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Opinion

Complex problem solving research and its contribution to improving work in High Reliabilty Organisations

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Research on complex problem solving (CPS) has reached a stage where certain standards have been achieved, whereas the future development is quite ambiguous. In this situation, the editors of the Journal of Dynamic Decision Making asked a number of representative authors to share their point of view with respect to seven questions about the relevance of (complex) problem solving as a research area, about the contribution of laboratory-based CPS research to solving real life problems, about the roles of knowledge, strategies, and intuition in CPS, and about the existence of expertise in CPS.

Why should there continue to be problem solving research (in addition to research on memory, decision-making, motivation etc.)?

CPS research is a very relevant bridge between basic research and applied research, for example in highly complex working contexts, so called High Reliability Organizations (HROs). HROs include organizations such as nuclear power plants, petro-chemical and pharmaceutical plants, hospitals, air traffic management, airline operation, disaster and crisis management by first responders, etc. In HROs, all single CPS research aspects such as memory, decision making, building mental models, etc. need to be conjointly applied in and transferred to acute problems in situ, for example, incidents and developing accidents, to mitigate risks and hazards for people and the environments. And each HRO is a unique field for CPS research. Central aspects such as non-transparency, dynamics, interconnectivity need to be analyzed related to a specific work context, e.g. operations in Air Traffic Management differ a lot from operations in a chemical plant. In that respect cognitive task analysis methods can be applied to elaborate on the particular quality of dynamics, non-transparency, interconnectivity, etc. for each operator.

What are the connections between current CPS research practice and real problems? Where do you see potential for development towards stronger relations?

As introduced above, working and operating in HROs is the best example where CPS research demonstrates its direct impact on safety and the mitigation of hazards. Safety Culture Intervention, Safety Management Systems and Safety Training for employees, supervisors and the management are directly affected by CPS research and builds on the results of CPS research. Additionally, CPS research results are very helpful for personnel selection (e.g. which cognitive abilities are extremely important in that particular work context that cannot be trained?), and for training (e.g. which knowledge, skills and attitudes [KSAs] need to be trained?)

Given the artificiality of the laboratory situation, do participants really adopt the presented problems? What insights can be gained despite this artificiality and which cannot?

CP are not artificial – they are directly taken from real life affordances. In HROs such as airline management, chemical plant operations, nuclear facility management simulator training is essential. To give an example, look at the work of a control room operator (CROP) who is operating a chemical plant (see Kluge et al., 2014 and Kluge, 2014) and who is interacting with a field operator (FOP). The daily work scenarios are trained in high fidelity simulator exercises that are not artificial, because they mirror 1:1 the real situation (Kluge et al., 2009):

Couplings and interconnections require the operator to simultaneously process the interplay of cross-coupled variables in order to either assess a process state or predict the dynamic evolution of the plant.

Dynamic effects require the operator to mentally process and envisage the change rates of cross coupled variables and to develop sensitivity for the right timing of decisions in order to be successful.

Non-transparency requires the operator to work with more or less abstract visual cues that need to be composed into a mental representation and need to be compared with the operator's mental model.

Multiple or conflicting goals require the operators either to balance management intentions or to decide on priorities

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in case of goal conflicts in the decision making process (e.g. which course of action to take).

Comprehension of MPC (model predictive control) *and RTO* (Real time optimization) philosophies and making sure that CROPs understand the advanced control and optimization philosophies that are at the basis of MPC and RTO, since they have to validate the proposed results before accepting/rejecting their implementation in the on-line control strategy model predictive control (MPC)/ real-time optimization (RTO).

Crew coordination complexity incorporates small crews, for example, CROPs, FOPs and supervisors, who are responsible for overall system operations and calls for the operators to concurrently interact with team members in order to orchestrate individual actions into a coordinated flow of actions to either assess the situation or choose a course of action.

What evidence exists for the influence of other kinds of knowledge besides structural knowledge on the results of CPS? Which of these kinds of knowledge should be examined in future research?

In applied research in HROs, situational awareness is the key knowledge-related construct to focus on and should be under investigation. Think of an air traffic controller: Situation awareness includes

- the knowing and awareness of the elements involved in a particular working context (e.g. planes and their different types, flight plans, weather conditions, special dates; is a politician visiting Berlin and the air space is closed for other traffic at a certain time? Is the plane of the politician accompanied by military planes?),
- to anticipate and monitor the elements' temporal changes and developments over time (who is flying where in which speed, altitude; are there problems with planes that are low on fuel; are there emergency landings because of a sick passenger; are planes delayed because of bad weather, etc.),
- possible decision making processes that are necessary due to the temporal changes (how needs the air space to be "managed" today? Is there a thunderstorm approaching? Are there abnormal situations emerging?).

I propose that in HROs with regard to the dynamic effects of CP, knowledge about the temporal dynamics of the involved variables or elements (planes, pilots, passenger, weather, consequences of technical failure in a chemical plant) is essential. For example, in air traffic management, the air traffic controller needs to consider the speed of the planes and the direction they are heading to. But the speed of commercial airplanes for civil aviation is different from the speed of military aircrafts. As a military tactical controller, you need to be aware of the higher speed of the fighter jets and their objectives.

What evidence is available for the impact of strategies (except VOTAT) on the results of CPS? Which of these strategies should be examined more closely?

It is known, that stress and its physiological consequences on information processing is very significant. There are several training strategies to mitigate and counteract the impact of acute stress on situation awareness and decision making processes. Three trainings approaches seem promising:

Stress exposure training includes preparatory information about the impact of stress, training skills for maintaining attentional focus, practice of the acquired skills in a simulated stress environment (Cosenzo et al., 2007; Driskell & Johnston, 2006) in order to maintain control of the stress response that would otherwise affect the situation awareness.

Decision skill training by Pliske et al. (2001) addresses attentional control exercises to practice flexibility in scanning situations, for example, practice seeing and assessing cues and their associated patterns.

Mindfulness-training fosters a state of restful alertness to present-moment experience, stressful or not, in order to reduce stress reactivity and increase situational awareness (Meland et al., 2015a; Meland et al., 2015b).

Is there intuitive CPS?

I assume that persons who are acting in complex environments early in their life, who learn to fly a glider at the age of 16, who are apprentice in a chemical plant or alike, familiarize with the aspects of CP early. By directly experiencing dynamic effects, interconnectivity and non-transparency I assume that these persons become "intuitive" CP solvers in their particular domain. But at the same time this intuitive CPS expertise is limited to their clearly defined profession, and the transfer to other domains is limited.

What distinguishes experts in CPS from laypersons?

As I introduced above, expertise in CPS relates to the situation awareness, the processing of dynamic changes and the consequences for decision making. Experts in CPS are highly trained, and have experienced a lot of routine and non-routine/critical situations in order to enhance their situation awareness. Expertise in CPS requires a very long and extensive training period, in the simulator and in "real" under the supervision of an experienced person. This is the reason why it takes many years to become an airline captain ("Der lange Weg nach vorne links", Rödig, 2000). You would not like to fly with a layperson.

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