Eliciting Control Errors and Measuring Error Correlates

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Introducing the PATRIA2 Project

In professions such as the medical sector, as well as in power plants, chemical plants and in transportation, people are often busy with work that can be risky. In many cases the fate or well-being of individuals depends on the people who are responsible performing their tasks correctly. A safe performance is crucial, but the structured or even repetitive nature of many tasks can lead to a worker's loss of attention, stress or other mental states which negatively affect performance by increasing the likelihood of human error. Errors may arise from haste, carelessness, fatigue, or deviating from prescribed procedures, and they often lead to avoidable adverse events (AAE).

The occurrence of AAEs can be reduced by monitoring the actions of workers by automatic systems. This means detecting deviations in task performance by observing it with cameras, extracting performance parameters, comparing the parameters to normative models for the correct implementation of the task, and initiating a corrective action when deviations are detected, either correcting the deviation or alerting the worker. It also means predicting the risk that an error might happen by detecting internal states of the worker that are correlated with error-proneness.

The goal of PATRIA2 – the project this presentation serves to introduce – is an integrated hardware/software solution to automatically assess behaviour and actions of a single operator interacting with a computer while engaged in some routine activity. The solution derives a parameter indicating the likelihood of an erroneous action in a specific task related setting. To this end, the PATRIA2 tool that is currently being developed non-invasively records eye gaze, head direction, gestures, facial expression, and user-input (keystrokes and mouse clicks). It relates operator's actions as indicated by user input with other properties of the operator's behaviour. In this way, the tool serves to mitigate risks posed by sub-standard task performance and human error.

Not every kind of error and associated risk lends itself to technical mitigation though. PATRIA2 concentrates therefore on slips and lapses (errors of attention or memory) rather than on rule-based or knowledge-based mistakes (i.e. the execution of a wrong plan of action), which require re-training and other organizational solutions. Measuring such errors can be difficult, owing to the low probability of their occurrence. Finding a way of improving the assessment of errors has been a crucial part of the project.

Analysing Error Proneness through Differentiation of Error Components

In our experimental scenario, participants are required to operate a computer-simulated medical device, with different user interface versions, while simultaneously working on a secondary task that consumes attention and thus increases the likelihood of making errors. Each use error is subdivided into two components according to the subtasks of action: execution and evaluation. Execution errors and evaluation errors, as components of use errors, have a higher probability than the use error as a whole and are therefore easier to measure. Under normal circumstances, evaluation errors can only be discovered if an execution error was made beforehand. To detect evaluation errors independently of execution errors, we simulate execution errors (e.g., entering a wrong number) and analyse the user's reaction in order to detect if they are followed by an evaluation error (also called a control error: failing to check if the input was done correctly).

Our studies use two different user interface concepts of a syringe pump, the pump being simulated on a computer screen. Using a simulation makes experimental manipulation, as well as data collection, easier. During the experiment, each participant is required to programme the pump a certain number of times, to operate at various different flow rates, as if they would give different drugs to various patients. The task is complicated by a secondary task that puts a strain on working memory capacity, by time pressure and a turbulent environment – circumstances that often appear, in principle, in the real application of medical and other devices (albeit in a different form), thus simulating a key feature of the final use cases in a controlled environment. The simulator introduces faked execution errors by replacing the user's input with a different number on a selection of trials. Depending on experimental conditions, subjects fail to detect up to 30% of these faked execution errors (about 10% on average), thus committing a control error.

This scenario can easily be adapted to the investigation of a related error class, namely mode errors – doing something that would be correct if the device was actually in the mode one thinks it is in. In this case, one would use or simulate a device with two or more modes and covertly change the mode in the course of the experiment. The scenario is therefore suitable for at least two relevant error categories: failing to control one's own input or failing to control the system state before or while making an input. These kinds of errors are among those that could possibly be compensated for by an automated behaviour observation system.

Conclusion

A method has been developed for studying the occurrence of control errors following an action that could be compromised by an execution error. This method introduces faked execution errors to enhance the likelihood that control errors can be detected. All keystrokes and mouse clicks are recorded together with the test participants' eye-tracking data, head movements, facial expressions and gestures. Data from these different sources can then be used to develop or test hypotheses about indicators of risks and critical situations. Applying such knowledge is a crucial part of the PATRIA2 project that aims at developing an automatic monitoring system to reduce human-error induced risks in critical, high responsibility tasks, either through training or real-time warnings.