American Journal of Traffic and Transportation Engineering
2023; 8(3): 76-81
http://www.sciencepublishinggroup.com/j/ajtte
doi: 10.11648/j.ajtte.20230803.14
ISSN: 2578-8582 (Print); ISSN: 2578-8604 (Online)

Impact of Situational Awareness of Controllers on Safety Behavior Capacity in the Context of Air Traffic Control System with Manmachine Integration

Wang Yonggang, Ma Wenting*

College of Safety Science and Engineering, Civil Aviation University of China, Tianjin, China

Email address:
caucwyg@163.com (Wang Yonggang), mwt13220956832@163.com (Ma Wenting)

*Corresponding author

To cite this article:
Wang Yonggang, Ma Wenting. Impact of Situational Awareness of Controllers on Safety Behavior Capacity in the Context of Air Traffic Control System with Manmachine Integration. *American Journal of Traffic and Transportation Engineering*. Vol. 8, No. 3, 2023, pp. 76-81. doi: 10.11648/j.ajtte.20230803.14

Received: May 17, 2023; **Accepted**: June 8, 2023; **Published**: June 14, 2023

Abstract: With the continuous growth of air traffic and the increasing diversification of flight activities, the airspace operation situation is becoming more and more complex and changeable. Air traffic management, as an important foundation to ensure the development of aviation business, its safe behavior capability is of great significance to the safety of civil aviation operation. In order to explore the internal influence mechanism of the situation awareness of controllers on their safety behavior capacity under the background of air traffic control system with manmachine integration, the controllers of an air traffic control branch in a certain area were investigated, and 258 questionnaires were analyzed using structural equation model. The impact of the situation awareness on the safety behavior ability of controllers was studied from three levels: information perception, information understanding, and information prediction. The research results show that the three levels of controller's situational awareness have a positive impact on the controller's safe behavior ability, and the degree of impact from large to small is information prediction (0.675), information perception (0.383), and information understanding (0.275). At present, with the continuous intelligent development of air traffic control system, for the selection and training of controllers, it is necessary to increase the content of investigation and training of controllers' situational awareness.

Keywords: Controller, Situational Awareness, Safe Behavior Ability

1. Introduction

In the context of the current high quality development of civil aviation, intelligent ATC is an inevitable trend of ATC development and a power source of high quality development of ATC [1]. The current highly developed communication technology, satellite navigation, computer technology, and automation control technology have made civil aviation air flight and operation safer and safer. While the reliability of current aircraft continues to improve, the probability of accidents due to mechanical causes has decreased from 80% in the 20th century to 3% today [2]. Human causes have become the most significant cause of unsafe events [3]. In the context of the current highly developed intelligent ATC, for civil aviation systems, aviation equipment is also becoming more and more advanced and intelligent, with increased reliability. However, no matter how advanced the current ATC system equipment is, it needs controllers to control and operate it. As one of the most flexible and adaptable factors in the ATC system, controllers are also particularly vulnerable to adverse factors due to the complexity and flexibility of human mental activities. Human errors in the ATC system often lead to aircraft incidents, which may lead to serious accidents in severe cases, and may also cause flight delays and control chaos due to controller operation, which directly affects the efficiency of civil aviation operations and affects the development of civil aviation seriously [4]. Therefore, for air traffic control systems, the study of controllers is particularly important.

For the high-quality development stage of civil aviation, more and more scholars have studied the intelligent air traffic management system, which is a system that applies Internet technology to manage aircraft in airspace. Specifically, it refers to placing sensors with powerful sensing functions in various equipment systems of air traffic control, and then using advanced IT technology to connect them to form an air traffic control whole, so as to conduct all-round monitoring and processing of air traffic control [5]. In the current context of smart air traffic control, controllers need to make decisions on various situations monitored in the system. Especially in emergencies, controllers play a crucial role in making decisions in emergencies. Some scholars have found that personal situational awareness will directly affect personal decisions. At the same time, good situational awareness of controllers is a necessary condition to ensure safe and efficient operation of air traffic control [6]. The wide application of automation technology in intelligent air traffic control system has effectively improved the reliability level of aircraft. However, in the case of rapid increase in air traffic flow, controllers need to make accurate judgments according to the changes in air traffic situation. The reliability of human-computer interaction and human factors of controllers is also a challenge in the current air traffic control safety. Therefore, the requirements for controllers' situational awareness are increasingly high. When Endsley analyzed the aviation accident report, he found that 88% of the aviation accidents caused by human factors were related to the situational awareness of personne [7]; Some scholars also found that in the aviation, natural gas, mining and construction industries, situational awareness is the closest indicator to personal safety performance [8]; It has been shown that half of the major accidents and one-third of the non-major accidents in aviation accidents are due to decision-making failure, and a large part of the reasons for decision-making failure are due to the operator's situational awareness errors, not decision-making errors [7]. At present, few scholars have studied the impact of controller's situational awareness on their safe behavior ability.

In view of this, the author, based on the research of existing scholars [9], combined with the current background of smart air traffic control, conducts research on the scene awareness of controllers and their safe behavior ability, which is conducive to the selection of excellent traffic controllers by air traffic management departments and is also of great significance for the future training of traffic controllers.

2. Theoretical Basis and Research Assumptions

2.1. A New Generation of Air Traffic Control System with Man-Machine Integration

In March 2019, China successfully achieved the first initial four-dimensional (i-4D) track demonstration and verification in the Asia Pacific region. This means that the new generation of communication, navigation and monitoring technology can greatly improve the time accuracy of operation and command, and it is possible to improve the original minute level control and operation control to the second level [10]. At present, the intelligence level of air traffic control system is constantly improving, and the operation and command time is also relatively short, so higher requirements are put forward for the situational awareness of control personnel. Under the current background of intelligent air traffic control, the intelligent air traffic control system is divided into five layers: perception layer, application layer, network layer, platform layer and decision-making layer [11]. As the basis of all management systems, the perception layer provides information for the operation of all links of the entire management system. The perception layer mainly relies on the sensor technology to communicate the induction to many important places of the management system, such as the airport surface, the management center and the navigation route, so as to quickly identify the hazards of potential failures; The application layer includes the network foundation layer and the service layer, which are mainly used to ensure the normal operation of the air traffic control system. The network foundation layer includes the AFTN network, the Internet, the local area network in the middle management and the latest mobile communication network. The service layer is mainly used to provide air management, traffic services, traffic monitoring and other information to the controllers; The network layer uses Internet, aviation fixed communication network, air traffic management LAN and other technologies to sort out the complicated air traffic management information; The platform layer is mainly a platform for the controller to use, through which the controller can conduct supervision management, data management and traffic management; The decision-making layer mainly assists the management personnel to make effective judgments on the information provided by the system. The decision-making layer makes judgments and analyses on the received system data to determine whether it can potentially threaten the air safety system, and then transmits the judgment results to the output end to assist the management personnel to make effective decisions.

2.2. Situational Awareness

The concept of situation awareness (SA) first appeared in aviation psychology, describing pilots' understanding of combat flight profile. Due to the extensive application of complex technology systems, people are gradually engaged in tasks from technical operational tasks to real-time dynamic monitoring and decision-making tasks in a dynamic operating environment. Situational awareness emphasizes that individuals quickly use their own psychological activities to support instant decision-making and performance in a dynamic and changing environment [6]. Therefore, in the field of human factors and ergonomics, more and more scholars have studied situational awareness. In the field of human factors science, situational awareness refers to the operator's understanding of the environment and how to manipulate the author to establish and maintain a full understanding of what is happening to successfully complete the current task. At present, there are multiple definitions of situational awareness, but the most widely used is the three level model theory on situational awareness proposed by Endsley, as shown in Figure 1. He believes that situational awareness is the perception of environmental elements within a certain time and space and the understanding of the meaning of the environmental elements in which it is located to predict what will happen.

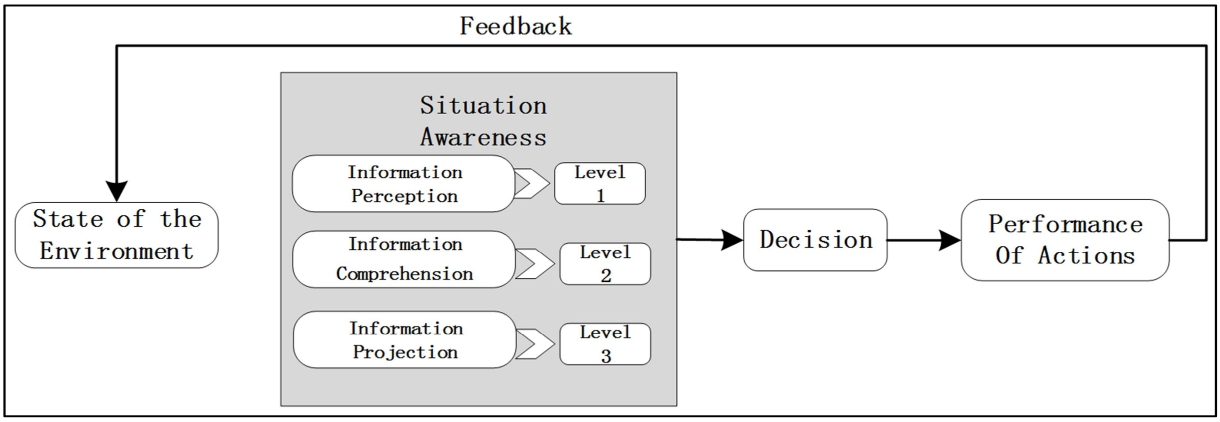

Figure 1. *Situational awareness model.*

As shown in the figure, the three levels of situational awareness are progressive, and information perception is the most basic level. For control, perception is the perception of the entire air traffic control environment. In addition to airspace structure and flight plan, it also includes progress sheets, aircraft positions on Rydak, radar tags, etc. [12] The perception level of situational awareness in regulation should include two aspects. On the one hand, accurately remember the airspace structure and airspace characteristics under jurisdiction (such as: composition route, control boundary point, handover point, handover agreement altitude, distance between each waypoint, etc.). This part of the content is stored in memory and belongs to the category of long-term memory. It can also be strengthened through learning. On the other hand, master the flight plan and relevant characteristics of each aircraft in the area (such as: each flight number, position, heading, altitude, flight plan, etc.). This part is the short-term memory of the training tester. Through external information, the tester can master the specific information of each aircraft in the area. This stage belongs to static data; the information understanding level is based on the controller's perception level, integrating the perceived information, forming the overall image of the important information and important events of the working environment in the controller's mind, and forming a fixed spatial structure map in the controller's brain. At this time, the controller has a basic grasp of the information of each aircraft, thus understanding the current form, The situational awareness at this level is not only the intuition of the key elements in the environment, but also the understanding of the meaning of the target elements; The last stage of situational awareness is the information prediction stage, which mainly predicts the future situation based on the knowledge and experience of the controller. Through the first two stages, the main basic information of static aircraft has been formed in the controller's brain, and then these information are processed. Through the accumulation of knowledge and experience, the controller puts forward possible assumptions about the operation status of the entire airspace aircraft and forecasts the expected estimates in the future.

2.3. Situational Awareness

Safety behavior capacity refers to the ability to take effective prevention, control and recovery measures to reduce the occurrence and loss of injury events [13]. The responsibility of civil aviation air traffic controllers is to ensure that aircraft can arrive at the destination safely and on time by providing air traffic control services. The most important issue for civil aviation is civil aviation safety. Combined with the work characteristics of civil aviation controllers, the safety behavior ability of controllers can be used to evaluate the safety performance of civil aviation controllers [14].

2.4. Situational Awareness

The perception layer and network layer of the intelligent air traffic control system mainly provide the controllers with various information about the operation of the air traffic control system. At this stage, the controllers need to perceive various information obtained by the perception layer. At the same time, the controllers need to have a general grasp of the information obtained for the faults or hazards identified by the sensors. Ignoring every tiny information may block the continuity of the air traffic control processing system, The investigation of aircraft accidents related to situational awareness shows that SA errors (SA1) related to attention perception constitute the majority of such accidents [15].

Therefore, the following assumptions are made:

H1: The perception layer of the controller's situational awareness has a positive impact on the ability of safe behavior;

The application layer and platform layer of the intelligent air traffic control system are mainly the process of sorting and processing the information obtained from the perception layer and the network layer, and then providing an information platform to the controller. The controller understands the information at this stage. The basic information of the air traffic control system obtained through the perception stage requires an understanding of the current and future state of the aircraft, Because the controller's understanding of the current flight scenario usually has a direct impact on future decisions, the understanding and prediction of the scenario are equally important to the task [9].

Therefore, the following assumptions are made:

H2: The understanding level of the controller's situational awareness has a positive impact on the safety behavior ability;

The decision-making layer of intelligent air traffic control mainly assists the controller to make correct decisions. The decision-making layer will have special intelligent judgment software to judge and analyze the data received from the system, and then transmit the results to the output terminal, and then the controller will make predictions based on the output information.

Therefore, the following assumptions are made:

H3: The prediction level of controller's situational awareness has a positive impact on safe behavior ability.

2.5. Model Construction

This paper takes the controllers of a regional air traffic control bureau as the research object, takes the three dimensions of situational awareness as the research variables, and takes the controllers' safety behavior ability as the dependent variable to build a structural equation model of the impact of controllers' situational awareness on their safety behavior capacity in the context of smart air traffic control, as shown in Figure 2.

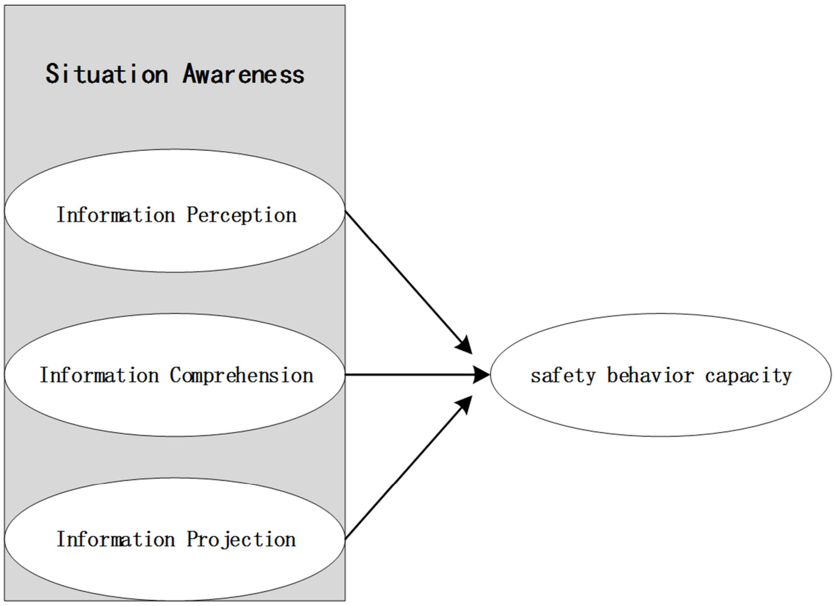

Figure 2. *Structural equation model of the impact of situational awareness on its safety behavior capacity.*

3. Model Testing and Analysis

3.1. Scale and Data Collection

At present, the most widely used method to measure situational awareness is SAGAT (Situation Awareness Global Assessment Technique) developed by Endsley. Its data collection method is basically consistent with SA's theory. It measures the level of operators' acquisition and integration of task information from three levels: information perception, information understanding, and information prediction. This measurement has high construct validity [16]. Using the relevant indicators in SAGAT for reference, a questionnaire was prepared to measure the situation awareness from three levels of information perception, information understanding and information prediction. See Table 1 for the key points of the measurement items on the situation awareness of controllers.

Table 1. *Questionnaire form and key items.*

Potential variables		Key points of measuring scale
Situational awareness (SA)	Information perception	aircraft position, course, route intersection, aircraft call sign
	Information comprehension	communication with pilots, other controllers and airports
	Information prediction	aircraft horizontal separation, vertical separation, aircraft level and crossing

As for the measurement of the safety behavior ability of civil aviation controllers, Wang Yonggang and others believed that the safety behavior ability of controllers can implement air traffic control through instruments and equipment, give full play to the best level during the duty phase, make the best effort to control the aircraft to operate at reasonable intervals and flows, and prevent unsafe incidents and accidents, as well as the ability to take recovery measures in a timely manner after the occurrence of hazards, In addition, a fuzzy comprehensive evaluation model based on analytic hierarchy process consisting of 3 secondary indicators and 17 tertiary indicators has been established, and an indicator system for the safety behavior ability of civil aviation controllers has been constructed, and its validity has been tested. Therefore, this paper uses its indicator system for the evaluation of the safety ability of controllers [16].

In this study, the controllers of an air traffic control branch in an area that implements intelligent air traffic control were selected as the subjects of the survey. A total of 300 questionnaires were issued. Finally, 258 valid questionnaires were recovered, with a recovery rate of 92.7%. 237 male controllers were selected, accounting for 79% of the sample, and 63 female controllers, accounting for 21% of the sample; The educational background of the selected sample subjects is mainly undergraduate and above. SPSS17.0 was used to calculate the mean, standard deviation, skewness and kurtosis of each measurement item in the questionnaire. Generally, the standard for samples to follow the normal distribution is that the absolute value of skewness is less than 3 and the absolute value of kurtosis is less than 10. After calculation, the measurement items basically follow the normal distribution, and the data structure is relatively reasonable.

3.2. Model Fit Test

In order to better explore the impact of the three dimensions of situational awareness on the safe behavior ability of controllers, the proposed model was analyzed using AMOS17.0, and the model fitting degree is shown in Table 2. The fitting degree index is an important indicator reflecting the consistency between the hypothetical model and the survey data. Generally adopted χ^2/df, RMESA, GFI, AGFI, NFI, CFI, IFI indexes are used as indicators for model fitting evaluation, and the fitting standard of each indicator is: $1 < \chi^2/df < 3$, indicating that the model is well adapted; GFI, AGFI, NFI, CFI and IFI should be greater than 0.9, and the closer to 1, the better; When RMSEA is less than 0.05, the model is fully fitted, and when RMSEA is less than 0.08, the model is well fitted. As can be seen from Table 2, The χ^2/df is 2.1370, which is less than 3, meeting the fitting requirements; The values of CFI, IFI, GFI and NFI are greater than 0.9, meeting the fitting requirements; Although the value of AGFI is less than 0.9, the gap with the standard is not acceptable; The value of RMESA is 0.0736, less than 0.08.

Table 2. *Model fitting indexes.*

Index	χ^2/df	GFI	AGFI	NFI	CFI	IFI	RMESA
Measured value	2.1370	0.9019	0.8728	0.9214	0.9237	0.9128	0.0736

Table 3 shows the path coefficient and significance level test results of the hypothesis model of the impact of the three dimensions of the controller's situational awareness on safe behavior ability. In, when the significance level of parameter estimation is 0.05, the p value is represented by "*"; When the significance level reached by parameter estimation is 0.01, p value is represented by "* *"; When the significance level of the parameter estimation is 0.001, the p value is represented by "* * *". It can be seen from the table that the information perception, information understanding and information prediction of the controller's situational awareness have a positive impact on the controller's safe behavior ability, and the information prediction has a significant positive impact on the controller's safe behavior ability.

Table 3. *Test results of path coefficient and significance level.*

Path	Normalized path coefficient	P value
IPe → SHC	0.383	**
IC → SHC	0.275	**
IPr → SHC	0.675	****

4. Conclusion and Application

Aviation is thought as a specific industry requiring great responsibility, and just a small mistake also leads to a considerable consequence affecting all passengers and crews on the flights [17]. In the intelligent air traffic control system, satellite based, ground-based monitoring and other monitoring means can be integrated to realize the dynamic collaborative monitoring of airspace operations between aircraft and air traffic control departments. On this basis, relevant application platforms developed can be used to assist controllers in making airspace management decisions such as airspace dynamic capacity assessment, airspace dynamic sector division, and temporary route opening and closing, according to different airspace environments and use needs. Situational awareness Situational awareness reflects the controller's ability to control the environment, which is not only derived from his own quality, but also depends on the coordination and communication with the environment. Safe behavior ability reflects the controller's ability to play the best role in preventing unsafe behaviors and taking timely recovery measures after the occurrence of danger in the actual operation process. The controller's safe behavior ability is directly related to air traffic control safety, However, the situation awareness of controllers has a positive impact on the safety behavior ability of controllers. Controllers have good situation awareness and their safety behavior ability is relatively high, which will also produce good safety results. Therefore, in the context of the continuous intelligent development of the air traffic control system, in the selection process of controllers, it is also necessary to increase the selection and inspection of the situation awareness of controllers, Because there is a more significant positive relationship between the information prediction of the situation awareness and the safety behavior ability of the controller, the information prediction ability of the controller should be emphasized in the investigation of the situation awareness; In the daily training of controllers, attention should also be paid to the cultivation of the situational awareness and information prediction ability of controllers.

Acknowledgements

Authors would like to express special thanks to all apron controllers for their contributions to this research. Their supports and the enthusiasm of their respective teams were invaluable in facilitating the authors' research efforts.

References

[1] Li Qiguo. Wisdom leads the high-quality development of air traffic control [J]. Military civilian integration of network information, 2021 (07): 33-35.

[2] You Xuqun, Ji Ming, Dai Kun, et al. Construction of multidimensional evaluation scale for flight safety behavior [J]. Journal of Psychology, 2009, 41 (12): 1237-1251.

[3] Civil Aviation Administration of China. Report on the Statistical Analysis of Civil Aviation Safety Information of China in 2018 [R]. China: Civil Aviation Administration of China, 2018.

[4] Xu Nuo. Research on Competency Characteristics of Air Traffic Controllers in China [D]. Jinan University, 2007.

[5] Bai Jidong. Intelligent Air Traffic Management System and Its Application [J]. Science and Technology Information, 2014, 12 (20): 22.

[6] Liu Jimin, Liang Ye. Research on scenario awareness model of controllers [J]. Civil Aviation of China, 2013 (12): 106-108.

[7] Endsley MR. Endsley MR. Towards a Theory of Situation Awareness in Dynamic Systems: Human Factors [J]. The Journal of the Human Factors and Ergonomics Society, 1995, 37 (1): 32-64.

[8] Zhongmin Wang, Zhou Jiang, Anna Blackman. Linking emotional intelligence to safety performance: The roles of situational awareness and safety training [J]. Journal of Safety Research, 2021, 78: 210-220.

[9] Feng Chuanyan, Wan Yan Xiaoru, Chen Hao, Zhuang Damin. Situational awareness model and application based on multi resource load theory [J]. Journal of Beijing University of Aeronautics and Astronautics, 2018, 44 (07): 1438-1446.

[10] Chen Qiang. New Ideas of "Involving" and Smart Operation and Maintenance Management of Air Traffic Control Communication [J]. Civil Aviation Management, 2021 (09): 64-68.

[11] Du Bingshuai. Research on Intelligent Air Traffic Management System and Its Application [J]. Digital Technology and Application, 2018, 36 (06): 235-236.

[12] Geng Huan, Wang Yanwei, Feng Yue, Zhang Shaoqing. Overview of Measurement Methods of Situational Awareness [J]. Aircraft Design, 2020, 40 (04): 30-34.

[13] XI AO Zhenfeng. Research on the evaluating indicator system of safe behavior ability for Beijing University of Chemical Technology, 2008.

[14] Wang Yonggang, Ye Shiqiang. Research on the Model of Safe Behavior Capacity of Civil Aviation Controllers [J]. Journal of Safety and Environment, 2012, 12 (04): 187-191.

[15] WICKENS C D, MCCARLEY J S, ALEXANDER A L, et al. Attention-situation awareness (A-SA) model of pilot error: ARL01-13/NASA-01-6 [R]. Washington, D. C.: NASA, 2001.

[16] YANG Jia-zhong, ZHANG Kan. Situation awareness: Approaches, measures and applications [J]. Advances in Psychological Science, 2004, 12 (6): 842-850.

[17] Ho T V H, Pham M V. Development of Air Traffic Control Simulator System Applied In Education And Training [J]. Transportation Research Procedia, 2021, 56: 47-54.