Overview:

This effort involves the use of goal-directed task analysis (GDTA) in combination with abstraction hierarchy (AH) modeling to describe the knowledge structure of biopharmacologists in planning, executing and analyzing the results of high-throughput screening (HTS) operations, as well as the lab automation and equipment that is used to facilitate these operations. GDTA has been used in many prior cognitive task analyses (CTAs) (e.g., Endsley, 1993; Endsley & Rodgers, 1994; Usher & Kaber, 2000; Bolstad, Riley, Jones & Endsley, 2002) and focuses on identifying operator situation awareness requirements in performing complex systems control. AH modeling has historically been used in complex work domain analyses (e.g., Rasmussen, 1985; Rasmussen et al., 1994) and has been found to be an effective tool for revealing how automated system processes and functions are facilitated through specific components and to provide explanations of why certain components are needed to achieve system purposes. The results of a GDTA include lists of critical operator decisions and information requirements that can be used as a basis for defining appropriate content of complex system information displays. The results of AH modeling can serve as a basis for developing system user manuals and training programs to educate operators on connections between automated control functions and software system functions as well as interface features and options. This approach to training can promote operator ability to potentially recover the system from error conditions.

The combination of the AH models with the results of the GDTA on biopharmacologist performance of HTS operations can provide a meta-method for understanding of how HTS operator needs are currently addressed (or not) by existing automation and information display technologies. This approach is speculated to be superior to using GDTA alone for cognitive work analysis (CWA) and identification of existing system shortcomings and future design needs. Specifically, the integration of the results of the AH and GDTA methods will allow for relation of a biopharmacologists’ goal structure and critical decisions (as part of testing processes) to the purpose of automated systems on an HTS line and functions and components. The approach is expected to identify which components of existing systems may be unnecessary or inadequate for operator system state/situation awareness and decision making processes. The results of the combined analyses may also serve as bases for formulating future automation design guidelines.

Approach to Applying CWA Methods:

The approach to the GDTA as part of this project involves a single analyst interviewing an expert biopharmacologist to describe knowledge structures relevant to the use of a highly automated, HTS line at the new Center for Life Sciences Automation (CELISCA) of the University of Rostock in order to test organic compounds that may have the potential to serve as bases for
drugs used in cancer treatment, virus treatment, etc. Initially, procedural task analyses were performed on biopharmacologist development of a basic HTS methods using existing commercial-off-the-shelf software and to identify the general steps as part of an automated enzyme-based assay of compounds for the potential to affect human cellular functions. Beyond this, the expert provided background information on the basics of enzyme reactions and the use of microplates for conducting life sciences experiments. (These analyses were presented in separate documents.) The analyses were used as stepping-off points for the GDTA, which focuses on biopharmacologist adaptation of a “bench-top” version of a screening assay to the HTS line in the CELISCA laboratory. The GDTA: (1) identifies the major goal of the biopharmacologist in the planning, execution and analysis of results of the enzyme-based screening process (i.e., to discover marine compounds leading to drugs); (2) identifies sub-goals that are supportive of this overall goal; (3) identifies the specific tasks to achieve the sub-goals; (4) creates critical questions aimed at addressing decision-making in the HTS operation; and (5) develops biopharmacologist situation awareness requirements to answer these questions.

The general approach taken to the AH modeling in the context of HTS operations includes developing models of both the physical devices as part of an HTS line and the software used to control the devices. In the current line setup at CELISCA, proprietary software developed by the manufacturers of each HTS device (e.g., barcode print and apply device, microplate incubator, optimized robot for biological sample analysis, automated pipetting (liquid transfer) device, and an automated plate reader) is used to program device methods. The devices on the line are integrated through a central process control system (SILAS) that includes a line “Method Editor”, which communicates with the user interface of the proprietary device software through an “Executive” software controller. The Executive also communicates via ActiveX with the device specific SILAS software modules. The Executive provides automated control of the entire HTS line. The SILAS Method Editor (SAMI) includes Action/Configuration dialogs for all devices on the HTS line. These dialogs are used during system programming to set device parameters, as part of a screening method, and to send data to device software modules via the Executive. Figure 1 presents a hierarchical diagram of the HTS equipment and forms of automation used to control it during test processes. The links in the diagram represent the relationships among the line components during runtime. (Different relationships may exist during test method creation.) Our AH modeling in this context targets multiple levels of this hierarchy, including the physical device, the device user interface (proprietary control software), and the SAMI.
In general, the SAMI modules are used to select and run HTS methods. The proprietary device software is used to edit methods for integration through the SAMI. It may also be used to handle certain types of errors during execution of an HTS method (see below). It is important to note that for some devices on the HTS line, no proprietary control software is provided by the manufacturer and only the SAMI is used to specify device settings through the Action/Configuration dialog for the device. At present, proprietary methods software is used with a Biomek2000 automated pipetting robot, a Fluostar automated plate reader, and an ORCA (Optimized Robot for Chemical Analysis), including “Bioworks”, “Fluostar” and “ORCA NT”, respectively. Currently, there are only Action/Configuration dialogs, as part of the SAMI, and SILAS modules available for control of the HTS bar coding device and incubator.

The type of error conditions that the proprietary (device) software may be used to handle includes the Biomek2000 failing to detect the presence of labware, such as microplates, pipette tip boxes, and reservoirs, on the “workbench” of the robot. In this event, the robotic system is programmed to halt and alert the HTS operator to the error condition (usually through a simple Windows application error message presented by the SAMI). Subsequently, the operator can access and use the proprietary software (Bioworks) to correct the error by informing the system through software dialogs of the location of labware on the Biomek2000 workbench. That is, an error recovery dialog exists and the operator can perform error correction steps.

**Current Results of CWA on HTS Operations:**

Our application of GDTA and AH modeling to HTS operations at CELISCA for testing of biological compounds, as part of new drug discovery, has lead to:
(1) a draft goal structure for biopharmacologists, along with lists of critical HTS decisions and SA requirements; and
(2) AH models of all devices on the existing HTS line (the bar coder, incubator, ORCA, Biomek2000, and Fluostar plate reader) for an enzyme-based assay of marine organism compounds.

The equipment models have been presented in a separate document, as will the GDTA and AH models of automation. We are currently in the process of creating AH models of the automation used to control the devices and expanding our initial pass at the GDTA with the expert biopharmacologist.

Once the AH models and GDTA are finalized, the results will be integrated in the manner describe above and used to begin development of a computational cognitive model of biopharmacologist behavior in planning, executing and analyzing the results of HTS operations. The CWA results will also be used as a basis for initial design and prototyping of futuristic supervisory control interfaces that might be used by HTS operators for programming, monitoring, controlling, and analyzing multiple screening lines performing simultaneous assays, all varying in terms of the enzymes being used and the compounds being tested.
References:


