rather, our findings suggest that pilots often use the term "startle" to describe surprising situations. Additionally, the term "startle" does not occur in ASRS reports nearly as often as the term "surprise." More importantly, of the 49 reports in which the term "startle" was used in a way to describe an actual case of startle, none led to a negative outcome for the pilots (e.g., flight envelope exceedance or LOC).

Since ASRS reports are submitted voluntarily, it is likely that the number of incidents involving startle and/or surprise is larger than what was found in our analysis. It may be that the physiological reflex aspect of startle is problematic and has led to incidents, but is simply much harder to discern or describe after the fact. Another explanation is that pilots tend to use terms besides "startle" and "surprise" to describe unexpected events. For instance, using terms such as derivatives of "froze," "stun," "confuse," or "perplex," could increase the number of incident reports involving startle and surprise situations, but we did not investigate the use of these terms in this exploratory analysis.

Overall, the findings of this initial analysis suggest the negative effects of startle on flight safety with regards to aircraft incidents may mostly be limited to startle being distracting, interrupting, and/or surprising, like many other events or situations. Training and Crew Resource Management (CRM) approaches may be helpful to further prepare pilots for unexpected, unusual, or distracting events and enhance their ability to quickly recover from them. For instance, there is evidence that training for judgment skills can improve a pilot's ability to recognize and adapt to unexpected events (Kochan, 2005). Other methods include the enhancement of training and testing practices to avoid predictability/anticipation of events and memorization of solutions, as well as utilizing low-cost strategies such as in-flight discussions about "what if" scenarios, and mental simulations to promote increased awareness and decision-making (Casner, Geven, & Williams, 2013; Martin et al., 2011; Roth & Andre, 2004).

Limitations and Future Research

It is important to make evident several limitations of our findings; all of which relate to the cited limits of using ASRS reports to create an accurate representation of a particular phenomenon's prevalence within the aviation domain. The ASRS is an incident database in which flightcrew members voluntarily report major/minor incidents that occurred during flight. Thus, the primary limitation of using ASRS to discern prevalence rates is that the reports are subjective and voluntary, and therefore, many incidents may go unreported (Chappell, 1994; Degani, Chappell, & Hayes, 1991). In addition, the ASRS does not make every report available on their public website. As a result, the incidents included in these reports cannot be considered a complete count of incidents that occur. Also, it needs to be noted that the analysis did not include NTSB accident reports. Further research of aviation accidents that led to loss of life and/or major damage to the aircraft is needed to make definite conclusions about the influence of startle and/or surprise in situations where the outcome might have been less fortunate than in the incident reports of the ASRS. Despite these limitations, ASRS reports have been a useful tool for identifying trends associated with automation surprises and unexpected events (Kochan et al., 2004; Palmer, Hutchins, Ritter, & vanCleemput, 1991; Vakil & Hansman, 2002).

Another limitation was that since this was an initial analysis, only one reviewer was assigned to code each ASRS report. Thus, there may have been some reports in which disagreements could have emerged. In the future, we plan to have at least two or three reviewers assigned to each report. This way, we can properly assess the inter-rater reliability of our coding scheme.

Lastly, the results may have been influenced by the limited number of keywords used. Expanding our search to include keywords or search phrases that are synonymous or compatible with startle and surprise may yield a more complete return of incidents related to startle and surprise. For example, using terms that are likely to be related to startling events such as "lasers," "loud explosions/bangs," "bird strikes," "loud alerts/chimes," "turbulence," "Near Mid-Air Collisions (NMACs)" can result in more incidents in which "startle" is a key factor. In the same vein, using keywords such as "freeze," "perplex," "confuse," or "shock" can result in more incidents in which "surprise" is the key factor.

Despite these limitations, the findings provide preliminary evidence that the surprising nature of events (whether described as startling or surprising by pilots after the fact), and not the physiological reflex of startle, has implications for the safety of flight deck operations. To follow up our initial findings, we intend on expanding our ASRS search and refining our coding process as well as analyzing additional aviation incident/accident databases such as NTSB accident reports. Whether experimental or observational, future research on startle and surprise within the context of flight deck operations will benefit from a clear delineation of how these constructs are being defined and which aspects are being studied.

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REFERENCES

Barnett, J., Wong, W., Westley, D., Adderley, R., & Smith, M. (2012). Startle reaction: Capturing experiential cues to provide guidelines towards the design of realistic training scenarios. *Proceedings of the 56th Annual Meeting of the Human Factors and Ergonomics Society* (pp. 2477-2481). Santa Monica, CA: HFES.

Blumenthal, T. D., Cuthbert, B. N., Filion, D. L., Hackley, S., Lipp, O. V., & Van Boxtel, A. (2005). Committee report: Guidelines for human startle eyeblink electromyographic studies. *Psychophysiology, 42*(1), 1-15.

Bradley, M. M., Cuthbert, B. N., & Lang, P. J. (1993). Pictures as prepulse: Attention and emotion in startle modification. *Psychophysiology, 30*(5), 541-545.

Bureau d'Enquêtes et d'Analyses [BEA] (2012). Pour la Sécurité de l'Aviation Civile. Final report on the accident on 1st June 2009 to the Airbus A330-203 registered F-GZCP operated by Air France, flight AF 447 Rio de Janerio–Paris.

Bürki-Cohen, J. (2010). Technical challenges of upset recovery training: Simulating the element of surprise. *Proceedings of the AAIA Modeling and Simulation Technologies Conference*.

Carlsen, A. N., Chua, R., Inglis, J. T., Sanderson, D. J., & Franks, I. M. (2008). Motor preparation in an anticipation-timing task. *Experimental Brain Research, 190*(4), 453-461.

Casner, S. M., Geven, R. W., & Williams, K. T. (2013). The effectiveness of airline pilot training for abnormal events. *Human Factors: The Journal of the Human Factors and Ergonomics Society, 55*(3), 477-485.

Chappell, S. L. (1994). Using voluntary incident reports for human factors evaluation. In N. Johnson, N. McDonald, and R. Fuller (Eds.), *Aviation Psychology in Practice* (pp. 149-172). Aldershot, England: Ashgate.

Davis, M., Gendelman, D. S., Tischler, M. D., & Gendelman, P. M. (1982). A primary acoustic startle circuit: Lesion and stimulation studies. *The Journal of Neuroscience, 2*(6), 791-805.

Degani, A., Chappell, S. L., & Hayes, M. S. (1991, May). Who or what saved the day? A comparison of traditional and glass cockpits. *Proceedings of the Sixth International Symposium on Aviation Psychology*. Columbus, OH: Ohio State University.

Ekman, P., Friesen, W. V., & Simons, R. C. (1985). Is the startle reaction an emotion? *Journal of Personality and Social Psychology, 49*(5), 1416-1426.

Federal Aviation Administration [FAA] (2012). *Stall and stick pusher training* (Report No. AC 120-109). Washington, DC: Author.

Grillon, C., & Baas, J. (2003). A review of the modulation of the startle reflex by affective states and its application in psychiatry. *Clinical Neurophysiology, 114*(9), 1557-1579.

Horstmann, G. (2006). Latency and duration of the action interruption in surprise. *Cognition & Emotion, 20*(2), 242-273.

Koch, M. (1999). The neurobiology of startle. *Progress in Neurobiology, 59*(2), 107-128.

Kochan, J. A. (2005). *The role of domain expertise and judgment in dealing with unexpected events* (Unpublished doctoral dissertation). University of Central Florida, Orlando.

Kochan, J. A., Breiter, E. G., & Jentsch, F. (2004). Surprise and unexpectedness in flying: Database reviews and analyses. *Proceedings of the 48th Annual Meeting of the Human Factors and Ergonomics Society* (pp. 335-339). Santa Monica, CA: HFES.

Kochan, J. A., Breiter, E. G., & Jentsch, F. (2005). Surprise and unexpectedness in flying: Database factors and features. *Proceedings of the 13th International Symposium on Aviation Psychology* (pp. 18-21). Dayton, OH: Wright State University/University of Dayton.

Landis, C., & Hunt, W. A. (1939). *The startle pattern*. Oxford, England: Farrar & Rinehart.

Martin, W. L., Murray, P. S., & Bates, P. R. (2011). What would you do if…? Improving pilot performance during unexpected events through in-flight scenario discussions. *Aeronautica, 1*(1), 8-22.

May, D. N., & Rice, C. G. (1971). Effects of startle due to pistol shots on control precision performance. *Journal of Sound and Vibration, 15*(2), 197-202.

Meyer, W.-U., Niepel, M., Rudolph, U., & Schützwohl, A. (1991). An experimental analysis of surprise. *Cognition & Emotion, 5*(4), 295-311.

Meyer, W.-U., Reisenzein, R., & Schützwohl, A. (1997). Toward a process analysis of emotions: The case of surprise. *Motivation and Emotion, 21*(3), 251-274.

Nakagawara, V. B., Montgomery, R. W., Dillard, A. E., McLin, L. N., & Connor, C. W. (2004). *The effects of laser illumination on operational and visual performance of pilots during final approach* (Report No. DOT/FAA/AM-04/9). Washington, DC: Federal Aviation Administration.

Palmer, E. A., Hutchins, E. L., Ritter, R. D., & vanCleemput, I. (1991). *Altitude deviations: Breakdowns of an error tolerant system* (NASA Technical Memorandum DOT/FAA/RD-92/7). Washington, DC: Federal Aviation Administration.

Roth, T., & Andre, T. S. (2004). Improving performance in pilot training by using the chair flying technique. In *The Interservice/Industry Training, Simulation & Education Conference (I/ITSEC)* (Vol. 2004, No. 1). National Training Systems Association.

Sarter, N. B. (2008). Investigating mode errors on automated flight decks: Illustrating the problem-driven, cumulative, and interdisciplinary nature of human factors research. *Human Factors: The Journal of the Human Factors and Ergonomics Society, 50*(3), 506-510.

Sarter, N. B., & Woods, D. D. (1995). How in the world did we ever get into that mode? Mode error and awareness in supervisory control. *Human Factors: The Journal of the Human Factors and Ergonomics Society, 37*(1), 5-19.

Sarter, N. B., Woods, D. D., & Billings, C. E. (1997). Automation surprises. In G. Salvendy (Ed.), *Handbook of Human Factors and Ergonomics* (2nd ed., pp. 1926-1943). New York, NY: Wiley.

Schützwohl, A. (1998). Surprise and schema strength. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 24*(5), 1182-1199.

Schützwohl, A., & Borgstedt, K. (2005). The processing of affectively valenced stimuli: The role of surprise. *Cognition & Emotion, 19*(4), 583-600.

Sherry, L., Feary, M., Polson, P., & Palmer, E. (2001). What's it doing now? Taking the covers off autopilot behavior. *Proceedings of the 11th International Symposium on Aviation Psychology* (pp. 1-6). Columbus, OH: Ohio State University.

Simons, R. C. (1996). *Boo! Culture, experience, and the startle reflex*. New York, NY: Oxford University Press.

Sternbach, R. A. (1960). Correlates of differences in time to recover from startle. *Psychosomatic Medicine, 22*(2), 143-148.

Thackray, R. I. (1965). Correlates of reaction time to startle. *Human Factors: The Journal of the Human Factors and Ergonomics Society, 7*(1), 74-80.

Thackray, R. I. (1988). *Performance recovery following startle: A laboratory approach to the study of behavioral response to sudden aircraft emergencies* (Report No. DOT/FAA/AM-88/4). Washington, DC: Federal Aviation Administration.

Thackray, R. I., & Touchstone, R. M. (1969). *Recovery of motor performance following startle* (Report No. FAA-AM-69-21). Washington, DC: Federal Aviation Administration.

Thackray, R. I., & Touchstone, R. M. (1970). Recovery of motor performance following startle. *Perceptual and Motor Skills, 30*(1), 279-292.

Thackray, R. I., & Touchstone, R. M. (1983). *Rate of initial recovery and subsequent radar monitoring performance following a simulated emergency involving startle* (Report No. FAA-AM-83-13). Washington, DC: Federal Aviation Administration.

Traut, L. (2014, January 14). Goose crashes through windshield of small plane in Downers Grove. *Downers Grove Patch*. Retrieved from http://downersgrove.patch.com/groups/around-town/p/goose-crashes-through-windshield-of-small-plane-in-downers-grove

Vlasak, M. (1969). Effect of startle stimuli on performance. *Aerospace Medicine, 40*(2), 124-128.

Wickens, C. D., Hooey, B. L., Gore, B. F., Sebok, A., Koenecke, C., & Salud, E. (2009). Predicting pilot performance in off-nominal conditions: A meta-analysis and model validation. *Proceedings of the 53rd Annual Meeting of the Human Factors and Ergonomics Society* (pp. 86-90). Santa Monica, CA: HFES.

Woodhead, M. M. (1969). Performing a visual task in the vicinity of reproduced sonic bangs. *Journal of Sound and Vibration, 9*(1), 121-125.

Yeomans, J. S., Li, L., Scott, B. W., & Frankland, P. W. (2002). Tactile, acoustic and vestibular systems sum to elicit the startle reflex. *Neuroscience and Biobehavioral Reviews, 26*(1), 1-11.