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Human-Machine Interaction in Avionic Systems Automation: An Analysis of the Asiana Airlines Flight 214 Accident[*]

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Abstract

The increasing level of automation in avionics systems of modern aircraft has significantly enhanced flight safety while fundamentally transforming the nature of human–machine interaction and the relationship between pilots and automated systems. This study aims to examine the effects of advanced automation in avionics systems on human–machine interaction from a human factors perspective. The focal point of the research is the Asiana Airlines Flight 214 accident, which occurred on 6 July 2013 during the approach phase to San Francisco International Airport. The accident analysis indicates that excessive reliance on automation, misinterpretation of automated flight control system modes, and the resulting loss of situational awareness played a critical role in the occurrence of the accident. Within this framework, the study employs a qualitative research approach based on document analysis of accident investigation reports published by national and international aviation authorities. The findings reveal that automation in avionics systems does not consistently support pilots' cognitive processes; rather, under certain conditions, it may contribute to human factors-related risks such as the automation paradox, automation dependency, and mode awareness issues. By identifying weaknesses in human–machine interaction within aviation operations, this study aims to provide practical insights and recommendations to support avionics system design and human factors–oriented training programs.

Keywords: Avionics Systems, Automation, Situational Awareness, Human Factors, Asiana Airlines Flight 214.

JEL Codes: D23, M12, J28

Aviyonik Sistemlerin Otomasyonunda İnsan-Makine Etkileşimi: Asiana Hava Yolları Uçuş 214 Hava Aracı Kazası Üzerine Bir Analiz

Özet

Modern hava araçlarında aviyonik sistemlerin otomasyon düzeyinin artması, uçuş emniyetini destekleyen önemli bir unsur olmakla birlikte, insan-makine etkileşiminin yapısını ve pilotların sistemlerle kurduğu ilişkiyi köklü biçimde dönüştürmüştür. Bu çalışma, aviyonik sistemlerde giderek artan otomasyonun insan-makine

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etkileşimi üzerindeki etkilerini insan faktörleri perspektifinden incelemeyi amaçlamaktadır. Araştırmanın odak noktasını, 6 Temmuz 2013 tarihinde San Francisco Uluslararası Havalimanı'na yaklaşma sırasında meydana gelen Asiana Hava Yolları Uçuş 214 kazası oluşturmaktadır. Kaza incelemesinde, pilotların otomasyon sistemlerine aşırı güven duyması, otomatik uçuş sistemlerinin çalışma mantığının yanlış algılanması ve buna bağlı olarak gelişen durumsal farkındalık kaybının kazanın oluşumunda belirleyici rol oynadığı tespit edilmiştir. Bu kapsamda çalışma, ulusal ve uluslararası havacılık otoriteleri tarafından yayımlanan kaza raporlarını esas alarak nitel araştırma yöntemi çerçevesinde doküman analizi yaklaşımıyla yürütülmüştür. Araştırma bulguları, aviyonik sistemlerdeki otomasyonun her durumda pilotların bilişsel süreçlerini desteklemediğini; aksine belirli koşullar altında otomasyon paradoksu, otomasyon bağımlılığı ve kontrol belirsizliği gibi insan faktörleri kaynaklı riskleri artırabildiğini ortaya koymaktadır. Çalışma, havacılık operasyonlarında insan-makine etkileşiminin zayıf yönlerini görünür kılarak, aviyonik sistem tasarımına ve insan faktörleri temelli eğitim süreçlerine yönelik geliştirici öneriler sunmayı hedeflemektedir.

Anahtar Kelimeler: Aviyonik sistemler, Otomasyon, Durumsal Farkındalık, İnsan Faktörleri, Asiana Hava Yolları Uçuş 214

JEL Kodları: D23, M12, J28

1. INTRODUCTION

With the technological advancements in the aviation sector, the automation aspect of aircraft systems has significantly improved. Particularly with the digitalization of user platforms in avionics systems, many functions such as flight management, navigation, and control of system parameters are now performed by automated systems instead of pilots. This transformation has contributed to achieving goals such as improving flight safety, reducing human error, supporting workload, and increasing system performance. However, the level of automation development has not completely eliminated the human factor, initiating a complex process in human-machine interaction and leading to the emergence of new risk areas (Endsley, 2017).

The advantages brought about by automation play a significant role in increasing flight safety in aviation operations. However, these advantages reduce the control that pilots have over flight systems. This transformation leads to cognitive errors such as automation dependency and control uncertainty. This situation, expressed in the literature as "the automation paradox", is explained by the fact that as systems become more reliable, humans monitor system actions less (Bainbridge, 1983). This resulting contradiction leads to automation creating a risk factor under certain conditions instead of increasing safety. The extent of the human-automation relationship, particularly during critical phases of flight such as approach and landing, directly affects flight safety (Degani & Wiener, 1997). In this context, automation systems lacking appropriate design and interaction elements can become a threat to flight safety.

The concept of human-machine interaction is not only a technological innovation in the aviation industry but also a matter that needs to be considered within the scope of cognitive design and human factors. While the pilot's job description in the traditional aircraft cockpit was to fly, in modern cockpits, with automation, it has been updated to monitor and manage the system. Pilots work as system operators in this situation, and this process requires focusing on information processing tasks, attention control, and situational awareness (Wickens, 2008).

As the complexity of avionics systems increases with automation in aircraft, it becomes more difficult for pilots to correctly perceive and monitor the behavior of these systems. In particular, the interaction of flight controls with each other makes it difficult to understand which function is being used in which situations. Various aircraft accident and incident analyses in the literature show that these uncertainties in human-machine interaction can directly affect flight safety and lead to unpredictable fatal consequences (Degani & Wiener, 1997).

The main objective of this study on human-machine interaction is to analyze the effect of automation in avionics systems on pilots' cognitive processes by examining the Asiana Airlines Flight 214 accident. Within the scope of the study, accident reports from national and international aviation authorities will be examined using document analysis methods. In particular, the effects of existing systems on pilot behavior will be investigated in light of concepts such as situational awareness, automation confidence, automation dependency, and decision fatigue. The contribution of this study to the literature is that it shows that automation is not only seen as a technical support element, but also as a dynamic factor that shapes human performance. The effect of automation on flight safety is determined by how humans interact with this system. The findings of this study are expected to offer significant implications for the development of aviation training programs, the improvement of system designs, and the more effective handling of human factors.

2. CONCEPTUAL FRAMEWORK

Human factors is a discipline that aims to improve safety by examining human performance and behavior in the interaction of multi-actor organizations, such as aviation, with technology. This approach considers the interaction between humans, technology, and the environment holistically, rather than solely focusing on individual inadequacy in addressing human error (Reason, 1990). With the increase in automation systems in modern aviation operations, the role of pilots in aircraft has also changed. This new role has reduced the pilots' direct control and increased their task of monitoring and managing the system. From a human factors perspective, this change has made situational awareness, cognitive workload, and decision-making processes critical (Endsley, 1995). In this context, human-machine interaction is considered a component of human factors that determines the effective and safe use of systems.

2.1. Human-Machine Interaction

Human-machine interaction (HMI) refers to the processes by which humans exchange information with the technical components of a system. In aviation, this interaction encompasses a number of processes such as pilots perceiving the aircraft's status, inputting functions, and interpreting system indicators through avionics systems (Lee & See, 2004). With the transition from traditional analog system displays to digital systems, this interaction has changed, and cognitive processes have gained importance.

Modern avionics systems consist of subsystems such as flight management systems, autopilot, automatic throttle, electronic flight information systems, engine display, and crew alert systems. These systems automate planning, steering, monitoring, and control functions in any flight operation, reducing the intensity of manual control for pilots (Degani & Wiener, 1997). However, this reduction makes it more difficult for humans to understand the working logic of the system they are using, transforming the user's role from direct control to background monitoring (Sheridan, 2002). This transformation makes it even more critical for pilots to recognize the limitations of automation.

Studies in the literature indicate that in aircraft with high levels of automation, human-machine interaction weakens, leading to new risks (Endsley, 2017; Casner et al., 2019). In particular, problems such as unexpected automation failures, failure to detect warnings and alerts in a timely manner, and failure to perceive mode changes cause erroneous or delayed decision-making in critical flight conditions (Young et al., 2020).

From a human factors perspective in aviation, creating situational awareness for the user, balancing cognitive load, and operating the feedback system are necessary for effective human-machine interaction. Failure in any of these tasks can lead to the loss of human control over the system. In this context, the human's ability to perceive this system according to technological developments is gaining importance in effective human-machine interaction.

2.2. Automation Paradox

The concept of the automation paradox in aviation operations was first introduced by Bainbridge (1983). This concept states that as the level of automation of systems increases, the ability of user personnel to understand system behavior, detect errors, and intervene in potential crises may decrease. The reason for the paradox is the decrease in the attention and motivation of the user in the monitoring function that requires continuous system control (Parasuraman & Riley, 1997).

The automation paradox arises in the flight control management processes in the cockpits of modern aircraft. Pilots must understand the status of the system during flight. However, the failure to notice the notifications on the indicators during transitions between systems and the inadequacy of visual signals can lead to confusion of control functions (Sarter & Woods, 1995). Therefore, while automation is designed to increase the safety of the system on the one hand, it can also reduce safety by leading to changes in human behavior on the other.

The automation paradox is not only a technical design problem but also seen as a cognitive and behavioral human problem. When empirical findings are examined, Endsley (2017) revealed that automation reduces pilots' situational awareness, leading to inadequacy in monitoring system behavior. In another study, Casner et al. (2019) reported that pilots' flight skills weaken over time with automation and they experience problems in correctly perceiving systems. In this context, automation reduces pilots' competencies and delays intervention in the system.

To mitigate the automation paradox, a human-centered automation approach and design are highlighted. Young et al. (2020) state that making automation control modes easier for pilots to follow and improving presentation designs reduces uncertainties in controls and increases system management performance. Similarly, Wickens et al. (2021) emphasize that automation should be placed in a structure that supports the process by placing the human at its center. Therefore, to manage the automation paradox, it will be necessary to implement human-centered designs and human-focused strategies in human-machine interaction.

2.3. Situational Awareness

Situational awareness is an individual's ability to perceive environmental variables, make sense of this information, and predict future situations (Endsley, 1995). In flight operations, this concept manifests itself as the pilot gathering information such as instruments, references, and audible warnings in the cockpit, making sense of it when needed, and mentally predicting future situations.

Automation in avionics systems affects the situational awareness process both positively and negatively. Reducing the information load is a positive aspect, while being detached from environmental variables is a negative aspect. The complex structure and lack of feedback in the system lead to a decrease in awareness (Casner & Hutchins, 2019). This problem directly affects flight safety.

Loss of situational awareness becomes more pronounced in situations where human-machine interaction is weak. Indeed, Endsley (2017) states in his study that automation reduces the cognitive effectiveness of pilots and that this negatively affects their situational awareness level. Furthermore, Young & Stanton (2015) emphasize that automation is crucial in pilots' access to flight information during the situational awareness process. Therefore, situational awareness depends both on the amount of information displayed and on the meaningfulness of that information.

The literature shows that the information overload paradox can lead to a loss of situational awareness (Wickens, 2008). Especially considering that avionics systems contain a large amount of visual and numerical data, important information may be lost without being perceived in emergency situations where quick decisions are required. Prioritizing and presenting important information in human-machine interaction ensures the preservation of situational awareness (Endsley & Jones, 2016). In this context, the effective role of situational awareness depends on the display of the amount of information in the HMI architecture in a way that is easily visible and perceptible.

2.4. Cognitive Load and Data Confusion

Cognitive load refers to the mental demands placed on an individual's information processing capacity during a task (Young & Stanton, 2002). In high-risk conditions such as aviation activities, increased cognitive load can lead to distraction, perceptual errors, and ultimately, delays in decision-making. Avionics systems automation contributes to reducing cognitive load by taking over routine functions. However, understanding the logic of the system's behavior, monitoring control transitions, and correctly interpreting them increases cognitive load (Hancock & Parasuraman, 1992). Therefore, it leads to insufficient use of attention capacity.

Cognitive load emerges as a condition related to the quality and complexity of the information presented in the automation of avionics systems. Pilots having to recognize and perceive a large number of visual, numerical, and symbolic data simultaneously during flight rapidly depletes attention resources and reduces performance (Wickens et al., 2015). This situation can lead to the ineffective use of cognitive resources and the emergence of cognitive problems such as attention blindness (Cummings, 2017).

The complexity of the data used in automation systems is a situation that increases cognitive load. This situation refers to pilots misinterpreting system data during flight and acting accordingly (Sarter & Woods, 1995). In advanced aircraft such as Boeing and Airbus, data is presented in a complex structure. In particular, data flow is displayed simultaneously during takeoff and landing. This situation causes stress factors in pilots with little flight experience (Casner & Hutchins, 2019).

The design of system interfaces, the priority of display according to importance, and the simplicity of the symbology used contribute to reducing cognitive load and data complexity. Cummings et al. (2021) and Wickens et al. (2021) reported that interface compatibility and task-oriented data presentations reduce the cognitive load of pilots and simplify complex data. In this context, compatibility in the design and presentation methods of the automation system supports the improvement of operational performance by balancing cognitive load.

2.5. Human-Machine Interaction Design Principles in Aviation

HMI architecture is central to human factors in aviation operations. This architecture is expected to be based on certain fundamental principles in terms of cognitive ergonomics, information hierarchy, and visual coding. In their study, Degani & Wiener (1997) emphasize that HMI should have four principles for its effectiveness. These principles are stated as follows:

- **Simplicity,** the goal is to prevent information overload by highlighting critical information.
- **Consistency,** it means that the same control function is displayed identically on different display screens.
- **Transparency,** It allows the user to clearly see the current state of the system parameters while they are running.
- **Feedback,** the system's response to user behavior must be predictable.

Certain design elements play a significant role in preventing confusion in automation systems. Standardized color hierarchies in indicators, highlighting critical warnings, and developing systems to support user situational awareness are some examples of these designs (Endsley, 2017). These human-centered design presentations reduce cognitive load and prevent errors (Cummings et al., 2021). In this context, applications in system design can contribute to achieving safe flight.

3. METHODOLOGY

3.1. Research Method

The aim of this study is to thoroughly examine the effects of increasing automation levels in avionics systems on human-machine interaction, using a concrete example of an aircraft accident. To this end, the research employs a qualitative research method, specifically document analysis. Qualitative research aims to understand complex social and technical phenomena within a specific context and to uncover the underlying causes of these phenomena (Creswell & Poth, 2018). The methodological process developed for this research is schematically represented in Figure 1.

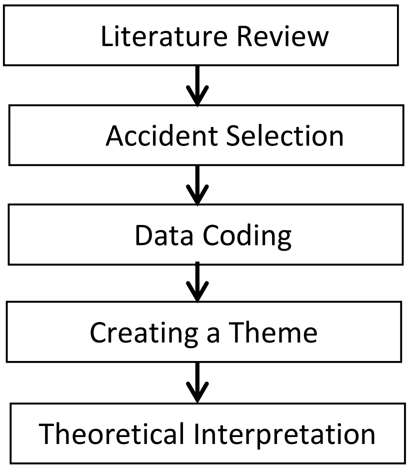

Fıgure 1: Research Process Methodology Flowchart

According to the research process flowchart shown in Figure 1, commercial accidents that occurred between 1972 and 2024 and are included in the literature were first subjected to a preliminary review to address the research objective. Accidents caused by mechanical failure or external environmental factors were excluded. Among the limited number of accidents associated with the misuse or misunderstanding of automation systems, Asiana Airlines Flight 214 was selected as a case study due to its comprehensive and detailed official accident report. The main reason for choosing this accident is that it is directly related to concepts such as human-machine interaction, automation dependency, data confusion, and loss of situational awareness. In the ongoing research process, data were coded and main themes were created. Finally, the findings stated in the accident report were interpreted and evaluated within a theoretical framework. In this respect, the study is a qualitative case study aiming for in-depth analysis from the perspective of human-machine interaction, rather than generalizable results.

3.2. Data Sources

The research dataset consists of secondary data sources. The sources examined and utilized within this scope are as follows:

- Official accident reports published by national and international aviation authorities, (DGCA, NTSB, ATSB, FAA, ICAO),
- Academic studies focusing on the accident and similar automation-based incidents, (Sheridan, 2002; Endsley, 2017; Kwak vd., 2018; Casner & Hutchins, 2019),
- Studies in the literature that have empirical findings on human-machine interaction, automation, and human factors (Degani & Wiener, 1997; Parasuraman et al., 2000; Cummings, 2017; Kilic & Gundogdu, 2020) has been used.

The literature review was conducted using the keywords “aviation accident”, “human–machine interaction”, “automation”, “situational awareness”, “feedback issues”, “cognitive load”, and “mode confusion” in Google Scholar, Scopus, Web of Science, IEEE Xplore, SpringerLink, and ScienceDirect databases. Of the 42 studies examined, 28 were excluded due to technical failure, repetitive nature, and irrelevant subject matter. The remaining 14 studies were included in the analysis.

3.3. Data Analysis Process

The document analysis process for the research was carried out in three stages. This process was based on the human-machine interaction model presented in the study by Parasuraman et al. (2000) and was conducted as follows:

First stage, the Asiana Airlines Flight 214 accident report and selected literature were examined in detail, and the terms automation behavior, pilot perception, situational awareness, feedback problems, cognitive load, and data confusion were identified using open coding.

Second stage, similar codes were combined to form main themes. These themes were reorganized to be consistent with the theoretical framework of the study.

Third stage, the themes obtained as a result of the reorganization were related to theoretical approaches in the literature regarding human-machine interaction and automation, and the findings were interpreted and a comparative analysis was performed.

Table 1: Qualitative Coding Table

CODE	THEME	DEFINITION	SOURCE
AB-01	Automation Behavior	Incorrect detection of automation mode	NTSB (2014)
SAL-01	Situational Awareness Loss	Inadequacy in monitoring aircraft speed	Casner & Hutchins (2019)
FBI-01	Feedback Issues	The system status is not clearly displayed	Lee & See (2004)
CL-01	Cognitive Load	Mental demands placed on information processing capacity	Young & Stanton (2002)
DC-01	Data Confusion	Misinterpretation of system data and acting accordingly	Sarter & Woods (1995)

3.4. Research Ethics

All data used in the research was obtained from digitally accessible, open-source official documents and published academic studies. Therefore, it does not contain subjective data, participant information, or any confidential records. Consequently, the research was conducted meticulously in accordance with academic ethical principles without requiring ethical committee approval.

4. FINDINGS AND DISCUSSION

4.1. Accident Summary

An Asiana Airlines Boeing 777-200ER aircraft, operating the Seoul (South Korea) – San Francisco (USA) route, crashed into a seawall ahead of the runway at approximately 11:28 a.m. local time on July 6, 2013, during landing at San Francisco International Airport (USA). Three passengers died and 187 were injured in the accident (NTSB, 2014). This is the second major accident involving a Boeing 777 aircraft. An examination of the circumstances of the accident indicates that the landing occurred under visual meteorological conditions. According to the accident report, the flight control system was deactivated during the final approach phase, the autopilot continued to be partially used, and the throttle system remained in a standby state, as recorded in the data log.

The NTSB (2014) identified the root cause of the accident as "the pilots' misinterpretation of the automation system's behavior, insufficient monitoring in the automatic control of aircraft speed, and loss of situational awareness." The pilots' misconception that the automatic throttle system was working during landing led to an error. As a result, the system was not actually working, causing the aircraft's speed to suddenly drop from 137 knots to 103 knots, resulting in a sudden loss of power and crashing into the wall in front of the runway.

4.2. Data Confusion and Feedback Issues Research Findings

In the accident, both the functional role and the perception of automation were decisive. The captain pilot assumed that the aircraft's automatic throttle system was active and that the selected speed would be automatically maintained by the system. The perception error here stemmed from their failure to realize that the aircraft had entered a holding position due to the deactivation of the flight level change information. This display, which was not clearly indicated on the instrument screen, caused the error (Casner & Hutchins, 2019).

This situation revealed in the analysis confirms the concept defined by Sarter & Woods (1995) as data confusion. The pilots misinterpreted the state in which the system was operating at that moment. Such errors often arise from a lack of cognitive recognition.

Although the information included in the automation design is technically correct, it can become meaningless to the user (Endsley, 2017).

Furthermore, the lack of information on the main flight instrument showing the current status of the automatic throttle system caused a feedback problem. To prevent this problem, the human-machine interaction architecture is expected to be designed in such a way as to directly show the user the status of the system (Lee & See, 2004). In the accident examined, it can be said that the captain pilot could not notice the sudden loss of power in the aircraft because no warning was received.

4.3. Situational Awareness Loss and Cognitive Overload Research Findings

It appears that the pilots suffered a loss of situational awareness during the accident. It can be said that the stages outlined in Endsley's (1995) situational awareness framework were not performed. Specifically, the pilots initially failed to notice the decrease in aircraft speed, then misinterpreted the operation of the automatic throttle, and finally, they failed to anticipate that the resulting speed reduction could negatively impact landing performance.

According to the analysis, one of the factors contributing to this problem was increased cognitive load. In visual approach conditions, it is normal for the captain to pay attention to both the external environment and the cockpit instruments. This simultaneous attention requirement led to an increase in workload (Young & Stanton, 2002). Therefore, the critical airspeed indicator for flight safety was not noticed.

4.4. System Software Design and Cognitive Adaptation Problems Research Findings

Another finding in the analysis of the accident is the inconsistency in the warning and transition display colors of the flight data displays on the aircraft. In particular, the transition from white to green appears to be cognitively imperceptible. It is not easy for the human eye to perceive changes in colors that are close together in daylight (Degani & Wiener, 1997). It is assessed that the transitions of color codes such as green, white, and red, which indicate the on, off, or malfunction status of the system controls, can be very rapid, and pilots cannot keep up with this speed.

This design in the aircraft automation system is an indication that it does not possess the design principles of the HMI presented in the conceptual framework. Considering the limited perceptual capacity of the human brain, the complex presentation of data in the system needs to be shown in a clear, transparent, and consistent manner (Sheridan, 2002). However, in this accident, the visual behavior of the system contradicted human expectations, resulting in a loss of perceptual awareness.

4.5. Team Resource Management and Communication Deficiencies Research Findings

One of the significant aspects of the accident under investigation is that it involved problems stemming from a lack of team coordination and communication. According to the accident report, the captain was hierarchically more senior than the co-pilot and evaluated the co-pilot's performance. Although the co-pilot actually noticed and warned about the decrease in speed, cockpit voice recordings revealed that the captain did not take this warning seriously enough.

This situation, frequently encountered in aviation operations, demonstrates a classic authoritarian approach. However, successful team resource management consists of open communication, mutual consent, and situational awareness sharing, regardless of hierarchy (Helmreich & Merritt, 2000). In this accident, it is considered that the co-pilot may have exhibited hesitant behavior due to the influence of organizational culture factors.

Communication-related problems are factors that directly affect human-machine interaction. Automation systems are built on the sharing of situational awareness among team members. Different perceptions of the system's status by team members can lead to conflicts in decision-making (Endsley, 2017). Indeed, in this accident, the pilots' differing perceptions of the reduced speed led to unforeseen consequences.

4.6. Research Findings General Evaluation and Discussion

Analysis findings regarding the aircraft accident show that the impact of automation in avionics systems on flight and ground safety is not one-sided. While automation is designed to reduce system errors, its first positive aspect is that it weakens human situational awareness of the system, revealing its second negative aspect. This assessment is presented as a situation where two types of automation failures, described by Parasuraman & Riley (1997) as misuse of automation or failure to use it when necessary, can occur simultaneously. This finding directly aligns with the concept of the automation paradox, as described by Bainbridge (1983) in the literature.

The misperception of the automatic throttle system and the inadequacy of the speed monitoring function observed in the Asiana Airlines Flight 214 accident exemplify instances where automation was misused by pilots. Similar findings were also reported in the Air France 447 (2009) accident. In the accident in question, it was stated that the autopilot failed due to the icing of the pitot tubes, resulting in the pilots being unable to correctly interpret the speed information and experiencing a loss of situational awareness (BEA, 2012). Both aircraft accidents demonstrate that unexpected behaviors in automation systems negatively affect the pilots' cognitive processes.

The data confusion and lack of feedback identified in this study are consistent with the mode confusion problem found in the literature. These findings are similar to the problem in

Turkish Airlines Flight 1951 (2009) accident, where the automatic throttle system retracted due to faulty radar altimeter data, and the pilots noticed this late and could not compensate for the speed loss in time (DSB, 2010). The data confusion problem shows that although automation systems are technically correct, they can create risky situations in flight safety by not providing sufficient and timely feedback to the pilots.

From the perspective of human-machine interaction, the cognitive capacity of humans to adapt to hardware and software developments in technological systems is limited. This situation leads to the incorrect operation of the decision-making mechanism. Indeed, in the analyzed accident, the failure to notice system warnings and alerts visually and audibly in a timely manner resulted in serious consequences. A similar situation was reported in the Colgan Airlines Flight 2407 (2009) accident, where cognitive load and inadequate attention management were overlooked in flight parameters (NTSB, 2010). Therefore, the principles of simplicity, consistency, transparency, and feedback in system designs will ensure accurate and timely decision-making (Lee & See, 2004). In this context, system presentations that lead to data confusion can also cause an excessive increase in cognitive load and the emergence of errors.

The analysis findings did not only reveal the effects of automation on flight safety. Communication problems and the incorrect operation of crew resource management were also seen as contributing factors in the aircraft accident. In high-risk activities such as aviation, the influence of cultural elements is strongly felt. In this accident, the hierarchical superiority of the captain pilot created a perception of being in the background for the co-pilot. It is stated that the communication and hierarchy-related problems experienced here are typical examples of what happened in the Korean Air Flight 8509 (1999) accident (Helmreich, 1999). However, flight operations require good teamwork. Communication problems resulting from not reporting a mistake or a critical situation can lead to fatal consequences in the future.

5. CONCLUSION AND RECOMMENDATIONS

This study analyzes the Asiana Airlines Flight 214 accident in the context of human-machine interaction and automation, examining the effects of increasing automation levels in avionics systems on pilot cognitive processes. The findings reveal that despite the goals of automation in modern aircraft to reduce workload and increase operational efficiency, human factors remain decisive in terms of system safety. In particular, the increasing complexity of automation systems can lead to weaknesses in pilots' processes of perceiving, interpreting, and predicting system conditions.

In the analyzed accident, the pilots' incorrect assessment of the automatic throttle system's operating status, their erroneous interpretation of autopilot mode transitions, and the resulting loss of situational awareness indicate that the accident was primarily a cognitively based human-machine interaction problem. This constitutes a concrete example of the automation paradox described by Bainbridge (1983). As emphasized in the NTSB (2014) report, the accident is considered to have resulted not from a technical malfunction, but from the automation system not being designed in accordance with the human mental model.

Research findings indicate that the failure to adequately ensure simplicity, transparency, and consistency in avionics system designs leads to data confusion and a lack of cognitive adaptation. Pilots' inability to clearly perceive which mode, logic, and limits the system was operating within resulted in weakened situational awareness. In addition, it was observed that the ineffective operation of crew resource management practices and communication deficiencies, influenced by hierarchical organizational culture, contributed to the accident.

In this context, the study offers some concrete recommendations for implementation. First, aircraft manufacturers should base their avionics system software designs on cognitive ergonomics principles; automation mode transitions should be supported by clearer, more intuitive, and standardized visual and auditory feedback. In particular, it is recommended that critical parameters such as speed management, automatic throttle status, and autopilot modes should be perceptible by the pilot at a glance and not open to interpretation. Second, airlines should include automation-related incidents and deviations as a separate category in their safety reporting systems and regularly analyze this data, which will support organizational learning.

In terms of training, it is suggested that scenarios based on automation misperceptions, rather than automation failures, be integrated into simulator training, going beyond classical flight training. Structuring such training in a way that allows pilots to understand “when and why” system behaviors change will increase cognitive awareness. Furthermore, more emphasis should be placed on practical scenarios aimed at reducing hierarchical communication barriers in crew resource management training.

This study, consistent with the human-machine interaction model proposed by Parasuraman et al. (2000), has shown that the progression of automation from decision support to fully automated takeover can weaken human monitoring and intervention capabilities. This finding indicates that future avionics system designs should adopt an adaptive automation approach that supports human cognitive capacity and maintains active participation, instead of “human-exclusionary automation.”

The study has some limitations. The fact that the analysis is limited to a single accident event restricts the generalizability of the findings. Also, the research was conducted solely using document analysis and does not include pilot interviews or direct observational data. Therefore, it is suggested that future studies should compare the Asiana Flight 214 accident with similar automation-based incidents such as Air France Flight 447, Colgan Air Flight 3407, or Boeing 737 Max accidents; and produce generalizable results across different aircraft types and cultural contexts.

In conclusion, the Asiana Airlines Flight 214 accident clearly demonstrates that safety in aviation can be sustained not only through advanced technology but also through healthy collaboration between humans and technology. The success of automation depends not on the accuracy of the algorithms, but on the ability of humans to correctly perceive, understand, and effectively control these systems when necessary. In future aviation systems, the key determinant of safety will be how humans work together with technology, rather than how they use it.

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