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Defining Aviation “Skills” to Ensure Effective, Safe, and Efficient Evaluations: A Qualitative Study

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Defining Aviation “Skills” to Ensure Effective, Safe, and Efficient Evaluations: A Qualitative Study

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The present qualitative case study strives to define the term *skill* within aviation, drawing from the cognitive psychology, organizational psychology, and training literature as well as input from subject matter experts in the aviation industry. A review of the published literature revealed no consensus for defining what constitutes a skill. While some definitions follow a task-based approach, others emphasize more cognitively based representations. Moreover, a formal, commonly accepted definition of the term skill within the aviation domain is lacking. The researchers employed a qualitative case study methodology to extract true descriptions from the subject matter experts to bound and expand from the current literature while rooting the findings within the theoretical model of situation awareness. Findings from this study indicate the term skill encompasses multiple high-order thinking processes. While these processes can be defined differently depending on the field in which one applies the term skill, they are still rooted in three common themes: goal-oriented, efficiency, and high proficiency.

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The learning process for humans can be considered a complex concept. From adaptation and representation to optimization and skills, the human sensory-motor learning process relies on understanding prediction errors (Krakauer & Mazzoni, 2011). Technology itself has played an important role in human learning and metacognition. Ignoring metacognitive domains during training, transferring information, the evaluation process, can lead to a deficit in performance (Turner, 2011). Technological advances have significantly intensified the challenges facing individuals performing complex operations in today's aviation domain, from commercial aviation and military aviation to uncrewed systems and commercial space operations. These operations can be broken down into component tasks and subtasks to identify the skills required to ensure successful outcomes. For example, in evaluating human performance factors for air traffic controllers, Pandey and Shukla (2019) found that human performance factors and technology-intensive systems require a thorough understanding of an individual's complex interactions and skills. A detailed specification of these required skills can inform the design of training programs to ensure mastery and proficiency in the aviation operational environment. Currently, a formal, commonly accepted definition of the term *skill* within the aviation domain is lacking. More importantly, the definition of skill should be directly rooted within the principles of situation awareness (SA) to further the mission of improving aviation safety. The present qualitative case study defines the term *skill* within aviation, drawing from the cognitive psychology, organizational psychology, and training literature as well as input from subject matter experts in the aviation industry.

Literature Review

A review of the extant literature reveals various approaches to defining what constitutes a skill, largely dependent upon the researcher's focus. Table 1 highlights these different approaches. While some definitions follow a task-based approach, defining criteria for objectively selecting and completing a complex task component (e.g., Fleishman, 1966; Pater, 2016), other approaches adopt more cognitively based representations, such as viewing a skill as an act that is well-organized and economical of effort (e.g., Chen et al., 2019; Chipman, 1992). In addition, some approaches define skills in terms of the processes people use to learn new things (e.g., Annett, 1991; Newell & Rosenbloom, as cited in Tenison et al., 2016). Finally, several definitions adopt a behavioral approach focusing on the level of automaticity of the task where execution of the skill-based behavior is autonomous (e.g., Brownstein, 2014; Logan, 1988; Rasmussen, 1986; Sadikot, 2014).

Notably, in his Skill-Rules-Knowledge (SRK) framework, Rasmussen (1983) describes these behaviors as skill-based, rules-based, or knowledge-based. *Skill-based* behaviors involve automatic sensory-motor performance of acts or activities and are represented by prototypical temporal-spatial patterns. *Rules-based* behaviors affect a goal-oriented sequence of subroutines typically controlled by a stored rule or procedure and demonstrate explicit know-how. *Knowledge-based* behaviors occur at a higher conceptual level, typically in unfamiliar situations where know-how or rules for control do not exist. Knowledge-based behaviors involve identifying an explicit goal, formulating a plan of action, and assessing the outcome.

In aviation, skills encompass both technical and non-technical skills. Technical skills involve applying specific expertise acquired through training to perform a task or set of tasks, such as an aviation maintenance technician repairing an aircraft engine or a flight crew executing a missed approach procedure (Federal Aviation Administration [FAA], 2017; U.S. Department of Transportation, 2018). In contrast, non-technical skills have been described in terms of social skills, such as cooperation, leadership, and managerial skills) and cognitive skills, such as situation awareness and decision making (Flin et al., 2018). Although specific criteria have been identified to evaluate how well these technical and non-technical skills are demonstrated, what is lacking is a clear consensus on what constitutes a skill.

Adding to the challenge of a lack of consensus on what a skill is, the FAA also does not provide a concrete definition of the term 'skill.' Currently, the "instructor assumes the total responsibility for training the student […] in all the knowledge areas and skills necessary to operate safely" (FAA, 2016, p. 1-7). In terms of risk management and SA, the FAA (2009) encourages to "use the same response to the same perceived level of risk, viewing any success as due to skill, not luck" (p. 1-7). Therefore, it is essential to properly define the term skill in the aviation context to further enhance SA in all facets of the industry.

Table 1

Different Approaches for Defining a Skill

Approach	**Definition**	**Citation**
Task-oriented	Level of proficiency on a specific task or limited group of tasks. Most skills involve (a) spatial-temporal patterning, (b) interaction of responses with input and feedback processes, and (c) learning	Fleishman (1966) p. 148
Task-oriented	Founded on experience and proficiency and does not include simple memorization and regurgitation of a task; requires acquiring and using new or upgraded skills until they become second nature	Pater (2016) p. 15
Cognitive-based	Involve orchestration and practical use of simpler skills	Chipman (1992) p. 129
Cognitive-based	Richly interrelated base of knowledge and its integration with basic perceptual and information-processing processes to produce a coherent emergent cognitive capability that adapts to complexity	Chen et al. (2019) p. 3
Process/practice -oriented	Behavior which (a) goal-directed, (b) well organized and economical of effort, and (c) acquired through training and practice rather than being innate or instinctive	Annett (1991) p. 13
Process/practice-based	Occurs gradually as the time it takes to solve a given problem decreases; accomplished through the "chunking of cognitive processes into fewer processes	Newell & Rosenbloom, as cited in Tenison et al. (2016) p. 2

Behavior-based	Consist largely of collections of automatic processes and procedures	Logan (1988) p. 492
Behavior-based	Acts or activities occurring without conscious control as smooth, automated, and highly integrated patterns of behavior	Rasmussen (1986) p. 100
Behavior-based	Behaviors as skill-based (e.g., routines), rules-based (e.g., procedures), or knowledge-based (e.g., handling unknown / novel situations)	Rasmussen (1983)
Behavior-based	Actions and behaviors are produced automatically with little or no attention	Schmidt & Wrisberg (2008)
Behavior-based	Mindless and automatic, like reflexes stored in muscle memory	Sadikot (2014)
Behavior-based	Occurs with little conscious awareness of what is being done, and difficult to explain one's own actions after the fact	Brownstein (2014)
Behavior-based	Coordination of component automatic processes to perform complex tasks	Strayer & Kramer (1994) p. 318
Behavior-based	More than 100 hours of training are required; substantial numbers of individuals fail to develop proficiency; and expert performance qualitatively different from novice performance	Schneider (1985) p. 285

Theoretical Framework

Situation awareness is a concept that has received continuous criticism in terms of its validity (Durso et al., 2007; Gorman et al., 2006; Wickens, 2008). Nevertheless, SA has been shown to be essential to successful performance in complex domains (e.g., Sharma et al., 2019; Skrypchuk et al., 2020), including aviation (e.g., Clark et al., 2019; Cuevas & Aguiar, 2017; Riley et al., 2006; Tsifetakis & Kontogiannis, 2019; van Benthem, 2020). Notably, SA is a crucial constituent in human information processing and essential for sound decision-making in aviation operations, including crewed and uncrewed aircraft (Nguyen et al., 2019). Therefore, Endsley's (1995) theoretical model of SA is fundamental to the definition of skill as SA supports the understanding of one's surroundings and enables the prediction of what might happen in the near future.

Theoretical Model of Situation Awareness

At its core, SA involves being aware of what is happening around you to understand how information, events, and your actions will impact your goals and objectives, both now and in the near future. More formally, SA can be defined as "…the perception of the elements in the environment within a volume of time and space, the comprehension of their meaning and the projection of their status in the near future" (Endsley, 1995, p. 36). Per this definition, SA is comprised of three levels. Level 1 SA, perception, involves the sensory detection of significant environmental cues, during which attention is directed at essential information while nonessential items are ignored. Level 2 SA, comprehension, consists in integrating and comprehending information in the working memory to understand how it will influence individuals' ability to achieve their goals. Level 3 SA, projection, involves extrapolating this information forward in time to determine how it will affect future states of the operating environment. A range of individual factors influences these three levels (e.g., abilities, experience) and task/system factors (e.g., task complexity, level of automation), which, in turn, influence the operator's decision-making and performance of actions (Endsley, 1995). Given its multifaceted nature, it is vital to identify and operationally define the underlying skills necessary for developing and maintaining SA. As a critical first step, one must begin by defining skill in the context of aviation.

Methodology

Creswell and Poth (2018) argued that qualitative research is an appropriate choice when the researchers intend to focus on the meanings that participants assign to a given phenomenon within a specific context. A case study design was selected because the researcher of the present study aimed to define a specific term within the context but also, case studies are best for generating a "detailed, in-depth data collection involving multiple sources of information-rich in context." (Creswell & Poth, 2018, p. 96). The goal of this design was to extract true descriptions from the subject matter experts (SMEs) to bound and expand from the current literature (Yin, 2018) while rooting the findings within Endsley's (1995) theoretical model of SA.

Because qualitative research focuses on the in-depth understanding of a small sample (Creswell & Poth, 2018; Yin, 2018), the researchers purposefully targeted ten SMEs in different aviation domains for this study, of which six accepted to participate. As shown in Table 1, the overall SME cohort represents the aviation industry at large. In addition, the researchers reviewed current certification documents used across the aviation industry to certify applicants within different domains (e.g., Airman Certification Standards, Federal Aviation Regulations, FAA Educational Publications, etc.). Lastly, while qualitative research only strives to achieve the transferability of results (Creswell & Poth, 2018; Yin, 2018), only logical generalizations were made given the small sample size.

Table 1

Participants Demographics

Pseudonym	Area of Expertise	Age	Years of Experience
Antonia	Airline Operations and Aviation Safety	50	13
Charles	Airline and Military Operations	53	20
Martin	General Aviation and Collegiate Aviation Education	60	22
Nilda	Aerospace Engineering and Aviation Maintenance	*	6
Phillip	Aviation Maintenance and UAS	*	7
Roberto	Aviation Maintenance and UAS	*	9

Notes. *Chose not to disclose; UAS = uncrewed aircraft system.

Procedures

At the time this research was conducted, Institutional Review Board (IRB) approval was not required before sending emails to the targeted SMEs. According to the Embry-Riddle Aeronautical University IRB decision tree, no IRB application is required if the focus of the project is only on products, methods, policies, procedures, or organizations. Therefore, the data collected for this study focused on the expert definition of skills and not a personal opinion. Participants who agreed to voluntarily participate emailed their availability to the researchers. The researchers conducted semi-structured individual interviews with all SMEs to capture their descriptions and definition of the term skill within aviation using Endsley's (1995) theoretical framework. Before commencing the interviews, the researchers briefed the participants on the nature of the study. Furthermore, the researchers asked the participant to disclose demographic and background data (e.g., age, gender, areas of expertise, years of experience in the aviation field) to establish their credibility.

The researchers made clear that the context of the interview questions was within the aviation context. To increase the comparability of responses, the interview instrumentation followed standardized open-ended interview guidelines (Patton, 2015). Table 2 shows the semi-structured, open-ended questions that were used for the interviews and ensure consistency with the inquiry of the case (Yin, 2018). To increase the validity, credibility, and transferability of the present study, the interview questions were rooted within the skill literature and a theoretical framework, namely Endsley's (1995) theoretical model of SA (Creswell & Poth, 2018; Patton, 2015); in addition, the interview questions were validated by a qualitative methodology expert. The interviews were audio-recorded, transcribed, and sent them back to the participants for them to check the accuracy of the data collected (member checking).

Table 2

Standardized Semi-Structured Interview Questions

1) How would you define the term "skill" in the aviation context?
2) How can one distinguish a "skill" from "knowledge" or "abilities"?
3) How can a skill be differentiated from proficiency?
4) What are the characteristics of an advanced skill versus a basic skill?
5) What behavioral characteristics are expected in the demonstration or evaluation of a skill?
6) What can be improved in order to assess the acquisition of a particular skill in aviation?
7) What skills do you consider important for sound situation awareness?
8) How would you integrate situation awareness in the assessment of a skill?
9) Describe how abilities and experience can influence the acquisition of an advanced skill.

Data Analysis

After transcribing the interview, two of the researchers became familiar with the data by reading and recording analytic memos through the transcripts multiple times (Saldaña, 2016).

Furthermore, the researchers used NVivo® to assist in the qualitative data analysis. Structural coding was selected as it enabled the researchers to "examine comparable segments' commonalities, differences, and relationships" (Saldaña, 2016, p. 98). Furthermore, Saldaña (2016) suggests that structural coding is most suitable for interview transcripts than other data. Based on the initial annotations, the researchers developed a tentative code list. The code list included the grouping of text into prevalent sub-themes as outlined by Creswell and Poth (2018). The final analysis resulted in the development of major themes as the data were interpreted within the context of Endsley's (1995) theoretical model of SA. The data analysis concluded once saturation was achieved, resulting in representative data (Saldaña, 2016). Merriam (2009) supports that data representation helps with the visualization of the themes and their relation to the phenomenon.

Trustworthiness

Given the limitations of qualitative research, it is important to determine scientific rigor and understanding of the methodology used. The researchers requested a member check from the SMEs to ensure that their essence was entirely captured and establish credibility (Creswell & Poth, 2018). Participants reviewed the transcripts primarily for accuracy and missing information or misinterpretation. Feedback from the participants showed that themes captured their own sense of reality through their descriptions. Dependability and confirmability were established by following the descriptive case study format outlined by Yin (2018). The researchers arranged the evidence in a visual representation to enable the readers to determine the reliability of the study (see Figure 1).

Figure 1

Visual Representation of Common Codes

Understanding and interpreting qualitative scientific rigor were crucial in the coding process and determining major themes. Information collected from SMEs' interviews and document analysis were used to define the term skill within the aviation context. Furthermore, each code, sub-theme, and major theme was interpreted within the context of Endsley's (1995) theoretical model of SA. After arranging large segments of text on broad topics, a structural coding categorization technique was employed to further the qualitative analysis (Saldaña, 2018). Three major themes emerged from the data after noteworthy statements were grouped into single open codes (see Table 3).

Table 3

Open Codes and Themes

Major Theme	Open Codes	Frequency
Goal Oriented	Focus	42
	Objective	28
	Targeted	14
	Leadership	13
	Direction	11
	Creative	10
	Control	10
	Recursive	5
Efficiency	Communication	23
	Adaptability	22
	Competence	13
	Productivity	11
	Talent	10
	Performance	10
	Organized	8
	Intuition	7
	Needs	5
	Realizing	5
High Proficiency	Detail Oriented	31
	Methodological	20
	Mastery	12
	Knowledge	12
	Aptitude	9
	Synthesize	8
	Ethics	7
	Judgment	6
	Critical	6
	Distinguish	4

Theme 1: Goal Oriented

The first major theme that emerged from the data analysis was goal oriented. The three major codes within these themes were focus, objective, targeted. Focus was the most prominent code as five out of the six SMEs indicated that the demonstrations of any given skill require high concentration. Martin mentioned, "[…] identifying higher levels of situation awareness, [or] ability to sustain longer periods of attention could all benefit and improve the monitoring [of a] skill." SMEs agreed that to acquire or demonstrate a skill one needs to set a goal(s), focus on it, and work until mastery has been achieved. However, the essence of a skill relies on being objective. For example, Antonia mentioned, "the demonstration of a skill, though specific and goal-oriented, it must be tied closely to the operations safety goals and objectives. This enables the identification of key performance indicators." Similarly, Martin added that a skill "is a goal-oriented behavior [that enables the pilot to] ensuring [sic] that the aircraft is doing what it is expected to do during each phase of flight while remaining objective." In addition to focus and objectivity, because skills are goal-oriented, they were also described as to be targeted. Nilda mentioned, "due to the wide range of knowledge that is required to perform a [given] task, each skill must be controlled and targeted. The use of references can narrow the scope of a task and ensure quality."

Theme 2: Efficiency

The second major theme that emerged from the data was efficiency. The two major codes that frame this theme were communication and adaptability. Effective communication was the common description among all SMEs to define the effectiveness of a skill. Phillip expressed that "evaluates, particularly those working in teams (or as a crew), have to demonstrate good communication; both as transmitters and receivers." Phillip further mentioned that "open and effective communication channels need to be [embedded] in the demonstration of a skill so that the evaluator can assess the effectiveness of the transmitter and the receiver." Conversely, to further achieve maximum efficiency in the demonstration of a skill, the SMEs agreed that both the evaluator and evaluatee need to share the same mental model while recognizing the importance of adaptability to different environmental factors. For example, Martin mentioned that "while skills should be general enough to apply to other types of [tasks], we have to recognize that external factors will influence the process necessary to achieve [a] predetermined goal."

Theme 3: High Proficiency

Lastly, the third major theme that emerged from the data was high proficiency. The two major codes that framed this theme were detailed oriented and methodological. Five out of the six SMEs stated that practical and theoretical assessment influence the determination of whether or not someone possesses a given skill. Roberto summarized this notion best by stating, "in order to perform a task effectively, [the individual] requires proficiency. Commonly, this is assessed through theoretical and practical assessments and requires to be performed without assistance." Yet while many tasks could employ the same skill, the principles of SA will suggest that all factors need to be considered before moving forward, making the demonstration of a given skill detailed oriented. For example, Martin stated that "an act becomes a skill when it meets a specified, predetermined level of proficiency." Similarly, the level of proficiency required to demonstrate a given skill requires a precise and methodological approach. Antonia mentioned,

> There are skills that are more hierarchal, [like] completing a before start checklist. Compared to, let's say, an airline pilot who is dealing with an emergency, who is having to deal with multiple complex checklists almost simultaneously, will need to use a more methodological approach to keep control of the situation.

Most SMEs mentioned that Cactus flight 1549 (The Hudson Miracle) is a good example of how detailed orientation and thoughtful methodological procedures, and analysis of external factors lead to success through the use of safety-oriented skills.

Study Limitations and Implications for Future Research

This qualitative case study aimed to define the term skill in the aviation domain. However, the study only examined a limited number of operational settings and involved only six subject matter experts. While qualitative research relies on the concept of saturation to establish reliable data, some researchers consider the inherited small sample size population of qualitative research a limitation of the methodology. The aviation domain is quite varied and comprised of numerous other settings (e.g., air traffic management, ground and ramp operations). However, the present study did not explore every single scenario within these settings; instead, it focused on developing a holistic skill definition through the lens of situation awareness. Thus, future research can be conducted to validate the definition of skill derived in this study with a larger number of SMEs in a variety of different aviation settings. For example, a Delphi Panel study will be beneficial to achieving expert consensus among a larger group of aviation experts from all aviation domains. It would also be of value to research how this study's definition of skill translates to aviation flight training – particularly, its effect on adult learning principles and teaching strategies.

Conclusion

A better understanding of how to define a skill can guide instructional designers in selecting the appropriate training content (what to train) and training strategy (how to train) to ensure the achievement of terminal proficiency objectives (end-status proficiency). The adequate selection of content and strategies will also enable the steps along the way in terms of supporting proficiency objectives (procedural knowledge) and enabling objectives (declarative knowledge) (Holden, 2009). Coupled with the literature and informed by Endsley's (1995) theoretical model of SA, findings from this study indicate the term skill encompasses multiple high order thinking processes. While these domains can be defined slightly differently depending on the field in which we apply the term skill, they are still rooted in three common themes: goal-oriented, efficiency, and high proficiency. Therefore, within the context of aviation, the term skill can be defined as a goal-oriented and efficient execution of a task or behavior that reflects high proficiency and synthesis of information.

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