IDENTIFYING TYPE OF EXPERTISE AS A MEANS TO MEASURE CRM KNOWLEDGE STRUCTURES

by

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ABSTRACT

Crew Resource Management (CRM) training has evolved since its inception in the 1980s to better accommodate the operational needs of flight crews. However, even as the aviation and research communities have pointed to the potential benefit of providing CRM training, some criticism continues to emerge periodically which claims that there is no concrete evidence of its impact on flight deck performance and safety. Therefore, it is imperative to develop tools that allow researchers and, more importantly, practitioners, to more effectively and objectively assess training effectiveness and identify whether or not desired CRM behaviors are being put to practice during line operations.

This study focused on evaluating pilots' CRM schemas and identifying differences in CRM knowledge structures among pilots. Differences in CRM knowledge and opinions about training could be an indication of the existence of what Hatano and Inagaki (1986) have described as two distinct types of expertise, namely, *routine* and *adaptive expertise*. The study sought to identify differences among routine and adaptive expert pilots in CRM knowledge structures (schemas), their perceptions on the value and efficacy of current CRM training evaluation, along with their opinion on how CRM training effectiveness could be more accurately assessed.

Results from over 250 pilots showed that, in general, participants had a positive view of CRM training and training evaluation, regardless of their type of expertise. Some evidence of potential differences in the structural knowledge of CRM between routine and adaptive experts, as well as, differences in their opinions about CRM training, evaluation, and automation on the flight deck was also identified. Additionally, analysis of survey scores and free response items indicate the existence of a third category of experts, between routine and adaptive expertise (whom I call *transitional experts*).

The study results provide evidence that assessment of CRM schemas could potentially be used as a way to evaluate CRM training effectiveness. The results of the study also indicate that identification of specific training needs for each group of expert may be possible through the assessment of CRM schemas and type of expertise. Implications for practice and theory, limitations of the study, and suggestions for future research are also provided.

Più avanti

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CHAPTER 1: INTRODUCTION

The Research Problem

Crew Resource Management (CRM) training has evolved since its inception more than three decades ago to better accommodate the operational needs of flightcrews, but still even relatively recently, it was unclear whether it is an effective way to train non-technical skills related to team performance on the flight deck (Salas, Rhodenizer, & Bowers, 2000; Weber, Mavin, Roth, & Dekker, 2016). Even as the aviation and research communities have claimed the potential benefit of providing CRM training, some criticism continues to emerge periodically which claims that there is no concrete evidence of its impact on flight deck performance and safety (see O'Connor, Jonzes, McCauley, & Buttrey, 2012; Salas, Rhodenizer, & Bowers, 2000). Therefore, it is imperative to develop tools that allow researchers and, more importantly, practitioners, to more effectively and objectively assess training and identify whether or not desired CRM behaviors are being put to practice during line operations.

In 1979, NASA conducted a study to examine the causes of accidents that were not related to technical or engineering issues (Cooper, White, & Lauber, 1980). The study showed that 66% of air transport, 79% of commuter, and 88% of general aviation (GA) accidents were related to poor decision-making, loss or degradation of situational awareness, and lack of leadership. These statistics prompted air carriers and aviation authorities to develop and implement training programs to help flightcrews reduce human error by providing tools that would aid pilots to make better use of their available resources (Helmreich, Merritt, & Wilhelm, 1999). The first programs were implemented by US carriers in the 1980s; shortly thereafter, air carriers in other parts of the world followed. First, the program was named Cockpit Resource Management (abbreviated

CRM). Later, the concept and programs evolved and were renamed as Crew Resource Management (also abbreviated CRM), so as to better reflect the inclusion of other crewmembers and personnel involved in flight operations, such as air traffic controllers (ATCs), dispatchers, flight attendants, and maintenance crews (Helmreich, Merritt, & Wilhelm, 1999).

Contemporary CRM training programs for Airline Transport Pilots (ATPs) are usually divided into multiple stages. The following description of CRM training is typical of US air carriers: The first stage of CRM training takes place after an ATP has been hired by an air carrier (Indoctrination). During indoctrination, pilots are introduced to the air carrier's philosophy of CRM and flight safety culture. CRM training during indoctrination typically lasts between half a day and a full day and topics covered include team coordination and communication, leadership, followership, team decision making, and proper use of available resources during flight operations. The second stage occurs during Initial Qualification training. During this stage CRM behaviors are usually practiced while in the flight simulator. The third stage takes place during Recurrent Qualification, here pilots usually spend a few hours reviewing CRM concepts, case scenarios, practicing briefings, and in some cases, interacting/training with other non-pilot groups (e.g., flight attendants and dispatchers). During Recurrent Qualification desired CRM skills are practiced while using Flight Training Devices (FTDs) and Full Flight Simulators (FFSs). Recurrent Training usually takes place every 6 or 9 months depending on the air carrier. Other CRM training is also provided when a pilot transitions to a new type of aircraft (Transition training), and when a pilot is promoted to captain (Upgrade training). It is important to note that every time an ATP is hired by a new air carrier, s/he has to attend Indoctrination training and the whole training cycle starts over again.

There is no doubt that the number of air carrier accidents has declined in the past decades, but the percentage of accidents and incidents related to CRM still remains high in commercial aviation. According to Wagener and Ison (2014), 50% of accidents during approach and landing continue to be related to CRM issues. A review of several case studies presented by Wagener and Ison showed that poor crew coordination was a causal factor in many aviation mishaps. Shappell et al. (2007) reported that 70% of incidents in airline commercial aviation were related to some aspect of CRM. At the same time, Airbus (2004) stated that more than 70% of accidents or incidents during approach and landing were related to CRM issues. The prevalence of CRM issues reflected in the high percentage of accidents and incidents in commercial aviation, indicates there is a need to re-evaluate the manner in which non-technical skills training, such as CRM, is being delivered and evaluated. Such a re-evaluation should focus among other things, on the need to develop CRM training assessment methods to better identify pilots' real understanding of CRM concepts, and identify future training needs to fill knowledge gaps. The end goal of re-evaluating CRM training and assessment should be to prepare flightcrews to deal with the realities of the complex, modern flight deck.

In the early years of non-technical skills training in aviation, researchers and training practitioners aimed to develop CRM training programs based on general managerial techniques with little connection to line operations. Eventually, CRM evolved into a more aviation-oriented training in which flightcrews were trained on behavioral skills necessary to effectively function as a team in conjunction with aspects related to aviation systems, including automation (Helmreich, et al., 1999). Even though CRM training has evolved since its inception, the evaluation of training effectiveness as reflected by its impact on overall flight safety has been somewhat difficult to measure (Salas, et al., 2000; Weber et al., 2016).

In order to develop alternative CRM training assessment methods that could help enhance air safety, it is necessary to approach CRM training evaluation from a different perspective. To achieve this goal, this study focused on evaluating pilots' CRM schemas and identifying differences in CRM knowledge structures among pilots. Differences in CRM knowledge and opinions about training might indicate the existence of what Hatano and Inagaki (1986) describe as two distinct types of expertise, namely, *routine and adaptive expertise*. *Routine experts* are defined as those who have procedural knowledge of a task in a specific domain; on the other hand, *adaptive experts* not only are good at performing the task fast and accurately, they also have a well-developed conceptual knowledge of the task (this is discussed at length in chapter 2).

This study's purpose was to (a) identify differences among pilots on aspects related to CRM knowledge structures (schema) they have developed throughout their flying career (e.g., procedural vs conceptual knowledge of CRM principles), (b) identify differences between pilots on aspects of CRM training, (c) assess flightcrew differences in the perception on the value and efficacy of CRM training evaluation along with their opinion on how CRM training effectiveness be evaluated more accurately, (d) identify differences related to the amount of CRM training desired, as well as the delivery tools that would enhance training and application of CRM during line operations, and (e) attempt to identify a relation between type of expertise, flight experience, and personality traits (discussed in chapter 2).

Studies That Have Addressed the Problem

Throughout the history of CRM, many researchers and practitioners have been interested in understanding flightcrews' perceived value of CRM training and training effectiveness and how CRM affects flight safety. Systematic evaluation of training effectiveness is not always easy. In

aviation, assessment of training effectiveness is typically performed using Kirkpatrick's (1976) typology for training evaluation (Salas, Burke, Bowers, & Wilson, 2001). Kirkpatrick's typology is composed of four different levels of evaluation: Level 1, reactions to training; Level 2, learning from training; Level 3, behavior change due to training; and Level 4, organizational impact. Most of the CRM training evaluation is done following Kirkpatrick's Levels 1 and 2. Even though the evidence is not as concrete as it should be after decades of CRM training and evaluation, it does suggest that CRM is effective as reflected in flightcrews' reactions and training attitudes toward CRM (Salas, et al., 2001). According to O'Connor et al. (2008), O'Connor et al. (2012), and Salas, Wilson, and Burke (2006), most of the evaluations done regarding CRM training effectiveness are limited to using questionnaires to assess participants' reactions/attitudes towards CRM training (e.g., Did participants like the training? Did they think it was useful?), and assessment of CRM concepts through the administration of post-training knowledge tests. Studies that have used Kirkpatrick's Level 1 of training evaluation typically asked participants about the perceived value of CRM training. Generally, these studies have found that participants tend to evaluate CRM training positively (O'Connor et al., 2008; O'Connor et al., 2012; Ritzman et al., 2011a). One popular tool to evaluate flightcrews' attitudes towards CRM is the Cockpit Management Attitudes Questionnaire (CMAQ; Gregorich Helmreich, & Wilhelm, 1990; Helmreich et al., 1999; O'Connor, 2008). The purpose of the CMAQ is to provide an objective evaluation of crewmembers' attitudes pre- and post-training, and identify CRM topics that need further reinforcement (Gregorich, Helmreich, & Wilhelm, 1990). Even though tools like the CMAQ and other questionnaires developed to assess training effectiveness have asked flightcrews about the perceived value of CRM training, one criticism of these tools has been that they seem to offer no

real indication that what is learned during CRM training will be translated to behaviors on the flight deck.

Deficiencies in the Studies

Even though there is a wealth of research in which pilots were asked their opinion on the perceived value of CRM training, there is no literature, to my knowledge, that focuses on assessing flightcrews' CRM schema and type of expertise to identify different levels of CRM knowledge outside of the training context. There is a lack of research that investigates aspects such as, what pilots believe CRM is, how they apply it on the flight deck, and if they apply CRM to other aspects of their life outside aviation (i.e., have they developed a schema that has allowed them to use this knowledge in other areas of their lives?), and how responses differ based on pilots' knowledge structure of CRM. At the same time, no studies to my knowledge have investigated pilots' opinions about CRM training and evaluation, and more importantly, how pilots' responses differ in reference to type of expertise. Only one study investigating opinions about CRM training was found, but was not directly related to pilots' opinions. For instance, in an attempt to identify the current state of CRM training in Europe, the European Aviation Safety Agency (2014) surveyed organizations and individuals involved in the aviation industry in Europe and asked questions related to the kind of CRM training they provided. The EASA study evaluated aspects such as training delivery methods, groups involved in CRM training (e.g., combined training incorporating flightcrews and cabin crews), and length of initial and recurrent training. Even though this study yielded important information about the aspects of CRM mentioned above, the survey did not query flightcrews about their opinions related to CRM training and assessment. Evaluating airline transport pilots' CRM knowledge and opinions about training could be useful in developing new

assessment tools based on CRM schema evaluation (as reflected by type of expertise) that could potentially give a better understanding of CRM training effectiveness.

The Significance of this Study for Particular Audiences

The present study could have a potential impact on current and future flightcrews, their line operations, as well as on aviation organizations interested in optimizing CRM training, assessment, and its application on the flight deck. Exploring the possibility of using alternative evaluation methods that focus on flightcrews' CRM knowledge structures (schemas), based not only on their knowledge of CRM, but also on the opinions of their training needs, is not only of interest to the aviation industry, but also to those concerned with air safety. As stated by Salas et al. (2001), CRM training evaluation should look into appropriateness of content and methods used, data obtained from trainees' evaluations should aid in the optimization of effective transfer of training (and find the most effective ways to do so), and finally, it should serve as a way to identify areas in which more training is needed at the individual and team levels. Following this same line of thought, flightcrews' feedback should be considered in the design of new and more effective training and evaluation methods that could help researchers and training practitioners in the development of training programs that are in line with the realities of flightcrews. Equally important is the need to evaluate CRM training effectiveness in aviation to assess its impact on the modern flight deck as aircraft, especially as aircrew demographics, and operational conditions and risks have changed (O'Connor et al., 2008). It is also worth noting that as CRM became more ubiquitous in the aviation industry, it was also embraced by other high risk industries. Therefore, training assessment methods that look into CRM knowledge structures, and not merely basic

attitudes or declarative CRM knowledge, could help other industries in optimizing their own training curricula.

Since its inception and implementation in the aviation industry, other high risk professions have turned to CRM to improve non-technical skills in their teams. Healthcare, for instance, has shown an increasing interest in CRM training for over 20 years, and it has modeled its CRM training from the aviation industry (Gaba, Howard, Fish, Smith, & Sowb, 2001). Therefore, developing methods that seek to understand practitioners understanding of CRM while identifying their training needs, should be of interest to those who have embraced CRM as a way to improve team performance, regardless of the operational environment in which it is intended to be applied.

At the same time, this study adds to the current literature related to *routine* and *adaptive expertise*. Even though type of expertise theory was first introduced in the mid-1980s by Hatano and Inagaki (1986), there is a lack of studies focusing on adaptive/routine experts whose work take place in highly dynamic and complex environments such as aviation. Adding to the body of knowledge in this area could contribute to have a better understanding of types of expertise, and more specifically, adaptive expertise. Researchers interested in the field of type of expertise may benefit from studies such as this one, which aims at researching experienced subjects (such as Airline Transport Pilots [ATPs]) and how different variables such as experience in a specific field (e.g., Aviation CRM) and personality traits might play a role in the development of adaptive expertise.

The Purpose Statement

In regard to training evaluation, this study's purpose was to look at the possibility of identifying other potential training evaluation methods outside of the ones traditionally used in

aviation. In this respect, I was interested in understanding whether or not flightcrews have been able to develop a CRM schema which they can transfer to different situations outside the cockpit and perhaps to different domains. Therefore, the present study's goal was to evaluate flightcrews' CRM knowledge structures and identity differences (types of expertise) among them. This was achieved by using questionnaires related to type of expertise, personality traits, CRM knowledge, and opinions about CRM training needs. As part of CRM training needs, this study conducted a *person analysis* based on the needs assessment model created by Goldstein and Foster (2002). A key aspect of the *person analysis* is to identify the type of training that is required for the proper performance of trainees in their operational environment. This study sought out to find whether opinions about CRM training differed according to pilots' *type of expertise* in CRM. Given that the objective of this study was to survey ATPs working at major US carriers operating under FAR 14 CFR part 121, this approach allowed me to provide some insight into the potential development of a CRM training assessment method that could help practitioners better identify pilots' strength, weaknesses, and future training needs related to CRM.

The information collected during this study could be used to identify differences among pilots (as reflected by type of expertise) which could help develop a new CRM assessment method. Such a method could be used to better understand whether non-technical skills, such as CRM, are being transferred from training to the flight deck. While I intended to investigate flightcrews' understanding of CRM and their attitudes toward it outside of training contexts (Kirkpatrick's Level 1 and 2 of training effectiveness assessment), this study's primary goal was to identify CRM knowledge structure differences among pilots as reflected by their knowledge of CRM and opinions about perceived CRM training needs, while investigating factors that could play a role in the development of adaptive expertise.

CHAPTER 2: LITERATURE REVIEW

Ever since the implementation of CRM training 35 years ago, researchers have tried to understand the impact of training on safety. Today, there is still no consensus as to which assessment method provides the best indication of whether or not CRM skills taught during initial and recurrent training are being implemented on the flight deck. The purpose of the present study was to research how assessing a pilot's CRM schema could be used as a way to assess their level of CRM conceptual knowledge. The evaluation of CRM schemas for this study was in part explored through the assessment of adaptive expertise.

In this chapter, I first explore the literature on the CRM training assessment methods currently used, and then, I build the theoretical framework for the present study by reviewing the existing literature on types of expertise and assessment methods associated with adaptive expertise. Then, I discuss how using adaptive expertise assessment as a way to explore pilots' understanding of CRM could supplement current evaluation methods and help better identify training needs. This could potentially help CRM researchers and training developers to design alternative assessment tools from the ones traditionally used and, also, design training programs that best accommodate to different levels of CRM understanding in the airline pilot population.

The Evaluation of CRM Training

Because CRM is in essence a non-technical type of skill in which the use of appropriate behaviors within the flight deck is desired as an outcome of training, evaluating training effectiveness as measured by its impact on overall flight safety (reflected by flightcrew behavior) has been challenging (Salas et al., 2000; Weber et al., 2016). During the history of CRM, multiple methods to evaluate training have been employed, ranging from questionnaires measuring

trainees' attitudes towards CRM, to assessing flightcrews' coordination during line operations by trained observers (O'Connor et al., 2008; O'Connor et al., 2012; Salas et al., 2001; Salas et al., 2006). As discussed in this section, there are multiple challenges in the evaluation of CRM training effectiveness. Some of these challenges revolve around whether or not some of the tools used to evaluate training effectiveness are appropriate to gauge trainees' acquisition, development, and maintenance of CRM skills (Salas & Maurino, 2010). Other challenges relate to the standardization of evaluation methods (Nullmeyer, Spiker, Wilson, & Deen, 2003). Over thirty years of evaluating CRM training, researchers and practitioners have tried to develop different techniques to effectively assess training, yet no consensus has been reached in the community on whether the available tools and techniques are true indicators of training success. Perhaps, a different approach to the question of training effectiveness evaluation is needed.

Kirkpatrick's (1976) training evaluation hierarchy is a popular method used to organize the evaluation of training effectiveness (O'Connor & Jones, 2012). Table 1 shows the four levels of the hierarchy.

Table 1

Kirkpatrick's Training Evaluation Hierarchy (after Kirkpatrick, 1976)

Hierarchy Level	Description
Level 1: Reactions	Participants' reactions to training
Level 2: Learning	Knowledge gained from training
Level 3: Behavior Change	Application of knowledge to operational environment
Level 4: Organizational Impact	Evidence of training influence on the organization (e.g., increase productivity and/or safety)

According to O'Connor et al. (2008), O'Connor et al. (2012), and Salas, et al., (2006), most of the evaluations of CRM training effectiveness have been limited to using Kirkpatrick's first two levels of the hierarchy. Level 1 involves reactions/attitudes towards CRM training (e.g., Did participants like the training? Did they think it was useful?). Studies that use Kirkpatrick's Level 1, for example, typically ask participants about their perceived value of CRM training. Generally, these studies found that participants tend to evaluate CRM training positively (O'Connor et al., 2008; O'Connor et al., 2012; Ritzman et al., 2011a). At this level, one popular tool to evaluate flightcrews' attitudes towards CRM is to use and administer the Cockpit Management Attitudes Questionnaire (CMAQ; Gregorich, Helmreich, & Wilhelm, 1990; Helmreich et al., 1999; O'Connor, 2008). The CMAQ (Helmreich, 1984) is a 25-item scale that measures attitudes related to CRM at the conceptual or empirical level. The purpose of the CMAQ is to provide an objective evaluation of crewmembers' attitudes pre- and post-training and at the same time, identify CRM topics that need further reinforcement (Gregorich et al., 1990; Helmreich & Wilhelm, 1991). The CMAQ has been useful in identifying differences in pilots' attitudes toward CRM prior to and after training, with pilots' scores on the CMAQ indicating more favorable ratings of CRM after having received CRM training (Helmreich et al., 1999).

Assessment of training at Level 2 of Kirkpatrick's hierarchy is related to the assessment of concept learning achieved during training. This type of evaluation is usually done by administering a knowledge test covering aspects of CRM. After CRM training, participants tend to achieve high scores on knowledge tests, which also may reflect their positive attitudes towards the CRM training (O'Connor et al., 2012).

Evaluation of training using Kirkpatrick's hierarchy at the first two levels might not be sufficient to evaluate training effectiveness, however. Level 3 evaluates behavior change (e.g.,

Does training have an effect on the everyday behavior of employees after receiving training?); while Level 4 evaluates the training's organizational impact (e.g., accident rate reduction). Unfortunately, change in everyday behavior (Level 3) and overall organizational impact (Level 4) are very difficult to evaluate, and are thus rarely evaluated after classroom CRM training (O'Connor, 2008). Although simulator performance provides a glimpse at whether trainees can execute the learned behaviors, actual observations of CRM in the everyday setting require trained observers who can, by necessity, only evaluate a small portion of crews and flights. Thus, Kirkpatrick's hierarchy Levels 3 and 4 are difficult to explore when evaluating non-technical skills training, such as CRM training.

As mentioned before, there is little in the literature regarding an objectively quantifiable impact of CRM training on behaviors and organizational influence. As a result, O'Connor et al. (2008) stated that there is no simple way to know whether CRM training can meet the industry's expectations of training (i.e., increasing performance and flight safety). In their meta-analysis, O'Connor et al. also argued that there is no conclusive evidence that CRM affects everyday team behaviors (Kirkpatrick's Level 3), although anecdotal evidence seems to support this claim. Similarly, O'Connor et al. (2008) concluded that it is equally difficult to assess the impact of CRM training at the organizational level (Kirkpatrick's Level 4) because of the already low accident rate in the industry, where a single accident can greatly affect the metrics.

Given these difficulties with quantifying CRM training's impact at Kirkpatrick's Levels 3 and 4, team performance and at least the ability to demonstrate CRM behaviors in a job-like setting are often assessed during simulated scenarios (e.g., LOS/LOFT[training] and Line Oriented Evaluation [LOE]), which could be seen as a midpoint between levels 2 and 3 of the hierarchy. As part of line-oriented training, regulatory entities such as the Civil Aviation Authority (CAA)

(2003) in the UK, the FAA (2004) in the US, the European Aviation Safety Agency (EASA) (2012), and the International Civil Aviation Organization (ICAO) (2013), suggested that assessment of CRM skills should include self-critique and feedback (either during or after training). In addition, the FAA (2004) and the CAA (2003) stated that CRM should not be assessed on a pass/fail basis. Instead, there should be a requirement that crewmembers show progress on topics related to CRM. Furthermore, when assessing CRM skills, there should be room for individual feedback, identification of topics in which a specific crewmember should be retrained, and identification of possible ways to improve training (at the organizational level). Crewmembers' assessment should be developed based on a required standard (which should be published in the air carrier's operations manual). If performance is unsatisfactory, then it should be noted as such and remedial training should be required. Assessment should be done at the crew level and, if possible, also at the individual level. Before CRM training implementation, the methods used to assess, record, and provide feedback should be agreed upon between trainers and trainees, and should also be validated. Finally, there should be established procedures for crewmembers who do not meet standards. These crewmembers should have access to supplementary training.

The need for a standardized form of evaluating flightcrews on non-technical skills arose in the mid-1990s. As such, the development of a tool that could facilitate the assessment of crew performance during CRM evaluation (in order to make it easier for examiners and airlines) and to control for cultural and corporate differences was deemed important. However, despite this need, no standardization occurred across airlines, types of certificate holders, or regulatory entities in different countries. One set of tools that was suggested by entities like EASA (2012), CAA (2003) and FAA (2004) for flightcrew evaluation is the use of behavioral markers in the form of what has

become known as NOTECHS (non-technical skills). Flin et al. (2003) stated that the objective of NOTECHS is to assess the pilot's non-technical skills at the individual level, rather than at the crew level. The goal during development was to create a tool that was robust enough that it could be used across countries in Europe and by large and small carriers. Similar systems of behavioral markers have been used elsewhere, and many air carriers use some form of tool similar to NOTECHS.

Another approach to evaluate CRM skills is through the Line Operational Safety Audit (LOSA). LOSA assesses threat and error management skills (TEM) as well as CRM skills (Wagener & Ison, 2014). The advantage of LOSA is that it uses trained observers to identify and record behaviors and strategies used by flightcrews in line operations. Although these observations are conducted with no jeopardy for the flightcrew, the presence of the observers may influence flightcrew behavior, however. That is, flightcrews might be more likely to implement correct CRM behaviors and strategies when they are observed, in comparison to when they are not (and more importantly, LOSA auditors do not provide any kind of feedback to flight crews, nor are they qualified to provide such feedback). Thus, LOSA is only one component to assessing the transfer of CRM training by crews on the line as a whole, in conjunction with SOPs and other technical skills. That said, LOSAs are clearly one useful method to collect data, and therefore, standardization of CRM behavior assessment techniques during LOSA should also be considered as a way to assess effectiveness of training during line operations.

As seen above, the literature shows there is a prevalence of training effectiveness assessment for CRM at Kirkpatrick's Level 1 and 2, but, as also discussed in this section, evaluations at these levels are not good indicators of transfer of knowledge and application of skills from the classroom to the cockpit. Even though observational methods such as LOFT and LOSA

have been used to assess flightcrews' CRM skills, these methods have their own limitations, as having observers during these exercises might influence flightcrews' behavior, thus affecting in some way the validity of the observations. It is imperative to develop tools that allow researchers and, more importantly, practitioners, to more effectively and objectively assess training and identify whether or not desired CRM behaviors are being put into practice during line operations.

In regard to training evaluation, this study aims to look at the possibility of identifying other potential training evaluation methods outside of the ones traditionally used in aviation. In this respect, I was interested in understanding whether or not flightcrews have been able to develop a CRM schema which they can transfer to different situations outside the cockpit and also to different domains. The next section discusses schemas, analogical thinking, and types of expertise. I present these with the intention of looking at finding novel ways to test for CRM skill acquisition at a more abstract and deeper level that goes beyond the standard attitude and knowledge tests administered after training and that could indicate whether or not CRM behaviors are being applied in the cockpit.

Schemas and Analogs

Schemas can be defined as generalized cognitive structures that are formed by previous experiences, and that allow for the processing and organization of information received from stimuli in the environment (Markus, 1977). In problem solving, schemas are cognitive frameworks that assist in organizing and interpreting novel information and relating it to past experiences (Gick & Holyoak, 1983). Schemas are useful in the sense that they provide a shortcut to interpreting new information or unfamiliar situations by using structured patterns of thought developed during past experiences. When two situations share similar characteristics, an

analog is identified. Analog identification is elicited by the similarity of situational characteristics, which in turn, can elicit the retrieval of stored information produced by past experiences, to solve a novel problem or situation by using structured schemas (Reeves & Weisberg, 1994). This process is known as analogical thinking. According to Gick and Holyoak (1983), analogical thinking can be defined as the transferring of knowledge from one situation to the next by finding the similarities of two different situations. The purpose of an analogy is to make an unfamiliar situation more relatable, by comparing it to previously-learned experiences. When two analogs share both structure and surface elements, a positive analogical transfer occurs. Novick (1988) claimed that positive analogical transfer is more commonly recognized in experts than it is in novices. When experts are faced with an unfamiliar situation, they can identify similarities both in structure and surface more easily than novices can, making the transfer of knowledge from one situation or task to other unfamiliar situations/tasks more accurately. Farrington-Darby and Wilson (2006) provided a series of characteristics that separate experts from novices. Some of these characteristics include, adaptation of decision strategies to new task conditions, the ability to code new information more quickly and comprehensively, and the possession of a wealth of up-to-date content knowledge. But the transfer of knowledge from one situation to another might not always be achieved even by experts who excel under familiar circumstances. In this sense, Hatano and Inagaki (1986) have identified two types of expertise that may explain why some experts are able to adapt their schemas to novel situations.

Routine and Adaptive Expertise. Hatano and Inagaki (1986) have described the two types of experts as *routine* and *adaptive experts*. Routine experts are defined as those who have procedural knowledge of a task in a specific domain. These experts can perform tasks fast and accurately, but in general, lack the conceptual knowledge of why tasks are executed in a given

way. On the other hand, adaptive experts not only are good at performing the task fast and accurately, they also have a well-developed conceptual knowledge of the task, which allows them to understand the meaning of the skill needed in a specific situation. Understanding the meaning of the skill is what allows adaptive experts to transfer those skills to a novel task or situation. In this sense, Kimball and Holyoak (2000) stated that:

> Adaptive expertise seems to require the development of flexible and abstract learning mechanisms and schemas to promote a deeper conceptual understanding of the expert domain and the transfer of knowledge to novel tasks and domains (p. 119).

Adaptive expertise appears to develop when conditions in the operational environment vary, forcing task performers to alter their schemas and adapt their procedures, as conditions in the environment change. This change in conditions allow task performers to put in practice their *know how* and experiment with procedures to help them achieve a desired outcome. The more variance there is in the environment, the more the task executioner needs to adapt his/her procedures (Barnett & Koslowski, 2002; Hatano & Inagaki, 1986; Kimball & Holyoak, 2000). It seems that it is the repetition of a task with certain degrees of variation that leads to adaptive expertise (Hatano & Inagaki, 1986). Based on these study goals and taking into consideration the literature on adaptive expertise, and personality traits, I present the following research question:

> *Research Question 1: Is there a relationship between pilots' flight experience variability and type of expertise?*

Characteristics of Adaptive Experts The literature pertaining to adaptive expertise describes certain characteristics that separate adaptive experts from routine experts. First, it is important to note that both routine and adaptive experts possess similar levels of performance in their domains of expertise under familiar circumstances (Hatano & Inagaki, 1986; Kimbal &

Holyoak, 2000). Both types are fast and efficient performers, and have similar levels of explicit and procedural knowledge. The main difference between the two types of experts is in the level of understanding of *why* certain steps or procedures within a process are executed (conceptual knowledge), allowing adaptive experts to use their schemas in adaptive and tuned ways that are far from the reach of routine experts (Hatano & Oura, 2003).

Adaptive experts have distinct characteristics that are absent in routine experts. The first characteristic as described by Hatano and Inagaki (1986) is the desire, or at least, willingness to engage in experimentation of alternative procedures. The second characteristic is the capacity of adaptive experts to transfer knowledge to novel situations, while using these situations as learning opportunities to deepen their conceptual understanding (Kimbal & Holyoak, 2000). The third characteristic is associated with epistemic (the philosophical view of knowledge; either being permanent and static, versus, the view of knowledge as being flexible and evolving) and metacognitive components that drive the development of adaptive expertise through active monitoring of their state of knowledge and understanding of a task/problem and its context (Charbonnier-Voirin & Roussel, 2012; Crawford, Schlager, Toyama, Riel, & Vahey, 2005). While the epistemic component in adaptive experts allows them to view the world as complex and constantly changing, pushing them to the limits of their knowledge and skill in their area of expertise, the metacognitive component urges them to monitor their level of understanding, by assessing their level of performance, not only in routine scenarios, but also in novel situations (Crawford et al., 2005). This procedure allows for processes of explanation testing, which can help adaptive experts to understand how and why a certain strategy or procedure works under certain circumstances but not in others (Bohle Carbonell, Konings, Seger, & Merrienboer, 2016; Schwartz, Bransford, & Sears, 2005).

In addition to the willingness to engage in experimentation of alternative procedures, the capacity to transfer knowledge to new situations, and the awareness of their level of knowledge combined with the view of knowledge as constantly evolving (metacognitive and epistemic components), a fourth characteristic is present in adaptive experts. This last characteristic is associated to their drive for innovation, creativity, and their desire to seek out challenges (Bohle Carbonell, Stalmeijer, Konings, Segers, & Van Merrienboer, 2014; Hatano & Oura, 2003). In this sense, Schwartz et al. (2005) and Wineburg (1998) claim that adaptive experts are not only efficient, but can also rearrange their thinking and use their existing knowledge as a way to create innovative solutions when faced with novel situations.

Bohle Carbonell et al. (2016) thus summarize characteristics of adaptive experts under three dimensions: (a) domain skills, (b) metacognitive skills, and (c) innovation skills. While the domain skills dimension is present in both routine and adaptive experts (Hatano & Oura, 2003), it is the metacognitive and innovation skills that prompt adaptive experts to develop greater levels of understanding, allowing for the development of conceptual knowledge (Hatano & Inagaki, 1986; Paletz, Kim, Schunn, Tollinger, & Vera, 2013). Even though metacognitive and innovation skills are particular dimensions belonging to adaptive experts, it seems that routine expertise, reflected by domain knowledge, is a precursor of adaptive expertise (Bohle Carbonell et al., 2014), but more research is needed in order to understand whether factors other than domain expertise are influential in the development of adaptive expertise.

The scientific community researching adaptive expertise has been able to identify particular characteristics of adaptive experts (as discussed above). At the same time, researchers have also tried to identify factors associated with the development of adaptive expertise. One of those factors is personality, which I discuss next.

Personality Factors and Adaptive Expertise The Big Five personality factors, (1) agreeableness, (2) conscientiousness, (3) extraversion, (4) neuroticism/emotional stability, and (5) openness to experience, have been used in the past to identify their relationship, among other things, to job performance (Barrick, Mount, & Judge, 2001; Goldberg, 1993; Le et al., 2011; Mount & Barrick, 1998) and problem solving (Athota & Roberts, 2015; O'Brien & DeLongis, 1996; Taggar, 2002). Personality traits, such as openness to experience (O'Brien & DeLongis, 1996; Taggar, 2002), conscientiousness (O'Brien & DeLongis, 1996; Taggar, 2002), and extraversion (Athota & Roberts, 2015; Taggar, 2002) have been associated with higher job performance and better creative problem solving. With respect to expertise, research examining the relationship between personality traits and type of expertise has not yielded concrete evidence. Bohle Carbonell et al. (2014) and Crawford et al. (2005) mention that there has been an interest in the scientific community to establish a relationship between adaptive expertise and personality factors. Bohle Carbonell et al. (2014) present a review of studies that have measured adaptive expertise as well as personality factors. The review of the literature done by Bohle Carbonell and colleagues shows that (a) there is a lack of studies that address the relationship between personality factors and adaptive expertise, and (b) the results of those studies show inconsistent evidence of the personality characteristics associated with adaptive expertise. Factors, such as conscientiousness, extraversion, and emotional stability/neuroticism, were significant factors in some studies but not in others. The main issue that might have contributed to the inconsistency of the results from the studies presented in Bohle Carbonell's et al. (2014) review, is that either adaptive expertise or adaptive performance was assessed. These two constructs are related but not analogous to one another. Scales reviewed by Bohle Carbonell et al. that measured adaptive performance did not include subscales on the unique epistemic and

metacognitive components that are associated with adaptive expertise (Charbonnier-Voirin & Roussel, 2012; Crawford et al., 2005), and which are part of the metacognitive skill dimension of adaptive expertise (Bohle Carbonell et al., 2016).

Even though personality traits, such as openness to experience, conscientiousness, and extraversion, have been linked to superior job performance and creative problem solving (e.g., Feist, 1999; McRae, 1987; Neuman & Wright, 1999; Taggar, 2002), a relationship between these personality traits and adaptive expertise has not yet been established. Therefore, it is important that more studies investigate the connection between personality traits and adaptive expertise, especially in highly dynamic fields such as commercial aviation. Investigating whether a relationship exists, could help expand the currently limited literature on adaptive expertise. Although not a main focus, the proposed study looked at the relationship between personality traits and adaptive expertise. For this purpose, I used one of the many available personality inventories, in this case the Big Five Inventory (BFI) developed by John, Donahue, and Kentle (1991). Based on these study goals and taking into consideration the literature on adaptive expertise, and personality traits, I present the following research question:

Research Question 2: Is there is a relationship between personality traits and adaptive expertise?

The Assessment of Adaptive Expertise Adaptive expertise is a construct that, while defined and described as a theoretical construct in the literature, has been difficult to measure in practice (Bohle Carbonell et al., 2016; Walker, Cordray, King, & Brophy, 2005). One reason may be that researchers have approached the assessment of adaptive expertise from at least two distinct perspectives. First, case studies and think aloud techniques have been used by some researchers (Crawford et al., 2005; Barnet & Koslowski, 2002; Walker et al., 2006). The

purpose of using this approach is to do a qualitative analysis of responses given by participants either through semi-structured interviews or open ended questionnaires. More specifically, these studies look into the richness of responses given by participants when exposed to uncommon/novel scenarios in their areas of expertise, which may indicate *adaptive tendencies* if responses are rich in structure, show complexity of concepts and ideas, and include comments in which participants question the accuracy of their own responses or understanding of the task at hand (Crawford et al., 2005; Barnett & Koslowski, 2002; Walker et al., 2006). At least one study (see Crawford et al., 2005), gave participants the option to explore novel material in their domain (which would allow them to better understand the task they were asked to perform). Willingness of participants to read the novel material was, according to the authors, an indicator of adaptive expertise. While such studies can provide valuable qualitative information about differences between routine and adaptive experts, they do not provide evidence of the influence of the epistemic and metacognitive characteristics of adaptive experts. Instead, questionnaires seem to be a better tool for the study of these characteristics.

Some instruments (Appendix B) have been developed in the past twenty years to measure either adaptive performance, using the Job Adaptability Inventory (JAI; Pulakos Arad, Donovan, & Plomondon, 2000); professional flexibility, using the Measurement of Professional Expertise (Van der Heijden, 2000); adaptive expertise, using the Adaptive Expertise Inventory developed by Bohle Carbonell et al. (2016); or attitudes of adaptive expertise, using a scale developed by Fisher and Peterson (2001). Bohle Carbonell et al. (2016) pointed out that none of the available scales are effective in measuring all three dimensions of adaptive expertise.

Even though Bohle Carbonell and colleagues developed an instrument to comprehensively measure adaptive expertise, this instrument has not been made public yet, and

even further, it measures only two of the three dimensions of expertise (domain skills and innovative skills). Another instrument, the Job Adaptability Inventory (JAI; Pulakos et al., 2000) is only available commercially. There are then only a couple of instruments available, Van der Heijden's (2000) and Fisher and Peterson's (2001) scales. Van der Heijden's (2000) instrument is available, but poses a few issues. First, it does not have a subscale embedded to examine the epistemic component associated with adaptive expertise (Bohle Carbonell et al., 2016). Second, Van der Heijden's questionnaire focuses on professional flexibility and not on adaptive expertise per se. Most of the 78 items in the instrument are difficult to use when assessing very specific aspects within a domain, as these items focus on general work skills and are worded to assess general job flexibility and performance (e.g., "During that period, I produced…[very little – a very great deal of] … work."). For instance, the questionnaire would be a good instrument to assess professional flexibility in aviation but not to identify adaptive expertise related to CRM. If this instrument were to be used to assess flexibility in relation to CRM, most of its items would have to be heavily modified to make them CRM specific, compromising the instrument's validity (see Appendix B). Fisher and Peterson's (2001) instrument is more oriented towards adaptive expertise and, even though it lacks a subscale to measure domain skills, it meets the criteria to measure for metacognitive and innovative skills dimensions (Bohle Carbonell et al., 2016). The lack of a domain skill component could be corrected by providing a domain specific knowledge assessment test.

Each of the studies that I reviewed, assessed adaptive expertise by either using case studies/interviews or questionnaires. None of the reviewed studies used a combination of both (only Fisher and Peterson [2001] conducted few, brief interviews to validate their scale). Using a combination of both techniques could give a better picture of how to better measure adaptive

expertise and develop more effective methods of measurement. Also, of the studies reviewed, only one (Crawford et al., 2005) used what would be considered experts (science teachers with multiple years of experience). All other studies either used college students, or dissonant samples (restaurant managers combined with business consultants). A study using a sample of experienced professionals (e.g., airline pilots) and examining specific areas of their domain of expertise (e.g., CRM skills), to my knowledge, had not been conducted yet.

Adaptive Expertise versus Recognition-Primed Decision Model (RPDM). As discussed, adaptive expertise describes those individuals who are not only good at performing a task fast and accurately in their domain of expertise, but also have a well-developed conceptual knowledge of the task, which allows them to understand the meaning of the skill needed in a specific situation. These characteristics allow adaptive experts to transfer those skills to a novel task or situation. It is easy to associate adaptive expertise with the Recognition-Primed Decision Model (RPDM) developed in the 1980s by Gary Klein, based on his observations of how fireground commanders made decisions under time pressure (see Klein, Calderwood, & Clinton-Cirocco, 1986). As described by Klein (1993), the RPDM model explains how people, and more specifically experts, make decisions by applying a combination of (a) situation assessment (pattern matching) and (b) mental simulation (deliberate analysis). Klein (2008) claims that a combination of (a) and (b) is necessary for an expert to make rapid decisions effectively, as relying on pattern matching alone is risky because it sometimes generates imprecise matches, and relying on mental simulation to explore all possible options is too inefficient. But even when a combination of both is used, sometimes generating an appropriate response is not possible, even by experts. Klein (1999) describes an episode in which, when faced with an unusual oil farm fire, fireground commanders (who had never dealt with this type of fire),

reverted to a novice state, generating inefficient strategies to both deal with the fire and coordinate efforts amongst different fireground commanders. Klein describes how fireground commanders generated multiple, unsuccessful solutions, but he does not describe (nor does RPDM) the reasons why these experts were not able to successfully adapt to an unusual situation in their area of expertise. Furthermore, in a postscript added to the seminal work on his RPDM, Klein, Calderwood, and Clinton-Ciroco (2010) recalled the oil farm fire (oil pumping station). Klein et al. (2010) claimed that the inability of fireground commanders to produce effective fire-containing solutions, was due to inexperience (despite of their extensive expertise as fireground commanders) and not due to failure to adapt to a novel situation. There is not to my knowledge any literature that explains this *novice reverted state* in Klein's RPDM.

Thus the RPDM model explains the process experts use to make decisions, but the model itself does not explain, or even addresses, why even some experts revert to novices when faced with unusual situations. Hatano and Inagaki's (1986) theory in types of expertise might help better explain why some experts are able to adapt to new situations and apply their skills in efficient ways and even sometimes, transfer those skills across domains.

Schema, Adaptive Expertise and CRM Assessment

As I discussed earlier, the assessment of CRM training effectiveness has been a challenge for the scientific community interested in studying team performance and measuring the implementation of non-technical skills in complex and dynamic systems. Tools historically used include attitude/knowledge tests and simulation scenarios. CRM training has faced some criticism as its impact on aviation safety is not clearly understood. Developing and using assessment tools besides those typically implemented in the aviation community should be

considered. In that aspect, the present study aimed to look at CRM assessment from a different angle. Besides looking at declarative knowledge (detached from a pre/post- training setting), I intended to study pilots' conceptual knowledge of CRM skills (type of expertise), as reflected by pilots' ability to (a) apply CRM skills outside the flight deck context, and (b) provide insightful information on the current state of CRM training and future training needs.

In the case of CRM in aviation, I expected that those who had a well-structured CRM schema, would also be able to provide rich explanations of what CRM is in relation to line operations (domain skill). A well-structured schema is indicative of domain expertise, especially when experts are probed for goal-relevant information in their domain (Kimball & Holyoak, 2000, Schvaneveldt et al., 1985). The present study also looked into the type of expertise (routine or adaptive) pilots possessed in relation to CRM skills. Differentiating between types of expertise was achieved by using a combination of instruments including, (a) administering an adaptive expertise assessment instrument (i.e., Fisher & Peterson, 2001), (b) a probe for whether or not pilots have used CRM outside of line operations (a set of questions in relation to context, reason, and outcome), and (c) by asking pilots to provide insights about the needs to improve CRM training. Pilots' CRM training insights could be examined by asking pilots about their opinion/training needs related to training length, topics within CRM, delivery methods, and training assessment techniques. Answers collected during the study were analyzed in order to identify patterns. It would be expected that adaptive experts would be more critical of current CRM training and provide well-structured ideas about how to better train and assess CRM skills. Based on these study goals and taking into consideration the literature on schemas, adaptive expertise, and CRM training assessment, I present the following research hypothesis:

Hypothesis 1: Adaptive expert pilots differ from routine expert pilots in their use of CRM skills outside the flight deck. Adaptive experts will be more likely to express that they have used CRM skills (or be able to identify how these skills could be used) in situations outside the flight deck.

As it has been discussed in the section pertaining to types of expertise, adaptive experts differ from routine experts. For instance, Hatano and Inagaki (1986) stated that adaptive experts have a well-developed conceptual knowledge of the task, which allows them to understand the meaning of the skill needed in a specific situation. Similarly, adaptive experts are characterized by their drive for innovation, creativity, and their desire to seek out challenges (Bohle Carbonell, Stalmeijer, Konings, Segers, & Van Merrienboer, 2014; Hatano & Oura, 2003). In the context of CRM training and evaluation, it would be appropriate to assume that there are differences between how routine and adaptive experts opinions about training and evaluation needs differ from one type of expertise to the other. In relation to how pilots perceive current CRM training length, I believed adaptive experts would perceive training length as insufficient, including the distribution of the time spent using different methods during training (e.g., time spent in class lectures vs time spent in the simulator). As mentioned before, adaptive experts have a desire for experimentation and for seeking out new challenges. In this context, adaptive experts might like more time training CRM, perhaps, more unstructured simulator time in which they can experiment different techniques in different situations (unusual situations), in lieu of for instance, class lectures, which they may not find as useful as free simulation time. In this aspect, adaptive experts may find that the distribution of time spent on different training methods may not be appropriate, they might favor using more time to train aspects such as crew communications and coordination, or even the opportunity to train with different groups (e.g., flight attendants,

dispatchers, or maintenance crews) with whom they usually don't have the opportunity to train. Adaptive experts recognizing the need of prioritizing certain training methods over others, and training with different groups, would influence their opinions about time needed for CRM training and also the distribution of the time spent on different methods within a training session. Based on these study goals and taking into consideration the literature on schemas, adaptive expertise, and CRM training assessment, I present the following hypothesis:

Hypothesis 2: Adaptive expert pilots differ from Routine expert pilots in their opinions about CRM training length and the distribution of time in relation to methods used within a given training session. Adaptive experts will be more likely to express that there is lack of time during training to engage in non-routine scenarios where CRM skills are most needed, and that too much time is used practicing/reviewing routine scenarios.

As mentioned above, adaptive experts would also have a different opinion about delivery methods in comparison to routine experts. While routine experts might be content with current training delivery methods, adaptive experts might see the potential of, for instance, training certain CRM concepts via mobile technology (in lieu of class lectures and as a way to optimize recurrent training). Adaptive experts might hold a less favorable view of class lectures and identify simulator time (e.g., LOS) as more favorable and desirable, as they can use this method to practice CRM skills, while flying different types of scenarios. Adaptive experts might be open to post-simulator exercise debriefings as a way to gain insights on their own performance and improve their own CRM skills. In general, adaptive experts would have a better idea about what training methods could be more beneficial to gain, maintain, and improve CRM skills. They could have a different idea about how current delivery methods are used and how other potential

alternative methods could be integrated with existing methods. Based on these study goals and taking into consideration the literature on schemas, adaptive expertise, and CRM training assessment, I present the following hypothesis:

Hypothesis 3: Adaptive expert pilots differ from Routine expert pilots in their opinions about the use of CRM training delivery methods. Adaptive experts will be more likely to express their desire to use novel training delivery methods in lieu of, or as a supplement to traditional training delivery methods.

In relation to training topics, adaptive experts, because of their better knowledge structure of CRM, might see the need to modify or eliminate current CRM topics from training (e.g., crew communications, leadership and followership), or even add new topics/concepts (e.g., intragroup communication and coordination, Intragroup SA, communication and coordination during unusual/emergency events). These opinions on CRM training topics could be due to adaptive experts understanding of CRM as a set of strategies used to reach the goal of flight safety, not only during routine operations, but also when faced with unexpected situations. Based on these study goals and taking into consideration the literature on schemas, adaptive expertise, and CRM training assessment, I present the following hypothesis:

Hypothesis 4: Adaptive expert pilots differ from Routine expert pilots in their opinions about CRM training topics. Adaptive experts will be more likely to suggest modifications (adding and/or eliminating) to currently trained topics in CRM.

Adaptive experts might also have a different opinion on current CRM training evaluation techniques. They might identify knowledge questionnaires as an ineffective way to comprehensively measure for CRM understanding and as predictor of future CRM

implementation on the flight deck. But adaptive experts might understand that there is some value in assessing a pilot's declarative CRM knowledge under certain circumstances (e.g., when someone is just starting to get familiar with CRM concepts or goals). They might identify LOFT and LOSA as an effective way not only to observe flight crews CRM skills, but also as a valuable learning opportunity by providing feedback in a non-punitive environment. Adaptive experts might know that CRM training evaluation might differ depending on a pilot's flight experience, and understanding of CRM principles. For instance, they might think it is perfectly fine to test novices on their declarative knowledge of CRM. But adaptive experts might recognize that, as novices develop a better understanding of CRM, other techniques might be necessary in order to assess whether or not a pilot has expanded his/her understanding of CRM principles. Adaptive experts might even suggest novel assessment methods that differ from the standard methods currently used to assess CRM training effectiveness. Based on these study goals and taking into consideration the literature on schemas, adaptive expertise, and CRM training assessment, I present the following hypothesis:

Hypothesis 5: Adaptive expert pilots differ from Routine expert pilots in their opinions about techniques used and their effectiveness to assess CRM training. Adaptive experts will be more likely to identify current evaluation methods as inadequate and insufficient.

Type of Expertise and Attitudes toward Automation Systems as Teammates. Hoeft et al. (2006) suggested that autopilots should be thought of as an additional crewmember with unique characteristics. Therefore, training should be developed to help pilots understand its capabilities and limitations emphasizing the need to not only monitor the system, but to coordinate with it while being cognizant of autopilot's own limitations. In their studies (Nass, Steuer, & Tauber, 1994) have shown that "experienced computer users do in fact apply social rules to their interaction with computers" (p. 77) and that the effects of working in a team with a computer is comparable to team dynamics shown in human-human teams (Nass, Fogg, & Moon, 1996). Even further, Nass et al. (1996) have suggested that perception of team identification with a computer is related to the sense of interdependence, that is, the human knows that his/her performance is influenced/affected by the computer's performance. It could be assumed that those individuals categorized as adaptive experts in relation to CRM skills, would be able to see a certain level of analogy between human-human coordination in the cockpit and human-computer coordination (especially when high levels of automation are used) in the cockpit. These experts may recognize that training to interact with automation as if it was another crewmember would be beneficial. While routine experts would be unable to make an analogy between human-human and human-computer interaction, thus, being reluctant to treat automation like another crewmember. Based on these study goals and taking into consideration the literature on adaptive expertise, and CRM training, and automation, I present the following hypothesis:

Hypothesis 6: Adaptive expert pilots differ from Routine expert pilots in their view of automation as a crewmember. Adaptive experts will be more likely to see automation as an additional crew member.

The aspects of the present study discussed in this chapter could help in the identification of the level of CRM understanding among flight crews. This could help training departments to identify different levels of CRM knowledge among crewmembers (i.e., explicit vs. procedural vs. conceptual), allowing them to better develop CRM training methods that adapt to different levels of expertise (allowing novices to become routine experts and routine experts to become adaptive experts). This is important because, a strong CRM schema can help flightcrews to effectively use CRM skills efficiently not only during routine operations, but to more effectively use these skills in emergency situations.

At the same time, being able to take into consideration different types of expertise could help practitioners develop more effective assessment methods. For instance, presenting flightcrews with a situation in which CRM skills are desired to effectively solve a problem where the problem/situation presented is not aviation related, could help training departments understand trainees' level of CRM understanding. This type of approach could test flight crews beyond Kirkpatrick's Level 1 (attitudes) and Level 2 (knowledge gained from training) by examining the strength of CRM schema and their conceptual understanding of CRM skills (type of expertise) acquired by pilots, not only after CRM training, but through their experience as pilots. Even though I acknowledge that testing schema strength is in essence testing for pilots' knowledge of CRM, it is done at a more abstract and less obvious level. The difference between declarative tests and testing for schema, is that the first assesses information recall ability, while the latter looks at CRM knowledge structure at a higher level. This could allow training practitioners to develop CRM training programs and/or supplemental material that can aid those with poor conceptual understanding of CRM principles (novices, and to a lesser extent routine

experts) develop better knowledge structures. This with the goal of training pilots who can better understand and properly apply CRM principles during line operations.

For the present study, it was important to identify participants' level of flight expertise and contrast this expertise with CRM expertise. In order to identify general flight expertise, questions related to current crew position, number of flight hours (total commercial flight time, and current air carrier flight time), and international route flight experience were asked. Subsequently, the present study asked pilots (through open ended questionnaires) whether or not they have applied CRM principles (or how CRM principles could be applied) to situations outside the flight deck in which team coordination is needed. A potential variance in responses could help identify pilots' CRM level of understanding and help differentiate routine experts from adaptive experts. At the same time, Hatano and Inagaki (1986) have suggested that those individuals who develop conceptual knowledge are capable of developing new procedures. In other words, are there any CRM strategies used by pilots (presumably those with adaptive expertise) that are not currently being taught during formal CRM training. I believe that pilots with different levels of CRM understanding (as reflected by the type of expertise) would provide different opinions about CRM training (i.e., training length, topics, delivery methods, training assessment, and automation management), being adaptive experts the ones who are less satisfied with current CRM training, thus providing insightful views and solutions about CRM training and assessment.

Table 2

Summary of the Hypotheses for the present Study

Hypothesis	Description
Hypothesis 1	*Adaptive expert pilots differ from routine expert pilots in their use of CRM skills outside the flight deck. Adaptive experts will be more likely to express that they have used CRM skills (or be able to identify how these skills could be used) in situations outside the flight deck.*
Hypothesis 2	*Adaptive expert pilots differ from Routine expert pilots in their opinions about CRM training length and the distribution of time in relation to methods used within a given training session. Adaptive experts will be more likely to express that there is lack of time during training to engage in non-routine scenarios where CRM skills are most needed, and that too much time is used practicing/reviewing routine scenarios.*
Hypothesis 3	*Adaptive expert pilots differ from Routine expert pilots in their opinions about the use of CRM training delivery methods. Adaptive experts will be more likely to express their desire to use novel training delivery methods in lieu of, or as a supplement to traditional training delivery methods*
Hypothesis 4	*Adaptive expert pilots differ from Routine expert pilots in their opinions about CRM training topics. Adaptive experts will be more likely to suggest modifications (adding and/or eliminating) to currently trained topics in CRM*
Hypothesis 5	*Adaptive expert pilots differ from Routine expert pilots in their opinions about techniques used and their effectiveness to assess CRM training. Adaptive experts will be more likely to identify current evaluation methods as inadequate and insufficient*
Hypothesis 6	*Adaptive expert pilots differ from Routine expert pilots in their view of automation as a crewmember. Adaptive experts will be more likely to see automation as an additional crew member*

What a CRM Adaptive Expert Pilot Looks Like. This individual has ample experience flying aircraft and has been exposed to different types of systems (e.g., Boeing and Airbus aircraft). S/he has been exposed to CRM principles for many years, and has undergone a series of CRM initial and refreshing training. The exposure to CRM principles has allowed the individual to apply these same principles to line operations. The pilot, can efficiently use these principles during routine operations (expertise) and is very effective in his/her communication exchanges

with other crewmembers (a characteristic of adaptive expertise even during routine operations [Bohle Carbonell, personal communication, December 9, 2016]). But this expert pilot does not only apply CRM principles as trained, s/he is constantly looking for new ways to try different alternatives to deal with CRM principles different from what s/he was taught in the classroom/training sessions (willingness/desire to experiment). At the same time, s/he is interested in acquiring up-to-date information related to CRM principles as new information might have emerged that s/he is not aware of (metacognitive component). S/he is the kind of expert that under unusual circumstances during flight can: exchange information in a more effective way; being able to articulate what is needed from the rest of the crew; and asks for more structured information to better deal with unusual circumstances and adapt procedures to challenging situations (adaptiveness). This is the kind of individual that would voluntarily fill out an Aviation Safety Action Program (ASAP) report (as s/he understands that it is unusual circumstances/close calls the ones that would help him and his colleagues in general to develop better techniques to augment crew coordination and hence, air safety). During CRM refresher training her/his attitudes toward CRM remain positive (as reflected by pre and post training CMAQ scores), as s/he understands the reasoning behind training and the importance of implementing CRM during line operations. When her/his knowledge and understanding of CRM is assessed, s/he can provide answers which structure reflects a higher understanding of CRM goals. When for instance asked about what CRM is, s/he could provide an answer describing the main ideas of CRM, perhaps detached from the aviation context (as s/he understands that these principles apply to any circumstance in which team coordination is necessary or desirable). S/he can provide helpful insights into what training should be like in the future (as technology evolves inside the cockpit, s/he understands that so should CRM training to better interact with newer

technology), suggesting topics, or even proposing new CRM strategies that s/he has been able to develop during her/his flying career, or that s/he has heard/seen others using (as s/he understands that knowledge is dynamic and constantly changing [epistemic component]). This expert cannot only apply CRM principles during line operations, but perhaps has been able to use it (or at least is capable of seeing how it could be used) in different aspects of her/his life, detached from the aviation context.

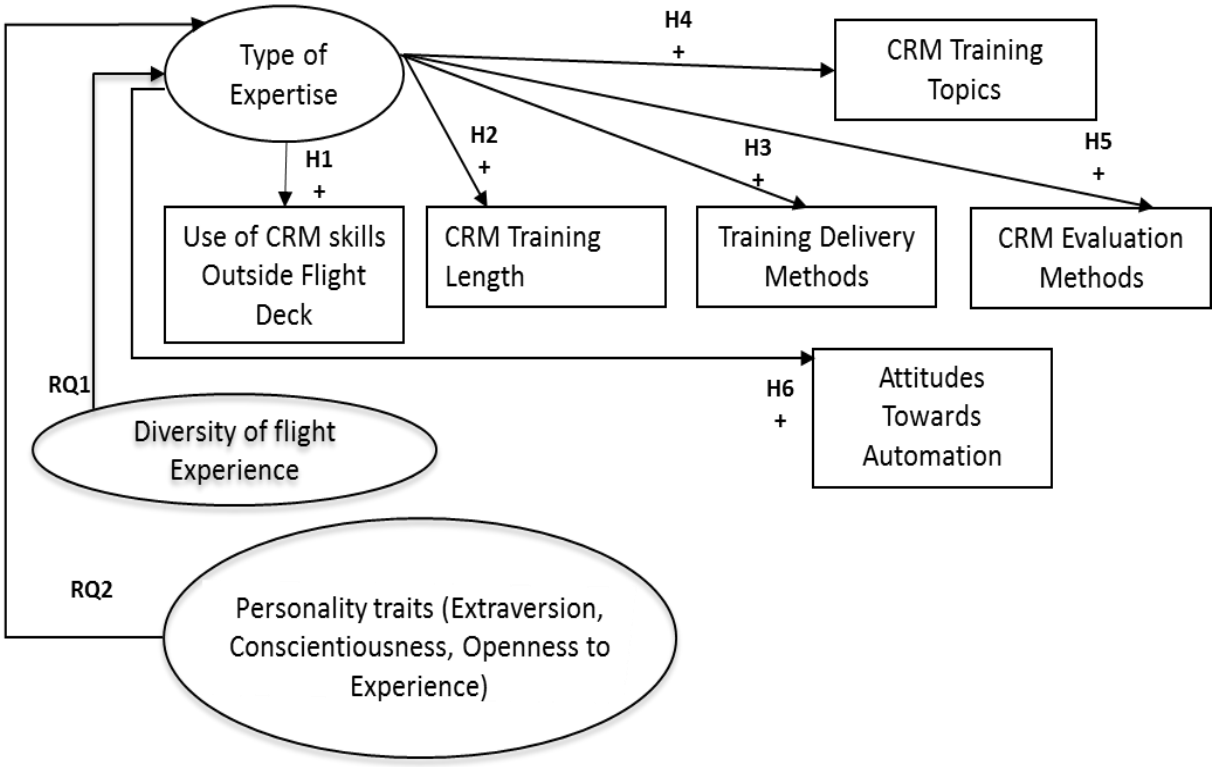


Figure 1: Relationship between constructs based on proposed hypotheses

CHAPTER 3: METHODOLOGY

Participants

The participants for the proposed study were Airline Transport Pilots (ATPs) with recent relevant airline employment (within the previous 18 months) at major and regional US carriers operating under 14 CFR part 121. Since the goal of this study was to identify type of expertise (routine vs. adaptive) differences in relation to CRM skills, a sample drawn from the current US ATP population was ideal for this study. ATPs are not only considered experts in flight operations (as they hold the highest level of pilot certification), but also they have an expert level understanding of CRM. In general, pilots are introduced to CRM concepts very early on during their first hours of flight training, and by the time they become ATPs they have been exposed to CRM training and concepts for multiple years. ATPs did not receive monetary compensation for their participation in the study and their participation was completely voluntary. A request for study participants was posted on web based pilot forums and other professional networking websites.

Roughly 3,000 ATPs were contacted and 459 agreed to participate in the study. Of the 459 that participated in the study, only 260 completed the survey (no missing answers) up to the Adaptive Expertise Questionnaire. Five responses were excluded from the analysis after these scores on the adaptiveness questionnaire were determined to be outliers and the response patterns suggested that the respondent was not carefully reading the survey items (e.g., respondents who marked all items with the most extreme response).

Design

For the present study, a survey approach was taken, and Mann-Whitney U tests were performed for hypothesis one and a one-way MANOVA was used to analyze the data for hypotheses two through six. Type of expertise (Routine vs. Expert) served as a quasi-independent variable. Use of CRM skills outside the flight deck, opinions on CRM training needs (i.e., training length, delivery methods, training topics, training assessment), and views on automation served as dependent variables. An a priori power analysis using G*Power (Faul, Erdfelder, Buchner, & Lang, 2009) indicated that in order to obtain medium effect size, an estimated sample size for a one-way MANOVA and five dependent variables (hypothesis one was excluded from this estimation since it was to be analyzed using non-parametric methods), with an alpha = .05 and power = .80 would be $N = 212$. Since the proportion of adaptive and routine experts in the sample was expected to be unequal, I calculated a total sample size taking into consideration the formula used by Whitley and Ball (2002) for estimating sample size for unequal groups. Making the assumption that there would be twice as many routine experts as there would adaptive experts, the total sample size for this study was estimated to be N = 239.

The present study was in nature cross-sectional, and data was collected once for each participant. The data collected then served as a snapshot of participants' current level of CRM understanding, opinions about CRM training needs, and type of expertise.

Apparatus

The surveyed was administered online through Qualtrics Survey Software. Participants were given a link they could follow to participate in the study. Data collected in this study were analyzed using IBM's (2016) Statistical Package for the Social Sciences Version 24.0 (SPSS).

Answers to open-ended questions were in part analyzed using IBM's (2017) SPSS Modeler Premium Version 18.1.

Measures

Demographics Questionnaire The demographics questionnaire was developed specifically for this study and it included items asking participants about age, gender, flight experience (number of hours), flight experience (number and description of aircraft type flown), type of airline they currently work for, rank, and last time recurring training was received. Other items, such as military experience and flight training background were also included in the questionnaire.

Personality Traits Questionnaire The Big Five Inventory (BFI) developed by John, Donahue, and Kentle (1991) was used in this study (Appendix C). The BFI is a 44 item personality inventory which measures all 5 factors (agreeableness, conscientiousness, extraversion, neuroticism/emotional stability, and openness to experience). Instead of using a single adjective descriptor format, like the one developed by Goldberg (1992), the BFI employs the use of "short phrases based on the trait adjectives known to be prototypical markers of the Big Five." (John, Nauman, & Soto, 2008, p. 130). Each phrase is accompanied by a 5 point Likert scale that ranges from 1 ("disagree strongly") to 5 ("agree strongly"). I considered that the concise nature of the BFI was ideal for this study, since multiple scales/question were administered throughout the study, and there was a risk for participants to lose interest if presented with a large number of psychometric items not related to CRM knowledge/opinions.

The BFI questionnaire was specifically used to study research question 2.

Type of Expertise Questionnaire Fisher and Peterson's (2001) questionnaire Adaptive Expertise Survey (AES) was used to assess participants' type of expertise (Appendix D). The AES consists of 42 items, these items have 6 point Likert scales ranging from 1 (strongly disagree) to 6 (strongly agree). This questionnaire is divided in 4 distinct sections: *Multiple Perspectives, Metacognitive Self-Assessment, Goals and Beliefs,* and *Epistemology*. The AES was validated by Fisher and Peterson (2001) and it has been used in several studies (e.g., Johnson, Ozturk, Johnson, Yalvac, & Peng, 2012; Martin, Petrosino, Rivale, & Diller, 2006; Ozturk, Yalvac, Johnson, Xiaobo, & Ke, 2015). The score range for the AES is 4 to 24. The cutoff score to divide adaptive from routine experts is not clearly identified by Fisher and Peterson (2001), but on their development and validation study of the AES, they identified significant differences between groups scoring below an average of 17.4 (SD = 1.60) and another group of experts scoring on average 18.58 (SD = 1.9).

Declarative CRM Knowledge Questionnaire A declarative CRM knowledge questionnaire was specifically developed for this study (see Appendix E). The purpose of the knowledge questionnaire is to assess participants' own definition of CRM (including how they would explain CRM to someone who has never heard of it before), as well as asses their understanding of CRM concepts. Another important aspect of this questionnaire was related to the exploration of participants' use of CRM principles/skills outside the flight deck. A combination of open – ended questions and Likert scale type of questions were used to assess participants' CRM knowledge.

The declarative knowledge questionnaire developed for the study was used to test for hypothesis 1 of the study (see Table 2).

CRM Training Needs Questionnaire A CRM training needs questionnaire was developed for this study with the goal of asking participants about their perceived needs in relation to CRM training. The survey covered aspects such as training length, topics, delivery methods, training assessment, and automation management training (see Appendix E). This questionnaire consisted of Likert type questions and participants were given the option to provide justifications for their answers, which were useful to discern differences between routine and adaptive experts.

The training needs questionnaire developed for the study was used to test for hypotheses two through six of the study (see Table 2).

Procedure.

The questionnaires for this study were administered online. Upon acceptance of participation in the study, participants clicked on a link that directed them to the study. First, participants read the informed consent, if they accepted, they were then directed to the first questionnaire of the study. On this first questionnaire, participants answered questions related to demographics. No personally identifiable data was collected. Upon completion of this questionnaire, participants completed the CRM knowledge questionnaire. After completion of the knowledge questionnaire participants answered a questionnaire related to airline pilots' perceived CRM training needs (training length, topics, delivery methods, training assessment, and automation management training). Finally, participants were asked to complete two psychometric questionnaires, first, the adaptive expertise questionnaire developed by Fisher and Peterson (2001), and second, the Big Five Inventory (BFI) developed by John, Donahue, and Kentle (1991). Once participants completed all questionnaires, they were thanked for their

participation in the study and a brief summary of the study's purpose was provided as well as researcher's contact information in case they had questions/concerns about the study.

CHAPTER 4: RESULTS

Data were collected from September 5th 2017 to December 29th 2017. Roughly 3,000 ATPs were contacted, and 459 agreed to participate in the study. Of the 459 who participated in the study, only 260 completed the survey (no missing answers) up to the Adaptive Expertise Questionnaire. Five responses were excluded from the analysis after their scores on the adaptiveness questionnaire were determined to be outliers and presented evidence of malingering.

The following paragraphs discuss the reliability and factor analyses performed on the metrics used for the present study, as well as the results of the analyses performed to test for the two research questions and six hypotheses that I had derived from my literature review on the subject of adaptive expertise.

Reliability of the Adaptive Expertise Survey (AES)

In order to understand the reliability of the AES, a reliability test was conducted by calculating Cronbach's alpha. It has been established that alpha scores of .7 or higher are considered to indicate, at least, acceptable reliability of a test (Cortina, 1993; Field, 2009; Kline, 2000). Kline (2000) and Field (2009) explain that when testing psychological constructs, even scores lower than .7 are to be expected due to the nature of psychological traits, which in many cases do not meet the assumptions of reliability testing (see Sijtsma, 2009). Sijtsma explained that when testing reliability of psychological measures, an alternative should be used, as alpha is notorious for underestimating reliability (unless test scores are identical to true scores as defined by psychometric theory). Alternatives include using one of Guttman's lower bounds (Guttman, 1945), the *greatest lower bound* (*glb*), although some issues with reliability overestimation is

possible when using small sample sizes. Alternatively Revelle and Zinbarg (2009), suggest using McDonald's ω since it does not suffer from issues with under or overcorrection. I report McDonald's ω, *glb*, and Guttman's second lower bound (λ_2) in conjunction with Cronbach's alpha (α) in order to have a better understanding of the subscales' reliability. Taking into consideration the issues of under and overestimation associated with the different reliability tests, it would be advisable to estimate that the reliability of a given subscale falls between the values provided by Cronbach's α and *glb*, with accurate reliability closer to the value provided by the *glb* test.

The reliability tests were conducted on each of the 4 subscales (Multiple Perspectives, Metacognitive Self-Assessment, Goals and Beliefs, and Epistemology), as well as on the positively stated items, negatively stated items, and all items combined. Steps were taken to eliminate outliers which can cause an inflation on the reliability test scores. Table 3 shows the results of the reliability analysis for the present study and it presents it side by side with the reliability analysis conducted by Fisher and Peterson (2001) for the AES validation study.

Table 3

Reliability tests for the AES

Subscale	Number of Items	Cronbach's α ATP Study	Cronbach's α Fisher & Peterson Study	Guttman's λ_2 ATP Study	*glb*	McDonald's ω
1a. Multiple Perspectives	11	.70	.77 - .80	.72	.85	.79
b. Metacognitive	9	.70	.78 - .79	.71	.79	.77
c. Goals and Beliefs	13	.67	.66 - .78	.70	.83	.77
d. Epistemology	9	.59	.71 - .72	.61	.77	.73
2a. Positively Stated Items	18	.78	--	.79	.91	.85
b. Negatively Stated Items	24	.80	--	.81	.84	.63
3. All Items	42	.83	.85 - .89	.83	.93	.66

In order to investigate whether subscales' reliability could be improved, I performed an item elimination process based on whether or not inclusion of each item in the subscale negatively affected reliability scores. The elimination process stopped when removal of any specific item stopped increasing reliability as reflected by the subscale's α and λ_2 scores. This process yielded the elimination of multiple items (15 in total), leaving 27 of the original 42 items. Table 4 shows the new subscales and their corresponding reliability test scores. Even though reliability scores did not dramatically increase (as reflected by α scores) after item elimination (except for the epistemology subscale), the item reduction and the moderate increase in reliability scores helped to correct for the measurement error reduction bias caused by the inclusion of large number of items in each subscale.

Table 4

Compressed AES after item elimination

Subscale (number of items)	Cronbach's α	Guttman's λ_2	*glb*	McDonald's ω	Subscale Items
Multiple Perspectives (7)	.74	.74	.83	.84	-Usually there is one correct method in which to represent a problem. -I tend to focus on a particular model in which to solve a problem. -I rarely consider other ideas after I have found the best answer. -I find additional ideas burdensome after I have found a way to solve the problem. -I solve all related problems in the same manner. -When I solve a new problem, I always try to use the same approach. -There is one best way to approach a problem.
Metacognitive (7)	.72	.72	.80	.82	-As I learn, I question my understanding of the new information. -I often try to monitor my understanding of the problem. -As a student, I cannot evaluate my own understanding of new material. -I rarely monitor my own understanding while learning something new. -I have difficulty in determining how well I understand a topic. -I monitor my performance on a task. -I seldom evaluate my performance on a task.
Goals and Beliefs (7)	.69	.74	.83	.81	-One can increase their level of expertise in any area if they are willing to try. -Expertise can be developed through hard work. -To become an expert in engineering, you must have an innate talent for engineering. -Experts in engineering are born with a natural talent for their field. -Experts are born, not made. -Even if frustrated when working on a difficult problem, I can push on. -When I struggle, I wonder if I have the intelligence to succeed in engineering.
Epistemology (6)	.68	.69	.82	.85	-Knowledge that exists today may be replaced with a new understanding tomorrow. -Scientists are always revising their view of the world around them. -Most knowledge that exists in the world today will not change. -Existing knowledge in the world seldom changes. -Scientific theory slowly develops as ideas are analyzed and debated. -Scientific knowledge is developed by a community of researchers.

After performing the item elimination process and subsequently executing a factor analysis on the original AES, and the abbreviated 27 item AES, it was determined that using the abbreviated AES minus the Epistemology subscale would produce more valid and reliable results (see Appendix F and Appendix G for the factors and item loadings for the AES and abbreviated AES as identified by the factor analyses). The following results are based on the analysis of a 21-item, 3-dimension (Multiple perspectives, Metacognitive Self-Assessment, and Goals and Beliefs) AES. Appendix H shows an equivalent analysis based on the original 42 item (4 dimensions) AES.

Research Questions Results

RQ1: Is there a relationship between pilots' flight experience variability and type of expertise?

In order to determine whether diversity of flight experience is correlated with adaptiveness, different questions inquiring about participants' flight experience were analyzed. The following variables were included in the analysis: Total flight time, Total flight time under Part 121, Number of aircraft operated underpart 121, total number of different aircraft make operated under part 121, whether or not participants held a certificate to operate other aircraft categories (e.g., rotorcraft, glider, or lighter than air aircraft), total number of flight instruction facilities attended by participants (e.g., flight school, private flight instructor, military, etc.), and total number of operations conducted as a pilot/other experience (banner towing, charter flying, air tours, etc.). None of the variables related to variability of flight experience were significant predictors of adaptiveness (see Table 5).

Table 5

Correlation between Adaptiveness and Variety of Flight Experience

		Aircraft Type Total	Aircraft Make Total	Holding Certificate for a Different Aircraft Category	Other Flight Experience Total	Flight Training Total	Total Flight Time	Flight Time under Part 121
Adaptiveness	Pearson Correlation	.050	.030	-.049	.112	-.006	-.032	.002
	Sig. (1-tailed)	.212	.316	.219	.038	.463	.307	.484

RQ2: Is there a relationship between personality traits and adaptive expertise?

Results of the study indicated that there was a significant correlation between all five personality traits and adaptive expertise. Although all of the personality traits were significantly correlated with type of expertise, it is important to note that these were small correlations. Openness and conscientiousness were both the highest correlated traits to adaptiveness (both r = .26 and .27, $p < .001$, respectively), while neuroticism was the only trait to be negatively correlated with adaptive expertise (r = -.22, $p < .001$). Table 6 shows the correlation between adaptiveness and the five personality traits.

Table 6

Correlation between Adaptiveness and Big Five Personality Traits

		Extraversion	Agreeableness	Conscientiousness	Neuroticism	Openness
Adaptiveness	Pearson Correlation	.17	.25	.27	-.22	.26
	Sig. (1-tailed)	.004	<.001	<.001	<.001	<.001

Assessing Cutoff Points for Type of Expertise on the Adaptive Expertise Survey (AES)

The score range for the abbreviated AES is 3 to 18. Scores from the present study ranged from 9.86 to 17.14 (M = 13.61, SD = 1.28). I conducted a correlation analysis between raw AES scores and dichotomous variables with the following cutoffs for type of expertise: (a) split (cutoff value of 13.571), (b) cutoff at 14.25 (an equivalent to my originally proposed cutoff of 19 for the original AES). Additionally, another variable was created in which responses were split into 3 groups (cutoff points 13 and 14.143). From the created categorical variables, the dichotomous variable with a cutoff score of 14.25 had the lowest correlation (r = .80); this is lower than the equally split scores dichotomous variables (r = .805) and the split into 3 groups variable (r = .89). I decided to use the latter variable to categorize types of experts since it had the highest correlation to the raw scores from the Abbreviated AES (see Table 7).

Table 7

Correlations between adaptiveness scores and cutoff points

		3 Levels	**Cutoff 14.25**	**2 Level Split**
Abbreviated Adaptiveness	Pearson Correlation	.89	.77	.81
	Sig. (1-tailed)	<.01	<.01	<.01
	N	255	255	255

Table 8 shows the means, standard deviations, and number of participants for each of the three levels of expertise. I decided to label the group that stands between routine and adaptive experts as *transitional experts.*

Table 8

Mean scores on the abbreviate AES by type of expertise

Type of Expertise	Mean	Std. Deviation	N
Routine	12.22	.68	88
Transitional	13.59	.29	73
Adaptive	14.92	.64	94
Total	13.61	1.28	255

A one-way ANOVA was conducted to examine whether scores on the abbreviated AES differed among the three groups. Results of the analysis showed that there was a significant difference between groups on the abbreviated AES scores $F(2,252) = 493.64$, $p < .001$. $\eta^2 = .80$, and the observed power was near 1. Post hoc comparisons showed there was a significant difference in scores between routine and adaptive experts, between routine and transitional experts, and between transitional and adaptive experts (all comparisons $p < .001$).

A reanalysis of research questions RQ1 and RQ2 was executed this time using the 3 type of expertise categories. Table 9 shows the results of the bivariate correlation between type of expertise and variance of flight experience, and Table 10 shows the results of bivariate correlations between type of expertise and personality traits. Note that results are similar as when using expertise raw scores (see Table 5 and Table 6).

Table 9

Correlation between type of expertise and Variety of Flight Experience

		Aircraft Type Total	Aircraft Make Total	Holding Certificate for a Different Aircraft Category	Other Flight Experience Total	Flight Training Total	Total Flight Time	Flight Time under Part 121
Type of Expertise	Pearson Correlation	.060	.038	-.061	.135	-.016	-.016	-.024
	Sig. (1-tailed)	.171	.273	.165	.016	.399	.401	.349

Table 10

Correlation between type of expertise and Big Five Personality Traits

		Extraversion	Agreeableness	Conscientiousness	Neuroticism	Openness
Type of Expertise	Pearson Correlation	.14	.20	.23	-.19	.23
	Sig. (1-tailed)	.01	<.01	<.001	<.01	<.01

After establishing the 3 groups of experts in accordance to their scores on the AES, a comprehensive analysis of the data was conducted. The next section shows a brief synopsis of the analysis of qualitative data and general findings for the three groups of experts.

Analysis of Qualitative Data

The study's questionnaire included 14 open ended questions that were included to provide further insights on the differences between routine and adaptive experts, and the third category of experts (transitional) which was identified in this study. Out of the possible 3,570 responses (255 participants x 14 questions), participants provided 2,395 responses (67.09% response rate). SPSS Modeler Premium Version 18.1.1(IBM, 2017) with the Text Analytics package was used to analyze qualitative data. Table 11 shows total response rate by type of expert as well as the mean number of concepts used by each group to answer open ended questions (see Appendix I) for number of concepts used by group for each of the 14 questions).

Table 11

Response rate and number of concepts used by type of expert

Type of Expertise	N	Possible Responses	Collected Responses	Response Rate	Mean Concepts
Routine	88	1,232	805	65.53%	190.50
Transitional	73	1,022	664	64.93%	171.29
Adaptive	94	1,316	926	70.33%	228.93
Total	**255**	**3,570**	**2,395**	**67.09%**	**196.90**

As can be seen from Table 11, adaptive experts used the highest number of concepts to respond open-ended questions (an indication of the richness of the vocabulary used to explain concepts, or express opinions in relation to CRM), followed by routine experts, and transitional experts, respectively. It can also be seen in Table 11 that the same was true for response rates. As a matter of fact, when response rates were broken down by question, Adaptive experts had the highest response rate on 11 of the 14 questions, and their response rate was never the lowest. Table 12 shows response rate rankings by type of expertise, and Appendix I shows the response rate broken down by question.

Table 12

Response rate rankings by type of expertise

Type of Expertise	Total of number 1 ranks	Total of number 2 ranks	Total of number 3 ranks
Routine	3*	5	6
Transitional	1	5	8
Adaptive	11*	3	0

* Share number 1 rank on 2 items

It is important to note that the intention behind the analysis of qualitative data is to serve as a supplementary analysis to the quantitative results of the present study. I do not intend to infer statistical significance with the qualitative analysis of free response items. Instead, I intend to show (a) trends in the responses provided by each group (as shown in Tables 11 and 12), and

(b) provide (or at least attempt to provide) an explanation as to why opinions about CRM and automation differ (or not) among groups of experts as reflected by their answers to free response items and their scores on the quantitative portions of the survey.

The following paragraphs describe the analysis of the results performed on the quantitative and qualitative data in order to test the proposed hypotheses. It is important to note that open-ended questions were included in sections of the questionnaire intended to test for Hypotheses 1, 3, 4, and 6. Therefore Quantitative and qualitative results are presented in conjunction for the hypotheses mentioned above.

H_1: Use of CRM skills Outside Flight Deck.

My first hypothesis for the present study stated that:

H_1: *Adaptive expert pilots differ from routine expert pilots in their use of CRM skills outside the flight deck. Adaptive experts will be more likely to express that they have used CRM skills (or be able to see how these skills could be used) in situations outside the flight deck.*

A total of four questions were asked of participants to test this hypothesis. These questions included three questions with dichotomous (yes – no) answers: (1) *I think CRM is a valuable skill I can also apply outside the flight deck, (2) have you used CRM outside the flight Deck?* (3) *Are there areas of CRM you believe can be applied to areas outside aviation?* And (4) *Are there areas of CRM you believe are only applicable to aviation and nowhere else?* A fourth question, *I think CRM is a valuable skill I can also apply outside aviation*, had a 6 point Likert scale (strongly disagree – strongly agree) for possible answers. One of these questions was removed from the analysis (*Are there areas of CRM you believe can be applied to areas outside aviation?)* since all 255 participants answered *yes.* As my hypothesis stated that there would be a

difference between routine and adaptive experts, I compared the answers of routine and adaptive experts for the remaining questions. This analysis found a significant difference between routine and adaptive experts on their answers to the question of whether or not they thought CRM is a valuable skill they could also apply outside the flight deck, $U = 3415.50$, $z = -2.41$, $p = .008$, $r = -.18$. It is important to note that as reflected by Table 13, the results to the answers for *Have you used CRM outside of the flight deck?* first appear to be significant ($p = .048$), but when a Bonferroni correction is applied, the p value needed to achieve significance increases to .0166.

Table 13

Ranks for Use of CRM outside the flight deck Questions

Question	Type of Expertise	N	Mean Rank	Mann-Whitney U	Z	Significance (1 tailed)
I think CRM is a valuable skill I can also apply outside the flight deck	Routine	88	83.31	3415.50	-2.41	.008
	Adaptive	94	99.16			
	Total	182				
Have you used CRM outside of the flight deck?	Routine	88	88.73	3892.00	-1.66	.048
	Adaptive	94	94.10			
	Total	182				
Are there areas of CRM that you believe are only applicable to aviation and nowhere else? -	Routine	88	94.22	3897.00	-.96	.169
	Adaptive	94	88.96			
	Total	182				

H_1 Qualitative results. Participants were allowed to further explain their answers on this specific item (use of CRM outside the flight deck) by providing free responses. A qualitative analysis was conducted to further examine differences between routine and adaptive experts. For this question, routine and adaptive experts had both the highest response rates. After extracting concepts used to provide answers to this question, it was discovered that adaptive experts as a group used the widest range of concepts, followed by routine, and transitional experts respectively (see Table 14). See Figure 2 for visualization of concepts related to this question

broken by type of expertise (Appendix J shows a similar visualization of concepts for how participants would explain CRM to someone who has never heard of this concept before).

Table 14

Mean word count and standard deviation by type of expertise for Have you used CRM outside of the flight deck?

Type of Expertise	Median	Mean	Standard Deviation	Response Rate(Rank)	Number of Concepts Used
Routine	14	18.12	16.89	94.3% (2)	267
Transitional	13	18.00	19.00	89.0% (3)	241
Adaptive	17	21.65	17.50	94.7% (1)	334

For routine experts, the most common concepts were related to people or crews other than pilots (e.g., passengers and dispatch). Some examples include: *"crew/airline personnel involvement in a situation not related directly to the flight but still important for overall mission"* and *"while working with gate agents, flight attendants and passengers to explain scenarios and work through problems."* While these types of answers to the question of having used CRM outside the flight deck are correct, routine experts were prone to use aviation themed scenarios in which they had used CRM skills. It is important to note that some routine experts mentioned having used CRM in other non-aviation related situations as well (e.g., with family or while driving a car), but, as a group, the tendency was to use aviation related examples.

Transitional experts, provided aviation-specific examples just as routine experts did, and some also provided examples related to transportation outside of aviation such as driving a car or a boat: "*driving a car in a high threat environment*" or "*...driving a large recreational boat, you need other people to be on the same page as you to assist you with docking.*" As was the case with routine experts, transitional experts used examples related to family, people in general, or as a way to improve communication with others.

When reviewing free responses from adaptive experts, I noticed that references to aviation specific CRM examples were scarce. The most common concepts used to describe the use of CRM outside the flight deck were *wife,* and *every day.* Examples include: "*I use it with my wife and kids all the time,*" and "*I use the elements of CRM every day. When I have problems I approach them from a CRM perspective.*" I found that besides providing non-aviation specific examples, some adaptive experts were able to provide multiple examples of situations in which CRM skills could be applied: "*driving in the car, cooking with wife at home, working on construction projects, building blocks with my daughter, etc.*" and "*I use it all the time. Projects at home, playing sports or games, discussions, chores, cooking…truly everywhere*."

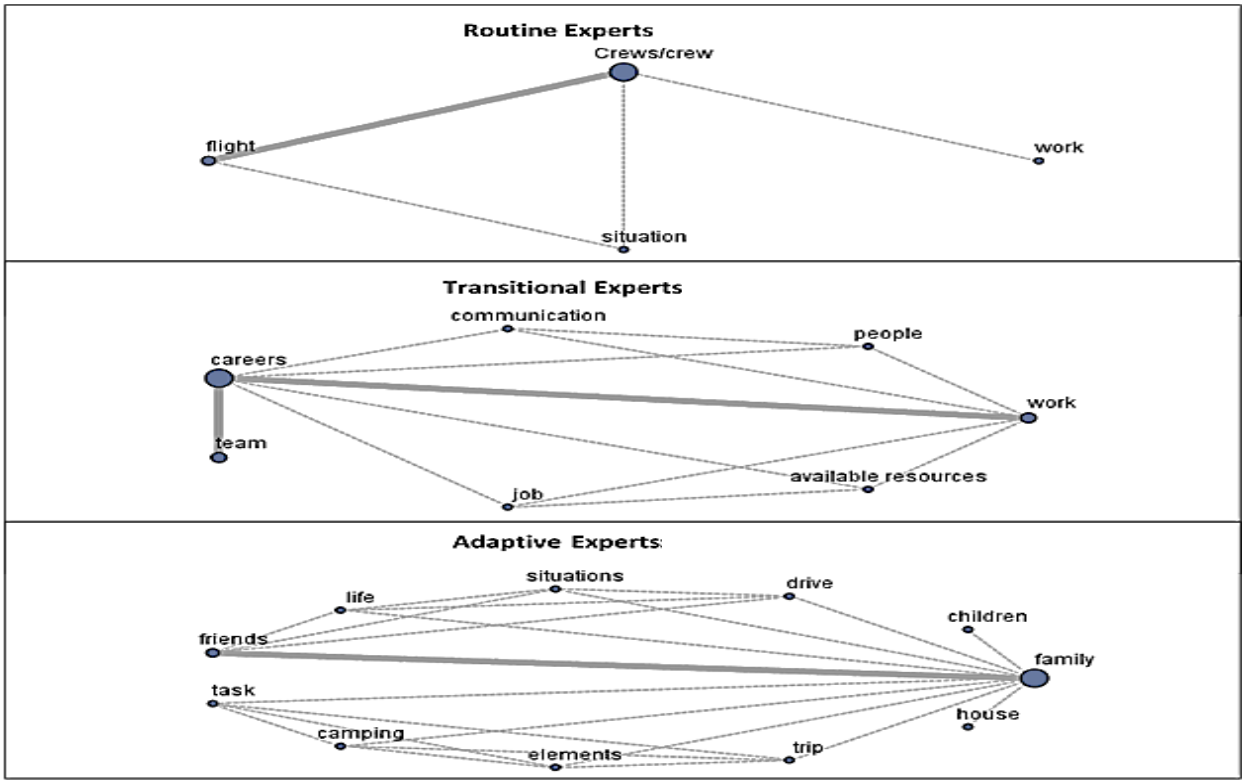


Figure 2: Visualization of concepts by expertise for have you used CRM outside the flight deck?

As mentioned before, the qualitative analysis is a supplement to the quantitative results on the use of CRM outside the flight deck. Therefore, quantitative results should be the main indicator of whether significant differences between the three groups exist. Next, an explanation of the statistical approach used for H_2 through H_6 is provided.

A MANOVA test was used to find whether there were differences between adaptive and routine experts as stated on Hypotheses 2 through 6 in their opinions related to CRM training and evaluation, and use of automation (as reflected by CRM questionnaire scores). Using Pillai's trace, there was a significant difference between types of experts in at least one of the hypotheses $V = .09$, $F(12, 490)$, $p = .027$, $\eta^2 = .05$, and the observed power was .92.

The following paragraphs present the results of hypotheses 2 through 6 as reflected by the univariate tests produce by the omnibus MANOVA.

H_2: Opinions on CRM Training Length

My second hypothesis stated that:

H_2: *Adaptive expert pilots differ from Routine expert pilots in their opinions about CRM training length and the distribution of time in relation to methods used within a given training session. Adaptive experts will be more likely to express that there is lack of time during training to engage in non-routine scenarios where CRM skills are most needed, and that too much time is used practicing/reviewing routine scenarios.*

Results from the univariate test failed to find a significant difference between any of the three groups of experts (i.e., routine, transitional, and adaptive), $F(2,249) = .57$, $p > .05$. There were no significant differences between types of experts on their mean score on opinions about length of training (time spent on role playing and practicing briefings; reviewing CRM concepts

and case studies; time spent during indoctrination; initial qualification, and recurrent training; and opportunities to practice CRM in the simulator). Scores were computed by averaging the scores on the sections described above. Possible scores range from 1 to 6 (1 strongly disagree to 6 strongly agree). Table 15 shows the means and standard deviations for each group.

Table 15

Length of training Mean Scores

Dependent Variable	Type of Expertise	Mean	Std. Deviation
Length of Training	Routine	4.54	.67
	Transitional	4.45	.49
	Adaptive	4.53	.57

A specific question related to length of training asked participants, *during initial and recurrent training, what percentage of time do you think should be spent on CRM specific training in relation to other topics?* The possible response range was 0 to 100 percent. The univariate test found a significant difference between the groups, $F(2,249) = 4.07$, $p = .018$, $\eta^2 = .03$, and the observed power was .72. Post hoc tests showed a difference between routine and adaptive experts ($p = .01$), all other pairwise comparisons were not significant. Table 16 shows the means and standard deviations for each of the groups.

Table 16

Percentage of desired CRM training in relation to other topics covered during training Scores

Dependent Variable	Type of Expertise	Mean	Std. Deviation
Percentage of CRM Training	Routine	41.95	23.64
	Transitional	35.66	20.15
	Adaptive	33.28	18.37

H_3: Opinions on CRM training methods

My third hypothesis stated that:

H_3: *Adaptive expert pilots differ from Routine expert pilots in their opinions about the use of CRM training delivery methods. Adaptive experts will be more likely to express their desire to use novel training delivery methods in lieu of, or as a supplement to traditional training delivery methods.*

Results from the univariate test failed to find a significant difference between any of the three groups of experts (i.e., routine, transitional, and adaptive), $F(2,249) = 1.73$, $p > .05$. There were no significant differences between types of experts on their mean score on opinions about CRM training methods (use of mobile technology, joint training, use of newsletters, and frequency with which methods to deliver CRM should be reviewed). Scores were computed by averaging the scores on the sections described above. Possible scores range from 1 to 6 (1 strongly disagree to 6 strongly agree). Table 17 shows the means and standard deviations for each group.

Table 17

CRM training methods mean scores

Dependent Variable	Type of Expertise	Mean	Std. Deviation
CRM training Methods	Routine	4.46	.55
	Transitional	4.40	.54
	Adaptive	4.57	.62

H_3 Qualitative results. Participants were given the option to supplement their opinion about training methods by providing free response answers. They were asked "i*n your opinion, what type of training should be provided for CRM*?" For this free response item, adaptive experts had the highest response rate, followed by transitional, and routine experts respectively. After extracting concepts used to provide answers to this question, it was discovered that adaptive

experts as a group used the widest range of concepts, followed by routine, and transitional experts respectively (see Table 18). See Appendix K for a visualization of concepts related to this question broken by type of expertise.

Table 18

Mean word count and standard deviation by type of expertise for in your opinion, what type of training should be provided for CRM?

Type of Expertise	Median	Mean	Standard Deviation	Response Rate(Rank)	Number of Concepts
Routine	11	19.5	22.80	77.3% (3)	225
Transitional	13	21.12	27.73	78.1% (2)	208
Adaptive	13	19.58	21.11	88.3% (1)	284

For all three groups of experts, the most common concepts used in their responses for this question were scenario-based training, case studies, role playing, and simulator training. Another common concept was joint training (training with other groups like cabin and maintenance crews, dispatch, and gate agents). Even though no particular patterns were identified for any specific type of expert, it is important to note that some adaptive experts mentioned using simulation sessions in innovative ways:

"*Scenario based training based on previous incidences. Let people see for themselves. Put them in the sim with sim sessions that are only designed to reenact scenarios with poor CRM and good CRM and let a lesson go from there.*"

Another suggestion provided by an adaptive expert was: "*Non-jeopardy simulator-based scenarios with a serious review/debrief afterward.*"

The results of the qualitative analysis of the data for H_3 are in accordance with the results of the quantitative results which found no significant differences between the groups.

H_4: Opinions on CRM training topics

My fourth hypothesis stated that:

H_4: *Adaptive expert pilots differ from Routine expert pilots in their opinions about CRM training topics. Adaptive experts will be more likely to suggest modifications (adding and/or eliminating) to currently trained topics in CRM.*

The univariate test found a significant difference between the groups, $F(2,249) = 3.76$, $p = .025$, $\eta^2 = .03$, and the observed power was .68. Post hoc tests showed a difference between routine and adaptive experts ($p = .04$), and transitional and adaptive experts ($p = .03$). There were significant differences between types of experts on their mean score on opinions about on CRM training topics. Scores were computed by averaging the scores on the sections described above. Possible scores range from 1 to 6 (1 strongly disagree to 6 strongly agree). Table 19 shows the means and standard deviations for each group.

Table 19

Mean scores on topics questionnaire

Dependent Variable	Type of Expertise	Mean	Std. Deviation
CRM training Topics	Routine	4.82	.45
	Transitional	4.80	.56
	Adaptive	5.00	.61

H_4 **Qualitative results.** Participants were given the option to provide their opinion about training topics when asked "*I think there are areas of flight safety that CRM does not cover*." For this free response item, adaptive experts had the highest response rate, followed by transitional, and routine experts respectively. Adaptive experts as a group used the widest range of concepts, followed by routine, and transitional experts respectively (see Table 20).

Table 20

Mean word count and standard deviation by type of expertise for I think there are areas of flight safety that CRM does not cover

Type of Expertise	Median	Mean	Standard Deviation	Response Rate(Rank)	Number of Concepts
Routine	15	20.81	17.74	30.7% (3)	94
Transitional	9	12.96	10.03	32.9% (2)	56
Adaptive	15	20.18	18.81	47.9% (1)	162

Routine and transitional experts' most common answer to this questions was that CRM training currently is complete and covers all or most aspects of flight safety. While, for adaptive experts, this was a popular answer as well, it was not among the top answers. The most common theme among adaptive experts was gaps exist in training to help crews to effectively deal with different types of personalities, personal factors affecting performance, and CRM self-assessment techniques. Some examples include: "*I believe tactics on handling cockpit personality differences are very poorly covered, if covered at all*" and *"[CRM training] can't simulate the different pilots you will fly with or the different stages & issues of their personal lives that may affect their performance on any given day."*

It is also important to note that adaptive experts expressed that not one single concept (CRM in this case) can address all safety issues, as new challenges will surface in the future which are currently unknown. One particular adaptive expert expressed: "*Although I can't think of any particular items that are not covered, I believe additional research, case studies, other industries, and actual events will find weaknesses in the current paradigm of CRM training. There is always room for improvement.*" In fact, this type of answer was the second most common among adaptive experts. Few transitional and even fewer routine experts addressed

CRM-Flight Safety from the *nothing covers everything/there is always room for improvement* approach.

H_5: Opinions on CRM training evaluation methods

My fifth hypothesis stated that:

H_5: *Adaptive expert pilots differ from Routine expert pilots in their opinions about techniques used and their effectiveness to assess CRM training. Adaptive experts will be more likely to identify current evaluation methods as inadequate and insufficient.*

Results from the univariate test failed to find a significant difference between any of the three groups of experts (i.e., routine, transitional, and adaptive), $F(2,249) = 0.65$, $p > .05$. There were no significant differences between types of experts on their mean scores on opinions about CRM evaluation methods (use of knowledge/attitudes questionnaires, need for developing new methods, and importance of evaluating CRM). Scores were computed by averaging the scores on the sections described above. Possible scores range from 1 to 6 (1 strongly disagree to 6 strongly agree). Table 21 shows the means and standard deviations for each group.

Table 21

CRM training evaluation methods mean scores

Dependent Variable	Type of Expertise	Mean	Std. Deviation
CRM training evaluation methods	Routine	4.36	.75
	Transitional	4.23	.74
	Adaptive	4.32	.74

No free responses to explore participants' opinions on CRM training topics were included in this section of the questionnaire, therefore no analysis of qualitative data was performed.

H_6: Opinions on automation on the flight deck

My sixth and final hypothesis stated that:

$\boldsymbol{H_6}$: *Adaptive expert pilots differ from Routine expert pilots in their view of automation as a crewmember. Adaptive experts will be more likely to see automation as an additional crew member.*

Results from the univariate test failed to find a significant difference between any of the three groups of experts (i.e., routine, transitional, and adaptive), $F(2,249) = 0.13$, $p > .05$. There were no significant differences between types of experts on their mean score on opinions about automation on the flight deck (views of automation as an additional crewmember, and lowering levels of automation during different stages of flight). Scores were computed by averaging the scores on the sections described above. Possible scores range from 1 to 6 (1 strongly disagree to 6 strongly agree). Table 22 shows the means and standard deviations for each group.

Table 22

Mean score for views on automation

Dependent Variable	Type of Expertise	Mean	Std. Deviation
Views on Automation	Routine	4.77	.54
	Transitional	4.77	.56
	Adaptive	4.81	.60

H_6 **Qualitative results.** Participants were given the option to provide their opinion about their views on automation when asked "*I can see how automation on the flight deck can be perceived as an additional member of the flightcrew.*" For this free response item, adaptive experts had the highest response rate, followed by transitional, and routine experts respectively. Adaptive experts, as a group, used the widest range of concepts, followed by transitional, and

routine experts respectively (see Table 23). Appendix L shows a visualization of concepts for this question broken by type of expertise.

Table 23

Mean word count and standard deviation by type of expertise for I can see how automation on the flight deck can be perceived as an additional member of the flightcrew

Type of Expertise	Median	Mean	Standard Deviation	Response Rate(Rank)	Number of Concepts
Routine	19	20.84	11.79	35.2% (3)	81
Transitional	15	21.65	18.87	39.7% (2)	84
Adaptive	13.5	22.46	20.69	48.9% (1)	140

The most common response among the three groups was a reference to automation as a *tool* or *resource* on the flight deck rather than as an additional flightcrew member. For example, a routine expert expressed that *"automation is simply another tool to be used by a crewmember, but still must be managed by a crewmember."* Similarly a transitional expert opined that *"automation only does what you tell it to do. By all means it shouldn't be perceived as [an] addition[al] crew member."* Other examples of opinions from adaptive experts include *"automation should only be used as a tool. If you rely on it too much you will lose your skills as a pilot."* This opinions are reflective of the results on the questionnaire section about views on automation.

One interesting observation from the analysis of responses for this item was that some of the adaptive experts referred to automation as a *dumb crewmember.* Some examples include: *"automation is a 'dumb' additional member to the cockpit. Must be watched constantly," "Only to the extent that it's possible to consider it a 'dumb' pilot,"* and *" Understanding the automation begins with understanding it is functionally and essentially the same as having a 'dumb' third*

crewmember who only can do very basic things when told what to do." No other participant from any of the other groups made this type of comment about automation. Adaptive experts agreeing with the idea of automation as a third flightcrew member was the second most common answer. This idea was less popular among routine and transitional experts.

The results of the qualitative analysis of the data for H_6 are in accordance with the results of the quantitative results which found no significant differences between the groups. Scores on the views on automation were not significantly different between all groups of experts. The qualitative results indicate that in general all experts see automation as a tool or resource to be managed by the crew instead of automation being perceived as a true crewmember.

CHAPTER 5: DISCUSSION

The present study's purpose was to evaluate flightcrews' CRM knowledge structures, and identify differences among them based on their types of expertise. Identification of types of expertise and CRM schemas was achieved by using questionnaires related to type of expertise, personality traits, CRM knowledge, opinions about CRM training needs, and views on automation on the flight deck. The idea presented in this study of evaluating CRM schemas and identifying how these schemas differ between routine and adaptive experts could help in the creation of novel evaluation methods that explore CRM knowledge structures at the conceptual level rather that the declarative level. Identifying differences in CRM schemas among experts could be important because, as discussed in the literature review, adaptive experts are more likely to adapt their knowledge structures to novel situations, allowing these experts to use their schemas in adaptive and tuned ways that are far from the reach of routine experts (Hatano & Oura, 2003). Being able to adapt one's knowledge structures is critical in high risk domains such as commercial aviation. Therefore identifying where on the spectrum of adaptiveness each individual pilot falls in regards to CRM could help tailor training to foster the conditions necessary to reach adaptiveness for routine and transitional experts, and even optimize CRM training for adaptive experts as well.

I hypothesized that a difference between routine and adaptive experts existed in relation to their use of CRM skills outside the flight deck, as well as in their opinions about CRM training, and views on automation on the flight deck. The following paragraphs will discuss the findings of the analyses that tested for hypotheses H_1 through H_6, and also discuss the findings in relation to the research questions that focused on the factors that may play a role in the

development of adaptiveness. Before discussing the results of the study I present a summary of the results in Table 24.

Table 24

Summary of results

Research Question	Results Significant?	Results Synopsys
RQ1: Is there a relationship between pilots' flight experience variability and type of expertise?	No	-No significant relationship identified between adaptive expertise and experience variability. -Potential relationship might exist between adaptiveness and the total number of experience in different flight operations (p = .048, critical p= .0071)
RQ2: Is there a relationship between personality traits and adaptive expertise?	Yes	-Small positive relationship between adaptive expertise and extraversion, agreeableness, conscientiousness, and openness. -Small negative relationship between adaptive expertise and neuroticism.
Hypothesis		
$\boldsymbol{H_1}$: Adaptive expert pilots differ from routine expert pilots in their use of CRM skills outside the flight deck.	Yes	-Adaptive experts considered CRM to be a more valuable skill to use outside the flight deck than routine experts did. -Potential significant difference between routine and adaptive experts in the use of CRM skills outside the flight deck (p = .048, critical p= .0167)
$\boldsymbol{H_2}$: Adaptive expert pilots differ from Routine expert pilots in their opinions about CRM training length and the distribution of time in relation to methods used within a given training session.	Yes	-No significant differences on the scores of length of training questionnaire (e.g., time spent time indoctrination; initial qualification, and recurrent training; and practicing CRM in the simulator). -Significant differences between routine and adaptive experts in the percentage of time that should be spent on CRM specific training (41.95% vs. 33.28% respectively, significant in the opposite direction).
$\boldsymbol{H_3}$**:** Adaptive expert pilots differ from Routine expert pilots in their opinions about the use of CRM training delivery methods.	No	-No significant differences between routine and adaptive experts on the mean score on opinions about CRM training methods (use of mobile technology, joint training, use of newsletters, and frequency with which methods to deliver CRM should be reviewed).
$\boldsymbol{H_4}$: Adaptive expert pilots differ from Routine expert pilots in their opinions about CRM training topics.	Yes	-Adaptive experts considered current training topics to be more important that routine experts did. -Qualitative results suggest that adaptive experts believe CRM does not cover all aspects of flight safety.
$\boldsymbol{H_5}$**:** Adaptive expert pilots differ from Routine expert pilots in their opinions about techniques used and their effectiveness to assess CRM training.	No	-No significant differences between routine and adaptive experts on the scores on opinions about CRM evaluation methods (i.e., use of knowledge/attitudes questionnaires, need for developing new methods, and importance of evaluating CRM).
$\boldsymbol{H_6}$: Adaptive expert pilots differ from Routine expert pilots in their view of automation as a crewmember.	No	No significant differences between routine and adaptive experts on the scores on opinions about automation on the flight deck (i.e., views of automation as an additional crewmember, and lowering levels of automation during different stages of flight).

Research Question 1 (RQ1)

The first research question of this study asked:

(RQ1) Is there a relationship between pilots' flight experience variability and type of expertise?

To answer this question, I measured different aspects related to flight experience including: (a) Total flight time, (b) total flight time under Part 121, (c) total number of aircraft operated underpart 121, (d) total number of different aircraft make operated under part 121, (e) whether or not participants held a certificate to operate other aircraft categories, (f) total number of flight instruction facilities attended, and (g) total number of operations conducted as a pilot/other experience. The results indicated no correlation between any of these factors and adaptiveness.

Adaptive expertise theory states that the repetition of a task with certain degrees of variation leads to adaptive expertise (Hatano & Inagaki, 1986). Even though there was no significant relationships found between adaptiveness and different factors of flight experience, it is worth noting that, based on the results of this study, there seems to be a potential but small relationship between adaptiveness and the total number of operations conducted as a pilot (r = .135, p = .016). That is, the more experience a pilot had flying under different types of operations (e.g., flying for regional carriers, banner towing, corporate flying, air tours, military flying, etc.), the more likely it was that such a pilot was classified as an adaptive expert. In this study, *total number of operations conducted as a pilot* failed to reach significance due to the corrections made in the analysis to control for familywise error rate (after Bonferroni correction the required p = .007). Even though the question about variability of experience as a pilot and adaptiveness

remains unanswered, the total number of operations conducted as a pilot could provide an idea about what factors related to flight experience are linked to adaptiveness.

Research Question 2 (RQ2)

The second research question of this study asked:

(RQ2) Is there a relationship between personality traits and adaptive expertise?

Results from the study show there is a significant, although small, correlation between the scores on the abbreviated (21 item) Adaptive Expertise Survey (AES) and the scores on the Big Five Inventory (BFI; John et al., 1991). As shown in the Results chapter, there was a significant, positive relationship between adaptiveness and extraversion (r = .14), agreeableness (r = .20), conscientiousness (r = .23), and openness (r = .23). As scores on the abbreviated AES increased, so did, albeit slightly, the scores on the BFI that measured for the aforementioned traits. On the other hand, as scores on the abbreviated AES increased, scores on the BFI that measured neuroticism decreased (this was also a small but also significant correlation [r = -.19]).

As discussed in the literature review, there is evidence that a relationship exists between creative problem solving and personality traits, such as openness, conscientiousness, and extraversion (Athota & Roberts, 2015; O'Brien & DeLongis, 1996; Taggar, 2002). On the other hand, a relationship between adaptive expertise and personality traits has not been clearly established (Bohle Carbonell et al., 2014; Crawford et al., 2005). This is, to my knowledge, the first study that finds a relationship between adaptiveness and personality traits while using true experts. Even though the relationships found in this study are small, they are significant nonetheless. The fact that the relationship between adaptiveness and personality traits is small

indicates that even though a significant relationship exists, personality traits are not determinant factors in whether an individual reaches adaptiveness.

H_1: Use of CRM Outside the Flight Deck Interpretation

My first hypothesis stated that routine and adaptive experts would differ in the use of CRM skills outside the flight deck. The results of the study indicate that there is evidence to support this hypothesis. When asked about CRM being a valuable skill that they could also apply outside the flight deck, routine and adaptive experts differed in their responses. Adaptive experts were more likely than routine experts to highly agree with the perception of CRM being a valuable skill outside the flight deck. And even though a significant difference between routine and adaptive experts was not found when asked whether they had used CRM skills outside the flight deck (non-significance due to Bonferroni correction applied to control for familywise error rates), the analysis of free responses yielded information about the nature of routine and adaptive experts interpretation of the *use of CRM skills outside the flight deck*. These differences may shed light on the nature of CRM knowledge structures (schemas) for each group. Routine experts' answers to the question of using CRM outside the flight deck were, for the most part, tied to other aviation scenarios. For instance, routine experts' tendency was to talk about the use of CRM with cabin crews, ground personnel, and even passengers. On the other hand, adaptive experts tended to provide non-aviation specific examples. Adaptive experts' tendency was to talk about the use of CRM skills outside aviation, and they provided examples that talked about the use of CRM with family members, friends, as well as references to using CRM skills every day. As a matter of fact, the most common concepts used by adaptive experts to describe their use of CRM skills outside the flight deck were the concepts *wife* and *every day*.

The patterns identified in the free responses provided by participants are in accordance with the adaptive expertise literature which states that one of the characteristics of adaptive expertise is the capacity of adaptive experts to transfer knowledge to novel situations (Kimbal & Holyoak, 2000).

There is an important component of the question *have you used CRM outside the flight deck?* that needs to be dissected. In the process of developing the questionnaire for this study, I wanted to include items that would help me better understand how far removed from aviation adaptive experts' CRM schemas were. Hence the key component of this question is *flight deck*, instead of asking for a general use of CRM skills outside of *aviation*, I wanted to be more specific and tie the question to using CRM skills outside the flight deck. When it comes to CRM, ATPs usually receive training in which the emphasis is on the use of CRM skills on the flight deck, that is, how the captain and first officer of an aircraft use their CRM skills to perform better as a team. CRM training may also include some low level of training in which CRM skills are put in context of coordinating and communicating with other personnel involved in flight operations, usually flight attendants, dispatchers, maintenance personnel, and to a lesser extent, air traffic controllers. So when this question was crafted, I expected routine experts to either say that they had not used CRM skills outside the flight deck or that their examples of using CRM would be mostly associated to aviation scenarios. On the other hand, I expected adaptive experts to provide few or no examples of the use of CRM in aviation scenarios outside the flight deck, which in fact was the case.

One final aspect that is worth noting in the discussion of the results for this hypothesis is that the logic that I applied to asking about using CRM skills outside the flight deck might have

had an opposite, unexpected effect on the item that asked participants to agree or disagree with the statement *I think CRM is a valuable skill I can also apply outside the flight deck.* Even though there was a significant difference between routine and adaptive experts, mean scores for both groups were close (5.36 for routine and 5.46 for adaptive experts). Scores for routine experts might have been influenced by their notion that CRM skills are valuable while working with other personnel involved in flight operations, while it could be possible that adaptive experts as a group were thinking about using CRM skills outside flight operations in general.

H_2: Length of Training Interpretation

The second hypothesis stated that there would be differences between routine and adaptive experts in their opinions about the length of CRM training. There are two main discussion points derived from the analysis of the results. First, there were no significant differences between routine and adaptive experts in their scores on the section of the questionnaire that asked participants about different aspects related to the appropriateness of time spent on different types of training (e.g., indoctrination, initial qualification, upgrade) and on specific training methods (e.g., role playing, reviewing case studies, practicing CRM during simulation sessions, etc.). One of the aspects related to this hypothesis explored the opinions about time spent practicing CRM skills during usual and unusual scenarios while using Flight Training Devices (FTDs) and Full Flight Simulators (FFSs). I expected that adaptive experts would be more likely to express that there is lack of time during training to engage in non-routine scenarios where CRM skills are most needed, and that too much time is used practicing/reviewing routine scenarios. The results do not show any differences between any of

the expert groups (routine, adaptive, or even transitional experts), and in general all three groups agreed that more time to practice CRM skills is desired.

The second discussion point is related to questions regarding the percentage of time participants thought should be spent on CRM specific training in relation to other topics during initial qualification and recurrent training. The results showed a significant difference between routine and adaptive experts. The percentage of training routine experts thought should be dedicated to CRM specific training was greater than what adaptive experts thought should be spent (41.95% versus 33.28%). When I thought about this question, I hypothesized that since adaptive experts would be more aware of the importance of CRM training, they would consider that a greater percentage of the time during initial qualification and recurrent training should be *CRM specific* training. The results although significant, are in the opposite direction of what I had predicted. In fact, it was the group of routine experts the one that consider that a greater percentage of the time during training should be *CRM specific*. After reviewing the results of the study as a whole, my interpretation of the results about percentage of time dedicated to CRM specific training is that routine experts may find CRM specific exercises (e.g., reviews of CRM concepts, case studies, and practicing briefings) more valuable than adaptive experts do. Perhaps routine experts see CRM as a more compartmentalized set of skills that need to be specifically trained. On the other hand, adaptive experts may understand CRM as a set of skills that should be embedded into every aspect of training, and because their CRM knowledge structures are richer and more complex, reviewing for example, basic concepts or briefings, may be viewed by them as less beneficial.

H_3: CRM Training Methods Interpretation

Hypothesis 3 stated that there would be a difference between routine and adaptive experts in their opinions about the methods used to deliver CRM training. The results of the study showed no significant difference between routine and adaptive experts in their scores on the questionnaire that asked them about methods used to deliver CRM training (e.g., mobile technology, joint training, and newsletters). Mean scores for all three group of experts showed that in general, all groups of experts share a similar perception of methods used. The main view is that current methods are useful in helping pilots develop and enhance CRM skills.

One particular item of the questionnaire on training methods asked participants, *"in your opinion, what type of training should be provided for CRM?"* The analysis of this free response question showed a few interesting points worth discussing. First, all three group of participants expressed that the most effective training methods they think should be widely used are (a) the discussion of case studies/case based scenarios, (b) joint training, and (c) simulator training. Second, even though there was not a distinct pattern of responses for any particular group, some participants in the adaptive expertise group suggested some innovative ways to train CRM, specifically using FTDs (see Chapter 4). Even though the comments provided by these specific participants are not representative of the thoughts of participants in the adaptive expert category, it should be noted that this type of comment was not given by any routine or transitional experts. Suggestions by the adaptive experts to use simulator sessions in novel ways is in agreement with the literature that indicates that adaptive experts are characterized by their drive for innovation, creativity, and their desire to seek out challenges (Bohle Carbonell, Stalmeijer, Konings, Segers, & Van Merrienboer, 2014; Hatano & Oura, 2003).

H_4: CRM Topics Interpretation

The fourth hypothesis stated that there would be a significant difference between routine and adaptive experts in their opinions about topics currently covered during CRM training. The results show there was a significant difference between routine and adaptive experts and transitional and adaptive experts. Scores on this section of the survey indicates that adaptive experts deemed current topics covered during training more important and more applicable to today's operation needs than routine and transitional experts did. Even though the scores are significantly different, in general, all three group of experts considered that topics covered during training are between moderately important and very important.

One item in this section of the questionnaire gave participants the option to express their opinions about the following statement: "*I think there are areas of flight safety that CRM training does not cover.*" The analysis of free responses from participants show that the most common responses provided by adaptive experts relates to their perception that current CRM training programs do not provide sufficient (if any) training on aspects related to *personal/individual factors* that affect performance. Personal/individual factors mentioned by adaptive experts and that they considered should be covered in training include techniques to effectively deal with different types of personalities, conflict resolution, and training pilots on techniques to self-evaluate their own performance on the line. The second most common response among adaptive experts was related to their perception that (a) not one single type of training can cover every aspect of flight safety, (b) there is always room for improvement and new challenges will come as operational needs change, and (c) there is aspects of flight safety that we might not yet be fully aware of and therefore CRM training is not currently covering. These type answers provided by adaptive experts are reflective of two characteristics described

in the adaptive expertise literature as epistemic characteristics (the view of knowledge as dynamic and constantly changing), and metacognitive characteristics (the monitoring and understanding of one owns knowledge) (Charbonnier-Voirin & Roussel, 2012; Crawford, Schlager, Toyama, Riel, & Vahey, 2005).

Routine and transitional experts did, to some extent, express the need to include training related to dealing with personal factors affecting performance, but not to the same extent as adaptive experts did. Routine and transitional experts' comments related to metacognitive aspects of their knowledge of CRM were scarce, and on the contrary, one of the most common themes in routine and transitional experts' comments was that CRM training is a complete program that covers all aspects of flight safety.

H_5: CRM Evaluation Methods Interpretation

The fifth hypothesis proposed for this study stated that a difference would exist between routine and adaptive experts in their opinions about methods used to evaluate CRM training effectiveness. Results indicate that no significant difference existed between any of the three groups of experts and that, in general, all participants agreed that (a) evaluating CRM skills is important, (b) using knowledge and attitudes questionnaires are good ways to assess pilots understanding of CRM principles, and (c) better evaluation methods to assess CRM knowledge and skills should be developed.

The results indicate that regardless of type of expertise, pilots agreed that both assessing understanding of CRM concepts as well as understanding the extent to which CRM skills are transferred from training settings and put into practice on the line are important. At the same

time, all three types of experts agreed that more effective methods to evaluate pilots CRM skills are needed. The notion that better assessment methods are needed is in accordance with the academic view that current methods used to evaluate CRM knowledge and skills are insufficient and that better assessment methods to measure at Kirkpatrick's (1976) levels 3 and 4 of training evaluation hierarchy are needed.

H_6: Views on Automation Interpretation

The sixth and last hypothesis stated that routine and adaptive experts would differ in their views about automation on the flight deck. I had hypothesized that adaptive experts would be more likely than routine experts to see automation as an additional crewmember. The analysis of the results showed there were no significant differences between any of the groups of experts. Scores on the automation questionnaire indicated that all participants, regardless of their type of expertise, considered that (a) integrating automation management training into CRM specific training is beneficial to enhancing crew coordination, (b) there was agreement among participants about their perception that the use of high levels of automation affect crew communication and coordination, and (c) all three group of experts generally agreed with the following statement: *"I can see how automation on the flight deck could be perceived as an additional member of the crew."* Their scores for this statement fell on average somewhere between *somewhat agree* and *agree*, but as will be discussed next, some differences may exist between the three group of experts.

Analysis of free responses for the item on views on automation as an additional member of the crew provide a more detailed view of the different groups of experts on this specific topic. All groups of experts expressed that (a) automation on the flight deck is just a tool and an

available resource to be managed, and (b) all three groups acknowledged that automation can decrease workload, allowing crew members to use more of their own cognitive resources during phases of flight where workload is high (some even compared this to almost as having an additional crewmember or extra hand in the cockpit). Even though this view was common across groups, there were some views on automation that seem to be different from group to group. For instance, some routine experts expressed that automation can increase workload and make things worse, while some transitional experts expressed that automation management is challenging. Some adaptive experts claimed that automation can both increase and decrease workload, therefore more emphasis on automation management should be provided during training (including CRM training). To the specific portion of the statement which presents the idea of automation as an additional member of the crew, routine and transitional experts made less literal references to automation as an additional member of the crew. Very few of these experts provided positive opinions about referring to automation as an additional crewmember on the flight deck. On the other hand, more adaptive experts expressed their agreement with the view of automation as a member of the crew. One of the interesting points identified in the opinions from adaptive experts is the reference of automation as a *dumb crewmember/pilot.* This analogy of automation to a pilot with limited capabilities was unique to adaptive experts and no routine or transitional expert referred to automation as a *dumb* pilot. This type of statements by adaptive experts is supported by the literature in human-computer interaction which states that *"experienced computer users do in fact apply social rules to their interaction with computers"* (Nass et al., 1994, p. 77) and that the effects of working in a team with a computer could be comparable to team dynamics shown in human-human teams (Nass, Fogg, & Moon, 1996). In this case, it seems that answers delivered by adaptive experts in their views of automation as a

crew member indicate that this group of experts has the ability to make analogous comparisons between automation and a flight crewmember (in this case a dumb/limited pilot), this analogous view perhaps makes adaptive experts more aware of the benefit of including automation management as part of CRM training. It is important to remember at this point that no significant differences were found on the scores of the views on automation questionnaire. The idea behind pointing out differences between the three groups of experts in their free responses is to merely highlight trends found in my analysis, and which I found to be relevant to the present study's goals. These trends should not be taken as concrete, supporting evidence of the potential differences between adaptive and routine experts.

Interpretation of Response Rate and Number of Concepts Used in Free Response Items

When I started conducting the analysis of the qualitative data collected during the study, I wanted to look into some of the quantitative aspects of free responses such as, mean number of words used per item, number of concepts used by each group for every open ended question, and the response rate for each item. This section discusses the patterns identified in the quantitative aspects of free response items.

For all fourteen items that allowed participants to provide their own thoughts about their views on CRM training, evaluation, and automation, adaptive experts tended to have the highest response rates (in 12 of 14 items), and they also used the most concepts in the majority of free response items as a group (again in 12 out of 14 items). One would expect that the opposite would be true for routine experts, but in actuality, it was transitional experts who trended

towards the lowest response rates (in 9 of 14 items) and smallest number of concepts used for most items as a group (in 11 of 14 items).

The explanation for adaptive experts having the highest response rate and using the most concepts for almost all items seems to be clear. Adaptive expertise theory as expressed by Hatano and Inagaki (1986) describes that one of the characteristic of adaptive experts is that they have a well-developed conceptual knowledge of the task, which allows them to understand the meaning of the skill needed in a specific situation. Understanding the meaning of the skill, is what allows adaptive experts to transfer those skills to a novel task or situation. In this case, it seems like the conceptual knowledge by adaptive experts on CRM allows them to use more concepts when answering questions regarding CRM. The high response rate could be explained by another of the characteristics of adaptive experts associated with their drive for innovation, creativity, and their desire to seek out challenges (Bohle Carbonell et al., 2014; Hatano & Oura, 2003). It could be speculated that adaptive experts' curiosity and willingness to seek out challenges drove them to answer free response items at a higher rate than their routine or transitional expert counterparts, whom according to theory (at least for routine experts) lack the drive for innovation and creativity as well as the level of conceptual knowledge about CRM in comparison to adaptive experts. The nature of some of the free response items required participants to think about CRM in a more structured manner, forcing them to think in a more critical way (e.g., I think there are areas of flight safety that CRM training does not cover). Such items might have not been appealing, or even difficult, for routine or transitional experts to answer. For the particular example item shown above, the response rate difference between routine and adaptive experts was 17 percentage points, and 15 percentage points between transitional and adaptive experts (adaptive experts response rate was 47.9%).

Transitional Expertise Interpretation

While the main focus of the present study was to identify differences between routine and adaptive experts, the emergence of a third type of expertise is fascinating. At the same time, transitional experts' scores on the CRM questionnaire, their response rates, and the number of concepts used in free response items generate more questions than possible explanations for the nature or characteristics associated with transitional experts. First, to my knowledge there is no reference of a third category which exists between routine and adaptive experts (transitional expertise) in the literature of adaptive expertise/types of expertise. The main reason why I decided to label this third category *transitional expertise* is because according to the adaptive expertise literature it seems that routine expertise, reflected by domain knowledge, is a precursor to adaptive expertise (Bohle Carbonell et al., 2014). Based on the ideas exposed in the adaptive expertise literature, it seems like a transitional state of expertise would seem logical (following the premise that routine expertise is a precursor to adaptive expertise), but as mentioned above, identifying characteristics associated with transitional expertise based on the results of the present study is difficult to achieve.

There is nonetheless an interesting pattern prevalent in the answers of transitional experts not only present in their free responses but also on the scores of the CRM questionnaire used for this study. Transitional experts had, in general, the lowest response rate and used the lowest number of concepts in the majority of the free response items. A similar tendency was present in the analysis of the scores on the CRM questionnaire. Transitional experts obtained the lowest score in the sections related to length of training, training methods, topics covered during training, assessment methods, and views on automation (routine experts obtained the same score on views on automation). One of the free response items may help answer the question of low

scores and response rates among transitional experts. This dichotomous (no – yes) item asked participants "*In your experience, is CRM practiced in the flight deck the way it is taught during training?*" The analysis of this item shows that 41% of transitional experts answered no to this question (compared to 28% and 24% of routine and adaptive experts respectively). After further analysis of the open ended portion of this question (the only item for which transitional experts had the highest response rate), the answers given by transitional experts indicate that a set of these answers mentioned that the use of CRM on the flight deck was more informal and less structured compared to how CRM is taught during training. The fact that 41% of participants expressed that CRM is not practiced the same way it is taught during training, and the view of some participants that CRM is less structured and formal in practice compared to the models and structures taught during training may help explain the lower scores of transitional experts on the CRM questionnaire used in this study.

As far as characteristics that may be shared between transitional and adaptive experts, the analysis of the data provides limited information. A couple of free response items may indicate how transitional experts have developed a certain level of conceptual understanding of CRM. For example, the question about the use of CRM outside the flight deck, transitional experts provided more responses detached from aviation than routine experts but less than adaptive experts did. In general the application of CRM skills seemed to be appropriate for all groups in an aviation context, and as presented in the Results chapter (see Figure 2), the conceptualization of CRM skills evolve from aviation specific scenarios (for routine experts) to more generalized aspects of life (adaptive experts). Transitional experts fell between aviation specific scenarios and use of CRM in daily life events/situations. The same is true for the question that asked about CRM not covering all aspects of flight safety. Transitional experts comments related to *nothing covers*

everything/there is always room for improvement (an epistemic characteristic of adaptive expertise) were fewer than adaptive experts' responses referencing the same idea, but more than routine experts. One section in the questionnaire that shows similarities between transitional and adaptive experts is in the length of training section, more specifically in the percentage of training that should be dedicated to CRM training. While routine experts in average estimated that 41.95% of training should be CRM specific, transitional and adaptive experts estimated similar percentages (33.28% and 35.66% respectively). This data, although limited, could provide a glimpse into the nature of transitional experts. More research will need to be done in order to corroborate the existence of transitional experts and their characteristics.

A final point that needs to be mentioned here is that type of expertise had no correlation to factors such as age, gender, level of education, number of flight hours (total, under part 121, and in current aircraft), position held (captain or first officer), or even the type of airline participants worked for. Therefore, results on the CRM questionnaire were not significantly impacted by any of these factors.

Implications and Conclusions

Theoretical Implications. One of the present study's goals was to further the understanding of adaptive expertise theory. The findings of the present research study can potentially contribute to the literature on adaptive expertise in several aspects. First, this study was able to identify a relationship between adaptive expertise and personality traits. Previous studies that have looked at the relationship between personality traits and adaptive expertise have reported mixed results (see Bohle Carbonell et al., 2014). This particular study was able to identify small but significant relationships between adaptive expertise and five personality traits

(i.e. extraversion, agreeableness, conscientiousness, neuroticism, and openness). To my knowledge the present study is the first one that has been able to identify a connection between the personality traits mentioned above and adaptive expertise while using a sample of true experts. These findings add to the literature on adaptive expertise by providing evidence that a relationship between adaptive expertise and personality traits exists. As mentioned above the relationships found were identified in a sample of true experts that work in a high risk, highly dynamic environment, therefore, a generalization of these findings to other types of experts in different types of industries is impossible to make at this point.

Even though a significant relationship was not found between diversity of flight experience and adaptive expertise, there seems to be an indication of a relationship between the number of different operations conducted as a pilot and adaptive expertise (this relationship was not significant due to a Bonferroni correction applied to correct for family wise error rates). This apparent relationship could help enrich the literature on adaptive expertise which claims that adaptive expertise is developed, in part, thanks to variations experienced by experts in their operational environment. This is especially important because in the adaptive expertise literature there is a lack of evidence showing that variations experienced by experts in highly dynamic environments are related to the development of expertise.

Although not all six hypotheses were supported by the results of this study, the ones that were supported (H_1, H_4, and to some extent, H_2) are not only in accordance with the literature but provide a glimpse into the differences between routine and adaptive experts regarding their knowledge structures, in this case, about CRM. This study is to my knowledge the first one that studied true experts (professional airline transport pilots with over 1,500 flight hours) who work in a high risk industry in which decisions are made in a dynamic environment. Previous studies

have for the most part looked at differences between either college students (e.g., freshmen versus seniors), or a have used dissimilar groups (e.g., college students vs college instructors). To my knowledge, only one study used true experts, but the experts used in that study were science teachers and did not work in a high risk-field (see Crawford et al., 2005). Therefore, the present study provides evidence that the existence of adaptive expertise is also present in experts that (a) are removed from the academic world (most studies have either used students, teachers, or a combination of both), and (b) work in a high risk, highly dynamic environment.

In the second chapter I explained the differences between adaptive expertise and Klein's RPDM model. Klein has explained that experts, make decisions by applying a combination of (a) situation assessment (pattern matching) and (b) mental simulation (deliberate analysis). Klein (2008) has claimed that a combination of (a) and (b) is necessary for an expert to make rapid decisions efficiently. But experts are not always able to generate appropriate solutions, especially when faced with a novel situation. Klein has described situations in which experts revert to a *novice state*, but RPDM does not provide a possible explanation of why this situation occurs. I stated then, that adaptive expertise theory might help better understand why some experts are able to adapt to new situations. Evidence from the present study shows the existence of adaptive expertise among experts that work in highly dynamic environments. The existence of adaptive and routine expertise in high risk fields could potentially help answer the question of why sometimes experts can adapt while others regress to a *novice state* when faced with novel situations.

Another theoretical implication of the present study in relation to the field of expertise is the identification of what I have called *transitional experts*. Adaptive expertise theory divides

experts into two categories, namely, routine and adaptive experts. Previous research on adaptive expertise has established differences between routine and adaptive experts not only on their scores on adaptive expertise questionnaires but also on knowledge structures. Adaptive expertise theory and the subsequent studies that followed its inception, have consistently divided expertise in a dichotomous manner, either routine or adaptive expertise. The present study has offered evidence of the existence of a third and distinct type of expertise that falls between routine and adaptive expertise and which presents interesting patterns as identified by the results of the CRM training questionnaire scores and free response items. Therefore the identification of *transitional experts* could have implication for adaptive expertise theory, and this finding should be taken into consideration in future studies investigating different aspects of adaptive expertise. Distinct characteristics of transitional experts remain unknown, therefore other than identifying their presence on the spectrum of adaptiveness, the present study cannot make further inferences about the uniqueness of transitional experts.

Practical Implications. One of the main goals of studying types of expertise in the context of professional airline pilots was to identify an alternative and novel way to assess CRM training effectiveness. The findings of the present study indicate that identifying pilots' type of expertise and assessing pilots' CRM knowledge structures could potentially be used for the assessment of CRM training effectiveness. This would allow training departments to determine how their training is helping pilots develop their conceptual understanding of CRM (which may indicate how this knowledge is being applied on the flight deck). More important is the idea that identifying pilots' types of expertise and CRM knowledge structures could help training departments create CRM training modules tailored to specific types of experts. The results of the present study provide some evidence that opinions about CRM training differ between routine

and adaptive experts, and between transitional and adaptive experts. Of particular interest is transitional experts' low scores on the CRM training questionnaire. This could be an indication that transitional experts might not find current CRM training methods as beneficial as routine and adaptive experts do, suggesting that, different training should be designed for this type of experts. As I mentioned in the transitional experts interpretation section, a portion of the participants in this group expressed that training was too structured and formal and not really reflective of the way CRM is practiced on the line. The structure of current CRM training programs could be perceived as more appropriate by routine and adaptive experts for different reasons. For routine experts, this may be because the structure of the training matches their expectations about what CRM is and how it should be implemented (procedural knowledge). To my knowledge, all CRM training programs relate to some sort of CRM model in which types of threats and errors are dissected, and resources are explained. Case studies are then mapped to that model and a discussion ensues about what went wrong in the presented scenario according to the CRM model used. For adaptive experts, this approach, although not as enriching for their own understanding of CRM, can be used to better conceptualize CRM models and map it to how CRM skills are to be used on the line, and perhaps in other domains, in an effective way. This is possible thanks to adaptive experts' better conceptualization and understanding of CRM principles.

Using adaptive expertise in conjunction with evaluation of CRM knowledge structures could also help training departments understand how CRM knowledge changes over time for their pilots, which could potentially be used as a way to measure training effectiveness (is CRM training helping pilots go from procedural knowledge to conceptual knowledge?). If adaptive expertise theory is correct, helping pilots develop conceptualized knowledge of CRM would

have a beneficial impact on flight safety .This is particularly important because adaptive expertise theory says that (a) adaptive experts can use their skills in an effective manner under unusual circumstances, and (b) are better at exchanging information with others, even during routine conditions.

Every day, thousands of flights take place in the US without any major anomalies, therefore CRM skills are practiced in normal/routine conditions for the majority of the career of an airline pilot. Ensuring that pilots not only have the CRM knowledge but also have the ability to adapt such knowledge to unusual circumstances is considered of great importance. Assessing CRM knowledge structures could help training departments better train their pilots to react in an effective manner when an emergency/unusual event occurs. Of course more research is needed to understand the real impact this approach could have on CRM training and evaluation.

Limitations of the Study. The present study has multiple limitations. First, recruiting participants for this study was challenging. Around 3,000 Airline Transport Pilots (ATPs) were contacted through professional networking platforms and professional pilot forums on-line, yet less than 500 participated in the study and only 260 completed the entire study. This means that data used for this study represented less than 10% of the potential participants that were invited to take part of the study. Even though the study's results show there are differences between routine and adaptive experts, the question remains about the other 90% of potential participants. How their answers would have affected the results of my study is a question that remains unanswered. Perhaps my sample was unique in the sense that they could be particularly interested in CRM, or they were more extroverted than other pilots therefore more likely to voice their opinions.

The second limitation of the study was the low number of female pilots that participated in the study. Only 7.5% (N = 19) participants were women. Even though this is a close representation of the real percentage of the female pilot population in the airline industry which is close to 5% (Women in Aviation International, 2017), the small number of female participants did not allow for the analysis of potential gender differences in relation to CRM knowledge structures and adaptive expertise.

The third limitation of the study is related to the Adaptive Expertise Survey (AES) used to measure for adaptiveness. As shown in the Results section, the reliability of the AES is less than optimal, therefore, a factor analysis needed to be carried out in order to determine the best way to increase the survey's reliability. This resulted in the elimination of multiple items, including an entire section of the survey (epistemology). Even though results of the abbreviated AES and the original AES (Appendix D) are in essence the same, the fact that the epistemology section of the survey has a low reliability indicate that issues with this section's items exist. After further inspection and in hindsight, the questions in the epistemology section may be appropriate for participants whose area of expertise is in a field in academia, but not for participants whose area of expertise is in a technical area such as commercial aviation.

Future Research. Future research on adaptive expertise should focus on studying true experts that work in high risk, highly dynamic fields such as first responders, military and the emergency room/operating room. As mentioned before, the majority of studies in the past have used college students and faculty. There is a need for more studies to help the research community understand how different types of true experts perform in a variety of fields,

especially in highly dynamic, high risk environments in which critical decisions ought to be made when unexpected events take place.

A second area of research should focus on replicating the findings of the present study in regards to transitional experts. As mentioned before, no study to my knowledge has identified a distinct type of expertise between routine and adaptive expertise. It is important that if results of this study can be replicated, future studies focus on identifying the unique characteristics of transitional experts as well as characteristics that are shared with routine and adaptive experts. It is important to note that transitional experts were identified in airline transport pilots and it may be the case that this is a unique case to airline transport pilots or experts that work in highly dynamic environments. It would be important to conduct studies that aim at identifying the existence of transitional experts in other domains as well (e.g., academia, business, even sports)

Another area of research that should be carried out in the future involves research that focuses on the development and validation of adaptive expertise metrics. There are very few metrics that have been developed, validated, and which are accessible to researchers. As it was discussed earlier in this document the original AES's reliability was somewhat questionable and steps needed to be taken to improve its reliability. To my knowledge my study is the first one to perform reliability and validity analyses on the AES (besides the original validation study) and it was the first one to use this metric with true experts (experienced ATPs). The reliability and validity analyses performed resulted in the modification of the original 42 item AES which produced a 21 item questionnaire in which a section on epistemology was completely removed. It should be noted that epistemology is an important component of adaptive expertise theory and future metrics should include a section on epistemology that can be easily used in research

studies that use experts in technical areas. I recommend that future studies use the 21 abbreviated AES plus an epistemology section carefully crafted or tailored towards the intended sample to be used in any particular study.

Finally, future research should continue to study the possibility of using adaptive expertise and knowledge structures (schemas) as a way to understand ATPs' knowledge of CRM which could help in the identification of related training needs. This study was able to provide some evidence about the differences between the three different groups of experts and their use of CRM outside the flight deck as well as their opinions about CRM training, evaluation, and views on automation. Participants of the present study, regardless of their type of expertise, agreed that evaluating CRM is important and also, that new and better evaluation methods should be developed to better measure pilots' understanding of CRM concepts and more importantly the application of CRM skills on the line. I believe that my study could be the foundation for future research that looks into innovative ways of evaluating CRM knowledge and identify training needs. As an example, possible evaluation methods could include presenting pilots with scenarios detached from aviation which require using other people and resources to successfully solve a problem, followed by a debriefing by the evaluator/instructor in which an analogy between CRM on the flight deck and the non-aviation problem is drawn. I believe these types of evaluation scenarios could be useful for routine, and especially for transitional experts. Gone are the days in which pilots showed reluctance towards CRM, yet most of accidents/incidents during high workload phases of flight continue to be related to CRM. It is time to start developing training and evaluation methods that ensure pilots effective use of CRM skills during unusual/abnormal circumstances.

APPENDIX A
IRB OUTCOME LETTER

University of Central Florida Institutional Review Board
Office of Research & Commercialization
12201 Research Parkway, Suite 501
Orlando, Florida 32826-3246
Telephone: 407-823-2901 or 407-882-2276
www.research.ucf.edu/compliance/irb.html

Approval of Exempt Human Research

From: **UCF Institutional Review Board #1**
FWA00000351, IRB00001138

To: **Camilo Jimenez** and Co-PI: **Florian G. Jentsch**

Date: **September 01, 2017**

Dear Researcher:

On 09/01/2017, the IRB approved the following modifications as human participant research that is exempt from regulation:

Type of Review:	Exempt Determination
Modification Type:	Updated questionnaire
Project Title:	Identifying Differences Among Airline Transport Pilots in Their Views of Crew Resource Management (CRM), CRM Training, and CRM Training Evaluation
Investigator:	Camilo Jimenez
IRB Number:	SBE-17-13368
Funding Agency:	
Grant Title:	
Research ID:	N/A

This determination applies only to the activities described in the IRB submission and does not apply should any changes be made. If changes are made and there are questions about whether these changes affect the exempt status of the human research, please contact the IRB. When you have completed your research, please submit a Study Closure request in iRIS so that IRB records will be accurate.

In the conduct of this research, you are responsible to follow the requirements of the Investigator Manual.

On behalf of Sophia Dziegielewski, Ph.D., L.C.S.W., UCF IRB Chair, this letter is signed by:

Signature applied by Gillian Amy Mary Morien on 09/01/2017 02:02:46 PM EDT
IRB Coordinator

APPENDIX B
INSTRUMENTS USED TO MEASURE ADAPTIVENESS AND ADAPTIVE EXPERTISE

Questionnaire	Developed by	Dimensions Measured	Number of Items	Sample Items
Adaptive Expertise Inventory	Carbonell, Stalmeijer, Konings, Segers, & Van Merrienboer, 2014	• Domain Skills • Innovative Skills	10	• During past projects, I was able to develop and integrate new knowledge with what I learned in the past. • During past projects, I concerned myself with the latest development in the domain of my discipline.
Adaptive Expertise Survey	Fisher & Peterson, 2001	• Multiple Perspectives • Metacognitive Self-Assessment • Goals and Beliefs • Epistemology	42	• Knowledge that exists today may be replaced with a new understanding tomorrow. • Scientists are always revising their view of the world around them.
Job Adaptability Inventory (JAI)	Pulakos Arad, Donovan, & Plomondon, 2000	• Handling Emergencies or Crisis Situations • Handling Work Stress • Solving Problems Creatively • Dealing with Uncertain/Unpredictable Work Situations • Learning Work Tasks, Technologies, • and Procedures • Demonstrating Interpersonal Adaptability, • Demonstrating Cultural • Adaptability • Demonstrating Physically Oriented Adaptability	132	• Tailor own behavior depending on others' needs and interests to help them feel more comfortable (Demonstrating Interpersonal Adaptability). • Change plans because the necessary supplies or equipment are unexpectedly unavailable (Dealing Uncertain/Unpredictable Changing Work Situations). • Develop new systems or procedures to improve efficiency or fix problems (Solving Problems Creatively). • Learn new technologies that apply to own work (Learning Work Tasks, Technologies, and Procedures).
The Measurement of Professional Expertise	Van der Heijden, 2000	• Knowledge • Meta-Cognitive Knowledge • Skills • Social Recognition • Growth and Flexibility	78	• I consider myself to be (not at all - extremely) competent to judge who can help me to supplement any deficiencies in my own knowledge. • In view of the latest developments, I consider myself to be (not at all - extremely) competent to judge whether my skills are sufficiently up to date.

APPENDIX C
THE BIG FIVE INVENTORY (BFI)

Here are a number of characteristics that may or may not apply to you. For example, do you agree that you are someone who likes to spend time with others? Please write a number next to each statement to indicate the extent to which you agree or disagree with that statement.

Disagree strongly	Disagree a little	Neither agree nor disagree	Agree a little	Agree strongly
1	2	3	4	5

I see Myself as Someone Who…

___1. Is talkative

___2. Tends to find fault with others

___3. Does a thorough job

___4. Is depressed, blue

___5. Is original, comes up with new ideas

___6. Is reserved

___7. Is helpful and unselfish with others

___8. Can be somewhat careless

___9. Is relaxed, handles stress well

___10. Is curious about many different things

___11. Is full of energy

___12. Starts quarrels with others

___13. Is a reliable worker

___14. Can be tense

___15. Is ingenious, a deep thinker

___16. Generates a lot of enthusiasm

___17. Has a forgiving nature

___18. Tends to be disorganized

___19. Worries a lot

___20. Has an active imagination

___21. Tends to be quiet

___22. Is generally trusting

___23. Tends to be lazy

___24. Is emotionally stable, not easily upset

___25. Is inventive

___26. Has an assertive personality

___27. Can be cold and aloof

___28. Perseveres until the task is finished

___29. Can be moody

___30. Values artistic, aesthetic experiences

___31. Is sometimes shy, inhibited

___32. Is considerate and kind to almost everyone

___33. Does things efficiently

___34. Remains calm in tense situations

___35. Prefers work that is routine

___36. Is outgoing, sociable

___37. Is sometimes rude to others

___38. Makes plans and follows through with them

___39. Gets nervous easily

___40. Likes to reflect, play with ideas

___41. Has few artistic interests

___42. Likes to cooperate with others

___43. Is easily distracted

___44. Is sophisticated in art, music, or literature

APPENDIX D
FISHER AND PETERSON'S (2001) ADAPTIVE EXPERTISE SURVEY

	Multiple Perspectives
1	I create several models of an engineering problem to see which one I like best.
2	When I consider a problem, I like to see how many different ways I can look at it.
3 (*)	Usually there is one correct method in which to represent a problem.
4 (*)	I tend to focus on a particular model in which to solve a problem.
5	I am open to changing my mind when confronted with an alternative viewpoint.
6 (*)	I rarely consider other ideas after I have found the best answer.
7 (*)	I find additional ideas burdensome after I have found a way to solve the problem.
8	For a new situation, I consider a variety of approaches until one emerges superior.
9 (*)	I solve all related problems in the same manner.
10 (*)	When I solve a new problem, I always try to use the same approach.
11 (*)	There is one best way to approach a problem.
	Metacognitive Self-Assessment
12	As I learn, I question my understanding of the new information.
13	I often try to monitor my understanding of the problem.
14 (*)	As a student, I cannot evaluate my own understanding of new material.
15 (*)	I rarely monitor my own understanding while learning something new.
16	When I know the material, I can recognize areas where my understanding is incomplete.
17 (*)	I have difficulty in determining how well I understand a topic.
18	I monitor my performance on a task.
19	As I work, I ask myself how I am doing and seek out appropriate feedback.
20 (*)	I seldom evaluate my performance on a task.
	Goals and Beliefs
21	Challenge stimulates me.
22 (*)	I feel uncomfortable when I cannot solve difficult problems.
23 (*)	I am afraid to try tasks that I do not think I will do well.
24 (*)	Although I hate to admit it, I would rather do well in a class than learn a lot.
25	One can increase their level of expertise in any area if they are willing to try.
26	Expertise can be developed through hard work.
27 (*)	To become an expert in engineering, you must have an innate talent for engineering.
28 (*)	Experts in engineering are born with a natural talent for their field.
29 (*)	Experts are born, not made.
30	Even if frustrated when working on a difficult problem, I can push on.
31 (*)	I feel uncomfortable when unsure if I am doing a problem the right way.
32	Poorly completing a project is not a sign of a lack of intelligence.
33 (*)	When I struggle, I wonder if I have the intelligence to succeed in engineering.
	Epistemology
34	Knowledge that exists today may be replaced with a new understanding tomorrow.
35	Scientists are always revising their view of the world around them.
36 (*)	Most knowledge that exists in the world today will not change.
37 (*)	Facts that are taught to me in class must be true.
38 (*)	Existing knowledge in the world seldom changes.
39	Scientific theory slowly develops as ideas are analyzed and debated.
40	Scientific knowledge is developed by a community of researchers.
41 (*)	Scientific knowledge is discovered by individuals.
42 (*)	Progress in science is due mainly to the work of sole individuals.

* Reverse Item

Since pilots were used for this study, the word aviation instead of the word engineering was used

APPENDIX E
DEMOGRAPHICS, CRM KNOWLEDGE, TRAINING NEEDS, AND AUTOMATION QUESTIONNAIRES

Demographics

1. What is your age?
   - Under 21 years
   - 21 – 29 years
   - 30 – 39 years
   - 40 – 49 years
   - 50 – 59 years
   - 60 years or older

2. What is your gender?
   - Male
   - Female
   - Other _____

3. What is your highest level of education?
   - High school graduate, diploma or the equivalent (for example: GED)
   - Some college credit, no degree
   - Trade/technical/vocational training
   - Associate's degree
   - Bachelor's degree
   - Master's degree
   - Professional degree
   - Doctorate degree

4. What is your current position?
   - Captain
   - First Officer

   Have you held the position of captain on an aircraft operating under Part 121 (or pilot in command on an aircraft in the military) before your current role in your current aircraft? Yes ___ No ___

5. What type of air carrier are you currently employed by?
   - Legacy
   - Major-National-LCC
   - Regional
   - Foreign air carrier authorized to operate in the US under Part 129

   Optional: Which airline are you currently working for? _____

6. How long have you been working for this carrier?
   - Less than 1 year
   - Between 1 and 5 years
   - Between 6 and 10 years

- Over 10 years

7. What make and model of aircraft are you currently operating?

8. How long have you been flying the aircraft you are currently operating?

9. Please list the types of aircraft (make and model) you have operated in the past under Part 121

10. What is your total flight time (hours)? (including general aviation, military and commercial experience):
    - 2,000 or less
    - 2,001-4,000
    - 4,001-6,000
    - 6,001-8,000
    - 8,001-10,000
    - 10,001-12,000
    - 12,001-14,000
    - Over 14,000

11. Total number of flight hours as an airline pilot working for a part 121 carrier only:
    - Less than 500
    - 500-2,000
    - 2,001-4,000
    - 4,001-6,000
    - 6,001-8,000
    - 8,001-10,000
    - 10,001-12,000
    - 12,001-14,000
    - Over 14,000

12. Total number of flight hours at your current airline:
    - Less than 500
    - 500-2,000
    - 2,001-4,000
    - 4,001-6,000
    - 6,001-8,000
    - 8,001-10,000
    - 10,001-12,000
    - 12,001-14,000
    - Over 14,000

13. Number of hours on current aircraft:
    - Less than 500
    - 500-2,000

- ○ 2,001-4,000
- ○ 4,001-6,000
- ○ 6,001-8,000
- ○ 8,001-10,000
- ○ 10,001-12,000
- ○ 12,001-14,000
- ○ Over 14,000

14. How many years/months since you completed initial qualification training in your current aircraft?
    Years: _____
    Months: _____

15. When did you complete your most recent recurrent training? _____ (MM/YY)
    If no recurrent training has taken place yet, please indicate when you completed your initial qualification _____(MM/YY)

16. Where did you obtain your flight training?
    Please mark all that apply

	Flight School	Independent Flight Inst.	Community College	University	Military	Other
Private	O	O	O	O	O	O
Instrument	O	O	O	O	O	O
Commercial	O	O	O	O	O	O
Multi-Engine	O	O	O	O	O	O
CFI	O	O	O	O	O	O
CFII	O	O	O	O	O	O
Airline Transport Pilot (ATP)	O	O	O	O	O	O

17. Do you have any military flight experience? (mark ALL that apply) Yes ___ No ___
    - ☐ Single seat
    - ☐ Dual seat Pilot/Weapons System Officer or equivalent
    - ☐ Multi-crew operations

18. In addition to your current airline, what other flying experience do you have? (mark ALL that apply)

- ☐ Legacy carriers
- ☐ Major-National-LCC carriers
- ☐ Regional carriers
- ☐ Supplemental/Cargo carriers
- ☐ Military
- ☐ Corporate/Charter
- ☐ Flight instruction (Civilian or Military)
- ☐ Crop dusting/Powerline Inspection/Banner Towing/Fish Spotting
- ☐ Air tours
- ☐ Other _____

19. Do you currently hold, or have ever held, a certificate for any of the following categories? (please mark ALL that apply)

- ☐ Glider
- ☐ Rotorcraft
- ☐ Lighter than air

CRM Knowledge Questionnaire

1. In your own words, could you describe what your meaning of CRM is?

2. If you had to explain CRM to someone who has never heard of this concept before, how would you explain it to them? (Open ended)

3. I think CRM is valuable on the flight deck

Strongly Disagree	Disagree	Somewhat Disagree	Somewhat Agree	Agree	Strongly Agree
1	2	3	4	5	6

4. In your opinion, is CRM effective at enhancing flight safety during line operations?
   Yes
   No
   Please explain:

5. I think CRM is a valuable skill I can also apply outside the flight deck

Strongly Disagree	Disagree	Somewhat Disagree	Somewhat Agree	Agree	Strongly Agree
1	2	3	4	5	6

6. Have you used CRM outside of the flight deck?
   Yes
   No
   Please explain, and provide a detailed example:

7. Are there areas of CRM that you believe can be applied to areas outside of aviation?
   Yes
   No

Please explain:
8. Are there areas of CRM that you believe are only applicable to aviation and nowhere else? Yes No Please explain:
9. In your experience, is CRM practiced in the flight deck the way it is taught during training? Yes No If no, please explain why:
10. During line operations, does effective use of CRM skills result in a different outcome than not applying these principles at all? Yes No Please explain:

In the following section, we will ask you a series of questions related to different CRM activities, and whether they would be time well spent during (a) Indoctrination, (b) Initial Qualification, (c) Recurrent Qualification, and (d) Distance Learning.

CRM Length of Training Questionnaire

1. Relative to other topics covered, the time dedicated to classroom presentations about CRM concepts during training is appropriate:

							If you marked 1, 2, or 3, please indicate one of the two:	
	Strongly Disagree	Disagree	Somewhat Disagree	Somewhat Agree	Agree	Strongly Agree	Time dedicated to lectures on CRM topics during training is insufficient	Time dedicated to lectures on CRM topics during training is excessive
	1	2	3	4	5	6		
For Indoctrination	O	O	O	O	O	O	O	O
For Initial Qualification	O	O	O	O	O	O	O	O
For Recurrent Qual	O	O	O	O	O	O	O	O
For Distance Learning	O	O	O	O	O	O	O	O

2. Relative to other topics covered, the time dedicated during (Maneuvers and Procedures training)/LOFT to practicing CRM skills is appropriate:

Strongly Disagree	Disagree	Somewhat Disagree	Somewhat Agree	Agree	Strongly Agree	**If you marked 1, 2, or 3, please indicate one of the two:** Time dedicated to lectures on CRM topics during training is insufficient	Time dedicated to lectures on CRM topics during training is excessive
1	2	3	4	5	6		
O	O	O	O	O	O	O	O

3. During Initial and recurrent training, what percentage of time do you think **should be spent** on CRM specific training in relation to other topics?
   Initial____%
   Recurrent____%

4. I believe that dedicating time during **Indoctrination** to engage in the following activities is time well spent:

	Strongly Disagree 1	Disagree 2	Somewhat Disagree 3	Somewhat Agree 4	Agree 5	Strongly Agree 6
Reviewing CRM concepts	O	O	O	O	O	O
Reviewing case studies	O	O	O	O	O	O
Role play exercises to practice CRM behaviors	O	O	O	O	O	O

5. I believe that dedicating time during **Initial Qualification** to engage in the following activities **would be** time well spent

	Strongly Disagree 1	Disagree 2	Somewhat Disagree 3	Somewhat Agree 4	Agree 5	Strongly Agree 6
Reviewing CRM concepts	O	O	O	O	O	O
Reviewing case studies	O	O	O	O	O	O
Role play exercises to practice CRM behaviors	O	O	O	O	O	O
Practicing Briefings (e.g., Pairing, Flight Attendant, Departure, Before Take-Off, Approach)	O	O	O	O	O	O

6. I think that dedicating time during **Recurrent Qual** to engage in these activities **would be** time well spent

	Strongly Disagree 1	Disagree 2	Somewhat Disagree 3	Somewhat Agree 4	Agree 5	Strongly Agree 6

Reviewing CRM concepts	O	O	O	O	O	O
Reviewing case studies	O	O	O	O	O	O
Role play exercises to practice CRM behaviors	O	O	O	O	O	O
Practicing Briefings (e.g., Pairing, Flight Attendant, Departure, Before Take-Off, Approach)	O	O	O	O	O	O

7. I think that dedicating time during **Distance Learning** to engage in these activities **would be** time well spent

Reviewing CRM concepts	O	O	O	O	O	O
Reviewing case studies	O	O	O	O	O	O
Role play exercises to practice CRM behaviors	O	O	O	O	O	O
Practicing Briefings (e.g., Pairing, Flight Attendant, Departure, Before Take-Off, Approach)	O	O	O	O	O	O

8. I wish there was more time available during **Procedures Training** to practice CRM skills:

	Strongly Disagree 1	Disagree 2	Somewhat Disagree 3	Somewhat Agree 4	Agree 5	Strongly Agree 6
Unusual scenarios	O	O	O	O	O	O
Usual scenarios	O	O	O	O	O	O

9. I wish there was more time available during **Maneuvers Training** to practice CRM skills:

	Strongly Disagree 1	Disagree 2	Somewhat Disagree 3	Somewhat Agree 4	Agree 5	Strongly Agree 6
Unusual scenarios	O	O	O	O	O	O
Usual scenarios	O	O	O	O	O	O

10. I wish there was more time available during **LOFT** to practice CRM skills:

	Strongly Disagree 1	Disagree 2	Somewhat Disagree 3	Somewhat Agree 4	Agree 5	Strongly Agree 6
Unusual scenarios	O	O	O	O	O	O
Usual scenarios	O	O	O	O	O	O

CRM Training Methods Questionnaire

1. I find that using home based simulators to practice procedures and maneuvers could help further develop my CRM skills

Strongly Disagree 1	Disagree 2	Somewhat Disagree 3	Somewhat Agree 4	Agree 5	Strongly Agree 6

2. I think using mobile technology (e.g., tablets and phones) to deliver CRM specific training would be helpful to supplement Recurrent Qual training

Strongly Disagree 1	Disagree 2	Somewhat Disagree 3	Somewhat Agree 4	Agree 5	Strongly Agree 6

3. Having the opportunity to practice flight scenarios in Joint CRM training sessions with the following personnel would better prepare me to use CRM skills during line operations

	Strongly Disagree 1	Disagree 2	Somewhat Disagree 3	Somewhat Agree 4	Agree 5	Strongly Agree 6
Flight Attendants	o	o	o	o	o	o
Dispatchers	o	o	o	o	o	o
Maintenance Crews	o	o	o	o	o	o

ATC Personnel	o	o	o	o	o	o

4. In your opinion, what are the most effective approach/approaches currently used for CRM training? Please explain:

5. How often do you think the methods in which CRM training is conducted should be updated/revised?

Never	Very rarely Every 7 to 10 years	Rarely Every 7 to 5 years	Occasionally Every 5 to 3 Years	Frequently Every 3 to 1 years	Very Frequently Twice a year
1	2	3	4	5	6

6. I think that the distribution of newsletters, pertaining to line operations that cover crew coordination and decision making issues would be a valuable tool to enhance my CRM skills

Strongly Disagree	Disagree	Somewhat Disagree	Somewhat Agree	Agree	Strongly Agree
1	2	3	4	5	6

7. In your opinion, what type of training should be provided for CRM? Please explain:

CRM Training Topics Questionnaire

- How important is it to train the following CRM topics during initial or recurrent training?

	Not at all important 1	Low importance 2	Slightly important 3	Moderately important 4	Very important 5	Extremely important 6
Crew Communication and Coordination	O	O	O	O	O	O
Stress Management	O	O	O	O	O	O
Fatigue	O	O	O	O	O	O
Leadership and Followership	O	O	O	O	O	O
Interpersonal Relationships	O	O	O	O	O	O

Workload Management and Situation Awareness	O	O	O	O	O	O
Workload Distribution and Distraction Avoidance	O	O	O	O	O	O
Team Decision Making	O	O	O	O	O	O
Conflict Resolution	O	O	O	O	O	O

- I think there are areas of flight safety that CRM training does not cover

Strongly Disagree	Disagree	Somewhat Disagree	Somewhat Agree	Agree	Strongly Agree
1	2	3	4	5	6

Please explain:

- I believe that topics covered during CRM training I have received <u>are not applicable</u> to today's operational needs

Strongly Disagree	Disagree	Somewhat Disagree	Somewhat Agree	Agree	Strongly Agree
1	2	3	4	5	6

- Topics covered during CRM <u>training help me understand</u> the importance of crew coordination and communication on the flight deck

Strongly Disagree	Disagree	Somewhat Disagree	Somewhat Agree	Agree	Strongly Agree
1	2	3	4	5	6

CRM Training Evaluation

1. I believe that questionnaires that gauge my attitude towards CRM training are an appropriate way to assess flightcrews' CRM skills

Strongly Disagree	Disagree	Somewhat Disagree	Somewhat Agree	Agree	Strongly Agree
1	2	3	4	5	6

2. I believe post training knowledge questionnaires are a good way to assess flightcrews' understanding of CRM principles

Strongly Disagree	Disagree	Somewhat Disagree	Somewhat Agree	Agree	Strongly Agree
1	2	3	4	5	6

3. I believe scores from CRM knowledge and attitude questionnaire administered post-training are good predictors of CRM being applied to line operations					
Strongly Disagree	Disagree	Somewhat Disagree	Somewhat Agree	Agree	Strongly Agree
1	2	3	4	5	6
4. I believe that better assessment methods are needed to evaluate with accuracy the effectiveness of CRM training					
Strongly Disagree	Disagree	Somewhat Disagree	Somewhat Agree	Agree	Strongly Agree
1	2	3	4	5	6
5. I believe evaluating flightcrews' understanding of CRM is not important					
Strongly Disagree	Disagree	Somewhat Disagree	Somewhat Agree	Agree	Strongly Agree
1	2	3	4	5	6
6. I think it is important to develop methods that allow airlines to understand the real impact of CRM training on line operations					
Strongly Disagree	Disagree	Somewhat Disagree	Somewhat Agree	Agree	Strongly Agree
1	2	3	4	5	6
7. I think LOSAs should be followed by a debriefing from the LOSA observer to inform flightcrews about their application of CRM behaviors on the flight deck					
Strongly Disagree	Disagree	Somewhat Disagree	Somewhat Agree	Agree	Strongly Agree
1	2	3	4	5	6

Views on Automation Questionnaire					
1. I believe integrating Automation Management into CRM specific training is beneficial to enhance crew coordination					
Strongly Disagree	Disagree	Somewhat Disagree	Somewhat Agree	Agree	Strongly Agree
1	2	3	4	5	6
2. I can see how automation on the flight deck could be perceived as an additional member of the flightcrew					
Strongly Disagree	Disagree	Somewhat Disagree	Somewhat Agree	Agree	Strongly Agree
1	2	3	4	5	6
Please explain:					
3. I believe there are differences in crew communication and coordination when full automation is used (i.e. Flight director [FD] on, autopilot [AP] on, autothrottle/autothrust [AT] on) versus when manually flying the aircraft and levels of automation are lower (e.g., FD off, AP off, AT on)					

Strongly Disagree	Disagree	Somewhat Disagree	Somewhat Agree	Agree	Strongly Agree
1	2	3	4	5	6

Please explain:

4. I would be willing to receive CRM training in which Automation is considered as another flightcrew member

Definitely Not	Probably Not	Possibly	Probably	Very Probably	Definitely
		3			
1	2		4	5	6

5. As a way to maintain situation awareness, especially when fully automated mode is used, I would be willing to temporarily switch to manual flying **at stages of flight where workload is low** (e.g., during level flight).

Definitely Not	Probably Not	Possibly	Probably	Very Probably	Definitely
		3			
1	2		4	5	6

6. I manually fly visual approaches and landings when meteorological conditions and established procedures allow it.

Never	Very Rarely	Rarely	Occasionally	Very Frequently	Always
1	2	3	4	5	6

7. I manually fly the aircraft during climb-out, level flight and/or descend stages when meteorological conditions and established procedures allow it.

Never	Very Rarely	Rarely	Occasionally	Very Frequently	Always
1	2	3	4	5	6

If you would like, you can provide general comments regarding CRM (applicability, training, evaluation, etc.) in this box. Feel free to elaborate as much as you want.

APPENDIX F
ORIGINAL AES ROTATED COMPONENT MATRIX FROM FACTOR ANALYSIS

Multiple Perspectives	Metacognitive	Goals and Beliefs	Epistemology	Component												
				1MP	2GB	3GB	4MC	5MP	6E	7MP	8GB	9E	10E	11MC	12MC	13E
I find additional ideas burdensome after I have found a way to solve the problem.				.740												
I rarely consider other ideas after I have found the best answer.				.707												
I am afraid to try tasks that I do not think I will do well.				.521												
There is one best way to approach a problem.				.504												
I tend to focus on a particular model in which to solve a problem.				.478												
Usually there is one correct method in which to represent a problem.				.455					.426							
Experts in aviation are born with a natural talent for their field.					.897											
To become an expert in aviation, you must have an innate talent for aviation.					.860											
Experts are born, not made.					.740											
One can increase their level of expertise in any area if they are willing to try.						.770										
Expertise can be developed through hard work.						.745										
Even if frustrated when working on a difficult problem, I can push on.						.560										
Challenge stimulates me.						.510										
As a student, I cannot evaluate my own understanding of new material.							.786									
I rarely monitor my own understanding while learning something new.							.702									
I have difficulty in determining how well I understand a topic.							.669									
When I struggle, I wonder if I have the intelligence to succeed in aviation.																
When I consider a problem, I like to see how many different ways I can look at it.								.818								
I create several models (solutions) of an aviation related problem to see which one I like best.								.768								
For a new situation, I consider a variety of approaches until one emerges superior.								.578								
Existing knowledge in the world seldom changes.									.741							
Facts that are taught to me in class/training must be true.									.714							
Most knowledge that exists in the world today will not change.									.531							
As I learn, I question my understanding of the new information.									.431							
I solve all related problems in the same manner.										.846						
When I solve a new problem, I always try to use the same approach.										.798						
I feel uncomfortable when I cannot solve difficult problems.											.762					

Multiple Perspectives	Metacognitive	Goals and Beliefs	Epistemology	Component												
				1MP	2GB	3GB	4MC	5MP	6E	7MP	8GB	9E	10E	11MC	12MC	13E
I feel uncomfortable when unsure if I am doing a problem the right way.											.641					
Scientific knowledge is developed by a community of researchers.												.798				
Scientific theory slowly develops as ideas are analyzed and debated.												.766				
Knowledge that exists today may be replaced with a new understanding tomorrow.													.805			
Scientists are always revising their view of the world around them.													.702			
I am open to changing my mind when confronted with an alternative viewpoint.																
As I work, I ask myself how I am doing and seek out appropriate feedback.														.716		
Although I hate to admit it, I would rather do well in a class than learn a lot.														.534		
I monitor my task performance on a task.							.425							.469		
I seldom evaluate my performance on a task.																
Poorly completing a project is not a sign of a lack of intelligence.															.681	
When I know the material, I can recognize areas where my understanding is incomplete.															.502	
I often try to monitor my understanding of the problem.															.455	
Scientific knowledge is discovered by individuals.																.837
Progress in science is due mainly to the work of sole individuals.																.654

APPENDIX G
COMPRESSED AES ROTATED COMPONENT MATRIX FROM FACTOR ANALYSIS

	Component			
	1 Meta-cog.	2 Multi persp.	3 G&Bs	4 Epist.
I monitor my task performance on a task.	.725*			
I rarely monitor my own understanding while learning something new.	.704*			
Even if frustrated when working on a difficult problem, I can push on.	.589			
Expertise can be developed through hard work.	.522			
I often try to monitor my understanding of the problem.	.518*			
As a student, I cannot evaluate my own understanding of new material.	.499*			
I have difficulty in determining how well I understand a topic.	.487*			
One can increase their level of expertise in any area if they are willing to try.	.472			
I seldom evaluate my performance on a task.	.431*			
When I struggle, I wonder if I have the intelligence to succeed in aviation.				
When I solve a new problem, I always try to use the same approach.		.677*		
I solve all related problems in the same manner.		.673*		
There is one best way to approach a problem.		.642*		
I find additional ideas burdensome after I have found a way to solve the problem.		.589*		
I rarely consider other ideas after I have found the best answer.		.554*		
Usually there is one correct method in which to represent a problem.		.511*		
I tend to focus on a particular model in which to solve a problem.		.498*		
Experts in aviation are born with a natural talent for their field.			.879*	
To become an expert in aviation, you must have an innate talent for aviation.			.849*	
Experts are born, not made.			.727*	
Most knowledge that exists in the world today will not change.			.463	
Scientific theory slowly develops as ideas are analyzed and debated.				.634*
Scientists are always revising their view of the world around them.				.631*
Knowledge that exists today may be replaced with a new understanding tomorrow.				.630*
As I learn, I question my understanding of the new information.				.532
Scientific knowledge is developed by a community of researchers.				.498*
Existing knowledge in the world seldom changes.				.433*

Extraction Method: Principal Component Analysis.

Rotation Method: Varimax with Kaiser Normalization.

a. Rotation converged in 7 iterations.

APPENDIX H
ORIGINAL AES RESULTS

Hypothesis 1: Use of CRM skills Outside Flight Deck.

Ranks

	Adaptiveness_3_Levels	N	Mean Rank	Sum of Ranks
I think CRM is a valuable skill I can also apply outside the flight deck	Routine	85	76.35	6489.50
	Adaptive	85	94.65	8045.50
	Total	170		
Have you used CRM outside of the flight deck? - C6#1 - C6#1	Routine	85	82.00	6970.00
	Adaptive	85	89.00	7565.00
	Total	170		
Are there areas of CRM that you believe are only applicable to aviation and nowhere else? - C8#1 - C8#1	Routine	85	91.00	7735.00
	Adaptive	85	80.00	6800.00
	Total	170		

Test Statistics[a]

	I think CRM is a valuable skill I can also apply outside the flight deck	Have you used CRM outside of the flight deck?	Are there areas of CRM that you believe are only applicable to aviation and nowhere else?
Mann-Whitney U	2834.500	3315.000	3145.000
Wilcoxon W	6489.500	6970.000	6800.000
Z	-2.885	-2.176	-2.080
Asymp. Sig. (1-tailed)	.002*	.015*	.018

a. Grouping Variable: Adaptiveness_3_Levels

* p = .0166 necessary to reach significance after Bonferroni correction

MANOVA test for H2 through H6

Multivariate Tests[a]

Effect		Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[d]
Intercept	Pillai's Trace	.995	7705.20	6	244.00	.00	.99	46231.22	1.000
Adaptiveness	Pillai's Trace	.160	3.55	12	490.00	.00	.08	42.64	.998

a. Design: Intercept + Adaptiveness_3_Levels

d. Computed using alpha = .05

H2: Opinions on CRM Training Length

Descriptive Statistics

	Adaptiveness_3_Levels	Mean	Std. Deviation	N
Training Length	Routine	4.5297	.60942	84
	Transitional	4.4290	.55097	84
	Adaptive	4.5740	.59280	84
	Total	4.5109	.58574	252
Percentage of CRM During Training	Routine	42.2500	24.13735	84
	Transitional	34.0536	18.94571	84
	Adaptive	34.5893	18.96369	84
	Total	36.9643	21.07941	252

Between Subjects Tests

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Observed Power[g]
Adaptiveness	Training Length	.928	2	.46	1.36	.26	.011	.29
	Percentage CRM Training	3532.339	2	1766.17	4.07	.01	.032	.72

Contrasts

			Dependent Variable	
Adaptiveness_3_Levels	Simple Contrast[a]		H2 Training Length	H2 Percentage During Training
Routine vs. Adaptive	Contrast Estimate		-.044	7.661
	Hypothesized Value		0	0
	Difference (Estimate - Hypothesized)		-.044	7.661
	Std. Error		.090	3.214
	Sig. (1-tailed)		.312	.009
	95% Confidence Interval for Difference	Lower Bound	-.222	1.332
		Upper Bound	.133	13.990

Post hocs

Dependent Variable	(I) Adaptiveness	(J) Adaptiveness	Mean Difference (I-J)	Std. Error	Sig.
Training Length	Routine	Transitional	.10	.090	.398
		Adaptive	-.04	.090	.500
	Adaptive	Routine	.04	.090	.500
		Transitional	.14	.090	.164
Percentage CRM During Training	Routine	Transitional	8.20	3.21	.017
		Adaptive	7.66	3.21	.027
	Adaptive	Routine	-7.66	3.21	.027
		Transitional	.54	3.21	.500

H3: Opinions on CRM training methods

Descriptive Statistics

	Adaptiveness_3_Levels	Mean	Std. Deviation	N
Methods Total	Routine	4.4933	.50478	84
	Transitional	4.3306	.55407	84
	Adaptive	4.6213	.63013	84
	Total	4.4817	.57557	252

Between Subjects test

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Observed Power[g]
	Methods Total	3.566	2	1.78	5.58	.00	.043	.85

Contrast

Adaptiveness_3_Levels	Simple Contrast[a]		Dependent Variable H3 Methods Total
Routine vs. Adaptive	Contrast Estimate		-.128
	Hypothesized Value		0
	Difference (Estimate - Hypothesized)		-.128
	Std. Error		.087
	Sig. (1 tailed)		.072
	95% Confidence Interval for Difference	Lower Bound	-.300
		Upper Bound	.044

Post hocs

Dependent Variable	(I) Adaptiveness	(J) Adaptiveness	Mean Difference (I-J)	Std. Error	Sig. (1 tailed)
Methods Total	Routine	Transitional	.16	.087	.095
		Adaptive	-.13	.087	.216
	Adaptive	Routine	.13	.087	.216
		Transitional	.29	.087	.001

H4: opinions on CRM topics

Descriptive Statistics

	Adaptiveness_3_Levels	Mean	Std. Deviation	N
Topics Total	Routine	4.7834	.52868	84
	Transitional	4.8089	.50693	84
	Adaptive	5.0450	.58053	84
	Total	4.8791	.55024	252

Between Subjects test

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Observed Power[g]
	Topics Total	3.495	2	1.75	6.00	.00	.046	.88

Contrasts

			Dependent Variable
Adaptiveness_3_Levels Simple Contrast[a]			H4 Topics Total
Routine vs. Adaptive	Contrast Estimate		-.262
	Hypothesized Value		0
	Difference (Estimate - Hypothesized)		-.262
	Std. Error		.083
	Sig. (1 tailed)		.001
	95% Confidence Interval for Difference	Lower Bound	-.426
		Upper Bound	-.098

Post hocs

Dependent Variable	(I) Adaptiveness	(J) Adaptiveness	Mean Difference (I-J)	Std. Error	Sig. (1 tailed)
Topics Total	Routine	Transitional	-.025	.083	.500
		Adaptive	-.26	.083	.003
	Adaptive	Routine	.26	.083	.003
		Transitional	.24	.083	.008

H5: Opinions about CRM Evaluation methods

Descriptive Statistics

	Adaptiveness_3_Levels	Mean	Std. Deviation	N
Evaluation Total	Routine	4.3690	.72813	84
	Transitional	4.1111	.75063	84
	Adaptive	4.4378	.71829	84

Between Subjects test

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Observed Power[g]
	Evaluation Total	4.984	2	2.49	4.64	.01	.036	.78

Contrasts

Adaptiveness_3_Levels Simple Contrast[a]			Dependent Variable H5 Evaluation Total
Routine vs. Adaptive	Contrast Estimate		-.069
	Hypothesized Value		0
	Difference (Estimate - Hypothesized)		-.069
	Std. Error		.113
	Sig. (1 tailed)		.272
	95% Confidence Interval for Difference	Lower Bound	-.291
		Upper Bound	.154

Post hocs

Dependent Variable	(I) Adaptiveness	(J) Adaptiveness	Mean Difference (I-J)	Std. Error	Sig. (1 tailed)
Evaluation Total	Routine	Transitional	.26	.11	.035
		Adaptive	-.07	.11	.500
	Adaptive	Routine	.07	.11	.500
		Transitional	.33	.11	.007

H6: Opinions on Automation

Descriptive Statistics

	Adaptiveness_3_Levels	Mean	Std. Deviation	N
Automation Total	Routine	4.7723	.55025	84
	Transitional	4.6637	.52604	84
	Adaptive	4.9211	.59610	84
	Total	4.7857	.56596	252

Between Subjects test

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Observed Power[g]
	Automation Total	2.806	2	1.40	4.50	.01	.035	.77

Contrasts

Adaptiveness_3_Levels	Simple Contrast[a]		Dependent Variable: H6 Automation Total
Routine vs. Adaptive	Contrast Estimate		-.149
	Hypothesized Value		0
	Difference (Estimate - Hypothesized)		-.149
	Std. Error		.086
	Sig. (1 tailed)		.043
	95% Confidence Interval for Difference	Lower Bound	-.318
		Upper Bound	.021

Post hocs

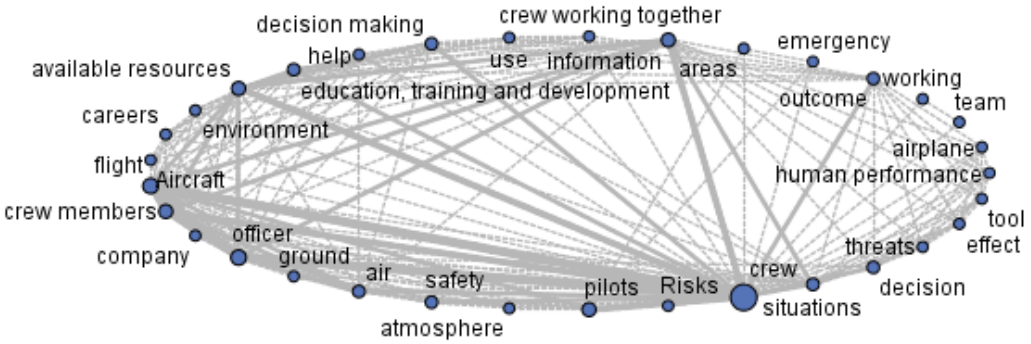
Dependent Variable	(I) Adaptiveness	(J) Adaptiveness	Mean Difference (I-J)	Std. Error	Sig. (1 tailed)
Automation Total	Routine	Transitional	.11	.09	.313
		Adaptive	-.15	.09	.128
	Adaptive	Routine	.15	.09	.128
		Transitional	.26	.09	.005

APPENDIX I
RESPONSE RATE AND NUMBER OF CONCEPTS USED BY TYPE OF EXPERTISE FOR FREE RESPONSE QUESTIONS

Question	Type of Expertise	Median	Mean	S.D.	Response Rate(Rank)	Number of Concepts
In your own words, could you describe what your meaning of CRM is?	Routine	18	23.93	19.20	100.0% (1)	273
	Transitional	19	24.26	16.84	95.9% (3)	248
	Adaptive	18	23.81	20.08	100.0% (1)	303
If you had to explain CRM to someone who has never heard of this concept before, how would you explain it to them?	Routine	22	29.45	23.58	100.0% (1)	314
	Transitional	25	30.17	24.84	95.9% (3)	287
	Adaptive	23	33.25	34.82	100.0% (1)	367
In your opinion, is CRM effective at enhancing flight safety during line operations?	Routine	17	20.24	13.80	71.6% (1)	179
	Transitional	21	23.75	12.19	65.8% (3)	197
	Adaptive	20	24.08	20.48	68.1% (2)	222
Have you used CRM outside of the flight deck?	Routine	14	18.12	16.89	94.3% (2)	267
	Transitional	13	18.00	19.00	89.0% (3)	241
	Adaptive	17	21.65	17.50	94.7% (1)	334
Are there areas of CRM that you believe can be applied to areas outside of aviation?	Routine	10	13.62	11.46	89.8% (2)	214
	Transitional	12	15.49	12.79	89.0% (3)	182
	Adaptive	11	14.25	12.86	90.4% (1)	217
Are there areas of CRM that you believe are only applicable to Aviation and nowhere else?	Routine	11	12.70	10.21	48.9% (2)	105
	Transitional	15	16.24	10.42	39.7% (3)	93
	Adaptive	13	14.51	10.24	50.0% (1)	107
In your experience, is CRM practiced in the flight deck the way it is taught during training?	Routine	29	30.92	25.15	45.5% (3)	156
	Transitional	23	23.97	16.57	52.1% (1)	122
	Adaptive	17.5	29.07	25.96	46.8% (2)	155
During line operations, does effective use of CRM skills result in a different outcome than not applying these principles at all?	Routine	18	21.34	14.94	73.9% (3)	177
	Transitional	15	22.09	21.70	76.7% (2)	177
	Adaptive	17.5	23.05	19.20	80.9% (1)	221
In your opinion what are the most effective approach/approaches currently used for CRM training?	Routine	12	20.68	23.36	83.0% (2)	240
	Transitional	17	21.74	21.20	80.8% (3)	232
	Adaptive	12	19.86	20.86	91.5% (1)	303
In your opinion, what type of training should be provided for CRM?	Routine	11	19.5	22.80	77.3% (3)	225
	Transitional	13	21.12	27.73	78.1% (2)	208
	Adaptive	13	19.58	21.11	88.3% (1)	284
I think there are areas of flight safety that CRM does not cover	Routine	15	20.81	17.74	30.7% (3)	94
	Transitional	9	12.96	10.03	32.9% (2)	56
	Adaptive	15	20.18	18.81	47.9% (1)	162
I can see how automation on the flight deck could be perceived as an additional member of the flightcrew	Routine	19	20.84	11.79	35.2% (3)	81
	Transitional	15	21.65	18.87	39.7% (2)	84
	Adaptive	13.5	22.46	20.69	48.9% (1)	140
I believe there are differences in crew communication and coordination when full automation is used versus when manually flying and the levels of automation are lower	Routine	20	23.58	16.79	35.2% (2)	97
	Transitional	18.5	24.21	18.77	32.9% (3)	104
	Adaptive	14	17.75	15.94	38.3% (1)	90
Final comments	Routine	47	58.76	41.83	33.0% (2)	245
	Transitional	47	46.91	27.02	30.1% (3)	167
	Adaptive	42	57.57	47.66	39.4% (1)	300

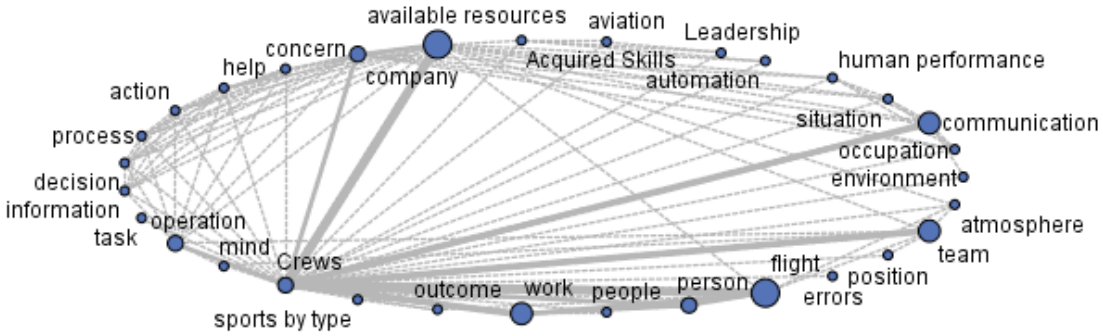
APPENDIX J
VISUALIZATION OF CONCEPTS BY EXPERTISE FOR *IF YOU HAD TO EXPLAIN CRM TO SOMEONE WHO HAS NEVER HEARD OF THIS CONCEPT BEFORE, HOW WOULD YOU EXPLAIN IT TO THEM?*

Routine Experts



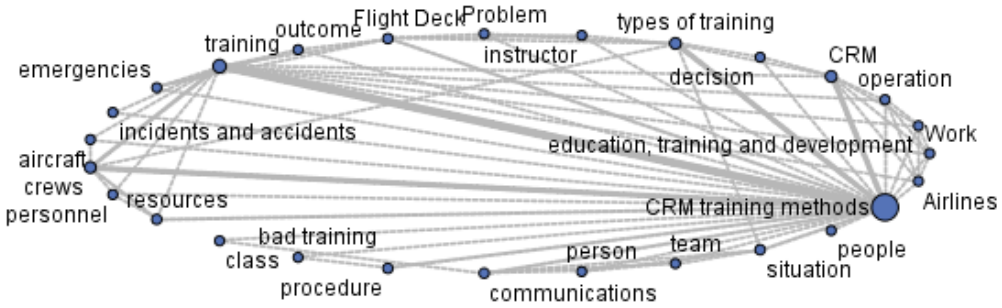
Transitional

Adaptive Experts

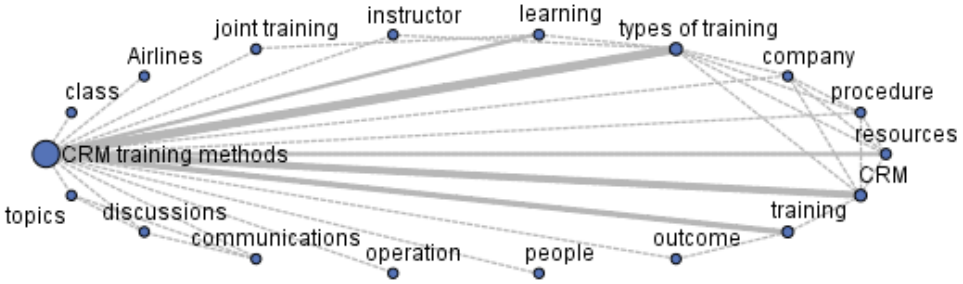


APPENDIX K
VISUALIZATION OF CONCEPTS BY EXPERTISE FOR *IN YOUR OPINION, WHAT TYPE OF TRAINING SHOULD BE PROVIDED FOR CRM?*

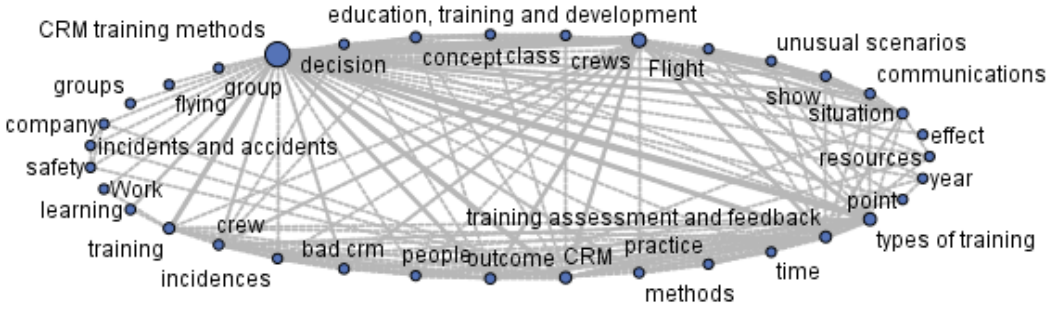
Routine Experts



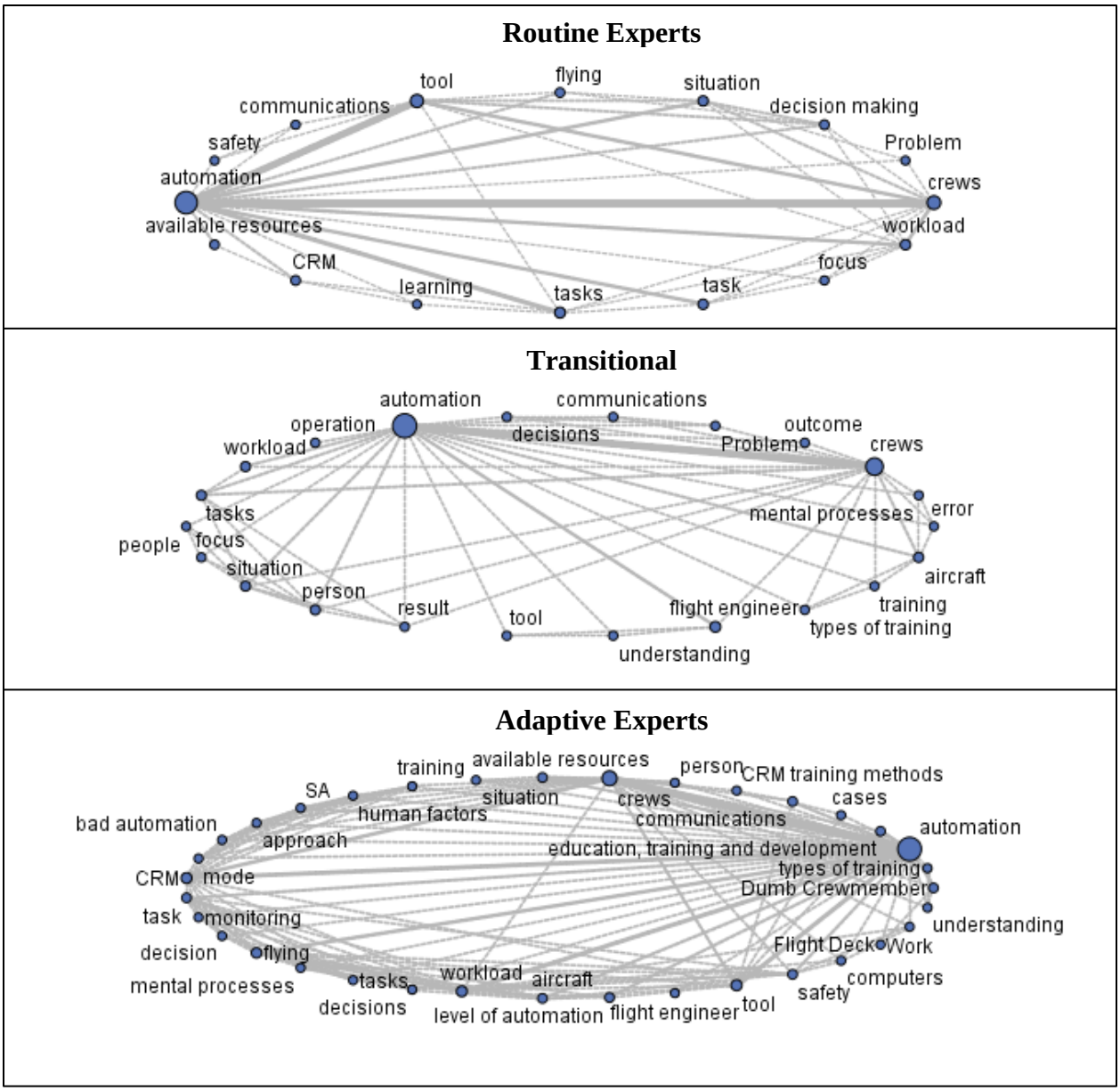
Transitional



Adaptive Experts



APPENDIX L
VISUALIZATION OF CONCEPTS BY EXPERTISE FOR I CAN SEE HOW AUTOMATION ON THE FLIGHT DECK COULD BE PERCEIVED AS AN ADDITIONAL MEMBER OF THE FLIGHTCREW


Routine Experts
tool
flying
situation
communications
decision making
safety
Problem
automation
crews
available resources
workload
CRM
focus
learning
tasks
task
Transitional
automation
communications
operation
outcome
decisions
Problem
crews
workload
tasks
mental processes
error
people
focus
aircraft
situation
person
training
result
flight engineer
tool
types of training
understanding
Adaptive Experts
training
available resources
person
CRM training methods
SA
situation
crews
cases
human factors
communications
bad automation
automation
approach
education, training and development
types of training
CRM
mode
Dumb Crewmember
task
monitoring
understanding
Flight Deck
Work
decision
flying
computers
workload
aircraft
mental processes
tasks
safety
decisions
level of automation
flight engineer
tool

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