Human Factors, Situation Awareness:

Joint-Cognitive System in Road Safety

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It has been made clear that machines and human-engineered systems have brought significant changes to our work and the underlying systems in the human workforce. Sheridan (2016) even stated that computers and machine systems are capable of reaching beyond human abilities and comprehension. Not only do these engineered systems relieve the humans, they are capable of replacing them completely. However, the same machines and systems humans rely so heavily on often are the culprit of many physical and financial destructions, and casualties. Therefore, many human-centered approaches in designing automation and safety controls have been adapted to resolve some of the problems faced during this time of machine ‘over-reliance’ (Nastaran, 2016). This ‘Human Factors’ is an approach engineers and psychologists use to set the focus of the design on human operators rather than the machine itself. Furthermore, as long as the human operator can develop and maintain Situation Awareness, the ultimate decision in every operation will be made by a human operator.

CLEM7 Bridge and Traffic Control in Brisbane, Queensland Australia provides a great usage of Human Factors and Situation Awareness in maintaining road safety. They separate the tasks of automations and operators to utilize the benefits of Human Factors and the operator’s Situation Awareness. It also highlights the adaption of a ‘joint-cognitive system’, a phenomenon that promotes humans and machines working together in order to compensate for the lack of multi-tasking abilities of humans (Hollnagel, 2006).

Human factors, the focus on human interaction on automations, with proper training in order to develop Situation Awareness, can create a system in which humans and automations collaborate together to provide Road Safety. Using CLEM7 Control Room as an example, this paper discusses the benefits of Human Factors, Situation Awareness, and discarding unreliable automated systems to create a Joint-Cognitive System in Road Safety.

What is Human Factors in Road Safety?

Human Factors is a term engineers, psychologists, and designers often use to label the interaction between human operators and systems. From designing process to the production, all possible human errors, interactions, and possible outcomes are tested for maximum efficiency and safety (NRC, 2011). It is essentially the human perspective in designing or creating a system. The system, in the context of Road Safety (RS) could range from automated alarms to security cameras that detect traffic movement and potential road-related incidents. It is the key to building the most sound environment that prevents accidents, casualties, and destruction of properties on and off the road. It is also important to note that strong emphasis on Human Factors (when designing RS controls and mechanisms) has proven to yield better results in dealing with RS and accident prevention (Inagaki, 1993).

By developing a human-oriented or a human-centered system of automations, CLEM7 Tunnel and road safety operators have proven accidents that occur in such active environments can be safely prevented given the authority and the control of properly-trained human operators. For example, all automated cameras, alarms, and other road safety assistants in the CLEM7 control room are under the command of a human operator. Without the final decision of a well-trained human operator, no automated processes such as sprinklers or emergency evacuations can be executed during the ‘accident-prevention protocol’, which is used to describe the grace period between the start of a potential incident and emergency protocol (Simpson, 2017). All automated systems are also designed in a way to satisfy human needs that maximize human information intake rather than machine workload. With this method, CLEM7 is able to emphasize human-machine interaction rather than workload, as it is critical to deter from overreliance on automated machineries (Parasuraman et al., 1997).

Situation Awareness and Road Safety

Situation Awareness (SA) of operators in control rooms is another key factor in creating Road Safety. Endlsey (2000) defined SA to be the *perception* of the environment, *comprehension* of its meaning, and the *projection* in the future in a three-stage construct. In the context of Road Safety, a human operator with good SA will be able to comprehend the details of a traffic event and perform the most optimal and efficient safety procedure to contain and/or prevent an incident.

Topics such as Road Safety often necessitate SA as road safety operators are required to be aware of what is happening in the rods around people, animal, and expensive property (Willems, 2002). Given the information fed by the automated systems, they make an informed decision to allow safe passage through tunnels and roads. For example, if an unidentified vehicle breaks down in the middle of a tunnel before the expected daily traffic congestion, the operator needs to be able to utilize the three-stage construct of SA to provide the safest traffic procedure in a limited amount of time. The operator must first perceive the environment for details such as the size of the car, the driver, its location, the time of the day to then comprehend what possible dangers the vehicle can potentially withhold. Lastly, with perception and comprehension, the operator makes a projection and carries out with the protocol.

Given the importance of SA, director and manager Brett Simpson (2017) of CLEM7 control room has noted that two operators, at all times, must be placed under specific conditions in order to maintain their steady level SA. For example, the layouts of cameras, screens, and other information feedback monitors must be placed in a specific area or in specific settings in order to minimize the number of extraneous stimuli that can potentially be distracting to the operators. Specific alarm tones, camera placements, and monitor placements are utilized so that when operators are to execute a specific protocol, they will be able to maximize the ‘usage’ of their Situation Awareness. As Per Tretmans and Pierre (2012), more appropriate actions are derived from sound SA.

Automated Systems, Alarms, etc. How Reliable are they?

There have been countless debates regarding the topic of automated systems and their reliability (Inagaki, 2000). Alarms, while their initial design is to alert the users of a potential or ongoing malfunction, can often throw users into a deeper hole of problems. In an experiment conducted by Nastaran et al. (2016), scientists analyzed the effectiveness of alarms and alarm handling activities through contextual observation. The experiment found that in many cases of alarms, operators dealing with the alarm feedback took twice as long to digest the information while handling high volume alarms (or high number of information per alarm) compared to low volume alarms. While obvious that humans do take longer to digest more information, it is important to understand most human operators spent less time reading high volume alert information than for the low volume. In other words, many modern-day alarm systems are built to take longer to categorize information in order to simplify the information for the operators, rendering it useless for operators who need to make quick decisions.

A lab experiment conducted by Inagaki and Furukawa (2004) has also proved machine unreliability in a collision avoidance simulation. In instances of dangers, a situation when humans were fed minimal information yielded better results in avoiding. Collision avoidance rate was at its highest when their Advanced Driver Assistance Systems (ADAS) ‘assisted’ the driver rather than ‘take’ over some functions. They also stated that humans and machines dynamically trading authority and information proved to be the safest method of collision avoidance. Furthermore, another relatable study was conducted by Dadashi et al. (2012) to find the most optimal usage of automation in railway systems. The study allowed experts to observe railway conductors to ‘respond accordingly’ to different types of alarms. The ultimate goal was to test if a number of different alarms indicating different problems would be more efficient in problem solving than the operators themselves. The researchers in this particular experiment found that extensive training for staff members and conductors proved to be more effective than proposing more alarms.

Overreliance on these unreliable alarms and automations is often the cause of many catastrophic disasters (Woods, 1989) and therefore more emphasis should be put on operators. An example of overreliance that caused catastrophic disasters is the BP Oil refinery incident in 1987. Health and Safety Executive report stated the catastrophic failure was due to malfunctioning sensors and faulty alarm systems that provided irrelevant information to the operators. Again, to resolve the issue, proper staff training and more reliance on Human Factors when dealing with automations have been proposed by many scientists (Dadashi 2012).

These cases of such overreliance only accelerate the need for a better system in handling emergencies and accident prevention protocols. Perhaps it is critical that Human Factors and Situation Awareness development processes should be the main highlight in creating an effective control room environment, especially in Road Safety.

The Most Effective System: Joint-Cognitive System

The product of combining Situation Awareness and Human Factors is ultimately the Joint-Cognitive System (JCS). JCS is defined as an ensemble of cognitive system and an artifact (Hollnagel, 2006). In other words, it is a system that can alter its behavior and decisions after a thorough analysis of its experience. In the context of RS, it is an automation (typically alarms and safety assistants as mentioned before) and human operator inside a control room modifying their behavior on the basis of what is happening on the roads. Since humans are not capable of multi-tasking at a maximum efficiency (Sanbonmatsu et al., 2013), it is difficult for a single operator to manage an entire RS control room alone. When the speed and multi-tasking abilities of automations serve to aid humans, the operators could heavily focus on making the correct decision rather than processing a mix of useless and critical information. In addition to proposal, an experiment conducted by Xu et al. (2013) in the Research of Highway Traffic Accident Management in China, researchers noted that current technology is not yet advance enough to duplicate the cognitive functionalities of a human operator. The most ‘perfect’ system of road safety management required functionalities only reachable with operators on duty. Given the current technology, JCS proves to be one of the best systems to adapt to provide effective and reliable road safety.

It was clearly visible that CLEM7 operators and managers adapted the JCS by allowing automations to handle information gathering while the operators made the final judgments. For example, high-tech cameras capable of capturing moving stimuli and detect the differences between human/animals and vehicles are set all over CLEM7 (including parts of Brisbane). Sounds and alarms are set up to only notify the operators if a vehicle has stopped or a threat to safe traffic has appeared. With the given the alarms and information, human operators can then make the correct protocol and execute the appropriate commands in order to prevent an accident from occurring.

DISCUSSION

The formula to creating an effective Road Safety control room environment is to combine Human Factors and SA into an effective JCS. CLEM7 is a great example of a well-managed environment that utilizes and considers these important factors when providing traffic safety in Brisbane. Control room manager Brett Simpson (2017) noted only one or two incidents go by unchecked or occur every year under his management. Based on Brisbane’s population and traffic, it is an incredible level of accident prevention that has been carried out by the team at CLEM7. It is arguable that the JCS they have adapted in their control room setting played a pivotal role in maintaining safety in CLEM7 tunnels/roads.

Security cameras, alarms, automated fire extinguishers, Warden Intercom Points (WIP), and other automated systems act only as assistants that follow the direct protocols made by human operators in CLEM7. Since tasks such as detecting a stopped vehicle, tracking pedestrians, and spotting wild animals are tedious and often impossible for an operator to observe, the control room utilizes automation to gather information. The operator then uses SA in order to assess the scenario and ultimately make the final decision whether to perform an evacuation protocol, or just simply leave the situation to be. By ‘working together’ with machinery, they displayed a joint-cognitive system, an effective system to carry out road safety.

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