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# 12 Usability Testing by Multimedia Video Task Analysis

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## ABSTRACT

An iterative cycle of usability testing is often employed to evaluate a product for its strengths and weaknesses. Video offers objective, quantitative, temporal, and motion-based information that would be very difficult and tedious to obtain through direct observation. Multimedia Video Task Analysis (MVTA™) is a software tool for analyzing observational data from video recordings that are both qualitative and quantitative, facilitates the analysis, and offers features that would be difficult to accomplish without a computer. MVTA offers flexibility in maintaining observational records and cataloging events from video recordings that can easily accommodate intentional and unexpected changes in the analyses. The software can extend the observational task analysis by providing time-based and posture-based data used to identify difficulties and barriers related to medical device accessibility. The richness of the qualitative and quantitative data adds a great deal of information

to the iterative design process, which can help developers produce better and more usable products, and obtain a better understanding of the user and environments in which they are used.

## 12.1 INTRODUCTION

Usability testing involves the collection of empirical data by observing end users of a product while performing representative tasks. An iterative cycle of testing is often used to evaluate a product for its strengths and weaknesses, applying redesign strategies to reduce the weaknesses, and then reevaluating it until the weaknesses are eliminated as much as practicable.

Video recordings provide off-line and detailed review of the user's actions that may not be possible in real time. Usability data generally involves qualitative information (e.g., was the user able to complete a task, what were the steps needed to complete a task, or which steps did the user have the most difficulty with and why?). Video offers objective, quantitative, temporal, and motion-based information that would be very difficult and tedious to obtain through direct observation. Quantitative data includes objective performance measures such as the time to complete a task or the number of errors made.

Multimedia Video Task Analysis (MVTA™) is a software tool for analyzing observational data from video recordings that are both qualitative and quantitative. This chapter is not intended to be a user's guide or tutorial to the MVTA™ software. The methods presented here can be accomplished using alternative means but MVTA™ is one tool that facilitates the analysis and offers features that would be difficult to accomplish without a computer. See also [Chapter 11](#) for a review of approaches that relate to ergonomic analysis.

## 12.2 MULTIMEDIA VIDEO TASK ANALYSIS

### 12.2.1 GENERAL DESCRIPTION

The MVTA™ system, developed at the University of Wisconsin–Madison, contains software for observational time-based activity and event analysis and synchronized analog data sampling. It helps reduce or eliminate tedious activities associated with manual timing and video analysis. An optional module allows the capture of video and sensor-based analog data that can be displayed simultaneously in synchronization with the video, allowing interactive exploration of relationships between the data and video recordings.

The software user interface facilitates information entry, data management, time analysis, and reporting. The computer keeps track of the time codes in video recordings that enable the program to link each occurrence of observed activities with the time it occurred. This makes it possible to locate previously identified events by having the computer find it in the video recording.

Arbitrary events are discerned by interactively identifying terminal break points in the video record. Break points are characteristic occurrences that define the start and end of an event. The video record may be reviewed at any speed and in any sequence (real time, slow motion, fast motion, or frame-by-frame in either forward or reverse direction). Analysts can review any event as long as desired, by stop-action or replaying it in a continuous loop. The software produces time study reports and computes the frequency of occurrence for each event. One of the unique features of this software is its ability to classify interactions among events. This feature enables the analyst to identify the occurrence of simultaneous events, and the computer can tabulate the frequency and duration of each incident.

Basic angle and distance estimation tools are also provided. By clicking on a frame of the recorded images, distance and angle estimations can be made. This application may be used for quantifying included angles between adjacent body segments or for estimating distances relative to an object of known size or other standard.

### 12.2.2 CURRENT AREAS OF USE

The MVTA software system was designed to be flexible and adaptable to many different applications and types of analyses [1]. Some of the analyses that the MVTA system can be used for include:

- Activity sampling
- Checklists
- Behavior observation
- Detailed job analysis
- Elemental analysis
- Event analysis
- Left-hand and right-hand analysis
- Micromotion analysis
- Posture analysis
- RULA or OWAS
- Task analysis
- Time and motion study
- Usability testing
- Work sampling

Typical fields of application include:

- Industrial engineering
- Biomechanics and kinesiology
- Work physiology
- Ergonomics
- Psychology
- Zoology
- Human factors engineering
- Training
- Sleep labs
- Sports and athletics
- Rehabilitation
- Human-computer interaction

This chapter will focus on just one type of application, usability testing of medical devices, which is the primary focus of this book. The human subjects data reported here was obtained from the Rehabilitation Engineering Research Center on Accessible Medical Instrumentation (RERC-AMI), which has used MVTA at Marquette University for a number of studies (see also [Chapter 13](#)).

## 12.3 USABILITY TESTING

Built into an iterative product development cycle is the ability for usability testing to detect design flaws and deficiencies. It is important that the focus is on the understanding of the product. This can be accomplished through four types of tests: (1) exploratory, (2) assessment, (3) verification, and (4) comparison tests, as described by Rubin [2].

### 12.3.1 EXPLORATORY TEST

The exploratory test is conducted early in the development cycle. The main objective of this test is to explore or examine the effectiveness of the preliminary design. The assumptions about the user are also verified (e.g., does the user perceive the design as intended?). It is at this stage that the

foundation design is set, and all future design decisions are based. Wrong assumptions must be corrected before continuing. A great deal of interaction between the tester and the user occur at this stage to establish the effectiveness of the preliminary design concepts through the use of prototypes [2].

### 12.3.2 ASSESSMENT TEST

The assessment test is the most typical of usability tests due to its simplicity. The assessment test is used to expand the findings of the exploratory test by evaluating performance of the lower level operations and aspects of the product. Beyond testing the intuitiveness of the product, how well the user performs the specified tasks is also assessed, such as developed in [Chapter 14](#). The use of an actual working prototype is needed. The researcher's interaction with the user is reduced, and more quantitative data is collected [2].

### 12.3.3 VERIFICATION TEST

The verification test, conducted later in the development cycle, is intended to verify the product's usability by comparing the current product to some predetermined usability standard or benchmark. These benchmarks can be either performance standards from previous tests, company or historical standards, or a competing standard. The verification test can also be used to ensure that all the components of the product work together especially when the components were developed in relative isolation from each other. This test ultimately must make sure that no flaws exist in the product, and necessary corrections are made before the product gets into the user's hands. Mostly quantitative data is collected [2].

### 12.3.4 COMPARISON TEST

The comparison test can be used at any stage of development, especially when a comparison is needed between two or more alternative designs. The test helps the researcher to better understand the strengths and weaknesses of the different designs. Performance data and preference data are collected for each of the alternative designs. A comparison test using objective, quantitative data allows the identification of the best design components from each of the alternative designs, especially when no single design produced the best outcome on the whole. Why one component performed better than another must be understood. The best components from all the alternative designs can be combined to produce a new composite design [2].

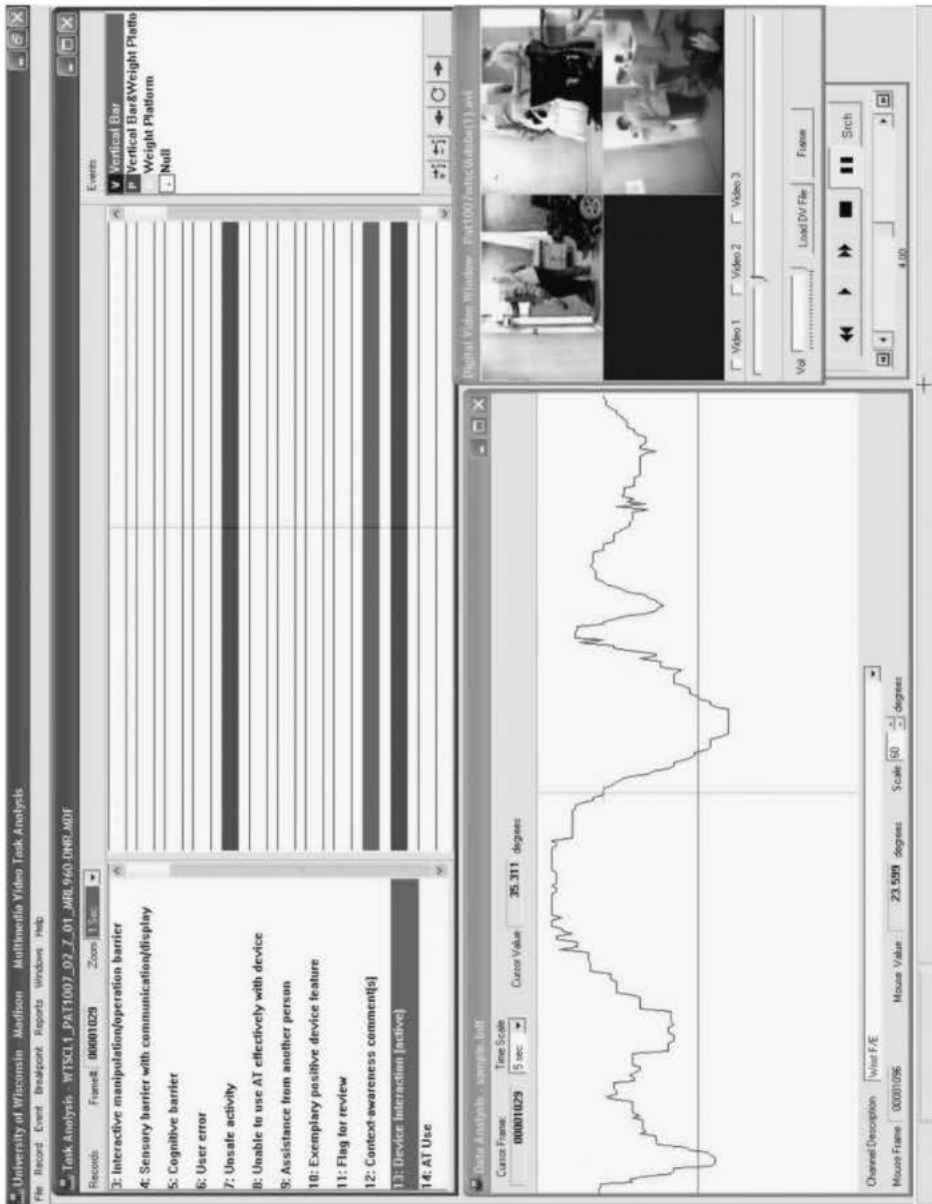
## 12.4 USING MVTA™

An MVTA screen containing both the Task Analysis and Data Analysis windows is shown in [Figure 12.1](#), which illustrates the analysis of a medical weight scale. The Data Analysis module provides the interactive link between analog sensor data and the video recordings, such as wrist flexion and extension, measured using an electrogoniometer. Although a great amount of data can be collected using sensors, which are especially useful for ergonomics analyses, the additional time and cost of equipment and its setup may not be necessary or practical in most cases. This chapter will deal mainly with the observational task analysis.

### 12.4.1 RECORDS AND EVENTS

#### 12.4.1.1 Representation of Time Information

Timelines are used for visualizing activities and events as a series of occurrences in order to understand temporal aspects of the events. An ordered sequence of related events can be organized by using a left-to-right timeline.



**FIGURE 12.1** MVTA software showing the main Task Analysis (observational) and Data Analysis (analog sensor–wrist flexion and extension) windows for the analysis of a weight scale. (Data file courtesy of Melissa Lemke of the RERC-AMI and Marquette University.)

### 12.4.1.2 Representation of Activities in Time

Activities may be described using a hierarchical framework as shown in Figure 12.2 (e.g., activities in a work shift). Such an organization provides a useful method for systematically documenting an activity using various levels of detail. The level of detail needed depends on the specific activity under study.

The top level of the hierarchy is the job in the example shown in Figure 12.2. A job delineates work performed by an individual and represents a specific work assignment, usually on a daily basis. The next level of detail breaks down the job into specific tasks or activities. A job may consist of one task performed throughout a shift, or it may consist of a variety of tasks. Tasks include all productive work activities in addition to scheduled rest allowances such as lunch breaks. Repetitive tasks can be reduced further into cycles. Each cycle may contain a series of elements. Elements represent sequential units of work that together constitute one cycle of a task. The bottom and most detailed description of work activities reduces each element to micro movements and exertions such as a reach, a move, or a grasp.

The hierarchical framework for usability studies (Figure 12.3) can be represented from the top level as the product to be evaluated (e.g., an ECG monitor). The next level of detail breaks down the product into the different tasks or activities that the user must perform to operate the product (e.g., turning on or off the device, adjusting monitor brightness, or displaying patient data). Within each task, a series of elements is identified (e.g., for the task “display patient data” the elements are press *data* key, press #2 key, turn input dial, and press *enter* key). Additional levels below the element, such as fundamental operations (like reach, grasp, etc.), are possible but often not necessary for usability analysis. Any hierarchical arrangement of this type can be represented in MVTA through the use records and events.

### 12.4.1.3 Hierarchical vs. Nonhierarchical Organization

Structured tasks with well-defined activities, as described in the previous section, lend themselves to hierarchical organization. There are also situations where no direct hierarchical

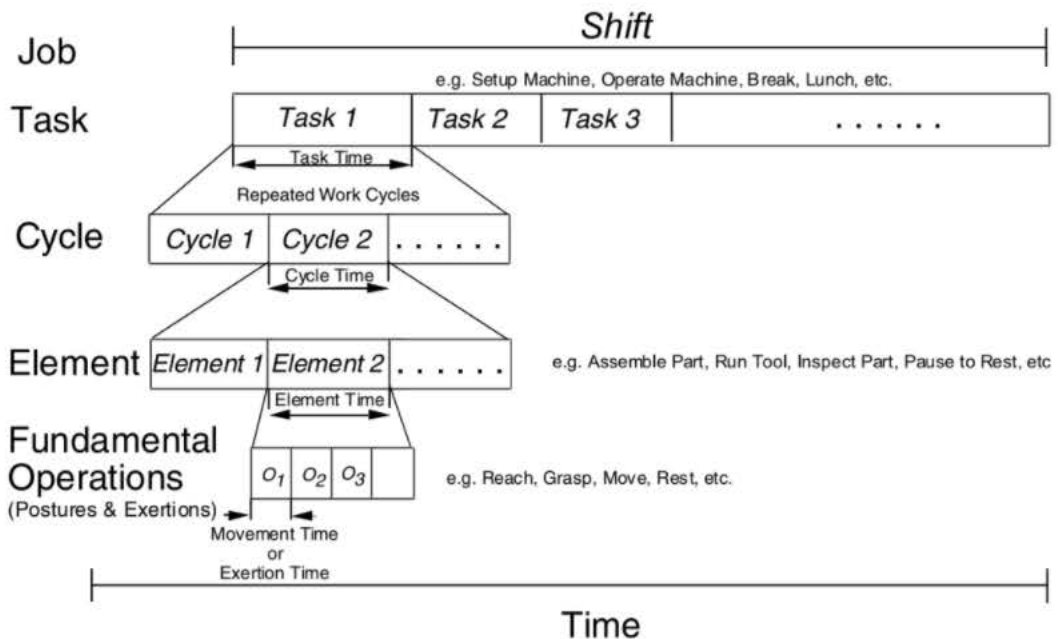


FIGURE 12.2 Example of hierarchical relationship between work elements, work cycles, tasks, and jobs.

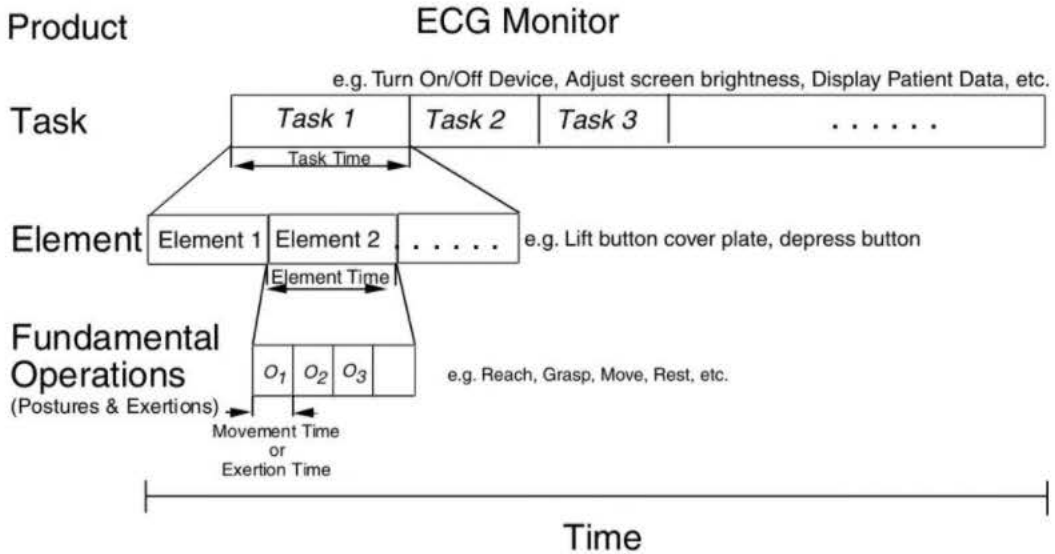


FIGURE 12.3 Example of hierarchical relationship for the analysis of an ECG monitor.

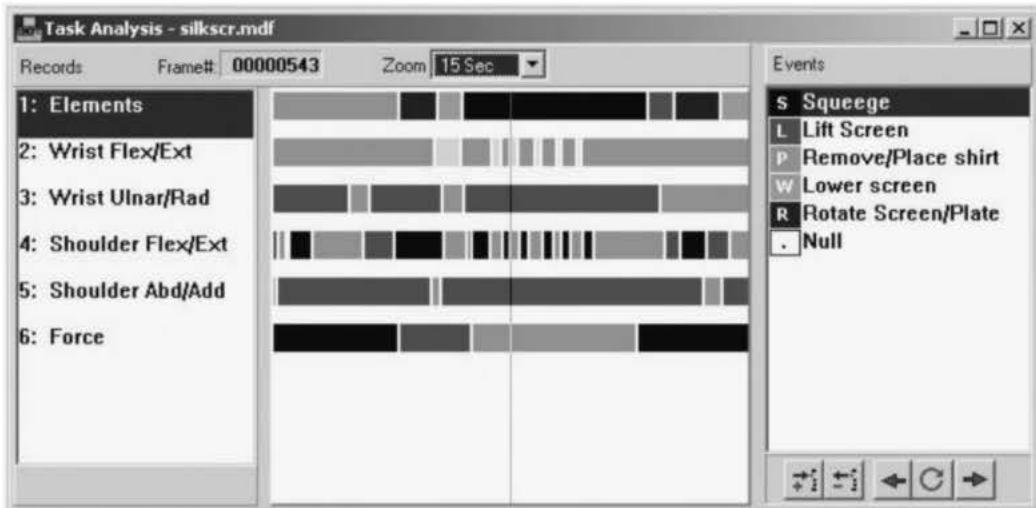


FIGURE 12.4 Task Analysis window highlighting the key controls and displays for a silkscreening task.

relationship exists between the record elements, but they can be grouped together in the same record list because they have the same nonhierarchical relationship. Two examples of nonhierarchical relationships are the right- and left-hand analysis, and the multiple operators (teamwork) analysis.

- *Right and left hand:* The individual activities of the right and left hands have no hierarchical relationship but have a clear relationship to how the activity is performed.
- *Multiple individuals and groups:* Members of a group may be represented as individual records. Activities of each group member are recorded as individual events, where each member represents a separate record.

## 12.4.2 TASK ANALYSIS

An example of the task analysis window is shown in [Figure 12.4](#). The *Record List Window* displays the different records associated with the analysis file. Each record is represented by a timeline in the *Timeline Window*. The *Frame Number* identifies the current video frame and timeline location of the *Time Cursor*. *Timeline Zoom* sets the time range displayed by the timeline window. The *Event List Window* shows the events associated with the currently selected record. Each event can have a different color to represent the different event segments in the timeline window. The *Event Speed Button* allows quick access to the assignment, editing, and deletion of event break points.

The graphical timeline representation interface permits quick navigation between the records and events. Additions, deletions, or modifications of the records and events are permitted at any time during the analysis.

### 12.4.2.1 Record and Event Setup

Usability testing typically starts by doing a task analysis. The individual activities and elements needed to operate the product are systematically identified. The activities and their corresponding elements are represented in MVTA in the Records List and Events List, respectively. For example, the following activities shown in [Figure 12.5](#) might be specified as records: (1) turn on or off the patient monitor, (2) adjust screen brightness, and (3) display patient data. The elements for each corresponding record can be: record 1 (lift cover plate; depress button), record 2 (press *screen control* button; press #1 key; turn input selection dial for desired brightness; press *enter* key), record 3 (press *data* button; press #2 key; turn input selection dial until patient name highlighted; press *enter* key). [Figure 12.5](#) shows that record 3, “display patient data,” is selected and its corresponding events. If at anytime during the analysis, additional activities are identified, a new record or event can be inserted without losing or affecting previous entries.

The usability analysis of a patient’s interaction with a weight scale and the surrounding environment are shown in [Figure 12.6](#). The study goes beyond a task analysis ([Figure 12.6c](#)) by not just looking at the tasks involved in the operation of the product but also studying how the user’s personal equipment and barriers to use that are presented by the equipment ([Figure 12.6a](#) and [Figure 12.6b](#)) affect use of the product. The events in [Figure 12.6b](#) represent qualitative levels of difficulty and reduced stability of the user caused by use of barriers confronting the user. Not only does this method provide qualitative information but also provides time information such as the duration and interval of periods of difficulty and reduced stability.

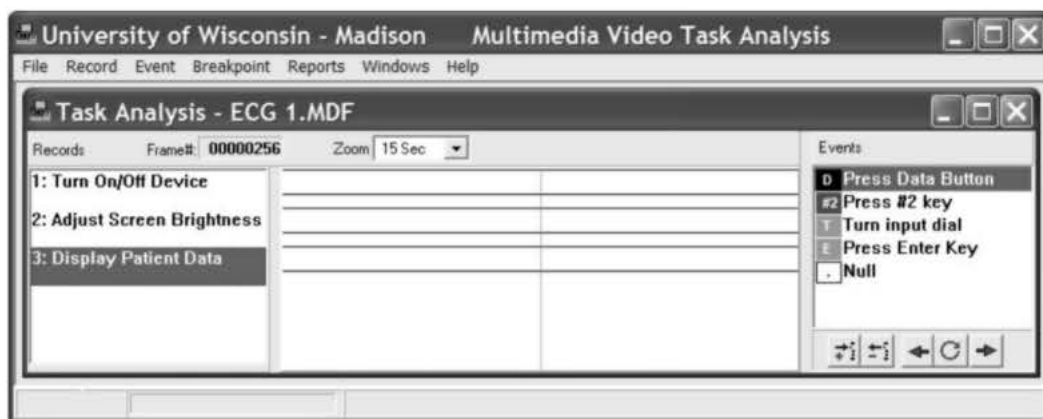
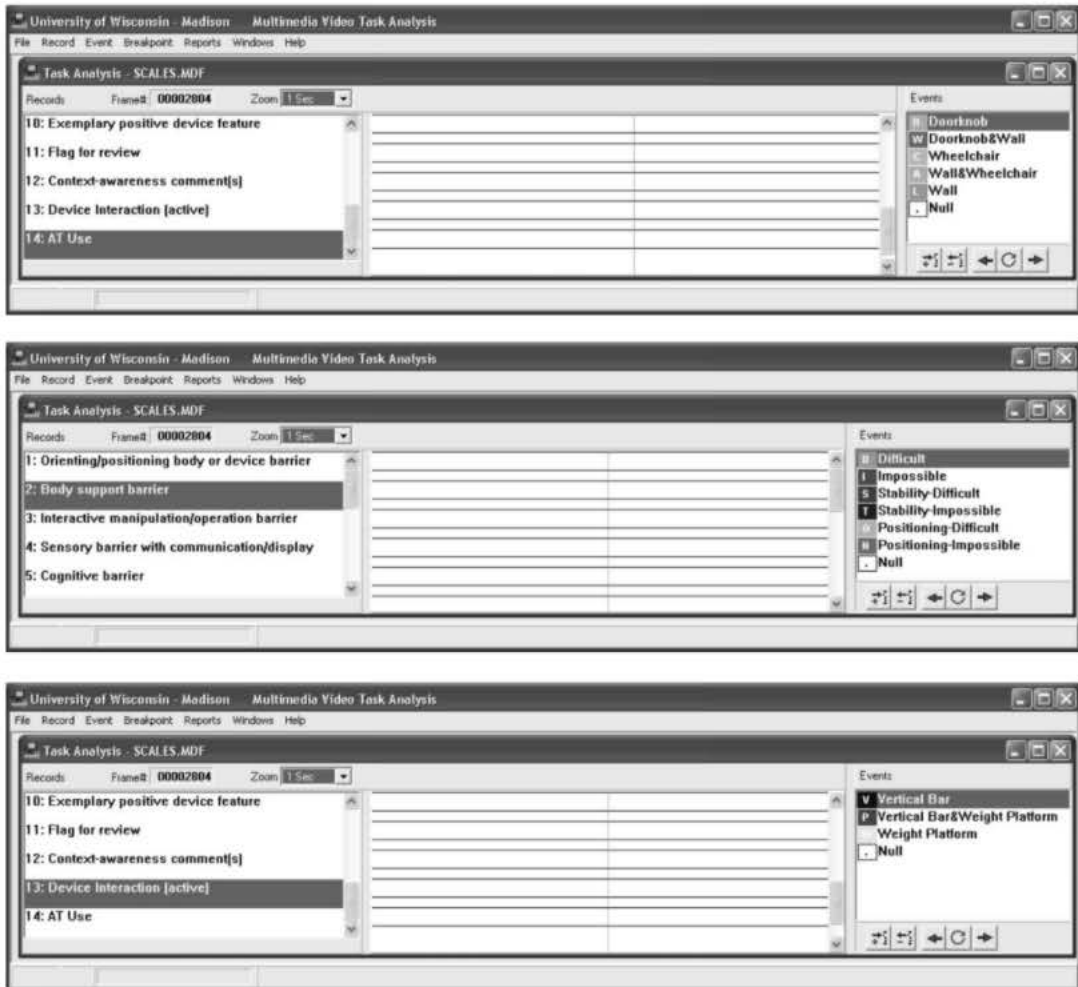


FIGURE 12.5 Records and Events list for a task analysis for an ECG collection task.



**FIGURE 12.6** Task Analysis windows for studying a patient's use of a weight scale, emphasizing records categories used by the RERC-AMI as a core set for an integrated accessibility and task analysis. (a) AT (assistive technology) use, (b) Body Support Barrier, (c) Device Interaction (active). (Records courtesy of Melissa Lemke, RERC-AMI.)

#### 12.4.2.2 Event Break Point Editing

The MVTA™ program contains features for event break point assignment and editing. An overview will be presented to provide a better understanding of the break point editing process used by MVTA™.

- *Inserting new event break points:* Event labels are created in the event list window. Each event list element can have a unique alphanumeric key associated with it. The corresponding key is pressed to mark the beginning of the event at the desired video frame. The timeline window is updated with the new break point. The break point can be edited at any time. Break points inserted in the timeline, after the “D,” “2,” and “T” keys were pressed, are shown in [Figure 12.7](#).
- *Deleting and changing event break points:* Two commonly occurring assignment errors are: (1) inserting a break point at the wrong video frame, and (2) marking the desired video frame using the wrong event break point. Break points marked at the incorrect video

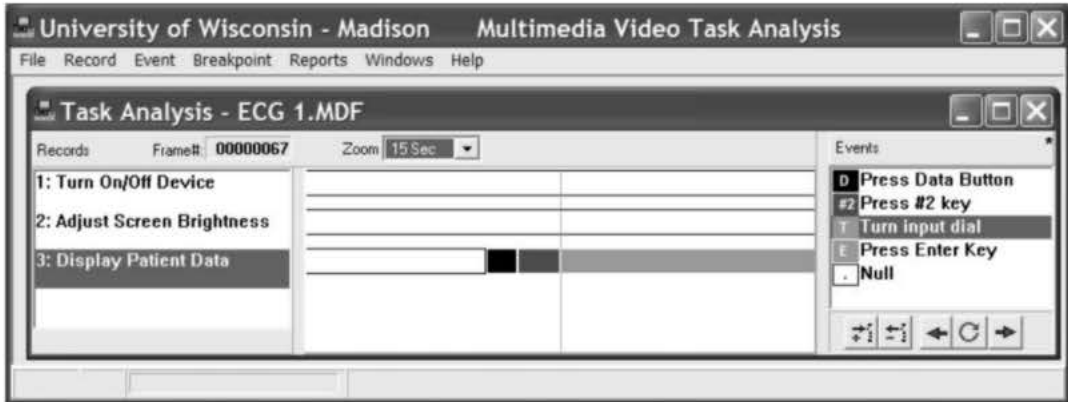


FIGURE 12.7 Inserting break points.

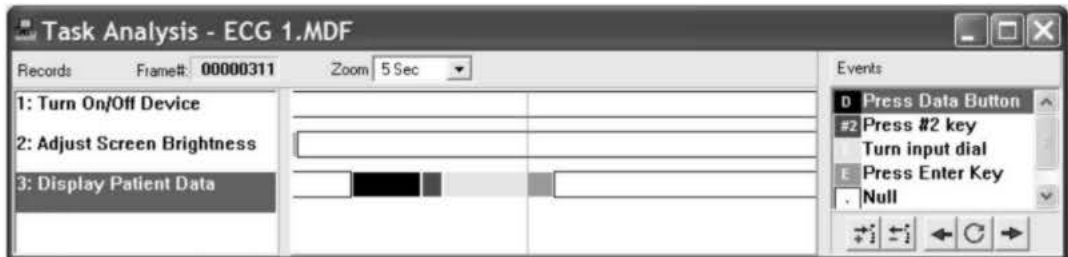


FIGURE 12.8 Deleting break points.

frame are corrected by moving the timeline cursor to any video frame in the event, deleting the event, then moving the timeline cursor to the correct video frame location and inserting a new event break point. A break point marked using an incorrect event label can be corrected by moving the timeline cursor into any video frame in the event, selecting the correct event from the event list window, and changing the event. The currently selected event label replaces the incorrect event label for the event break point. (see Figure 12.8.)

- *Undefined events:* There are situations when the analyst may be unable to determine which event is occurring until continuing to review activities later in the video record. Marking break points in this situation would require constantly shuttling the video to a video frame where the event can be determined, and then shuttling back to the beginning of the event. The “undefined” event feature can help solve this problem. At the video frame when the event begins, the analyst inserts an “undefined” event to mark the time by pressing the Escape key. After the video frame is advanced and the event is identified, the analyst marks the appropriate event by selecting the correct event label. The undefined event is then replaced by the actual event. This feature saves a great deal of time.



FIGURE 12.9 Interaction record for a silkscreening task.

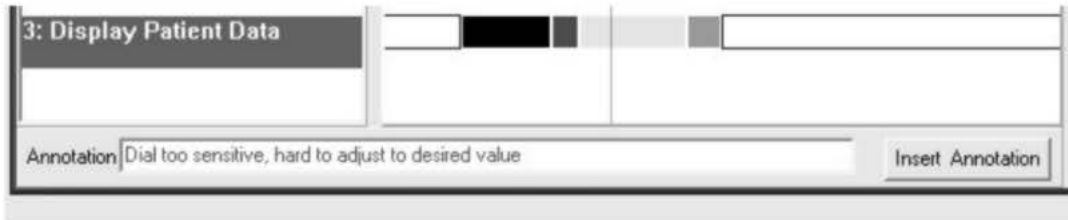
- *Null event:* A “null” event is a special predefined event that is excluded from the analyses. Often this is because a portion of the recording is not stored. All new analyses begin with all record list elements initialized as null events. Null events are ignored by MVTA™ when generating reports and analyses. Null events should be used for segments of video that have discontinuities in time (such as when the recording was paused) or to break up unrelated analyses in the record timeline. Duration and frequency intervals are never calculated across null events.
- *Record interaction:* A very useful feature of the MVTA™ program is record interactions. Interactions reveal the relationship between two activities at the record level. MVTA™ allows two independently observed events to be combined to produce a new event that represents the coincidence of the two. For example, one may be interested in determining the intersection between events in record 1 and record 2 in order to determine the duration and frequency of the simultaneous occurrence of each combination of events. If record 1 contains five events and record 2 contains three events, the analyst would have to keep track of fifteen ( $3 \times 5$ ) different combinations. In Figure 12.9 the interaction between the Elements record and the Wrist Flex/Ext record was created and displayed at the bottom of the records list. Note the interactions visible in the event list.

### 12.4.2.3 Annotation

Supplemental information associated with an event can be entered and displayed in the annotation window (See Figure 12.10). This information may be any alphanumeric string desired. Only a single annotation can be associated with an individual event, up to 255 characters. With the timeline cursor located at an element of the desired record, pause or stop the video. Click in the edit box for the text bar to appear, and type the desired annotation. If previous annotations were assigned and the annotation window is displayed, the annotation message will appear in the edit box as the timeline cursor moves while the video advances.

## 12.5 TIME- BASED USABILITY DATA WITH MULTIMEDIA VIDEO TASK ANALYSIS

After a task analysis has been completed, the exploratory and assessment stages of usability testing begin. Some of the basic quantitative timing data is collected. In some cases, the verification stage is completed with respect to the subjective and qualitative data on the user and product interaction (e.g., were the tasks completed and what difficulties were encountered?). The verification stage



**FIGURE 12.10** Annotation window for an ECG collection task.

can be extended by extracting time-based data from the task analysis. By using the timing information associated with the recordings used in the task analysis, data such as the time needed to complete tasks and the frequency of task failure can be collected.

MVTA reports time data in two ways: (1) time study and (2) frequency analysis. Time study computes the time for individual events, whereas frequency analysis computes the interval of occurrence or repetition rate of all events such as the frequency of failure or the need to repeat a particular element too many times.

If multiple replications are recorded, a statistical analysis is provided including the mean, standard deviation, the number of data points, along with confidence intervals, percent error, sample size needed for a given percent error, total cumulative event time, and percent of total cycle values. The upper and lower 95% confidence interval values are provided. The percent error (%error) is the ratio of the 95% confidence interval to the average event time as a percentage. The sample size required (N (5% Err)) value provides an estimate of how many data samples are needed for a percent error of 5%. Percent error levels of 1, 5, 10, and 20 are selectable.

The time-based data can be used in the comparison stages of the testing as changes are made to the product during the iterative design process. The designers can use this data to compare competing product designs. The quantitative data can also show how subsequent reiteration in design may not substantially improve the product, when a barrier to further improvement has been reached or a design approach is yielding negative outcomes.

## 12.6 POSTURE-BASED USABILITY DATA WITH MULTIMEDIA VIDEO TASK ANALYSIS

MVTA can provide basic estimations of distance and angle. An object of known dimensions must be identified in the frame of the recording, and after some simple calibration procedures, distances and angles can be determined. By clicking on two points in the image frame to define a line segment, the distance can be computed. By clicking on three points to define two line segments, the angle between the line segments can be computed. Parameters such as reach distances and elbow or shoulder angles can influence the time to complete a task by affecting the physical requirement to do the task. The accuracy of the angle or distance estimation is dependent on the view of the video to the object. An orthogonal view of the object is essential for accurate estimations.

## 12.7 CONCLUSIONS

Usability testing is a very important part of the design and evaluation of a product. MVTA offers flexibility in maintaining observational records and cataloging events from video recordings that can easily accommodate intentional and unexpected changes in the analyses. Observational task analysis provides data that are subjective and qualitative. The MVTA software can extend observational task analysis by providing time-based and posture-based data that are objective and quantitative. As shown here, it has also been used to identify difficulties and barriers related to medical device accessibility (see also [Chapter 13](#) and [Chapter 14](#)). The statistical reports of the

quantitative data can provide additional validity to the results. MVTA provides the additional benefit of offering a detailed, frame-by-frame analysis. The richness of the qualitative and quantitative data provided by MVTA adds a great deal of information to the iterative design process, which can help developers produce better and more usable products, and obtain a better understanding of the user and environments in which products are used.

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