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The role of Situation Awareness for the Operators of Process Industry

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Situation awareness (SA) is commonly described as the challenges encountered by an operator and it appears during the course of interaction with either the process itself or a human machine interface. Application and significance of SA is well established in different production sectors such as aviation, armed forces, and air traffic. The importance and significance of SA for Field Operators (FOPs) and for Control-Room Operators (CROPs) is highlighted and discussed in this paper. The major factors that influence the SA of operators in the process industry are identified, presented, and discussed. Furthermore, the career track of operators with respect to its effect on SA is also analyzed and the concept of Team Situation Awareness (TSA), which is the coordination among different operators (intra and inter teams) is presented.

1. Introduction

Situation Awareness (SA) is the term that was first proposed in World War I by Oswald Boekle to reference the capability of getting awareness of the enemy prior to the similar awareness gained by the enemy and eventually the target achieved by the one who has more and better awareness (Gilson, 1995). The importance of situation awareness was initially understood neither by the industry nor by the scientific community. The topic has started gaining the interest of several researchers from different scientific fields since late eighties of the last century. The scope of the application of this terminology is wide open including safety-critical sectors such the aviation (air traffic control) and the nuclear industry (the first to tackle this point) together in the following a variety of other sectors such as the civil protection (first responders), the medical sector and eventually reaching the process and sport ones as extensively discussed in the literature (Endsley and Robertson, 2000). In the process industry, the last two decades have been marked by a significant increase of automation, advanced control, on-line optimization, and supply chain tools and technologies that have significantly increased the complexity and sensitivity of the role of the operator(s) and team(s) (Salmon *et al.*, 2009). The interaction of the operator with complex computer interfaces calls for more efficient SA (Endsley and Garland, 2001). The industrial operator of the process industry is no longer simply a well-trained worker with limited knowledge of his/her prescribed field of work. Conversely, the role of operator is more demanding and important than ever before (Skjerve, 2004). Specifically, an industrial operator before the automation era used to be active physically by operating the process manually. In the past, the control loops were locally distributed in the field or concentrated in local control-rooms. Consequently, fewer trips to the field were sufficient to gather process information and to make process adjustments. Conversely, the operator of modern industrial plants faces different challenges due to the involved complexity. Hence, this not only increases the chances of possible errors but also results in a set of factors, which may be

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potentially the reason of an accident caused by human errors. According to Endsley (1995), 88% of the accidents in aviation are due to some human errors. The complexity involved in aviation resembles the one originated by the complex dynamics of industrial plants, such as:

1. The flexibility required to the field operator to handle various and overlapping sensitive jobs;
2. Real-time data, process parameters, alarms and parameters to be handled and evaluated simultaneously;
3. The coordination among field operator(s) and control-room operator(s);
4. The importance of decisions and actions taken by the operator(s) that may either lead to severe process malfunctions (and even accidents) or may assure the smooth operation of the plant.

Various literature studies were conducted on industrial accidents (Khan, 1999) and the incorrect manipulation of process units by the operators(s) was found to be the main source (Coleman, 1994). An industrial accident can result in the disruption of workflow, equipment damage, operator injury, and even death. Moreover, an industrial accident may even produce severe consequences on the environment and on the population surrounding the plant. Finally, an accident usually stops the operations with loss in the production and major consequences on the economic balance of the company due to penalties, refunds for damage, court and attorney expenses. Aim of this manuscript is to depict the different facets of SA and Team SA (TSA), highlight the differences in the role of operators and the respective factors which can influence their SA, categorize TSA and to illustrate the SA as function of career track.

2. Role of Operator and Situation Awareness

One of the main tasks of an industrial worker is to ensure smooth operation of the process within the constraints set by safety and operating requirements. For the accomplishment of this goal, the operator has to regularly update himself about both process and environmental changes and developments. Being aware of one situation is the simplest meaning to refer to the so-called Situation Awareness. However, a definition of SA, which can be accepted universally, is yet to emerge in the scientific community. The widely accepted three-level model of SA, proposed by Endsley (1995), is considered as one of the best elucidations in describing SA. Such a model can be summarized as follows:

Level 1 - Perception. The perception of the condition, attributes, and dynamics of relevant elements in the environment.
Level 2 - Comprehension. The understanding of the situation based on an amalgamation of elements of Level 1 to form the whole picture of the environment.
Level 3 - Projection. The projection of the near-future of the elements in the environment.

Endsley's model shows that the lack of developing and maintaining awareness may lead to serious problems. For instance, a brief loss of SA by a combat pilot, arising from the failure to detect or perceive changes in the position of a hostile aircraft, might allow the hostile artificing into a superior tactical position. The failure to perceive the change might lead to an incorrect understanding of the situation and hence to a wrong prediction of where the hostile aircraft would be. This results in poor decisions such as placing one's own aircraft at an unfavorable position. On similar lines the SA for CROP and FOP, as proposed by authors, is represented in Figure 1 and 2 respectively.

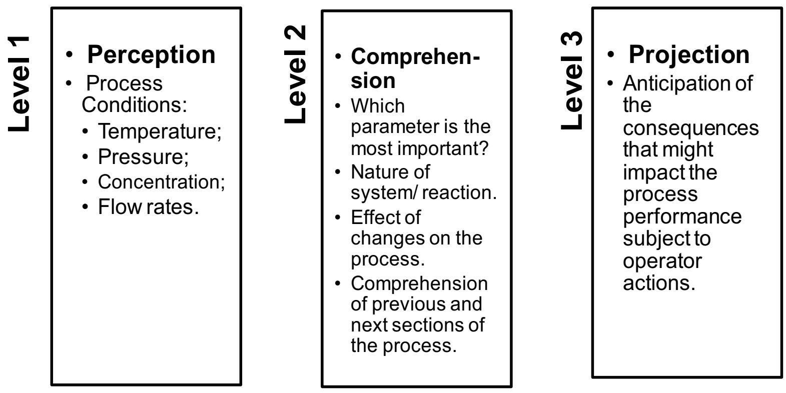

Figure 1 – Three-level model for Control-room operator.

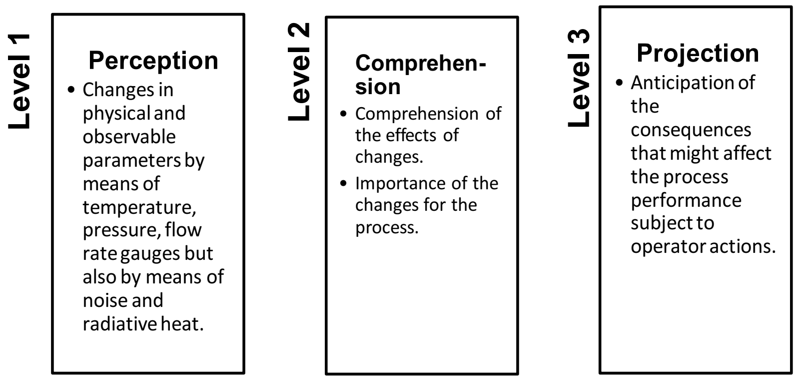

Figure 2 – Three-level model for Field operator.

3. Factors affecting Situation Awareness of industrial operators

A FOP daily faces different challenges with respect to those faced by a CROP, therefore, there exist differences in the factors that can influence the SA of both of them. Table 1 covers the factors and parameters that can affect the SA of FOP and CROP.
It is worth observing that there are several factors influencing the SA of both kinds of operator. In some cases, the factors are very subjective and depend on the location of the operator. For example, process features and plant layout are responsible for the complexity of the whole picture and therefore play a major role in the response from the operator. This factor is quite important for the CROP and applies to the complex synoptic panels of the DCS with ever changing parameters. At the same time, a rather different effect can be observed for the FOP that has to physically know and understand the plant layout, the equipment names as well as the interconnections, functions, roles, process schemes, ways of interacting with valves and switches, and finally the correct sequence and timing to perform specific in-the-field operations. This factor, *i.e.* the nature of the process, has different levels of influence on the SA of either FOPs or CROPs.

Table 1 – Factors affecting the SA of FOPs and CROPs

Factors affecting SA of FOPs	Factors affecting SA of CROPs
• Training • Experience • Time Pressure/Work Load • Motivation • Stress level • Time of shift • Panic • Work fatigue • Abnormal Situation • Thermal Radiation • Coordination with co-workers • Confidence in co-workers • Dependence on others • Influence of other operators • Weather conditions • Visibility • Complexity of process • Equipment sounds and process noise • Process plant typology • Location/site of the plant	• Training • Experience • Motivation • Stress level • Deadlines/workload • Abnormal Situation • Nature of Data • Data consistency • Flow of Information • Coordination with co-workers • Coordination with co-workers • Confidence in co-workers • Dependence on others • Influence of other operators • Software Knowledge • Complexity of process • Process plant typology

Similarly, both site and weather conditions are more important for FOPs than CROPs. Visibility and weather conditions such as temperature, humidity, rain, snow, sun, wind, and fog can negatively affect the SA of FOPs. In addition, thermal radiation from either hot units or accident pool/jet fires plays a role only on the SA of FOPs. Nonetheless, the SA of both kinds of operators is influenced by their experience, training, level of understanding, emotional stability, age, mental toughness, stress level, work fatigue, time of the shift (morning, afternoon or night), motivation for work, influence of other operators, and confidence in team members.

4. Team SA in the Process Industry

In the process industry, a range of tasks require a collaborating collection of operators, which can be referred to as a team. According to Brannick and Prince (1997), there is a clear difference between group and team; where the rational is the presence of shared goal in a team, which a group does not possess. The knowledge possessed by teams has been referred to as shared knowledge, shared mental models, and shared cognition (Cooke et al., 2000). The accomplishment of a task by a team requires a shared knowledge, collective dynamic understanding, and shared mental modeling (Orasanu, 1990;). The task may also be so large and complex that the workload must be shared (i.e. a main task is split into some sub-tasks) among individual team members. In case of complex industrial processes, teams of operators are needed to complete some procedures (mainly start-ups and shutdowns) because a single operator or even a couple of operators, i.e., a FOP and a CROP, cannot handle all the required tasks because it is either physically impossible (e.g., more than one button to press simultaneously) or a sufficient level of safety and efficiency is to be guaranteed. Moreover, it is rather common that industrial plants, especially refineries, are spread over areas of few square kilometers. In these circumstances, mastering Team Situation Awareness (TSA) is mandatory.

The importance of SA among operators of the same team (*i.e.* intra-TSA) becomes even more significant during malfunctions and abnormal situations, where the decisions have to be taken quickly in order to avoid an accident. A good individual SA does not guarantee a good TSA. Poor TSA can result in bad coordination among operators, which eventually can lead to an accident, and where the decisions may be completely non-standard, and therefore unexpected and unforecasted, due to the specific evolution of the process and the sequence of events.

TSA in the process industry can be divided with respect to the job location and duties of the operator. A possible categorization is shown in Figure 3. Since the SA of FOPs is completely different from that of CROPs, it follows that the mutual mental mapping of the situation between them is more crucial.

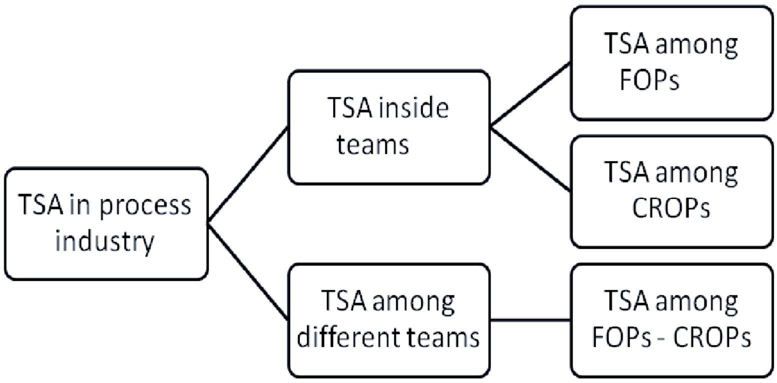

Figure 3 – Categorization of TSA according to operator tasks

5. SA and Career Track of Operators

As mentioned earlier, there is an explicit difference between the circumstances that FOPs and CROPs may be faced with. Let us assume that two process industries, respectively A and B, are of similar nature. Conversely, the career track of an operator in company A is different from the career track in company B. As shown in Figures 4 and 5, the operator of company A has experience in both field and control-room profiles since, periodically, s/he switches between field and control-room tasks. On the contrary, the operator working in company B is only skilled either in field or in control-room duties. As SA is directly influenced by the understanding and anticipation of surrounding events, therefore according to Figures 4 and 5, after $N_1+N_2+N_3+N_4$ years of working experience the situation awareness of operator at company A should be better than that of operator at company B on account of a better understanding of the multifaceted aspects of the process/plant, conjugated to both field and control-room issues and dynamics. The advantages that may be attained by the operator of company A over operator of company B are:

- Clearer anticipation or projection of the consequences of the actions made;
- Deeper understanding of process dynamics and phenomenology;
- Quicker assessment of abnormal situations;
- Higher certainty of his/her decisions made during an abnormal event;
- Higher effectiveness in communicating and understanding messages from control-room to field and vice-versa;
- Better interpretation and comprehension of diagnosis and trends that appear on the digital screens of Distributed Control Systems (DCS).

6. Conclusions

The significance and need for application of SA beyond aviation, military and nuclear industry has been discussed in this work. The paper showed that the conscious realization of SA and TSA can result in continuous production of the industrial process and also in reduction in abnormal situations which can lead to an accident. Development of sophisticated methods for evaluation of SA of operators and its improvement, practical significance, cognitive and bioengineered approaches, can be anticipated as future work in the field of industrial safety.

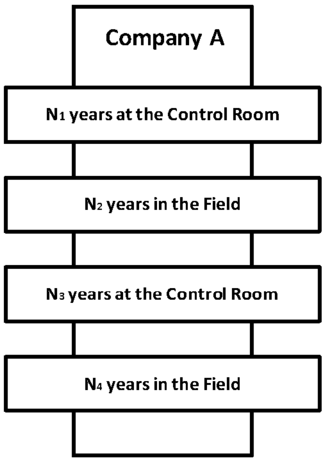

Figure 4 – Career track of operators in Company A.

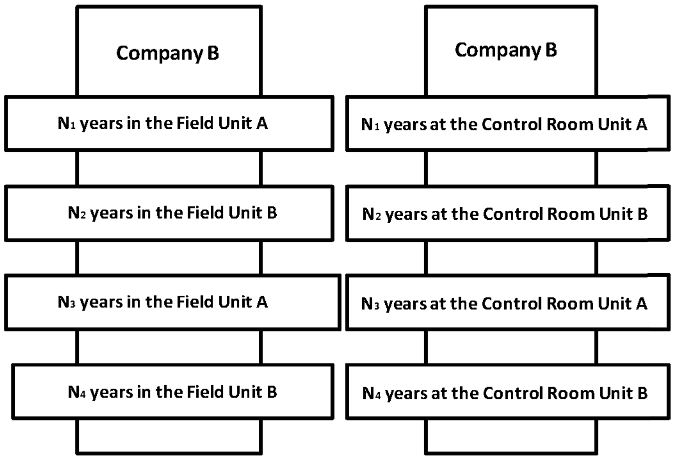

Figure 5 – Career track of operators in Company B.

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