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Developing a Taxonomy for Success in Commercial Pilot Behaviors

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Human error has been well studied in aviation. However, less is known about the ways in which human performance maintains and contributes to aviation safety. The lack of data on positive human performance prevents consideration of the full range of human behaviors when making safety and risk management decisions. The concept of resilient performance provides a framework to understand and classify positive human behaviors. Through interviews with commercial airline pilots, this study examined routine airline operations to evaluate the concept of resilient performance and to develop a taxonomy for success. The four enablers of resilient performance, anticipation, learning, responding, and monitoring, were found to be exhaustive but not mutually exclusive. The tenets of resilience theory apply in airline pilot behavior, but operationalizing a taxonomy will require more work.

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Human error is thought to account for 80% of aviation mishaps (Shappell & Wiegmann, 2001). As a result, human error has been well studied in aviation (Helmreich, 1997; Kontogiannis & Malakis, 2009; Wiegmann & Shappell, 1999). Researchers and practitioners are able to speak a common language due to the development of a well-accepted taxonomy, the Human Factors Analysis and Classification System (HFACS) (Wiegmann & Shappell, 2017). The widespread acceptance of models such as Threat and Error Management (TEM) have helped valuable concepts of human error move into operational settings as diverse as aviation, medicine, and nuclear power. (Boy & Schmitt, 2013; Helmreich & Musson, 2000). Most data sources in aviation, such as the Aviation Safety Reporting System (ASRS), the Aviation Safety Action Program (ASAP), and Line Operations Safety Assessments (LOSA), are *event* or *error* driven, which enables and reinforces the study of error.

However, much less is known about how human performance actively builds and enables system safety and efficiency (Holbrook et al., 2019). In complex, high reliability systems such as aviation, resilience has emerged as a key factor in safe and efficient operations. Resilient performance occurs when a system can "adjust its functioning prior to, during, or following changes and disturbances, so that it can sustain required operations under both expected and unexpected conditions." (Hollnagel, 2011, p. xxxvi). Studying how human performance contributes to system resilience can offer a new perspective on how to improve system performance and safety, and will offer a more complete picture of the role humans currently play in complex systems. As Holbrook et al. (2019) point out, understanding the full range of human contributions to system performance is critical at a time when the role of the human in the aviation system is changing.

Background

Safety I and Safety II

In its earliest days, aviation safety was reactive, with most safety improvements driven by mishap investigations. With the introduction of incident reporting systems and the development of hazard identification and risk mitigation strategies, aviation safety entered a period of proactive safety management, in which mishap precursors could be identified and mitigated prior to mishaps occurring. This approach, known as *Safety I*, concentrates on identifying, trapping, and mitigating error in order to reduce the number of negative outcomes to as low as reasonably practicable (Hollnagel, 2018; ICAO, 2009).

A number of challenges emerge with the Safety I approach as systems become safer. First, data is only systematically collected on operations with error or negative outcomes, so as operations become safer, a smaller and smaller proportion of actual operations are analyzed (Holbrook et al., 2019). Therefore, opportunities to learn and improve become increasingly limited. Second, the focus on prediction and prevention of negative outcomes does not accommodate unknown or unknowable threats. Third, if safety is measured by the absence of events that are extremely rare, it becomes increasingly difficult to assess the impact of system changes (Holbrook et al., 2019). Finally, it is intuitively obvious that studying failure when you are trying to ensure success tells only part of the story. In a comment first attributed to Marit de Vos of Leiden University, it is as if we are trying to learn about marriage by studying divorce (de Vos, 2018).

Data Sources

A key tenet of Safety Management Systems is the collection and analysis of safety data, so that the impact of changes to the system can be measured and monitored (ICAO, 2009). Aviation has a rich variety of data sources that drive safety decision making. The Aviation Safety and Reporting System allows anonymous reporting of incidents from private and commercial pilots, air traffic controllers, mechanics, dispatchers, and cabin crew (NASA, 2019). The Aviation Safety Action Program fulfills a similar function among air carriers and repair stations (FAA, 2002). The Flight Operational Quality Assurance (FOQA) program collects vast amounts of data on routine flights that is analyzed by individual operators for exceedances and trends. Finally, the Line Operations Safety Assessment program uses expert observation of routine flights to identify threats and errors, based on the Threat and Error Management model (FAA, 2014). Finally, the National Transportation Safety Board (NTSB) and the Federal Aviation Administration (FAA) collect data on aircraft mishaps and publish detailed accident reports and analyses.

These data sources primarily focus on errors or incidents, and therefore do not represent the population of routine and ordinary flights. Robust data sources on successful flights are lacking. Therefore, most safety recommendations derive from a non-representative data set, and the routine and successful operations that make up the vast majority of commercial aviation operations are not documented.

Human Error

The abundance and quality of data concerning human error has made it possible to create a taxonomy of human error that has been widely accepted. The Human Factors Analysis and Classification System was derived from extensive analysis of aviation mishaps and incidents, and has been applied to diverse industries outside aviation (Wiegmann & Shappell, 2017). HFACS has enabled a common language to be used in government, academia, and industry, and among researchers as well as practitioners. The ubiquity of HFACS has made it a powerful tool in identifying and addressing problems in human performance. Similarly, ASRS categorizes incidents using a taxonomy that focuses on outcomes and failures in human performance, which has resulted in a body of rich and consistent information about adverse events and errors (NASA, 2019).

However, no such common vocabulary exists for discussing *successful* behaviors that actively contribute to system safety. The lack of a taxonomy to categorize and classify positive behaviors adds to the difficulty of studying successful performance.

Resilience Theory

Safety II depends not only upon reliable data sources and a common vocabulary, but also on a theoretical underpinning. Just as models of human error are anchored by theories of human information processing and cognition, so models of successful behaviors must be anchored by theories of human and system performance. Accident causation models have typically been linear, leading to the approach that preventing bad outcomes involves preventing or mitigating precursors. However, some mishaps cannot be explained by linear models. Rather, they are the result of a complex interplay of events that affect each other (Woods, 2017). In this model of accident causation, safety results from the ability of a system to accommodate these events. Resilience theory concentrates not on the response to the specific disturbance, but on the system capabilities that allow it to accommodate the disturbance.

Resilient performance is thought to be enabled by four key system attributes, specifically, the ability to:

- Anticipate future events or situations
- Monitor both its own performance and environmental factors
- Respond to expected and unexpected events
- Learn from experience

These four abilities form a model of resilient performance based on the underlying theory of resilience (Hollnagel, 2011).

Problem

The study of error has been instrumental in achieving the safety improvements that commercial aviation has enjoyed. However, the reduction in negative outcomes creates problems for using the Safety I approach to further improve safety. As negative outcomes decline, the proportion of flights studied becomes smaller and less representative. Further, the impact of safety interventions becomes very difficult to assess. Also, a system that concentrates on identifying and mitigating threats may become vulnerable to threats that cannot be predicted. Instead, a Safety II approach is needed that supplements Safety I by examining the qualities that allow a system to respond flexibly in response to threats and disturbances, both anticipated and unexpected.

The Safety I approach has been successful in improving commercial aviation safety, but further safety advances cannot depend only on reducing the occurrence of negative outcomes. Safety in complex systems depends on the ability of a system to accommodate disturbances. System resilience depends upon behaviors that reflect the key attributes of anticipation, monitoring, responding, and learning. However, the error and event-based reporting approach common in commercial aviation does not fully capture the range of pilot behaviors corresponding to the key attributes of system resilience. As a result, much of the pilot’s contribution to system resilience is not measured, and therefore not studied systematically.

In order to understand how system resilience is built and maintained, data must be collected on routine successful operations. Currently, aviation has rich data sources and robust taxonomies to study error, but insufficient ways to identify and categorize success.

Purpose

The purpose of this study is to identify behaviors that increase system resilience in routine commercial airline operations, and to begin to articulate a taxonomy for behaviors that contribute to system resilience. Data on successful routine performance in commercial aviation is not systematically collected or analyzed in a way that allows for exploration of the qualities and attributes that enable system resilience. LOSA assesses routine flights, but focuses on error management. FOQA records information on routine flights, but the data analysis focuses on exceedances, rather than the data that might correspond to corrections that prevent exceedances. These data sources are tremendously valuable, but incomplete in the effort to study the contribution of routine pilot performance to system resilience. This study aims to fill a small part of that gap by studying specific events that involve unexpected or unplanned events and exploring pilot behaviors that contributed to successful conclusion of these flights.

Significance of the Study

The Safety I approach of reducing negative outcomes has natural limits as systems become safer. Further improvements in safety and efficiency must come from expanding data sets to include analysis of successful outcomes in order to understand the antecedents of successful performance as well as the antecedents of unsuccessful performance. Safety II is still in its early stages of acceptance. This study adds to the growing body of literature that uses a Safety II approach to understand the full range of human performance contributions to system resilience. Learning more about successful human behaviors that contribute to system resilience can help training organizations cultivate and enhance resilient performance. Further, with the increase in interest in autonomous systems in aviation, it is vital to understand the human contribution to system performance so this ability can be accounted for in any new system design.

Research Questions

Can commercial airline pilot behaviors be classified according to the four key attributes of resilient performance?

Can a taxonomy of resilient performance be articulated from investigating airline pilot behaviors in routine operations?

Methodology

This project used a qualitative, case study approach based on incident debrief interviews with commercial airline pilots. The study was designed to utilize purposeful sampling of the participants' viewpoints and expert opinions regarding their decision-making processes in aviation. Qualitative research is the traditional method for discovering a deeper understanding of a subject in a way that quantitative-only data cannot give us.

The interviews were based on the critical incident approach in which a participant was asked to recall a particular type of event (Hobbs, Cardoza, & Null, 2016). The interview protocol contained a greeting, description of the purpose of the research, event prompt, follow-up questions, and space for reflective notes. Using research questions developed by NASA, the researchers developed an open-ended question with follow up questions to probe for deeper meaning (Holbrook et al, 2019). The interview questions are presented in Appendix A.

Institutional Review Board permission was obtained from the sponsoring university prior to any participant recruiting or data collection. To maintain the confidentiality of the participants, all identifying information was redacted from the transcripts.

A case study methodology was employed to examine the various aspects of the pilots' thought processes within the theory of resilient performance. This case study was designed to bring the researchers to a deeper understanding of this issue, adding depth to what is already known about this phenomenon. As a result, 16 unique perspectives were obtained, analyzed, and placed into specific themes for the purpose of addressing the research questions.

Participants

Sixteen pilots from major U.S. airlines were recruited for participation in this study. Fourteen pilots were actively flying for a major airline (including eight captains and eight first officers); and, two were actively flying for a regional carrier (one captain and one first officer). Saturation of the data was met through this sample by ensuring that adequate quality data was collected to support the study; no new information was expected to be added to the emerging patterns that would enhance or change the findings of this study.

The 16 purposely-selected participants were pilots from different airlines, which allowed for different perspectives from a cross section of cultures, experiences, and situations. In the data collection and analysis process, each participant read and signed a confidentiality consent form, was assigned a code to ensure confidentiality and privacy was maintained.

A high degree of validity was designed into the research process. The first step to ensure validity consisted of inter-rater reliability (IRR) training. Interviewers discussed potential biases and then met to create mock interviews, thereby ensuring consistency of questions and follow up techniques. Next, the researchers ensured that an appropriate sample was selected, by interviewing both captains and first officers from different airlines. Finally, triangulation was also used to ensure validity. Interviews were conducted by three IRR-trained researchers in different locations. Once the interviews were complete, the researchers individually analyzed the data before meeting to compare and integrate their individual results.

Procedures

As an initial study, this data is intended to support a foundational understanding of pilots' thought processes and behaviors within resilient performance. As in any research, ancillary findings (which are not the primary target of the planned procedures) can greatly contribute to the results of this study. Further, understanding the thought processes in real-world situations was envisioned as a secondary function of this research.

The researchers voice-recorded each participant's discussion throughout the interview. A written transcript was developed for each participant after de-identifying each participant's information. Each of the participants' responses offered insight into their perceptions, opinions, and personal recommendations of airline operations. The MAXQDA qualitative analysis software was used to organize and analyze the data. The participants were assigned a sequential identification number (i.e. Participant 1 [P1]). Using the inductive approach to data analysis, the researchers then extracted key statements and phrases while organizing them into broad patterns that corresponded with the research questions and finally summarized what was communicated within each statement. From this extraction, the researchers identified primary themes.

While the researchers had specific interview questions that were asked during each of the semi-structured interview sessions, the interviewers also permitted the free flow of dialogue. This approach provided a broader set of information, yielding richer overall data than is presented in this discussion.

Through the data collection process, the researchers were able to freely engage with the participants, which yielded additional unexpected findings. While not initially planned, the additional dialogue provided a wealth of interpretive data to support the findings from the original structured research questions.

The data reduction process was helpful in further identifying patterns and alignment to the research questions. In the review of themes, the above connections were drawn based on similar participant responses and the interpretation of this data. It is important to be mindful that qualitative data analysis is ongoing, fluid, and sheds light on the broader study questions.

Limitations and Delimitations

This study included only pilots employed full-time with airlines based in the United States. Additionally, participants were limited to those who were available and willing to be interviewed. Purposive sampling allowed for the representation of a variety of airlines, but may have introduced other biases.

Results and Discussion

As an initial study, this data is intended to investigate the practical application of resilience theory in real-world setting. Holbrook et al. (2019) categorized behaviors in terms of strategies for resilient behavior, such as “Anticipate resource gaps” and “Anticipate procedure limits”. The authors focused on observable behaviors rather than underlying strategies, since the research objective was to develop a taxonomy of behaviors that an expert observer could use in safety audit setting. However, the theoretical framework and major categories were the same. Our intent was to begin a discussion among researchers and practitioners, rather than to prescribe an exact taxonomy. The model for the taxonomy is shown in Figure 1.

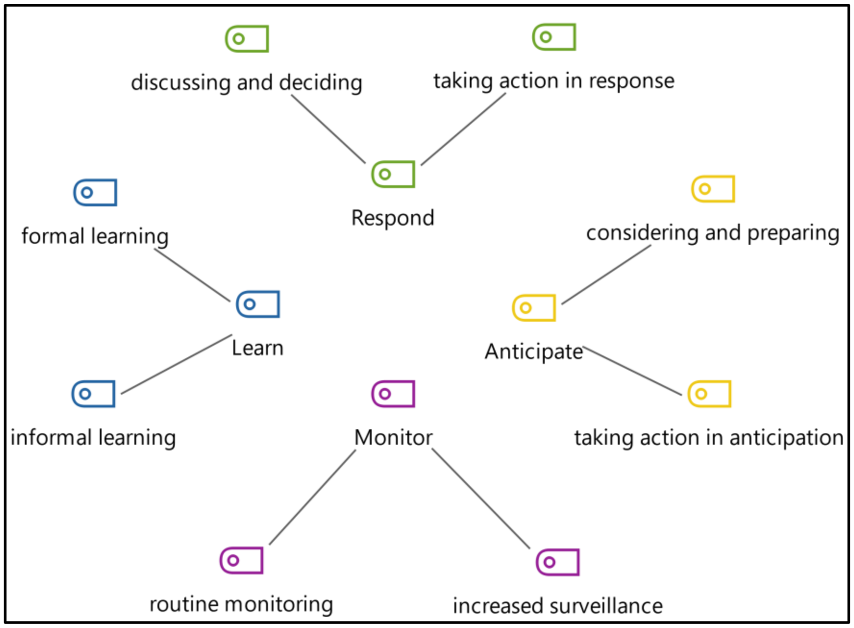

Figure 1. Taxonomy for observable behaviors of resilient performance.

The four categories of *Anticipate*, *Monitor*, *Respond*, and *Learn*, are discussed below.

Anticipate

When asked the first research question, *Were there things you were aware of at the start of your flight that you thought increased the likelihood that this event might occur during that flight?,* there were two themes identified in the data:

Considering and Preparing. These behaviors consisted of gathering information, discussing what to do, and deciding on action. For example, in response to noticing that an aircraft ahead got diverted, P9 stated, "Then we started talking to dispatch, and started trying to coordinate to go somewhere else in case in we needed to do that." As P3 stated, "Once we got up with the Washington Center frequency that was starting to do the traffic delays we had a plan in place so we knew once we got into holding we'd already calculated that we could hold for about 20-25 minutes before we'd have to go to our alternate."

Taking Action in Anticipation. In some cases, pilots became aware of potential disruptions, and took action in anticipation of them. As P8 stated, "We knew thunderstorms were forecast, so we added extra fuel to give us maximum holding time." During an uncertain maintenance delay, P13 explained "It's just really important to manage your sleep. And so I slept as much as I could during that day, not knowing when we were leaving."

Monitor

When asked the second research question, *Were there things that you experienced during that flight that you though increased the likelihood that this event might occur?*, there were two themes identified in the data:

Routine Monitoring. Responses from pilots indicated there are known factors they routinely monitor on every flight, for example weather, crew rest, the aircraft interphone system, or traffic in the area. P4 stated "Just for myself, usually anytime I'm on a more than like an hour long flight pretty much as soon as I get up to cruise I update and monitor all my weather information. Just to have like the earliest heads up if something is starting to change. And that's when we first got up to cruise, I got an updated ATIS for Baltimore and it was already showing thunderstorms at the field."

As another example, P9 stated "I was just flying from Charlotte to San Francisco, and I'd say probably almost, a little over halfway into the flight, I actually monitor the flight attendant conversations over the interphones. I'm sure like you guys have, we have a way to monitor their intercom conversation. So, I keep that available. I started noticing they were calling about a passenger that was having some kind of medical distress. So I became aware of something that could potentially be developing with a medical issue. And I typically just wait and let it play out and then eventually they're going to contact me and let me know. But at least now I have an idea that at least something's transpiring or beginning to transpire so I can start to... It lessens the startle effect later."

Increased Surveillance. In addition, there were factors that pilots paid more attention to due to certain circumstances, for example holding and diversion of aircraft ahead on the flight path in areas of bad weather, fuel state when other aircraft were diverting for weather, and traffic in the area when conditions made VFR traffic likely. P6 stated "You know it was August in Miami. So, you always have to be aware of the potential for the airfield getting soft in the thunderstorms. Typically, in Florida they move through fairly quickly and we do have holding fuel for that contingency. And then sometimes there's a little extra. So, we look at the fuel more carefully based on experience with the weather and actual weather."

P2 explained, "You know that busy airport on a VFR day you're going to have VFR traffic in addition to traffic that are filed with the FAA or you know… you've got guys that are not filing. So just more of an awareness that this trip I needed to be on my A game, you kind of keep an eye out for this basically."

Respond

When asked the third question, *How did you respond to this event?*, there were two themes identified in the data:

Discussing and Deciding. This included gathering information, discussing alternatives, and deciding on action to take. For example, P8 stated "Between the two or three of us with dispatch, we continually monitored the weather and tried to make the best possible decision. Like I said, I was more for going to Dulles, which was open at the time, and they were both like, 'Yeah, but Dulles, they've got that thunderstorm there, close by, and they're predicting it's going to move in. I think BWI is clear and a million, and we're going to be pretty safe going in there'. . . It was actually a little bit closer than Dulles, although either one of them were super close. Between the three of us, we gathered the information, made a decision we were all comfortable with. I was comfortable going with Baltimore."

Taking Action in Response. This category included all actions taken in response to unexpected events or situations, for example following a checklist, initiating a divert or complying with a collision avoidance procedure. Pilot explanations of this were typically simple and direct. P4 stated “And then you break out the checklist. And do the normal things declare an emergency break out the checklist. Go ahead start running the checklists.”

Learn

When asked the fourth question, *What did you learn from this event?,* every participant stated that learning from previous experience increases the safe operation of a flight. Every pilot specifically mentioned learning from previous events. This was the most discussed aspect of resilient performance for these pilots. Pilots stated that both *formal* and *informal learning* guided their actions.

Formal Learning. P16 stated “Training. . . So, any pilot that experiences any non-normal situation relies on their training methodology to solve the problem, resolve it.” In addition, P15 included “Every year we train in the simulator for all kinds of different problems”. Moreover, P1 included “I think there is pattern matching that goes on. I think I find in other emergency situations I have handled in my career there's pattern matching. It seems to me that, have I seen this kind of scenario before and it goes all the way back to my primary training we did simulated engine failures unexpectedly. So pattern matching to me can be helpful. Pattern matching can also retrieve some skills, some primal skills, positive primal skills that might help you deal with it.”

Informal Learning. As P10 stated, “They may be able to trigger in their mind oh you know I talked to somebody about this once and I think that's really a huge hugely important thing in aviation is that is those little things that you have in your mind of past experiences and past stories that you've heard so that when symptoms of a problem do present themselves to you, you can kind of reach back to those tidbits of information and maybe use that to analyze and figure out what's going on in your situation.”

Moreover, airlines have robust safety feedback programs. As P2 stated, “Well, we have a very robust ASAP, where we have access to a lot of information de-identified of incidents and events that occur. I think with a strong safety management system, through our FOQA program, our ASAP system and LOSA. I think there is power in learning and when you read these things you can be very arrogant and say well that would never happen to me. I look at it and say I could see that happening to me and... So I think learning about lessons learned from other people are very powerful.”

In addition, P13 added “There's our debriefing afterwards. We talked about what had happened. Like I told my first officer, I said he did a fantastic job at coordinating with the flight attendants. Especially at the end when I was doing a lot of the flying, doing the diverting and talking to ATC, he did a lot of the behind-the-scenes stuff, which really helped. We debriefed what things could have gone better, what went well, and then how would we do things differently.”

Ancillary Findings

As in any research, often the data collected yields information, ideas, or additional themes that were not anticipated. When this occurs, a rich and detailed set of findings can support the gap in the literature and further support the research questions. In this case, there were two major unintended findings that were common throughout the interviews. While this later theme may not be directly aligned to the original research question, it is related to the perceptions and opinions of the participants.

Enablers of Resilient Performance

Training. Training was a topic that was discussed in 12 of the 16 interview sessions. Every participant complimented the quality of training received from the respective airline. As P5 stated, “Yeah I lost an engine on takeoff a couple of years ago. And it was just sort of fall back on your training. . . Because you're trained for it all the time you know to lose an engine on takeoff.” P12 stated, “You see you start falling back on what you've been taught to do.” As P7 added, “yeah, simulator training. We had seen it before in the simulator. . . I followed the emergency procedures we were trained to do.”

Experience. In addition to training, experience was mentioned by 14 of the 16 every participants as a huge factor in how they responded to an event. As P1 stated, “On my last trip to Dulles, I mentioned it to the co-pilot what had happened, and if we were offered that again on an afternoon flight, that we would probably end up doing the same thing, or at least considering it.” P11 included “Experience because many airports that have construction anywhere near the end of the runway, have frequently had their instrument or glide slope and localizer antennas interfered with construction or vehicles driving right in front of them… Personal experience, since I was a private pilot, you just land the airplane.”

P4 handled an emergency by recognizing that *something just wasn’t right*, stating, “I guess I mean just from flying this aircraft for the past several years knowing what the speed schedule would be upon reaching the thrust reduction altitude it'll start commanding a nose down pitch attitude and the speed bug would switch up to two hundred and fifty. And just witnessing that not happening is something very different occurring. That was just outside of the normal pattern that you're accustomed to seeing.”

As P9 stated, “As experienced dictates, you try and avoid surprises, anything with startle effects, so I always anticipate or try to become cognizant of any potential threats to a flight. And like I said, the longer flights I'm aware that options could be limited to divert. A lot of international experience like yourself. So you realize there are areas where you have really limited options. You try and think ahead, "what would I do in this case?" Because you don't want to be caught behind the power curve and have a surprise and have to play catch up.”

Despite the importance of informal learning, pilots did not generally share these lessons through any established process. Rather, pilots reported sharing their lessons with others in one-on-one conversations, but generally they regarded what they learned as not significant enough to share through the more formal mechanisms available at their airlines. As Holbrook et al (2019) point out, “no methods exist to systematically report or capture this information. This is a missed opportunity for developing training, data systems, and procedures whereby operators could systematically benefit from others' lived experiences, not just their own" (p. 17). Further, several pilots noted that their airline experience differed from their previous military experience in this regard, with more opportunities to share informal lessons in their military flying background.

Crew Climate

Most participants discussed crew climate and crew coordination as major factors in their decision making, hence resilience. For example, as P14 stated, "But then you could almost call it if anything like a sort of like team building type thing. Because at that point we had kind of like faced, nothing major, but we faced an abnormal situation and worked through the issue and come to a conclusion there." As P7 stated," I learned that the people that I worked with during the emergency were awesome. The controllers were very helpful in getting us back around. Everything went very, very easily just because of the training, and the working together from the airline perspective." P8 added "The most important thing is having a crew that can work together. That can say, Hey, we're gonna check all the other stuff when we come to work, and just work together the best we can to handle any kind of a situation."

The contribution of the crew concept to resilience is an especially important topic to explore in future research, as the idea of single pilot operations gains more traction. Any changes to accommodate single pilot operations must also be able to incorporate the resilience that is an emergent property of team performance in the cockpit.

Categories Are Not Mutually Exclusive

It became apparent early in the interviews that often a response could be used in more than one category. For example, P9 stated "As experienced dictates, you try and avoid surprises, anything with startle effects, so I always anticipate or try to become cognizant of any potential threats to a flight. And like I said, the longer flights I'm aware that options could be limited to divert. A lot of international experience like yourself. So, you realize there are areas where you have really limited options. You try and think ahead, "what would I do in this case?" Because you don't want to be caught behind the power curve and have a surprise and have to play catch up." This example could easily fit into the categories of *Anticipate*, *Monitor*, or *Learn*.

Conclusion

Resilient performance, as a theory, appears to have practical application in aviation. Purposeful sampling of 16 airline pilots show resilient performance does occur on flights. The categories of Anticipate, Monitor, Respond, and Learn were exhaustive, but not mutually exclusive. Thus, the tenets of resilience theory are initially validated, but operationalizing a taxonomy will require more work.

Recommendations for the Instructional Environment

As noted previously, the highest response was in the category of Learning. Although each category is important in the decision-making process, opportunities to create better learning environments will continue to enhance safety. This gives great opportunities to enhance student learning with the incorporation of resilience theory.

As both formal and informal training were highlighted by the participants, three areas to create better learning for students:

Flight line Operations: as part of the brief/debrief time, instructors should build in scenarios where students need to think through a situation. Situations could include abnormal engine indications, unexpected weather, equipment malfunction, etc. This gives the student the opportunity to chair fly (practice on the ground) the thought process and resources available.

Curriculum Developers: a similar process can be used in any classroom setting (air traffic control, maintenance, UAV operations, etc.). Curriculum developers/instructors can build in “what would you do if” scenarios into lectures. This helps reinforce the law of primacy (learn it correctly the first time) for situations that may be encountered later in more stressful environments.

Capturing Positive Performance/Resilience: this gives opportunities to reinforce correct thought processes. Often times, people critique negative/incorrect application, yet fail to reinforce the overwhelming part the process that was done correctly. This is a great opportunity to correct faulty thoughts, but also praise and reinforce correct thought processes.

Future Research

Future research is suggested with a larger sample size, across numerous airlines, worldwide. Also, future research should include less-experienced pilots, to see if the theory holds at different levels of experience. Further, research should include different operational domains, such as flight instruction. Holbrook et al. (2019) discussed the need to be able to correlate safety data, such as FOQA data with crew behaviors. Future research should attempt to connect disparate data sources to develop a more robust and complete picture of resilient behaviors. Finally, carefully-scripted follow up questions should be introduced to include crew dynamics with resilient performance.

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Appendix A
Pilot Interview Protocol

Initial Question: Unplanned and unexpected events happen routinely during operations in the NAS. We are interested in how pilots make adjustments before, during and after these unplanned or unexpected events in order to maintain safe operations. Can you tell me about a specific unplanned or unexpected event that you have experienced in the course of routine operations?

Follow-up Questions:

- Were there things you were aware of at the start of your flight that you thought increased the likelihood that this event might occur during that flight?
- How did you know that this event might occur?
- How else might you have been able to anticipate that this event would occur?
- Were there things that you experienced during that flight that you thought increased the likelihood that this event might occur?
- What signaled/indicated to you that this event was about to occur, was occurring, or had occurred?
- How did you know what indicators of this event to look for during your flight?
- What other indicators could have alerted you to this event?
- How did you respond to this event?
- How did you know what to do in response to this event?
- If you had not already known what to do to respond to this event, how would you have figured out what to do?
- What did you learn from this event?
- How did what you learned impact the remainder of your flight or that operation?
- How did what you learned impact how you prepare for future flights or operations?
- Have you shared what you learned with others in your organization? How did you do that?
- In general, what practices are in place in your organization for pilots to share lessons learned?
- Is there anything further you'd like for us to know about this event that we haven't already discussed?