On the Complexity of Situation Awareness

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Situation awareness (SA) has been a topic of interest for more that two decades in human factors and ergonomics. This paper proposes a critical account on this useful concept for human-centered design. First and foremost, it proposes various meanings of the concept of situation, ranging from the real, available, perceived, expected, to desired situations. In addition, a situation is not a snapshot; it should be investigated as a dynamic set of states. This paper proposes two perspectives of situation models: extrinsic and intrinsic. The extrinsic-intrinsic distinction is interesting because it can support deeper analysis of SA complexity. In particular, human operator's expertise and experience is central to the concepts of SA and associated mental models, especially in safety-critical systems and environments. For example, aircraft pilot's mental models are incrementally formed by training and extensive experience. This is the intrinsic account of SA complexity. In addition, aeronautical operational situations can be very complex (e.g., high density traffic or bad weather conditions). This kind of "external" situation cannot be represented by a set of states only, but requires multi-agent models. This is the extrinsic account of SA complexity. Human-systems integration cannot be done correctly if both intrinsic and extrinsic SA complexities are not properly taken into account.

Keywords: Situation Awareness, Complexity, Human-Centered Design, Human-Systems Integration, Consciousness, Aeronautics, Tangible Interactive Systems.

1. Introduction

For more that two decades, situation awareness (SA)[1] has been a recurrent topic in the human factors and ergonomics (HFE) community, and Endsley's SA model was, and still is, very influential (Endsley, 1995ab, 1998, 2000). This model typically claims that SA is "the perception of elements in the environment within a volume of time and space, the comprehension of their meaning, and the projection of their status in the near future" (Endsley, 1995b). Several other authors worked on variations of this model such as (Smith & Hancock, 1995; Vidulich, 2000; Stanton, Chambers & Piggott, 2001; Dekker, Hummerdal & Smith, 2010). SA is thought as knowledge we have about the environment, which can guide our actions. Problem is that the perceived environment (i.e., what we usually call the situation) constantly evolves, and people need to constantly update knowledge they have on this environment. People have several limitations, one of them being their working memory saturation. In addition, their level of familiarity with various types of situation makes the situation awareness process more or less easy to perform. This depends on the mental model that they have developed (e.g., expert, occasional or novice human operators do not have the same operative mental model, and therefore will not derive the same meaning or interpretation of a same situation). These factors need to be addressed in more details and depth than they have been until now. For example, humans do not naturally fly; they need to "wear" a prosthesis, called an aircraft, to be able to fly. It takes some time to become a pilot; and it takes even more time to become a proficient pilot. Proficiency is expressed in number of flight hours. The main reason for this proficiency acquisition is the need for flight embodiment. In the aviation community, we say that pilots need to acquire the "sense of air."

This paper proposes an experience-based[2] critical analysis of the concepts of "situation" and "awareness" from different points of view. What do we mean by a "situation"? Is it what we perceive in the environment or

[1] After producing the latest version of this paper, I discovered the existence of a 2015 special issue of the Cognitive Engineering and Decision Making Journal on situation awareness (SA). I then realized that other people currently have strong opinions on this subject. This paper is not a reaction to the whole content of this journal special issue. For now, my point is clear: SA is an important concept and deserves to be treated in more depth! More specifically, human-centered design of complex life-critical systems cannot be done correctly if expertise, familiarity, tangibility, situation complexity and the notion of consciousness are not taken into account seriously.

[2] Thirty-five years of continuous experience (practice and research) in the field of aircraft cockpit design, and more generally human-centered design of life-critical systems.

what the environment really is? Is it what we expect to happen or what really happens? Is it a snapshot or a dynamic evolution of the environment where we are? How do we model a situation? Is it a set of environment variables or sophisticated model of the environment? What do we mean by environment? Is it what surrounds us? Are we part of it? About awareness: is awareness an intentional cognitive (i.e., conscious) process, a reactive (i.e., subconscious) process or both? In other words, we need to address the distinction conscious-subconscious processes. This discussion leads to a more philosophical analysis of awareness, consciousness[3] and embodiment. These concepts will be analyzed breaking with the Cartesian approach that separates mind and body, and shifting to a phenomenological approach that puts forward experience (Derida, 1954). Edmund Husserl broke with positivist philosophy (Comte[4], 1865; Zahavi, 2003). He studied the structure of consciousness, making a distinction "between the act of consciousness and the phenomena at which it is directed (the objects as intended)." He also developed the concept of intersubjectivity (i.e., the psychological relation between people – which I extend to relations among humans and/through interactive systems), which today makes a lot of sense when we study multi-agent systems, emergent properties of multi-functional tasks and collective SA (Salmon et al., 2009; Kasdaglis et al. 2014). For example, automation, as it is implemented and used up to now, is often considered as an agent (i.e., a third crewmember in current commercial aircraft cockpit), and should be analyzed as such.

2. Extrinsic versus intrinsic situation models

The "situation awareness" concept is two-fold: "situation" and "awareness"! Let's analyze the concept of situation first. I looked at several dictionaries and encyclopedia, and the most frequent definitions (or most related concepts) for the concept of situation are the followings: location; set or combination of circumstances; state of affairs; condition; case; position; post of employment; job. It can be also defined as a set of fact, events and conditions that affect somebody or something at a particular time and in a particular place.

Situation may refer to a dynamic set of states including multiple derivatives, in the mathematical sense. Let's try to construct a model of the various kinds of situations (Figure 1). Ideally, the real world is characterized by an infinite number of highly interconnected states. This is what we call the "real situation". It may happen that some of these states are not available to us. For example, many states describing aircraft engine health are not directly available to pilots. States available to a human observer define the "available situation" (e.g., aircraft engine health states available to pilots). Note that the "available situation" is typically part of the "real situation". In addition, the "available situation" may not be totally perceived by the observer. What he/she perceives is called the "perceived situation". Of course, the "perceived situation" is part of the "available situation", but is also directed by what is being expected. The "desired" situation typically expresses a goal-driven behavior (e.g., we want to get to this point). The "expected" situation expresses an event-driven behavior (i.e., we anticipate a set of states to happen).

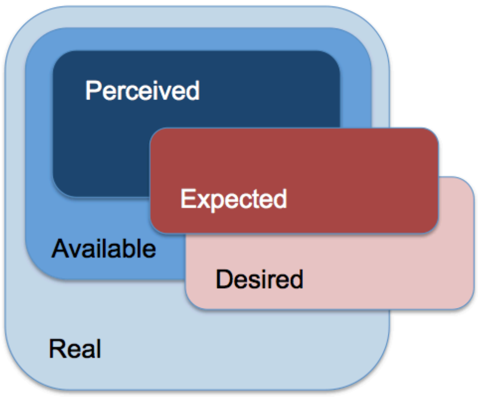

Figure 1: Various kinds of situations.

[3] In this paper, consciousness is taken in the sense of a compilation of "experiences" that results in combined mental and physical skills.
[4] Auguste Comte (1798–1857) founded positivist philosophy and is the first philosopher of science in the modern sense.

When people expect something to happen very strongly, they may be confused and mix the "perceived situation" with the "expected situation" (i.e., this is usually related to cultural context, distraction and focus of attention). There is huge difference between monitoring activities and control activities. People involved in a control activity are goal-driven. Their SA process is directed by the task they need to perform. Conversely, people who only have to monitor a process (and who do not have to act on it) need to use, and sometimes construct in real time, an artificial monitoring process that may be difficult, boring and sometimes meaningless. In this second case, the situation awareness process has many chances not to be accomplished correctly.

Finally, the "perceived situation" is not necessarily a vector of some available states, but a model or image that emerges from a specific combination of these states, incrementally modified over time. This is called experience acquisition. Human operators build their own mental models or mental images of the real situation. This mental image depends on people, cultural context, current people's activity and other factors that are specific to the domain being studied.

Consequently, human operators subjects, who are not familiar with situations in laboratory setups, may lead to false interpretations in the long term. For this reason, human-centered design formative evaluations dealing with complex systems require training, minimal experience acquisition and longer involvement of human operator subjects. At HCDi for example, we choose to design new systems using realistic aircraft simulators and professional pilots.

Real and available situations are categorized under the concept of extrinsic situations. Expected and desired situations characterize the concept of intrinsic situation. Perceived situations belong to both concepts of extrinsic and intrinsic situations. Extrinsic situations are related to the complexity of human operator's environment. Intrinsic situations are related to the complexity of human operators' capabilities. Both types of complexity could be expressed in terms of number of states and interconnections among these states. In both cases, appropriate models need to be developed.

3. Awareness and consciousness

Many SA models forget to mention what mental processes they are referring to. As already introduced above, SA could take place at a subconscious level (e.g., the skill-based behavior level of Rasmussen's model) because human operators tend to compile their knowledge to become expert, proficient and effective in their activities (Rasmussen, 1986). This compilation results from training and experience. The concept of compilation should be understood as an analog of software programs compilation (i.e., once compiled it is very difficult and most of time impossible to decompile). This compilation leads to a set of skills (i.e., executable routines). We will say that resulting situation awareness is embodied. Of course, SA could also take place at the conscious level (e.g., the rule-based or knowledge-based behavior levels of Rasmussen's model). In this case, situation awareness is purely cognitive (i.e., interpreted following the software engineering analogy of the compilation concept), and corresponds to HFE classical definitions.

In a recent article, Dekker started a debate on the circularity of complacency, intentional bias and loss of situation awareness, where he stated that complacency causes losing situation awareness, and losing situation awareness causes complacency (Dekker, 2015). This debate can be quickly ended if we consider the distinction between awareness and consciousness seriously. Of course, consciousness includes awareness (i.e., the awareness of something by a person), but it also includes the fact of being awake (Farthing, 1992). In human-systems interaction, being awake means not being complacent. For this reason and referring to Dekker's article, I much prefer to use the term "consciousness" instead of "awareness" to denote this overall SA concept that the HFE community is using for more than two decades.

Consciousness could be seen as an emergent phenomena resulting from interactivity among million of billion of synapses and 50 to 100 billion of neurons in the brain and the whole nervous system of a human being. No computer system can simulate this phenomenon yet. Therefore, it is difficult to formally validate any model of consciousness at this point. However, artifacts (our objects of studies in HCD) are concrete representations of human intelligence, whether they are physical or figurative. According to Changeux[5], complexity of brain connectivity increased dramatically in the course of human evolution. He claims that Darwinian epigenetic human brain evolution, combined with social evolution, is translated into art production

[5] Jean-Pierre Changeux is a French neuroscientist known for his research in biology, from the structure and function of proteins to the early development of the nervous system up to cognitive functions.

evolution (i.e., art productions are interpreted as extra-cerebral memories). He also claims that human brain is not a sponge, but constantly projecting, testing hypotheses, exploring, self organizing and engaging in social communication (Changeux, 2008). Consequently, consciousness should be considered as a highly non-linear dynamic process that produces and constantly refreshes our operative image (in Ochanine's sense) of the world that surround us in both physical and figurative meanings.

4. Cognition, embodiment and familiarity

Situational complexity needs to be analyzed both extrinsically and intrinsically. In aeronautics for example, pilot's mental models are incrementally formed by training and incremental construction of experience and skills. Consequently, human operator's expertise plays an important role when we want to analyze and assess situation awareness (i.e., the intrinsic account). In addition, aeronautical operational situations, for example, need to be modeled to better understand interactions among the various agents involved including automation (i.e., the extrinsic account). Therefore, multi-agent models and expert users (e.g., experimental test pilots in aeronautics) are required.

At this point, it is important to explain what we mean by complexity. First, the opposite concept of complexity is not simplicity, but familiarity. When we are moving from one place that we know well to another region of the world, one way or another, we always find this new place complex and difficult to handle. However, after a few months of stay, we start to be familiar with lots of details that were not salient, and sometimes not perceived at all, in the beginning. We become familiar with the environment. Familiarity decreases the perceived complexity of this new place. In other words, the emergent mental model increasingly becomes more familiar to the observer. We will see later that once this "familiar" mental image of the situation is learned, it depends on the way people use it (i.e., it could be located at the sub-conscious level or the conscious level of the brain, and sometimes embodied in our senses). Professional dancers, for example, learned through intensive training to embody jumps, spins and pirouettes, so they do not think about at a conscious level to execute these kinds of movements. They concentrate on more complex endeavors.

Figure 2. Classical commercial aircraft's navigation display. The left vertical line is the initial trajectory. The right one is the offset. The pilot estimates the distance between these two lines, here about 3 NM.

Expertise and familiarity (i.e., the intrinsic account) are not sufficient to characterize complexity of the way situations are perceived. Another type of complexity needs to be understood and handled. Complexity of the available situation needs to be analyzed and understood also (i.e., the extrinsic account). A pilot cannot fly if he/she does not understand flight physics and meteorology. He/she should have a tangible perception and comprehension of the extrinsic situation of his/her environment. This account is consistent with current HFE mainstream SA definition in terms of perception, comprehension and projection of the available situation. Note that this does not remove the need for usability engineering (Nielsen, 1993) tests at design time in order to improve the available situation.

Let's take a real world example in commercial aviation. When air traffic control asks the aircrew to offset 3 NM on the right from their trajectory, on classical commercial aircraft, the pilot typically manually turns the heading knob to the right until the 3 NM offset is reached and re-establish the original heading. This is an embodied gesture (Figure 2). Conversely, in modern automated cockpits, the same maneuver is performed using the Flight Management System (FMS). The pilot enters "3R" (i.e., 3 NM offset on the right) on the flight plan page (Figure 3). The FMS computer (considered as an artificial agent) automatically takes the requested offset and re-establishes the original heading. In this case, the pilot delegates the offset task to the FMS agent. This is a cognitive act. In these two cases, SA is not managed in the same way. In the former case, the pilot has to estimate that the offset is reached by monitoring the evolution of the aircraft on the navigation display (ND). This monitoring is not a difficult task, but it is not as accurate as what an automated system can do. The SA process should take into account aircraft inertia for the estimation of the offset on the ND. In the latter case, the pilot does not have to worry about this estimation because it is entirely done by the system, including inertia management. We see that in modern cockpits SA has to be thought as a human-systems multi-agent activity.

Figure 3. (Left picture) The pilot enters "3R" on the user interface of the FMS under the prompt "OFFSET", and selects "INSERT"; (Right picture) The navigation display shows the initial trajectory (dotted line) and the offset trajectory (plain line).

5. Human activity and tangibility

The distinction between body and mind, proposed by René Descartes (Mattern, 1978)[6], leads to a definition of consciousness, and then awareness, that is purely cognitive. This approach directly leads to the conception the HFE community currently has of situation awareness. However, there is another approach, which privileges embodiment, where body and mind are interconnected. This corresponds to the phenomenological thought (Heidegger, 1927). This philosophical approach is both sociological and tangible.

[6] In this short essay, Ruth Mattern analyzes René Descartes' correspondence with Princess Elizabeth of Bohemia on the mind-body distinction.

On the sociology side, Lucy Suchman's work introduced the concept of situated actions (Suchman, 1987). Suchman introduced a novel reactive approach to HCI (i.e., event-driven), contrasting with the classical cognitive approach (i.e., goal-driven). She used ethnomethodology to better understand social actions (Garfinkel, 1967). Ethnomethodology focuses on people's activity (i.e., what people actually do) and not on tasks (i.e., what people are prescribed to do). This distinction between task and activity was already described to define the cognitive function representation for the implementation of cognitive function analysis (Boy, 1998, 2013), as well as activity theory (Leont'ev, 1981; Kaptelinin, 1995). The concept of activity is related to Ochanine's concept of operative image (Paris I Seminar on D. Ochanine's Operative Image, 1981). More recently, exploring the social aspects of interactive systems, Paul Dourish proposed the foundations of a new approach on human-computer interaction through embodied interaction (Dourish, 2001). The concept of activity has then to be understood as both cognitive and embodied.

Whenever we explore human interaction with the world, whether it is physical or virtual, tangibility is an issue (Boy, to appear). Situation awareness has to do with tangibility. Tangibility can be understood in a physical sense (i.e., an object that you can physically grasp). For example, when you are driving and need to change the volume of your radio, a rotary knob with physical notches enables you to physically feel how much you turn. Tangibility can also be understood in a figurative sense (i.e., a concept or idea that you can mentally accept). In a discussion, we sometimes argue, "this is not tangible, I don't buy it!" This is because interaction is not only rationally cognitive (i.e., people often use heuristics and practice abduction instead of rational demonstration using deduction). Human interaction can be embodied (i.e., physical tangibility) and/or involve educated common sense (i.e., figurative tangibility). Educated common sense was already defined in (Boy, 2013).

6. Discussion

In the early eighties, I was an engineer freshly graduated with a Ph.D. in automatic control and computer science, and started learning HFE and cognitive science. At that time, my job was to design and develop new methods to help in the certification of commercial aircraft two-crewmen cockpits (Boy, 1983). This was the beginning of a new kind of flying, where automation became a new crewmember onboard. We were worrying about workload because we thought that removing one crewmember from the cockpit was going to add more work to the two pilots remaining. In practice, we incrementally discovered that automation created the opposite trend. Instead of creating more stress, automation created problems of vigilance, and later on complacency. Situation awareness was put forward during the nineties because we started to understand the effect of distance between what pilots perceived in the cockpit and the real world environment (i.e., aircraft systems and mechanical parts, air traffic control and physical environment). Cognitive ergonomics became dominant and HFE models became almost entirely cognitive. We started to neglect the physical aspect of things.

One of the main reasons for this was that information technology penetrated mechanical parts (i.e., we massively put software into hardware), creating deeper automation issues. Today, things are totally different. We start designing systems in virtual worlds by developing software to the point that we can test human factors issues very early on during the design process. Automation is no longer an issue because we design and test software and interactivity before we develop hardware. The main issue then becomes tangibility because hardware is developed around and from software, to the point that we can now 3D-print hardware from software. In fact, we design and develop tangible interactive objects (Boy, 2014), which more generally become tangible interactive systems or TISs (Boy, to appear). These TISs need to be integrated, as Salmon and his colleagues suggested in a response to Dekker's article, by using their distributed situation awareness approach (Salmon et al., 2015). These authors claimed that systems can be responsible for loosing situation awareness. Consequently, the right approach for situation awareness today is to investigate interactivity of multi-agent (humans and systems) consciousness. System consciousness can be defined as both awareness of something by the system and lack of complacency (i.e., the system does not fail while working).

In addition, consciousness is also as much embodied as cognitive; this is what Merleau-Ponty calls corporeity, based on the distinction between phenomenology and positivism philosophies (1964). For that matter, it is crucial that investigators and scientists studying situation awareness for human-systems integration clearly understand how cognition and embodiment are interrelated. In other words, on the one hand, investigators and scientists should understand human operator's level of expertise and proficiency, and on the other hand, they should have experienced these cognitive and embodied skills by themselves in order to set up experiments and interpret results correctly. In particular, in life-critical domains such as aerospace, they need to understand that expertise is most of the time more important in experimental setups than usual statistical requirements to produce an "accepted" scientific paper (e.g., instead of taking 30 students to satisfy statistical requirements, it is often much better to take 4 professional pilots and a few aerospace experts to derive meaningful conclusions). The experience-based approach is often more effective and meaningful than the statistical approach for human-centered design of complex life-critical systems. Of course, this observation goes beyond the situation awareness issues being discussed, and statistical analyses should be promoted anytime meaningful experimental setups and results are guaranteed.

7. Conclusion

Situation awareness complexity comes from several causes. First, as already explained, "awareness" does not include the notion of complacency or its opposite concept, "awakeness." For that matter, the term (and concept) "consciousness" is more complete than awareness. Second, complexity of the situation itself matters. We call it extrinsic complexity. Third, complexity of the awareness process is crucial and involves not only conscious and subconscious mental mechanisms, but also physical sensing and feelings. We call it intrinsic complexity.

The extrinsic-intrinsic distinction is interesting because it can support our understanding of situation awareness complexity, even if extrinsic and intrinsic complexity could be ultimately merged into a single model. The extrinsic perspective includes situation models that enable analytical interpretation of situations. This type is commonly used in the HFE community to better understand and assess situation awareness in work environments. It is based on a very simple model that involves three cognitive processes: perception, comprehension and projection. The intrinsic perspective attacks model-based behavior modeling, which considers that people use operative mental models to act. Operative mental models are incrementally learned by people to interact with systems and, more generally, their environment. In addition, these models include a physical part and a mental part. These models are evolving as people learn about their environment (i.e., as they become more familiar with their environment). Consequently, familiarity plays an important role in situation awareness.

Acknowledgements

The author would like to thank Sébastien Boulnois, Nicholas Kasdaglis, Jean-Floris Lang, Anouk Mirale and Wei Tan for insightful comments contributing to the improvement of this paper.

References

Boy, G.A. (to appear). *Tangible Interactive Systems*. Springer, U.K.

Boy, G. A. (2014). "From automation to tangible interactive objects." Annual Reviews in Control, Elsevier (1367-5788). 10.1016/j.arcontrol.2014.03.001.

Boy, G.A. (2013). *Orchestrating Human-Centered Design*. Springer, U.K. ISBN 978-1-4471-4338-3.

Boy, G.A. (1983). Le Système MESSAGE : Un Premier Pas vers l'Analyse Assistée par Ordinateur des Interactions Homme-Machine (The MESSAGE system: A first step toward computer-supported analysis of human-machine interactions). *Le Travail Humain* Journal, Tome 46, no. 2, Paris, France.

Changeux, J.P. (2008). *Du vrai, du beau, du bien : Une nouvelle approche neuronale* (About truth, beauty and good: A new neuronal approach). Editions Odile Jacob, Paris, France. ISBN-13: 978-2738119049.

Comte, A. (1865). *A General View of Positivism*. Translated by Bridges, J.H., Trubner and Co., 1865 (reissued by Cambridge University Press, 2009; ISBN 978-1-108-00064-2).

Dekker, S.W.A., Hummerdal, D. H., & Smith, K. (2010). Situation awareness: Some remaining questions. *Theoretical Issues in Ergonomics Science*, 11, pp. 131–135.

Dekker, S.W.A. (2015). The danger of losing situation awareness. *Cognition, Technology and Work*. DOI 10.1007/s10111-015-0324-4.

Derrida, J. (1954 French Edition; 2003 English Edition). *The Problem of Genesis in Husserl's Philosophy*.

Chicago & London: University of Chicago Press.
Dourish, P. (2001). *Where the Action Is: The Foundations of Embodied Interaction*. MIT Press, Cambridge, MA.
Endsley, M.R. (1995a). Measurement of situation awareness in dynamic systems. *Human Factors*, 37(1), pp. 65–84.
Endsley, M. R. (1995b). "Toward a theory of situation awareness in dynamic systems." *Human Factors: The Journal of the Human Factors and Ergonomics Society*, *37*(1), pp. 32-64.
Endsley, M.R. (1998). A comparative analysis of SAGAT and SART for evaluations of situation awareness. In *Proceedings of the Human Factors and Ergonomics Society 42nd Annual Meeting* (pp. 82–86). Santa Monica, CA: The Human Factors and Ergonomics Society.
Endsley, M.R. & Garland, D.J. (Eds.) (2000). *Situation awareness analysis and measurement*. Mahwah, NJ: Lawrence Erlbaum Associates.
Farthing, G. (1992). *The Psychology of Consciousness*. Prentice Hall. ISBN 978-0-13-728668-3.
Garfinkel, H. (1967). *Studies in Ethnomethodology*. Englewood Cliffs: Prentice Hall.
Heidegger, M. (1927). *Being and Time*. Tr. Macquarrie and Robinson (1962). New York: Harper and Row.
Kaptelinin, V. (1995). Designing learning activity: a cultural-historical perspective in CSCL. *Proceedings of the Computer Supported Cooperative Learning (CSCL'95).* Indiana University, Bloomington, IN.
Kasdaglis, N., Newton, O., & Lakhmani, S. (2014). 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* (Vol. 58, No. 1, pp. 305-309). SAGE Publications.
Leont'ev (1981). *Problems of the development of the mind*. Moscow: Progress.
Nielsen, J. (1993). *Usability engineering*. Academic Press, Boston, ISBN 0-12-518405-0.
Mattern, R. (1978). Descartes' Correspondence with Elizabeth Concerning both the Union and Distinction of Mind and Body. In *Descartes: Critical and Interpretive Essays*, Michael Hooker (Ed.). John Hopkins University Press, Baltimore, pp. 212-222.
Merleau-Ponty, M. (1964). *The Primacy of Perception*, Northwestern University Press.
Paris I Seminar (1981). *Operative Image* (in French). Actes d'un séminaire (1-5 juin) et recueil d'articles de D. Ochanine. Université de Paris I (Panthéon-Sorbonne), Centre d'éducation Permanente, Département d'Ergonomie et d'Ecologie Humaine.
Rasmussen, J. (1986). *Information Processing and Human-Machine Interaction: An Approach to Cognitive Engineering*. Elsevier Science Inc., New York, NY, USA. ISBN: 0444009876.
Salmon, P.M., Walker, G.H. & Stanton, N.A. (2009). Broken components versus broken systems: why it is systems not people that lose situation awareness. *Cognition, Technology and Work*. DOI 10.1007/s10111-015-0324-4.
Salmon, P.M., Stanton, N.A., Walker, G.H., & Jenkins, D.P. (2009). *Distributed Situation Awareness - Theory, Measurement and Application to Teamwork*. Ashgate, U.K.
Salmon, P.M., Stanton, N.A., Walker, G.H., Jenkins, G., Ladva, D., Rafferty, L. & Young, M. (2009). Measuring Situation Awareness in complex systems: Comparison of measures study. In: International Journal of Industrial Ergonomics, Vol. 39, No. 3, 05.2009, pp. 490-500.
Smith, K., & Hancock, P.A. (1995). Situation awareness is adaptive, externally directed consciousness. Human Factors, 37 (1), pp. 137-148.
Stanton, N.A., Chambers, P.R.G. & Piggott, J. (2001). Situational awareness and safety. *Safety Science*, 39, pp. 189-204.
Vidulich, M.A. (2000). Testing the sensitivity of situation awareness metrics in interface evaluations. In M.R. Endsley & D.J. Garland, (Eds.), Situation awareness analysis and measurement (pp. 227–246). Mahwah, NJ: Lawrence Erlbaum Associates.
Zahavi, D. (2003). *Husserl's Phenomenology*. Stanford University Press, Stanford, CA.