Abstract

This thesis explores the shortcomings in evaluating human-in-the-loop (HiTL) performance and providing adequate situational awareness and decision support within process control room HiTL settings. It examines how decision support tools, specifically, alarm response procedures, can influence operators' cognition, behaviour, performance and consequently, safety, during human-system interactions. Secondly, it explores how operators can be supported in real-time with an understanding of their potential performance and risks. Therefore, two research phases and objectives are defined for this thesis. The first phase, which focusses on situational awareness and decision support through alarm response procedures, explores the benefits of transitioning to digital procedure options, specifically electronic procedures (EP), from current paper-based procedures (PBP). The key problem explored is how a setup with these two different procedural formats influence operators with implications for process safety in the process industry. The second phase explores a framework with a set of methods to predict human performance in real-time, understand and guide operators' behaviour based on risk-informed decisions.

The main research objectives include: (1) analysing the impact of transitioning from paper-based and digital procedure options on operator performance, behaviour, and cognition. This will involve identifying factors that affect human performance in current and near-future human-in-the-loop configurations and factors that can be used to describe the impact of alarm response procedures on operators. (2) developing a real-time, risk-based framework (R^2HiTL) to predict operators' performance and make risk-informed decisions to guide operator behaviour.

The methodology was split into two phases, one focused on the experimental performance analysis to address objective one and the other on the development of a novel framework. For the first phase, the outcomes from both PBP and EP experimental study groups were compared using workload, situational awareness, behavioural, and performance metrics. Furthermore, a hybrid method was developed for the second phase that integrates logistic regression and Bayesian Network standardised plant analysis risk-human reliability for real-time prediction of operator failure probabilities, allowing adaptive decision support tailored to individual needs.

Key findings reveal that while paper-based procedures were associated with a higher perceived workload, they lead to better situational awareness and performance in the most complex scenario. In contrast, electronic procedures, though reducing perceived workload, resulted in lower situational awareness and more errors in high-stress situations. However, the electronic procedure from further analysis with the eye tracking provided some cognitive and behaviour benefits compared to PBP's. The research also demonstrates that the real-time, risk-based decision support framework can be applied for operator performance predictions by integrating expert knowledge with live performance data, enhancing decisions on how to guide operators' behaviour and provide recommendations.

This work contributes to the field of alarm handling and process control for process safety, decision making, human centred design, human performance and interaction modelling. Potential applications include improving alarm management systems, improving operator training programmes, and designing adaptive support tools for high-risk industries such as process, manufacturing, energy, and healthcare. The research offers valuable implications for improving safety, reducing operational risks, and optimising human-machine interactions in critical environments.