# A Complex Perspective of System Situation Awareness

Lei Wang(✉) and Yong Ren

Research Institute of Civil Aviation Safety, Civil Aviation University of China, Tianjin 300300, China
wanglei0564@hotmail.com, renrxy@outlook.com

**Abstract.** Though the concept of Situation Awareness (SA) was put forward over two decades, it is still a popular issue in the field of human factors. However, the current 'situation' has been changed a lot from the times when SA theory was born. More and more system parts have been designed to meet the requirement of context-aware, which means they have been distributed some cognitive function in a system. We propose out the concept of System Situation Awareness (SSA) and try to extend the range of awareness from human to system. SSA is influenced by the system's ability of context-aware and human's ability of situation awareness. The complex mechanism exists between human and system when maintaining SSA. This concept implies that the system would probably lose its SA when its context-aware ability gets weaken or lost. We should focus more on system design to enhance SSA with the approach of human system integration.

**Keywords:** Situation awareness · System situation awareness · Complexity

## 1 Introduction

Situation awareness (SA) has been developed as an important construct in field of human factors in the past two decades. The most prestigious definition on SA was put forward by Endsley who defined situation awareness as 'the perception of the elements in the environment within a volume of time and space, the comprehension of their meaning and the projection of their status in the near future [1] '. There is no doubt that Endsley's SA model and theory is still very dominant and influential in human factors and ergonomics community.

However, the discussions and even arguments on this concept and its inner mechanism never stopped since when it was born [2–13]. One of researcher's focus points is that whether SA is a pure psychological phenomenon. Endsley's definition [1, 14, 15] emphasizes mainly on perception and understanding of the environment with some aspects of future projection. Lots of researchers with psychological background are favourable to this definition and they have been drawn to study largely on the awareness, the cognitive side of SA. By contrast, less researchers like Smith and Hancock emphasized more on the interaction between the human and the environment [16]. Smith and Hancock pointed out that situational awareness is the invariant in the agent-environment


D. Harris (Ed.): EPCE 2016, LNAI 9736, pp. 97–103, 2016.
DOI: 10.1007/978-3-319-40030-3_11

system that generates the momentary knowledge and behaviour required to attain the goals specified by an arbiter of performance in the environment [16].

Generally to say, current researchers focused more on awareness and less on situation. As a matter of fact, nowadays the 'situation' has been changed a lot from the times when the SA theory was put forward, e.g. more and more tangible interaction objects are being introduced in our working environment. We started to neglect the physical aspect of things [17]. In this study, in order to adequately understand the new features between situation and awareness, we try to put forward the concept of System Situation Awareness (SSA) and extend the range of situation awareness from human to system.

## 2 System Situation Awareness

With the development of information and interaction technology, more and more products or system parts have been designed to meet the requirement of context-aware. This means some parts have been distributed cognitive function in a system. We take the evolution of flight deck as an example and find that there is huge change from B727 to B787 (see Fig. 1), especially the difference on displays, more new information systems such as Head-Up Display (HUD) were introduced into B787. The flight deck system of B787 provides crew with more support on information collecting and analyzing.


**Fig. 1.** The evolution of flight deck from B727 to B787

The systems are designed with more new functions which will help human operators to finish some tasks more easily. However, sometimes they will lose the ability of situation awareness when their functions get failed. Stanton pointed that sometimes it is the system that 'loses' situation awareness, not individual operators [19]. Salmon and his colleagues claimed that systems can be responsible for losing situation awareness [20, 21]. If the system awareness is considered in, previous situation awareness models focusing on the side of human cognition are probably not suitable for use. Therefore, the right approach for situation awareness today is to investigate interactivity of multi-agent (humans and

systems) consciousness [11]. We propose out the concept of System Situation Awareness (SSA) and try to extend the range of awareness from human to system. System Situation Awareness can be defined as the situation awareness of human and environment agent in system. SSA would be influenced by the system's ability of context-aware and human's ability of situation awareness.

## 3 Complexity of System Situation Awareness

Firstly we should see situation awareness from a systemic perspective. The 'situation' means environment around operators who possessing the 'awareness'. Apparently there are two ways to improve SA. It is as showing as Fig. 2, one way is from situation side to improve 'situation' by human centered design and another one is from awareness side to improve human ability and performance by training. But in fact now we have a black box here, we do not know the complex mechanism between them exactly. We just know that they are two elements keeping dynamic and interactive in complex systems such as flight deck, nuclear power control room and so on. So the key question is to know the complex mechanism between situation and awareness.

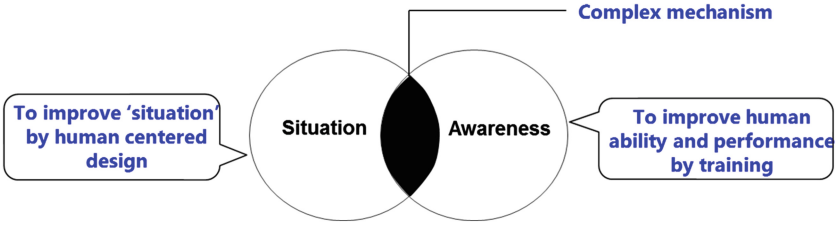


**Fig. 2.** The complex mechanism between situation and awareness

We think System Situation Awareness is an interactive and adaptive process between human agent and environment agent. For human operator, the situation is not a static picture in mind but keep changing all the way. The awareness process is complex and lots of conscious and subconscious mental mechanisms are involved in it. Due to the intermediary role of a long term working memory, several human cognitive stages are connected in the process of human-computer interaction. In this process, new information and stored information are integrated together and system situation awareness is enriched step by step, eventually forming a complete understanding of the system states and environment, this kind of interaction between human consciousness and system environment could be seen as an adaptive process. According to the complexity theory, the initiative and positive interaction between agents and environment is the basic driving force of system development and evolution. For example in modern cockpits, SA has to be thought as a human-systems multi-agent activity [11]. The study of Radvansky and Copeland shows that spatial shifts requires the participants to update their situation model of the environment, which demands cognitive

effort, which then makes information about associated objects less available [22]. Boy pointed out that situations are related to the complexity of human operator's extrinsic environment and intrinsic capabilities [11]. Flach proposed that SA defines the problem of human performance in terms of understanding the adaptive coupling between human and environment [18]. Seeing it from methodology level, it is a reflection of reduction method if we just take the human agent's awareness into consideration. It is a holistic view if we take human agent and environment into account but neglect the interaction between them. The view of complexity has surpassed the view of reductionism and holism, which takes the dynamic, non-linear and emergence issue of system into thinking. To some extent, we think that SSA has the characteristic of complexity.

## 4 Implications of System Situation Awareness

Firstly, this concept implies that we should pay more attention on system design to improve the situation awareness of whole system. Decker pointed out that it leads the term of situation awareness is overused in accident investigation while we always just regard SA as human agent's business [10]. Eighty-five percent of reports produced by the Australian Transportation Safety Bureau in 1996 contained references to a 'loss of situation awareness' [23]. Loss of situation awareness has become the favored cause for mishaps in aviation and other settings [10]. Thus we generally think that accidents were caused by error of human agent instead of system agent. To some extent, the effects of system design flaw on accidents were easily neglected or mitigated. As a matter of fact, the complexity of many systems coupled with poor designs makes system awareness difficult to maintain [2]. Considering the principles of human centered design, we feel that a context-aware computing approach can produce automation that is capable of adapting to its location of use and changes in the environment. For example, a good display designer must create displays that can effectively integrate the representation of two classes of information for routine performance and the broader environment (in anticipation of unexpected events) [24]. Then enhancing System Situation Awareness will become the main goal of system design. Dey define context as 'any information that can be used to characterize the situation of an entity' [25]. Context-aware devices may also try to make assumptions about the user's current situation. Moreover, social context could be taken into consideration in flight deck design for improving SSA. We know that there is a huge difference between eastern culture and western culture. Western technology and eastern culture would clash within the flight cockpit [27]. For the western make aircraft, the culture context should be better considered in for users (eastern pilots) in the design stage.

Secondly, this concept implies us to reconsider the measurement of situation awareness. Current method of measuring situation awareness generally is to estimate the perception, comprehension and projection level of perceived situation in a subject way. If we expand the definition of Situation Awareness to System Situation Awareness, previous SA measurement method which focusing on cognition side of human agent will be not be suitable. Previous SA measurement methods focused more on human instead of the whole system. A new method or criterion of measuring SSA should be developed. Boy [11] constructed a model of the various kinds of situations

ranging from the real, available, perceived, expected, to desired situations. Probably we can assess the level of available situation in a system. That means the availability of situation for human operator would be an important index of measure SSA.

In addition, from the perspective of complexity and adaption, the arguments on product or process concerning situation awareness could be unified. Because the SA is a dynamic process, it is a product at any time point.

## 5 A Case Study

In this section we give a case study on an aviation accident to illustrate the importance of improving SSA. On February 12, 2009, Colgan Air Flight 3407 crashed when instrument approaching to Buffalo International Airport of United States. The aircraft crashed into a residence around 8 km from the Buffalo airport. The aircraft type is Bombardier Dash 8. All passengers on board and one person on the ground lost their lives. The final investigation indicated that this crash was a Loss-of-Control (LOC) accident [26]. LOC is the flight accident type with the largest occurrence rate.

The report pointed that at first Air Traffic Controller cleared the aircraft to descend to 2300 feet and intercept the instrument approach course. The auto flight system was set to hold at 2300 feet. Once this auto flight was set, the pilot in flying kept the engine power near idle and slowed to flap-extension speed. As the landing gear lowered and flaps extended, the auto flight system continually pitched the aircraft nose-up to increase Angle of Attack (AOA) and maintain lift and altitude, causing the airspeed to decay. The cue of indicated airspeed and low-speed converged, and the stick shaker started to alert of an impending stall. At the same time, the auto pilot system disconnected – as it was designed. In a condition of great surprise, the captain finished a wrong operation and applied inappropriate nose-up inputs and failed to increase engine power. This Dash 8 aircraft experienced a full aerodynamic stall, the pilot counteracted the stick pusher but it's too late to recover it.


**Fig. 3.** The primary display in flight deck

In this case, in fact the automation had access to the data needed to make it 'aware' of its low-energy state, but the display in flight deck did not convey the implications of this important information to pilot in the right time. The flight crew members seemed to have been frozen by surprise, likely because they had not noticed the decay of airspeed from display. This was an automation surprise [2, 25]. Crew members have not noticed that the speed was dangerously slow. The National Transportation Safety Board (NTSB) concluded that the airspeed indicator in this cockpit lacked low-speed awareness features [26]. The primary display in this flight deck is as showing in Fig. 3. In this case, it is hard to say pilot lost the situation awareness or the system lost situation awareness. This accident may have been avoided if the primary display system had incorporated a context-aware design solution.

## 6 Conclusions

The traditional concept of situation awareness was put forward nearly thirty years ago. However, most SA models focused more on the awareness, the cognitive side of SA. Meanwhile nowadays the 'situation' updated quickly, many new technologies have been introduced into working environment. Many system parts have been distributed some cognitive function in a system. Therefore we proposed out the concept of System Situation Awareness (SSA) and extended the range of awareness from human to system. SSA is influenced by the system's ability of context-aware and human's ability of situation awareness. Meanwhile, the complex mechanism exists between human and system when maintaining SSA.

This concept implies that the system would probably lose its SA when its context-aware ability gets weaken or lost. It concluded that we need to focus more on system design to enhance SSA with the approach of human system integration.

**Acknowledgments.** We appreciate the valuable suggestions from Dr. Guy A. Boy of Florida Institute of technology in improving this paper. We also appreciate the support of this work from the National Natural Science Foundation of China (No. 61304207) and the China Scholarship Council.

## References

1. Endsley, M.R.: Design and evaluation for situation awareness enhancement. In: Proceeding of the Human Factors Society 32nd Annual Meeting, Santa Monica, CA (1988)
2. Sarter, N.B., Woods, D.D.: Situation awareness – a critical but ill-defines phenomenon. Int. J. Aviat. Psychol. **1**, 45–57 (1991)
3. Smith, K., Hancock, P.A.: Situation awareness is adaptive, externally directed consciousness. Hum. Factors **37**(1), 137–148 (1995)
4. Vidulich, M.A.: Testing the sensitivity of situation awareness metrics in interface evaluations. In: Endsley, M.R., Garland, D.J. (eds.) Situation Awareness Analysis and Measurement, pp. 227–246. Lawrence Erlbaum Associates, Mahwah (2000)

5. Stanton, N.A., Chambers, P.R.G., Piggott, J.: Situational awareness and safety. Saf. Sci. **39**, 189–204 (2001)
6. Hollnagel, E.: Extended cognition and the future of ergonomics. Theor. Issues Ergonomics Sci. **2**(3), 309–315 (2001)
7. Wickens, C.D.: Situation awareness: review of Mica Endsley's 1995 articles on situation awareness theory and measurement. Hum. Factors **50**(3), 397–403 (2008)
8. Dekker, S.W.A., Hummerdal, D.H., Smith, K.: Situation awareness: some remaining questions. Theor. Issues Ergonomics Sci. **11**, 131–135 (2010)
9. Kasdaglis, N., Newton, O., Lakhmani, S.: System state awareness a human centered design approach to awareness in a complex world. In: Proceedings of the Human Factors and Ergonomics Society Annual Meeting. SAGE Publications (2014)
10. Dekker, S.W.A.: The danger of losing situation awareness. Cogn. Technol. Work **17**, 1–3 (2015)
11. Boy, G.A.: On the complexity of situation awareness. In: Proceedings 19th Triennial Congress of the IEA, Melbourne, Australia, pp. 9–14 (2015)
12. Stanton, N.A., Salmon, P.M., Walker, G.H.: Let the reader decide: a paradigm shift for situation awareness in socio-technical systems. J. Cogn. Eng. Decis. Making **9**(1), 44–50 (2015)
13. Endsley, M.R.: Situation awareness misconceptions and misunderstandings. J. Cogn. Eng. Decis. Making **9**(1), 4–32 (2015)
14. Endsley, M.R.: Measurement of situation awareness in dynamic systems. Hum. Factors **37** (1), 65–84 (1995)
15. Endsley, M.R.: Toward a theory of situation awareness in dynamic systems. Hum. Factors: J. Hum. Factors Ergonomics Soc. **37**(1), 32–64 (1995)
16. Smith, K., Hancock, P.A.: Situation awareness is adaptive, externally directed consciousness. Hum. Factors **37**(1), 137–148 (1995)
17. Boy, G.A.: From automation to tangible interactive objects. Ann. Rev. Control J. **38**(1), 1–11 (2014)
18. Flach, J.M.: Situation awareness: proceed with caution. Hum. Factors **37**, 149–157 (1995)
19. Stanton, N.A., Salmon, P.M., Walker, G.H., Jenkins, D.P.: Is situation awareness all in the mind? Theor. Issues Ergonomics Sci. **11**, 29–40 (2010)
20. Salmon, P.M., Stanton, N.A., Walker, G.H., Jenkins, D.P., Ladva, D., Rafferty, L., Young, M.S.: Measuring situation awareness in complex systems: Comparison of measures study. Int. J. Ind. Ergonomics **39**, 490–500 (2009)
21. Salmon, P.M., Lenne, M.G., Walker, G.H., Stanton, N.A., Filtness, A.: Exploring schema-driven differences in situation awareness across road users: an on-road study of driver, cyclist and motorcyclist situation awareness. Ergonomics **57**, 191–209 (2014)
22. Radvansky, G.A., Copeland, D.E.: Walking through doorways causes forgetting: situation models and experienced space. Mem. Cogn. **34**, 1150–1156 (2006)
23. ATSB: Human factors in fatal aircraft accidents. Australian Transportation Safety Bureau. ACT, Canberra (1996)
24. NTSB: Accident report - Loss of control on approach Colgan Air, Inc. operating as Continental Connection Flight 3407 Bombardier DHC-8-400. National Transportation Safety Board, Washington, D.C (2010)
25. Wickens, C.D.: Situation awareness and workload in aviation. Curr. Dir. Psychol. Sci. **11**, 128–133 (2002)
26. Dey, A.K.: Understanding and using context. Pers. Ubiquitous Comput. **5**(1), 4–7 (2001)
27. Jing, H.S., Batteau, A.: The Dragon in the Cockpit: How Western Aviation Concepts Conflict with Chinese Value Systems. Ashgate, Farnham (2015)