

# TAPRAV: A Tool for Exploring Physiological Data Aligned to Task Models

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## ABSTRACT

The use of continuous, physiological measures such as pupil size is becoming increasingly important in user interface design, attention management, and affective computing. While this data is best explored in context of ongoing task execution, existing information visualizations do not support such exploration. In this design study, we present an interactive tool called TAPRAV, which provides an interactive focus+context visualization of physiological data aligned to a hierarchical model of task execution. This visualization, along with built-in data analysis tools, allows users to rapidly explore relationships among the data that would otherwise be extremely difficult to recognize. We present lessons from the iterative design process that led to our particular implementation and show how features of our tool help bridge rationale and worldview gaps. Our work contributes a tool that can be used to aid ongoing efforts in specific research areas and lessons learned from following an iterative design process can inform the development of similar tools.

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**Keywords:** workload, focus + context, pupil size, iterative design

## 1 INTRODUCTION

To explore user interaction with complex systems, researchers have begun using streams of continuous data to study human task engagement or workload. Often the measure of task engagement is physiological like GSR [11], HRV [41], EEG [21], or pupillary response [18], and this data is used for attention management [18, 19], affective computing [32], and user interface design [14, 26]. For example, designers could align mental workload to a model of task execution and target areas of unacceptably high workload in the interface for re-design. Our work has used workload aligned to task models to identify opportune moments for interruption [19]. In these and many other cases, the physiological data is best understood in context of the ongoing task – as changes in the data are often tied directly to changes in the execution of the task.

Unfortunately, this area of research is hindered by the difficulty of examining this kind of data in context of models of task execution [18]. For example, analysis software that ships with commercial eye trackers does not typically provide an aligned view of pupil dilation, task models, and screen interaction videos.

This inhibits the researcher’s ability to explore workload in detail at specific points in the task. This is due not only to the lack of effective tools, but also to the lack of thorough evaluations of

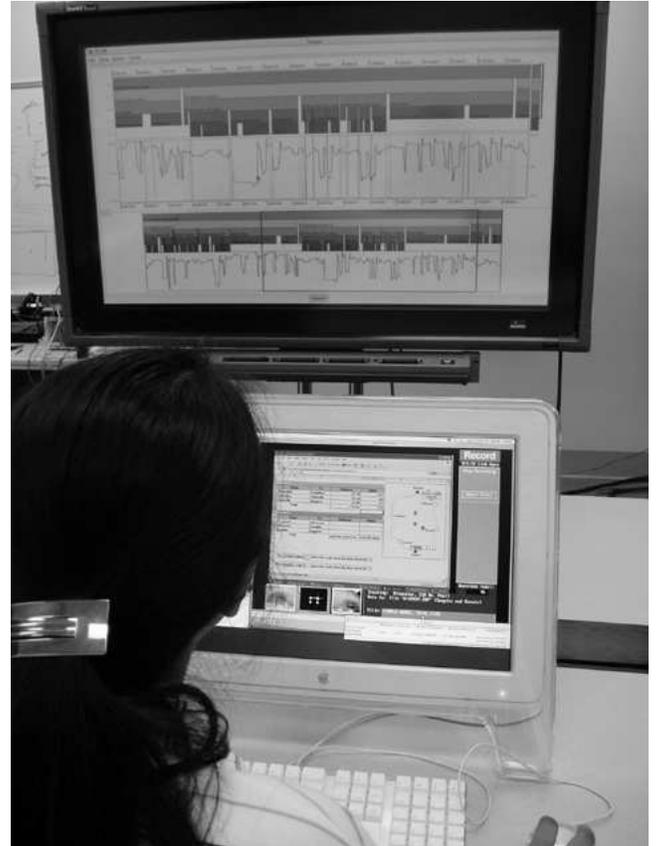


Figure 1 - TAPRAV running in a dual display environment. The large screen shows the task model and pupil response curve visualization. In the foreground, a researcher tries to make sense of a particular change in workload by examining the task model and viewing the integrated video of task execution.

the visualizations used in those tools. This can lead to rationale and worldview gaps, as described by Amar and Stasko [3].

In this design study, we present an interactive visualization tool called TAPRAV (Task Aligned Pupillary Response Analysis and Visualization). As shown in Figure 1, our tool provides a focus+context visualization of a continuous data stream aligned to a hierarchical model of task execution and video of on-screen interaction. This allows users to explore relationships that would otherwise be difficult to recognize. In addition to discussing our tool’s features, we discuss lessons from an iterative design process that led to our implementation, which helps bridge rationale and worldview gaps. Our work provides the following contributions:

- We provide a tool tailored to aid ongoing research in our target domain. For example, Iqbal et al.’s [18] analysis of pupillary response data consisted of tedious labor and complex macro writing. Through our discussions and subsequent evaluations with researchers in this domain, we have produced a tool that effectively meets those needs.

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- We show how a sequence of low investment evaluations can overcome gaps found in domain specific visualizations [3, 8]. By following an iterative design process, we learned design lessons that can be reused when building similar tools. This further supports the value of iterative design for developing information visualizations.
- We designed the architecture of our visualization to support analysis of any continuous data stream aligned to any hierarchical model. This allows our tool to be used by a broad range of target application domains.

## 2 RELATED WORK

We discuss our problem domain in some detail, visualizations that motivated the initial prototypes we considered, and our approach to the visualization of continuous data.

### 2.1 Use of Physiological Data

Physiological data can be used in many research areas such as interface design [14, 26], affective computing [32], and attention management [18, 19]. To illustrate our specific design problem, we discuss how a particular physiological measure of workload (pupillary response) was used for interruption management.

Research shows that pupil size is a reliable indicator of mental workload [5, 20]. Rapid advances in eye tracking hardware are now enabling a broader range of researchers to exploit the use of pupil size for interface design, interruption management, and other research. For example, researchers have proposed using mental workload (as measured by pupil size) as a new metric by which to evaluate complex interfaces [26, 27].

Also, researchers are using workload to identify moments in a task sequence that would be most opportune for interruption [15-17]. Researchers have postulated that opportune moments for interruption occur at periods of low mental workload [4, 9, 13], and that these moments occur at subtask boundaries in the task model [29]. It remains an open question as to which boundaries are most appropriate for interruption.

We investigated how a user's mental workload changes during execution of an interactive task [18], focusing on subtask boundaries. After developing a validated GOMS model for the task, and aligning it with the pupillary response data, analysis was attempted with software packages that shipped with two existing eye trackers. However, the software was not able to meet our needs and as a result, the analysis process required significant tedious labor and complex macro writing. For this design study, and guided by our experience with existing tools, we aim to provide an effective visualization that significantly reduces the complexity of similar data analysis processes.

### 2.2 Motivating Visualizations

For visualizations of datasets requiring large and complex layout space, an appropriate visualization metaphor aids in navigation. Spence and Apperley proposed a number of novel approaches for retrieving information in an office environment [37]. They addressed the problem of data context, specifically how a user could quickly become aware of the entire contents of an in-tray and rapidly examine any individual item in detail. They proposed a bifocal display partitioned into 3 separate viewports; focused central viewport with full detail, and two flanking, demagnified views of the entire contents of the in-tray. Users would select an item for interest and drag it to the central viewport for closer inspection, similar to a Fisheye Lens [12]. A fisheye lens is used to produce very wide-angle aspect ratios, making areas directly ahead appear in greater detail, while off-focus regions are

shown in progressively less detail. This makes it possible to maintain focus while being aware of surrounding context.

The Focus + Context paradigm has since been the basis for a variety of visualization techniques. In Document Lens [35], a 3D visualization for exploring multi-page documents, users grab a rectangular lens and move it to focus on an area of interest at a chosen magnification level. Sarkar et al. [36] proposed a rubber sheet metaphor for visualizing large and complex layouts within small display areas. The original layout is rendered on a rubber sheet that users hold and stretch with a set of tools called handles. This approach allows the user to hold multiple regions of interest and assures their content is rendered with uniform scaling.

Zoomable User Interfaces (ZUIs), and related drill-down techniques, are another method for visualizing complex or large data sets [6, 10, 31, 39, 40]. ZUIs display information on a high resolution virtual canvas, a portion of which is displayed through a virtual camera that pans and zooms over the canvas surface.

Both ZUIs and focus + context visualizations motivated our initial design. As we outline later, through our process of prototype evaluations, users gave invaluable feedback, narrowing the design space by pointing out overly complex or non-intuitive parts of the visualizations and interactions.

### 2.3 Continuous Data Visualization

Mackinlay et al. [25] address common issues involving visualization of time-varying data. These visualizations in particular often contain linear components that can result in 2D layouts with wide and inefficient aspect ratios. As a solution, they outline The Perspective Wall: a visualization metaphor for viewing linear information by smoothly integrating detailed and contextual views in a three-dimensional space. Navigation is accomplished by a panning motion across the wall.

The Hierarchical Video Magnifier [28] allows users to work with video content at varying levels of detail while keeping awareness of the timeline. The coarsest view is at the top of the hierarchy, and users decompose the timeline into children clips, drilling in and out to navigate the dataset. Other techniques have been used for additional facets of video content manipulation [1, 7]. Time-varying visualizations are also common in information technology [33] and various medical visualization needs [22].

Our own needs when dealing with continuous data were governed by the requirements of our users. Namely, our design required a distortion free representation that could easily show the relationship between time and moments in the task model. Though our visualization is not necessarily novel, our contribution is in composing a visualization from elements of related work, producing a tool that more directly addresses a real world need.

## 3 GOALS AND ITERATIVE DESIGN

In this section, we outline our design goals for developing an effective tool for analyzing pupil data aligned to task models. Then, we discuss the process through which an interface and visualization that meets these goals was developed; performing a user and task analysis followed by an iterative design process.

### 3.1 Design Goals

To identify goals for building an effective visualization tool, we worked with researchers familiar with pupillary response analysis, learned from the limitations of existing analysis software, and applied several proven information visualization techniques. This process resulted in several key design goals:

- *Provide a simple and intuitive visualization of pupillary response aligned with a task model and allow for direct*

*manipulation.* We wanted to provide researchers with an immediately usable and useful tool that would aid them in related research efforts.

- *Design interaction mechanisms that support a discovery driven analysis process.* This means providing functions that allow researchers to capture meaningful parts of the analysis for later review and collaboration.
- *Use a visual vocabulary and interface elements understood by researchers interested in pupillary response analysis.* An interface that better matches a user’s mental model of the problem domain would allow them to focus more on the analysis task and less on interacting with the visualization.
- *Support any continuous data aligned to any task model.* Our immediate interest is for pupillary response aligned with hierarchical task models, but the visualization should be flexible enough to support other data and task models.

Although our current implementation may not fully meet all of these design goals, we felt that it was important to define them up front to guide our design decisions throughout the process.

### 3.2 User and Task Analysis

As a first step in the design process, we performed a detailed analysis of the tool’s intended audience and their tasks. The audience for the tool was mainly computer scientists and psychologists working with physiological data and task models. This community is currently small, but growing, and our experience indicates that there is a large need for better tools.

We performed a task analysis to identify common and important tasks. These tasks included importing various data sets, clamping data sources to a common timeline, zooming in and out of the visualization, and retrieving statistical information for selected parts of the task. While not exhaustive, we felt that these tasks would most influence the early design of our tool. As such, these tasks were used to evaluate successive interface designs.

### 3.3 Low Fidelity Iterations

To develop an interactive visualization that met our design goals, we followed an iterative design process [34]. This involved building low fidelity paper prototypes, evaluating them with users, and using the lessons learned to refine the prototypes. Rather than having users interact with the low fidelity prototypes directly, we used video prototyping techniques to give users a more realistic simulation of the interaction. Following procedures in [24], we recorded numerous short video clips of task sequences that the prototype supported, asked users to view the clips, ask questions, and comment on the tool’s interaction and visualization design.

The value of iterative design in information visualization is in the rapid exploration of a design space with minimal investment. In our iterations below, major flaws that may have contributed to rationale or worldview gaps [3] were caught without the time and effort required to build fully functional visualizations. Also, due to the comments received early in the design process, the overall structure of our tool (related to both interaction and visualization) changed dramatically from the initial concept. We believe the practice of iterating on low fidelity prototypes is useful for many information visualization applications, and support this point by showing how our tool evolved from concept to implementation.

While many design iterations were performed, we discuss three representative examples next. In each evaluation of a prototype, the number of user ranged from 3-5.

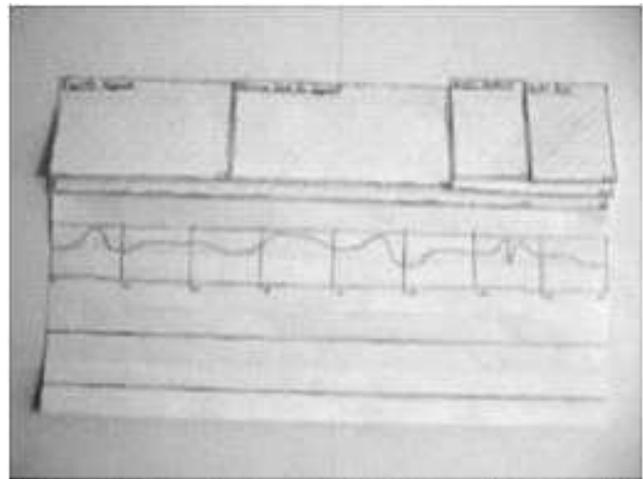


Figure 2 – A frame from a low fidelity prototype video. The task model occupies the top third of the visualization. The central portion is the global pupillary response curve, with the local curve immediately below (in a separate overlay, not pictured).

#### 3.3.1 Iteration 1 – Drill-down Metaphor

As shown in Figure 2, the initial visualization used a focus + context view for the pupillary response graph and a drill-down metaphor for exploring the task hierarchy. Users were presented with a view of the task model with only the top level rendered. To inspect lower levels of the task hierarchy, the user would click individual task nodes to drill down and recursively split the node into component subtasks. By clicking the subtask root, the view would back up a level, effectively moving to the parent subtree, merging the nodes. In addition to the task model, the interface included a viewport into a timeline showing the response curve.

Evaluation showed that this design was too complicated for exploring the data. Users were often disoriented when navigating the hierarchy. The drilling interaction was confusing and non-intuitive. But, in general, users liked the block metaphor for representing subtasks, as well as alignment of the local viewports. Users also requested an extension of the focus + context metaphor for the task hierarchy.

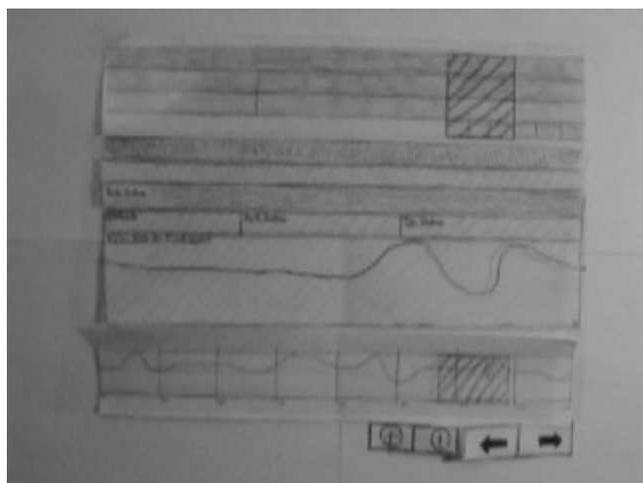


Figure 3 – In this prototype, a focus+context visualization was extended to the task model with the two local viewports aligned in the center. Additional buttons were added for navigation and zooming by constant factors.

### 3.3.2 Iteration 2 – Orthogonal View

Influenced by this feedback, our second iteration (Figure 3) used a two dimensional orthogonal view for the task model. The height of the subtask blocks was reduced to fit the entire task model in the viewport. Higher levels of the model were placed towards the top of the visualization. These changes removed the need for the drilling interaction. We added a fourth viewport allowing for a focus + context view of the task model as well as the pupil graph, as in iteration 1. Temporal zooms could be performed in any of these time-aligned viewports. A selection of a range of time in a local viewport leads to highlighted regions in both the task model and pupillary response global viewports. We also added buttons for shifting the focus by a constant factor and for navigating between view states. The feedback from evaluations of this new design was much more positive, with users finding it simpler to understand and follow. However, users wanted the visualization to better convey relationships between the local and global viewports and the alignment between the two data sets. Our next step was to address these issues and refine the interface with a higher level of detail.

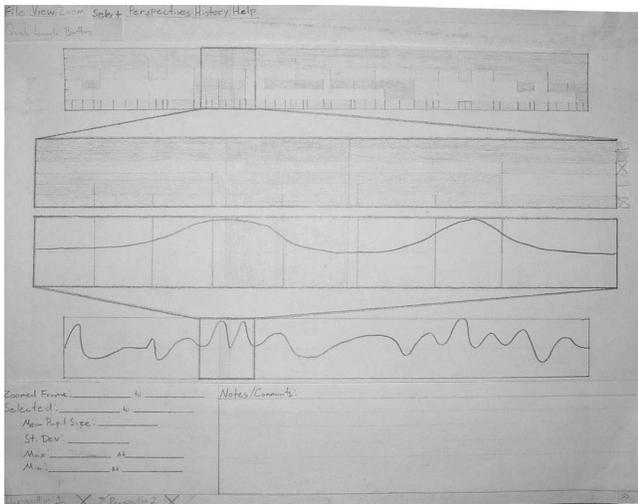


Figure 4 – A refinement of the interface used in Iteration 2.

### 3.3.3 Iteration 3 – Refined Orthogonal View

We added drawings of interface components such as menus and other controls, perspective guide lines that associated the local frame to the relative span in the global frames. See Figure 4. This technique was also used in [28, 38]. Panels were added to the main window for statistics and notes. A selection frame specifies the region for which a detailed statistical analysis is provided, and can be defined in either local viewport.

To mimic diagrams in [18], we included an interface control that allowed users to overlay task boundaries on the pupillary response curve. This allows users to gain a stronger sense of how the curve aligned to the task model. We also added views to allow users to index and switch between different perspectives on the data. At this stage user comments suggested that a significant number of the large scale usability issues had been addressed, and that a functional prototype would now be more appropriate for capturing finer-grained interaction and visualization issues.

## 3.4 Functional Design Iterations

From the lessons learned in the low fidelity iterations, and following our own design discussions, we produced a computer-

based prototype. All of the key design components from the most recent low fidelity prototype were implemented for the functional prototype. We performed additional formative evaluations using the functional prototype. Unlike the first set of evaluations, during these sessions the users were asked to perform tasks with the tool directly rather than watch video recordings of the tasks.

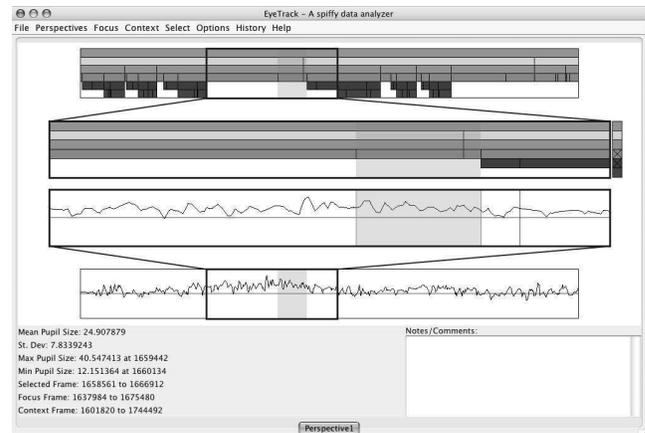


Figure 5 – The initial functional prototype. Focus + context views for both the task model (above) and response curve (below) are presented. The local viewports are grouped in the center, with the global viewports at the top and bottom.

### 3.4.1 Iteration 1 – Functional prototype

Our first functional prototype is shown in Figure 5. Users found the statistics and notes panels a welcome addition, as well as the tabbed perspectives interface. However, we were surprised to find that the guide lines that had no influence in the low fidelity prototypes were found to be distracting in the functional prototype. The value of the lines was recognized by the users; however, the angle of the lines produced a disorienting 3D effect. Similarly, feedback on the task boundaries overlay was mostly positive, but the interface control for selecting the drawn boundaries was found to be counter-intuitive. Many of the users thought that the checked boxes indicated that the boundaries for that level would not be drawn (opposite of the actual function). Users indicated a desire to move and resize the magnification lens directly in the global viewports. We also found that color deficient users had difficulty in discerning the color mapping used in the task model hierarchy.

### 3.4.2 Iteration 2 – Final prototype

From the lessons in the preceding evaluation, we made a number of changes to the functional prototype, and added several features. As shown in Figure 6, this prototype includes video playback functionality, along with notes and statistics panels. These panels were displayed as separate windows from the main visualization window.

Based on user suggestions from previous evaluations, we made a significant change to the how the viewports were positioned. The two local and the two global viewports were now adjacent to each other (contrast Figure 6 with Figure 5). This allowed us to collapse the two distinct magnification lenses in the previous design into just one lens, which could be manipulated from either viewport. The guidelines from the previous design were removed, the color mapping of tasks was resolved, and the controls for selecting whether to view the boundary overlays were redesigned.

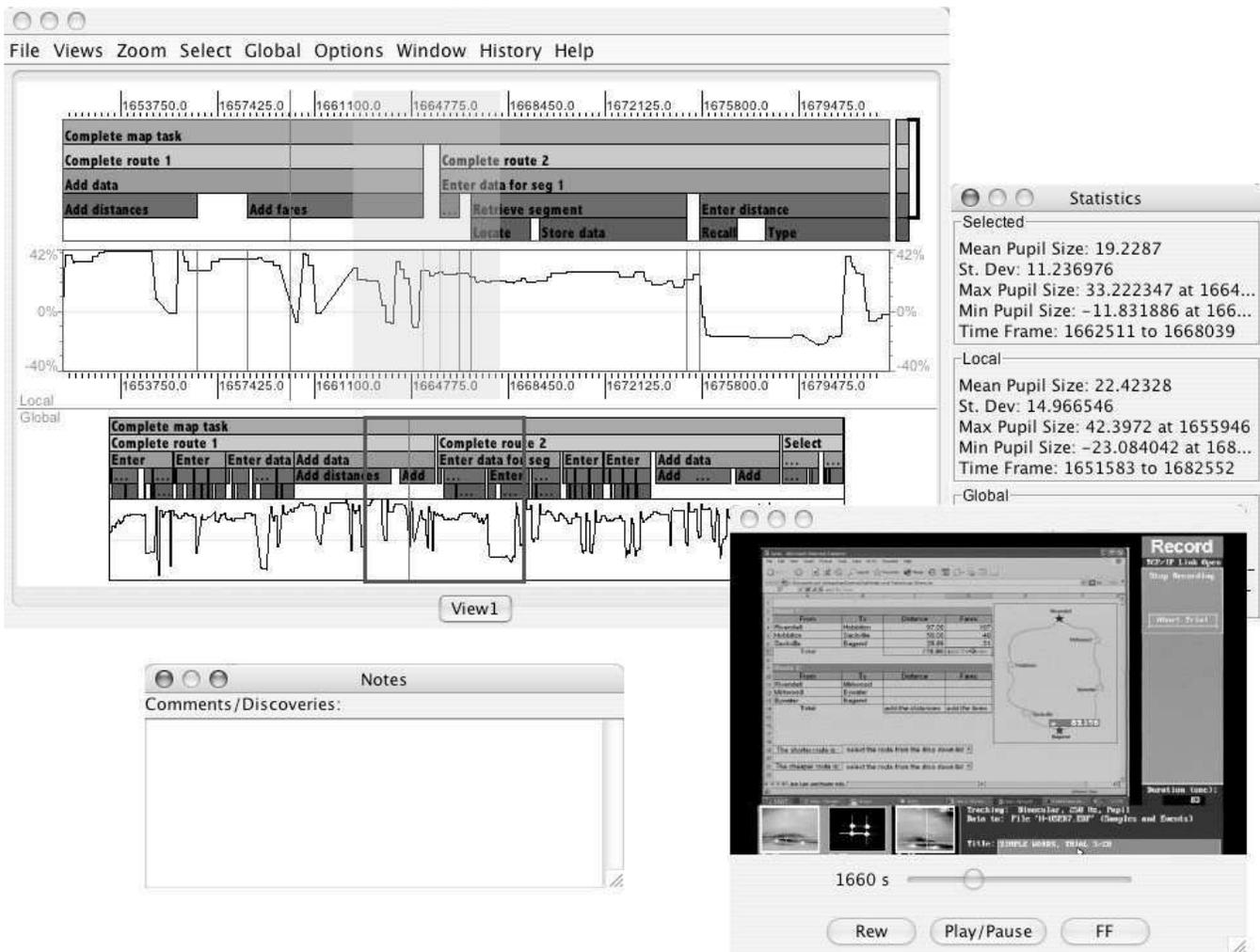


Figure 6 – In our final prototype, the two local and the two global viewports are adjacent to each other (local on top). Functionality includes the ability to play video content bounded by the time span of the local viewport. To allow the tool windows to be moved and sized independently, including being moved to additional monitors (see Figure 1), the video, statistics, and notes windows were separated from the main visualization. Based on lessons learned from evaluations of the previous prototypes, this prototype used a new color mapping for the task model as well as a new interface control for toggling task model boundary overlays.

## 4 TAPRAV

In this section, we outline the key features of the most current implementation of TAPRAV, how they aid users in their analysis tasks, and how various features help combat rationale and worldview gaps [3].

### 4.1 Pupillary Response Visualization

Pupil size is plotted on the vertical axis over a horizontal timeline, and is measured as a percentage change in pupil size. This was done to make the visualization consistent with common research practices [18]. The red line running horizontally across the pupil response viewport represents the baseline value (0% PCPS). Both the vertical and horizontal axes are of linear scale. Placing the mouse over a point on the graph displays the PCPS for that particular point, allowing for immediate and detailed data inspection.

### 4.2 Task Model Visualization

A rectangular block represents each task in the task model. The width of a given task block corresponds to the duration of the task. The name of a given task block is drawn within the bounds of the block (space permitting). For more detailed information for a given task block, the researcher passes the mouse cursor over the task block for a tool-tip task summary. The task model itself is composed of a collection of these task blocks. The ordering of the task blocks along the timeline gives the ordering relationships of the tasks in the model. The task hierarchy is shown by placing the blocks into successive horizontal rows from top to bottom.

### 4.3 Focus + Context: The Local and Global Frames

Given the high sampling rate of eye tracking hardware and the long durations of experimental trials, it is a significant challenge to manage large data sources during analysis. TAPRAV supports a focus + context framework to aide the researcher in navigating these large datasets. The viewport visualizations of the task model

and pupillary response are replicated twice, once in the local and again in the global frame. The viewports of these two frames are aligned by time. This design allows the researcher to explore an area of interest while still being aware of the overall data context.

The top-most portion of the visualization panel is reserved for the local “zoomed-in” frame of the task model and pupil data. The local frame viewports are slightly larger and offer higher fidelity labels than their global frame counterparts. The researcher uses the viewports for detailed analysis.

The bottom-most portion of the visualization panel holds the global frame of the task model and pupil data. The magnification lens, represented by a blue rectangle, is shown in the global frame and defines the time span of the data shown in the local frame. The global frame is useful for identifying approximate areas of interest during the analysis and discovery process.

#### 4.4 Setting the Global and Local Frames

With a potentially very large data set, the researcher may be concerned with only a fraction of the collected data. Menu bar actions allow the user to set the global frame to cover a portion of the imported data.

To set the local frame, the user zooms in on an area of interest by sweeping across one of the local frames to zoom in on the area of interest. Upon releasing the mouse button, both of the local viewports are adjusted to reflect this selection (which zooms in on the data).

The magnification lens is consistent with the time span of the local frame. When inside of the magnification lens, the cursor becomes a “sticky hand” cursor, and the lens can be moved within the bounds of the global frame by dragging. When released, the local frame will adjust to match the repositioned lens.

#### 4.5 Video Playback

Imported video content is visible in a popup player window. The video clip in this player window corresponds to the time span of the local frame. During video playback, the current frame is represented by a moving red vertical line displayed in visualization panel. The availability of video, and its alignment with the task model and response curve, helps researchers examine important features in the data in greater detail, and gain confidence when attributing changes in the response graph to specific user behavior.

#### 4.6 Overlaying Task Boundaries

To get a better sense of task model and pupil data alignment, TAPRAV includes a feature to render task boundaries over the local pupil visualization. This gives users an immediate visual cue when inspecting the task model and response curve for notable alignments. The interface control to the right of the local task model viewport is used to control the task level boundaries that are drawn over the local pupil response viewport. The interface control is composed of a column of colored cells matching the task level colors. A black bracket on the right of this column covers the range of task levels boundaries that will be drawn to the local pupil viewport. Showing boundaries is important for gaining a more precise understanding of the alignment and for analyzing how workload changes at these points during task execution.

#### 4.7 Selection and Statistical Analysis

If an interesting pupil response feature is identified, the user can request statistical details of the area. The user can open a dialog window showing statistics from the global, local, and currently

selected frames. Mean, minimum, and maximum pupil size, as well as standard deviation are presented in tabular form for each of these frames. This feature in particular aids researchers in confirming that the salient features in the visualization are actually statistically meaningful.

#### 4.8 Multiple Views and Comments

By supporting multiple views, TAPRAV allows users to save particular views of the data and return to them later. For each view, the tool records the current global, local, and selection frame. Views are controlled through a tabbed interface, shown at the bottom of the visualization panel. Any number of views can be created and, when selected, the tool sets the current view to the stored values. This feature allows users to save snapshots of interesting parts of the data while continuing to explore other parts of the data in the same session. Those views can also be examined by collaborators wanting to review the data.

For each view, a user can enter comments into a notes dialog. Notes associated with a particular view are available whenever the corresponding view is active.

### 5 IMPLEMENTATION

TAPRAV was coded in Java, consisting of approximately 5,000 lines of code. Java was chosen for both the relative ease afforded for multi-platform development and the vast number of APIs available. The viewports in TAPRAV are drawn using the Java2D API. Other user interface elements make use of the Swing API, and videos are handled through the QuickTime for Java API [2]. As much as possible, we placed related sets of controls into separate dialogs to support the use of multi-display environments (e.g., see Figure 1). The tool is available for download at (link removed for blind review).

### 6 INFORMAL EVALUATION

To gain user feedback on the functional prototype, we conducted a heuristic evaluation with multiple participants. Six evaluators with interface design experience participated in the heuristic evaluation. Following procedures outlined in [23], evaluators were given a brief introduction to the tool and its features, and evaluated the interface using Nielsen’s ten usability heuristics [30]. The participants were encouraged to be open in their comments regarding design flaws and usability issues.

Even after numerous evaluations of the low fidelity and functional prototypes, over 40 usability issues were discovered. For example, the operation of the view tabs was meant to mimic the tabbed browsing functionality used in many web browsers. Results from the evaluation pointed out that, in browsers, all actions affecting tabs are located in the File menu, while in our prototype, tab actions were located in the View menu. To resolve this, we relocated the relevant View actions to the File menu.

The “Panels” menu was renamed to “Tools” to better reflect the user expectations of the actions in that menu. We moved the pupil mask settings action from the Options to the Tools menu, allowing us to remove the Options menu entirely. From these and other fixes we were able to simplify the menu grouping, reducing the number of menu groups from 7 to just 4. This reduction is important as it should allow users to interact with the visualization more effectively and efficiently. Overall, the use of the heuristic evaluation led us to numerous substantive improvements related to interactions with the visualization – improvements that would not have been easily discovered otherwise.

While it is beyond the scope of this design study, we plan a formal comparative evaluation of TAPRAV against existing

methods of data analysis in this domain. As a first step, in addition to the heuristic evaluations outlined above, we were also able to solicit informal feedback from an outside researcher, expert in pupillary response analysis, but not computer science. Due to distance, the evaluations were done without an observer present. The user downloaded the tool and sample data, and was able to install and run the tool without assistance. After having explored the tool for 3 weeks, the user sent detailed feedback via email. In all, the user felt the tool would be useful for performing this kind of data analysis. Most suggestions were geared towards adding additional functionality to the tool, such as highlighting potentially interesting patterns in the data, as opposed to reworking general notions of its utility.

## 7 DISCUSSION

In this section, we describe how our existing implementation meets our design goals. To provide a simple and intuitive visualization, we performed numerous iterations on low-fidelity and functional prototypes. Results from the evaluations led to many improvements in the interface, reducing the complexity of the interaction and making the visualization more effective.

To facilitate discovery driven analysis, the tool includes functions for annotating data, indexing multiple views of the data, and controlling the visualization from any of the data sources (task model, pupil graph, or video). To make the interface understandable to target users, we rely on familiar visualization techniques like focus + context zooming, timeline visualization, and a straightforward hierarchical task representation.

To support any continuous data, we make very few assumptions about the underlying structure of the data representation. Our existing implementation supports any data formatted as time-value pairs. Alternatively, our architecture allows for reader plugins to parse different formats. To support any task model, we use a simple set of XML tags from which users can build models of varying complexity, from deep hierarchies to flat execution sequences. To align the data sets, users place time references into the task model description. Overall, we believe that our tool has made significant strides towards meeting our design goals.

Our future work is to continue refining the functional prototype based on usability issues discovered by users as well as our own experience using the tool. In addition, we see several directions for future work:

- *Conduct a field study to understand how the use of the tool affects analysis of physiological data aligned to task models.* This would involve comparing one set of users using our tool and another set of users using existing practices. Lessons would lead to a better understanding of how our tool affects the analysis process.
- *Support multiple graphs of continuous data.* Our existing implementation supports one user's response data. However, the expert user pointed out that data from multiple users is typically collected and aligned to the same model. It would thus be useful to see data from multiple users aligned to the task model.
- *Extend TAPRAV to include a feature for interactively constructing task models.* The current method of model creation requires the user to specify the models in a textual form. By interacting with the model viewports in TAPRAV, users could construct task models through direct manipulation.

## 8 CONCLUSION

Researchers need more effective tools for analyzing continuous measures aligned with task models. This is becoming increasingly important for researchers involved in interface design, interruption management, affective computing, and other areas.

To meet the specific data analysis needs in these research areas, we developed TAPRAV. Our tool provides an interactive focus + context visualization of continuous data aligned to a hierarchical model of task execution, and provides an integrated set of analysis tools for saving views on the data, statistical analysis, capturing annotations, and viewing videos of on-screen interaction.

The tool was informed through an iterative design process in which more than five major prototypes (and many iterations on smaller parts) were designed and evaluated based on their ability to support appropriate tasks. This was done in much less time and with much less effort than if we have developed functional versions of each. Lessons from the evaluations helped reduce the complexity of the resulting visualization and interaction.

The most recent version of the tool can be freely downloaded and used, which we hope will enable and encourage the use of physiological data in many research areas.

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