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One approach to limiting the consequences of error-prone human performance is to automate as much as possible in a system. However, accidents and near-misses have occurred when automation fails to perform as desired, and the people "supervising" the automation have trouble determining the state of the automation, the state of the underlying process being controlled, or the implications of how changes to the state or to the automation parameters will affect overall performance. Other classic problems with automation include loss of human skill as tasks become automated and brittleness (the automation works well for the situations for which it is designed but can otherwise give up control or attempt a solution that is completely inappropriate).

Often, much effort goes into the design of computerized algorithms, but relatively little effort is put into the user interface. To design explicitly for *mixed-initiative interaction,* one needs to design a system where both the automation and the human operator have the capability to guide or perhaps even take over control of the system being controlled and that both the human and the automation each has the information and communication means necessary to make his/her, or its own "judgments" about the situation and to guide and perhaps critique the other's behavior. Clearly, due to the well-known differences between information systems' and humans' strengths, weaknesses, and means to: 1) sense information, 2) make judgments, and 3) execute actions, both the types of information required and the means for gathering and communicating that information will necessarily be different for each type of agent. Recent research has suggested certain strategies for safer automation design (assuming humans must monitor or guide the automation's behavior). These are:

1. <u>Interactivity</u> (allow humans to generate alternative automated *and* manual solutions, with the automation providing a comparison across all these solutions) (Guerlain, 2000).
2. <u>Include user-initiated notification and critiquing</u>. User-initiated notification (Guerlain & Bullemer, 1996) allows the human operator to set up temporary, context-sensitive "monitors" and to define who to be notified (person or system) and what to do when such conditions are met. These alerts can be process-specific, temporal, or a combination of the two. User-initiated notification can be turned into a critiquing strategy (Fischer, Lemke, Mastaglio, & Morch, 1990; Guerlain et al., 1999; Silverman, 1992) when these types of context-sensitive alerts are programmed in at design time (e.g., not by the operator, but by the engineer or knowledge expert), and are designed to be more generic and continuous monitors for faulty or important conditions that are in general rare, but would require operator or automation attention.
3. <u>Use appropriate representation aiding and workspace navigation techniques, to minimize errors and difficulties associated with excessive cognitive integration and to maximize effective decision making</u>. The goal of representation aiding is to represent relevant domain, task, and system constraints through visual properties of the display, and thus encourage people to perceive these relationships with little cognitive effort. Workspace management refers to the window manipulation, command input, and navigation activities required when working with computer-based systems(Guerlain, Jamieson, Bullemer, & Blair, 2002).

These techniques have been successfully applied across diverse domains, such as petrochemical, medical, and military. These solution strategies are by no means foolproof, but they are as generic as the problem of how to design for safety when humans and automated agents are involved.

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