Choosing the Right Task Analysis Tool

By Anne E. Adams, Wendy A. Rogers, & Arthur D. Fisk

Applying one or more task analysis method can result in safer and more efficient products and systems.

FEATURE AT A GLANCE:
A variety of task-analytical tools are available to the human factors/ergonomics practitioner, who is challenged to find the right tool for the task at hand and to apply it appropriately. In this article, we compare a number of task analysis methods, including each method’s unique contribution and the expertise required to apply it. We describe how different task analysis methods can build on each other and provide examples to illustrate.

KEYWORDS: levels of analysis, design principles, task analysis, hierarchical task analysis, HTA, cognitive task analysis, CTA, ecological task analysis, ETA, goals/operators/methods/selection rules, GOMS

H uman factors/ergonomics (HF/E) professionals who face the task of (re)designing a system or developing a training program may find themselves at a loss for what to do. At first, this task appears straightforward, yet it involves more skill and continuous work than meets the eye. Some initial confusion involves how and where to start and how the information gleaned informs design. However, HF/E professionals can make use of available tools to aid the process of designing and redesigning systems and training programs.

Task analysis is a common tool used by HF/E professionals, and there is general agreement that it is a very important step in the product and instructional design process. However, task analysis is not well defined (e.g., Jonassen, Hannum, & Tessmer, 1989), and neither is the process for selecting an appropriate or effective task analysis method. How does one choose a task analysis method from the plethora of available methods?

Our goal in this article is to provide some guidance on this issue. We review a select number of task analysis methods and their analytical focus, unique contribution, required expertise, and link to different levels of analysis. Through this review, we illustrate that each task analysis method can shed a different light on a task and that, in combination, the methods can provide answers to questions that are of interest to the HF/E professional. Viewing the same task from different angles can improve system design as well as assist in the design of training programs or job aids to ultimately enhance people’s safety, effectiveness, and efficiency.

UNDERSTANDING TASK ANALYSIS

Definitions and methods. Task analysis is both a methodology and a large set of methods. The novice to task analysis soon discovers that the term task analysis refers not to one specific method but rather to a concept or goal: namely, to understand what a user is required to do. However, understanding a user’s task is also not as straightforward as it may appear, because a task has many facets and thus can be viewed and analyzed in many ways (e.g., goals, actions, cognitions). As a result, a plentitude of methods have emerged over the decades that target those aspects, accounting for the change in the nature of the work over time (e.g., from physical to cognitive) and the emphasis (e.g., from time or movement efficiency to safety).

From the many available, Jonassen and colleagues reviewed 27 task analysis methods in 1989. Only 3 years later, Kirwan and Ainsworth (1992) reviewed 25 methods in detail; and between these two books, only 3 methods overlapped! The challenge then becomes to decide which method to choose.

Challenge of fitting the analysis with the task. Organizing frameworks exist to aid analysts in selecting a task analysis methodology. A variety of criteria can guide such selection: the purpose, scope, and phase of the analysis; the specific task; cost and time factors; expertise; and the underlying design model (e.g., Kirwan & Ainsworth, 1992;
Jonassen et al., 1989). Yet, providing help with the selection of one method is not enough guidance, because practitioners may need to use a variety of analysis techniques across different levels of analysis (Redish & Wixon, 2003). No overarching framework is sufficiently specified to guide the novice through the task analysis process. We discuss three general levels of analysis to guide method selection.

The levels of analysis are based on Marr’s (1982) conceptualization wherein he argued that an information-processing system is understood on three levels. The highest level of analysis is the computational level. Questions at the computational level include “What is the purpose of the system?” and “What problem(s) is the system trying to solve?” and “Why is the system solving this problem?” Task analysis methods at this level focus on discovering the higher-level functions, goals, and subgoals to be accomplished. For example, short-order cooks working in a variety of kitchen settings share the goal of preparing eggs for breakfast. The benefit of starting at this macro level is that the task analysis is independent of the technology or tool used to accomplish the goals and thus can be reused across contexts.

The second level of analysis is the algorithmic level. Questions at this level of analysis include “How does the system solve the problem?” or “What is the underlying algorithm?” Task analysis methods supporting this level of analysis will focus on specifying the methods, rules, strategies, and sequence of actions used to accomplish the goals discovered from the higher-level specification (computational level). For the short-order cooks, different methods would be specified for poaching, frying, or boiling an egg.

The third level of analysis is the implementational level, and the question is, “How is the algorithm implemented?” Task analysis methods geared toward this level of analysis focus on the kind of architecture or technology used to accomplish the goals and methods. For example, does the cook use a gas stove, an electric stove, or a microwave? In addition, one might ask what visual cues the cook uses to implement and complete the task.

To summarize, we suggest that the optimal task-analytic approach depends on the level of analysis of the task; different levels of analysis require different task-analytic approaches. The task analysis methods reviewed hereafter are useful for providing insight into these different levels of analysis, but none is optimal across all three levels.

### COMPARING TASK ANALYSIS METHODS

The reviewed task analysis methods were selected on the basis of their broad use and applicability. The methods were

<table>
<thead>
<tr>
<th>Task Analysis Method</th>
<th>Expertise Required</th>
</tr>
</thead>
<tbody>
<tr>
<td>HTA</td>
<td>Performing HTA requires much expertise on the part of the analyst, who somewhat contradictorily already has to anticipate the results at the onset of the analysis. Logic, domain knowledge, interviewing, and knowledge about training approaches are necessary.</td>
</tr>
<tr>
<td>GOMS</td>
<td>Background in cognitive psychology and domain knowledge are needed by the analyst. One challenge that is only slowly being met (e.g., Fisk, Rogers, Charness, Czaja, &amp; Sharit, 2009) is providing the analyst with relevant data to substantiate judgment calls and avoid the need to bypass complex cognitive processes.</td>
</tr>
<tr>
<td>CTA</td>
<td>CTA requires time, resources, and expertise in cognitive science. Although the streamlined version, ACTA, was developed for the noncognitive expert, it still requires interviewing skills and domain knowledge. Background knowledge in cognition or cognitive science is beneficial.</td>
</tr>
<tr>
<td>ETA (Davis &amp; Burton, 1991)</td>
<td>This method is intended for the practitioner – in this case, the teacher – who needs to understand and manipulate relevant parameters and dimensions provided by the literature.</td>
</tr>
<tr>
<td>ETA (Kirlik, 1995)</td>
<td>Background in cognitive engineering or cognitive psychology is required.</td>
</tr>
</tbody>
</table>

Note. HTA = hierarchical task analysis; GOMS = goals, operators, methods, and selection rules; CTA = cognitive task analysis; ACTA = applied CTA; ETA = ecological task analysis.
also chosen to be complementary; that is, we aimed at diversity in task analysis methods to capture a variety of approaches. The methods hierarchical task analysis (HTA), GOMS (goals, operators, methods, selection rules), cognitive task analysis (CTA), and ecological task analysis (ETA) were compared on their analytical focus and general process, required expertise (see Table 1), products, and the question(s) they address.

**HTA.** Hierarchical task analysis refers to ideas developed by Annett and Duncan in the late 1960s (e.g., Annett & Duncan, 1967) and is suggested as a framework for task analysis because methods stemming from time and motion studies in the 1910s (Gilbreth, 1911; Taylor, 1911) were too simple, available skills taxonomies and definitions too fuzzy, and behaviorism too restrictive. HTA is a top-down process that results in a hierarchy of goals that need to be accomplished. Based on information from interviews, observations, and documents, the analyst identifies top-level goals and then redescribes them into subgoals. This illustrates two important aspects of HTA: It is hierarchical (divides goals into subgoals) and functional (focuses on goals rather than action).

Plans are specified and contain information about the sequence in which subgoals are accomplished as well as conditions that activate the goals. Because goals tend to be more stable and can be accomplished by different actions, the focus on goals rather than actions can make HTA a general, independent analysis tool (Annett, 2004) and neutral with respect to its solution. Furthermore, the analyst can decompose and analyze each subgoal with respect to variables of interest, such as task frequency, task difficulty, and errors.

Figure 1 shows a high-level HTA of cooking an order presented in a hierarchical diagram format. HTA can provide a high-level analysis of the goals and subgoals to be accomplished.

**GOMS.** With GOMS, the aim of the analysis is to create a complete description of experienced users’ procedural knowledge and their representation of the task. This procedural knowledge is described in terms of goals, operators, methods, and selection rules and is represented in a production system as the underlying cognitive architecture (if-then rules, with the basic unit being one if-then rule). A GOMS model of a routine task can be simulated and allows calculation of estimates for learning time, execution times, and degree of transfer (Kieras, 1988).

GOMS uses the same principle of hierarchical redescription as put forth by HTA (Annett, 2004) but is applied at a more detailed level (Schraagen, 2006). The primary focus lies in specifying the methods — that is, outlining how to achieve the goals. Complex cognitive processes often have to be skipped because available data are lacking. GOMS models are typically created only for routine expert performance.

Figure 2 shows how one of the lower-level subgoals identified by HTA, mixing ingredients, can serve as a starting point for specifying the method in GOMS of how to accomplish the subgoal of mixing ingredients. The specified method is linked to the actual tool used to mix ingredients and is often described in even more detail.

**CTA.** Cognitive task analysis is a collection of methods that was developed to address two problems: Work had become more cognitively demanding, and analysis methods available at the time did not explicitly consider cognitive elements of work (Militello & Hutton, 1998).

CTA identifies and describes the cognitive structures (e.g., knowledge-base organization and representational skills) and processes (e.g., attention, problem solving, and decision making) underlying job expertise, and the knowledge and skills required for similar job components. (Seamster, Redding, & Kaempf, 1997, p. 4)

**Method to accomplish the goal of mixing ingredients**

- **Step 1.** Accomplish goal of obtaining hand-held mixer
- **Step 2.** Accomplish goal of adding ingredients
- **Step 3.** Take mixer into one hand
- **Step 4.** Place mixer over mixing bowl
- **Step 5.** Power on mixer
- **Step 6.** Stir ingredients
- **Step 7.** Power off mixer
- **Step 8.** Verify ingredients mixed
- **Step 9.** Report goal accomplished.

**Figure 1.** Sample redescription of the task of cooking orders by short-order cooks (hierarchical diagram format).

**Figure 2.** Sample GOMS (goals, operators, methods, and selection rules) method to accomplish goal of mixing ingredients.
We review one CTA method developed for the nonexpert in cognitive science: applied CTA (ACTA). Generally, CTA is based on interviews with subject matter experts and is often conducted by scientists. In ACTA, the task redescription, decomposition, and identification of cognitive skills are done by the expert rather than the task analyst. The analyst uses a set of predefined probes that help guide the expert’s exploration of the topic. With ACTA, one considers select aspects of cognition, focusing on aspects that are challenging (Militello & Hutton, 1998).

ACTA has three intermediary products and one final product. First, the expert outlines the task, segmenting it into 3 to 6 substeps, called the task diagram, which guides the remaining analysis. This could result in general high-level goals as identified by HTA. The second product is the knowledge audit table, which illustrates various aspects of expertise, cues, strategies, and why these aspects may be difficult (see Table 2 for an illustration using the short-order cook example). The third product is the simulation interview table, in which information gathered from a challenging scenario or critical incident is summarized: events, actions, assessment, critical cues, and potential errors. These data are summarized in the final product, the cognitive demands table, which outlines difficult cognitive elements, why they are difficult, common errors, and the cues and strategies that are used.

ETA. In the ecological approach to task analysis, the environment is an important variable. Two task analysis methods with the name ETA exist (Davis & Burton, 1991; Kirlik, 1995), although they were developed in different domains (physical education vs. cognitive engineering). Both are informed by Gibson’s ecological approach to perception (e.g., 1979), but not exclusively. The environment is viewed as representing a problem. For Davis and Burton (1991), skill development is the solution to this problem, whereas Kirlik (1995) posited that a skilled person restructures and exploits the environment, choosing a perception-action solution to a cognitive task. For example, cooks structure their environment, such as the location of items on the grill, to offload memory about cooking time.

ETA (Davis & Burton, 1991) is intended for the teacher to plan and apply during training—that is, to assess and instruct simple motor skills. The development of this method was prompted by a lack of consensus about terminology and operational definitions. Procedures of applying traditional task analysis to physical education were unclear (Davis & Burton) and did not include information on how to account for variations of environment and person when assessing and instructing movement (Burton & Davis, 1996). Fundamental is the idea that a movement form is dynamic and influenced by a variety of factors. Thus, the focus is on the constraints of the triad: task goal, environmental conditions, and performer characteristics (Davis & Burton, 1991). ETA maintains focus on the goal and acknowledges that many roads lead to accomplishing it.

The analyst selects a task goal and allows the student to choose the skill and movement form to accomplish the goal. Then the analyst adjusts task difficulty during training by varying parameters of task and person. ETA relies on tables published from previous research for relevant task and person

<table>
<thead>
<tr>
<th>Aspects of Expertise</th>
<th>Cues and Strategies</th>
<th>Why Difficult?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Past and future e.g., A large group of people walks in and orders at once as you start your shift</td>
<td>Change in rate of influx of people Anticipate larger orders of similar items Ensure sufficient supply of basic ingredients</td>
<td>Have to get all orders ready at once without much delay between orders at one table Novice tends to get stressed, makes timing errors, and loses track of orders</td>
</tr>
<tr>
<td>Big picture Big picture includes all the orders you have to keep track of and the timing of individual items</td>
<td>Coordinate some items indicating when to begin/end preparing other items Communicate with others when reaching bottlenecks</td>
<td>Novice focuses on one order at a time and loses track of other orders Novice has problems predicting bottlenecks</td>
</tr>
<tr>
<td>Noticing Change in sound level in the restaurant</td>
<td>Listen to people speaking louder Listen to people start repeating what they say</td>
<td>May be distracted by preparing food Noise from equipment and cooking makes hearing difficult</td>
</tr>
</tbody>
</table>

Note. The table is adapted from Militello and Hutton (1998).

Table 2. Sample Knowledge Audit Table From Applied Cognitive Task Analysis (ACTA) Showing Results of Expert Interviews With Short-Order Cooks
dimensions that influence a student’s performance. This method makes ETA strikingly different from other task analysis methods, in that it is not an analysis completed beforehand and then implemented. Instead, ETA is a process, and the analysis is applied in real time during training.

This form of ETA does not have a specific product comparable to products from the other methods. Part of the product lies in the factors provided by the literature, and part of the product is the training and application itself. For the short-order cooks, the ETA would involve identifying the triad for this task space. The task goal, for example, would be the number and type of orders to be prepared; the environmental conditions would include how constrained the work space is, whether there is one person or multiple people, and the noise level; and the performer characteristics would include experience preparing food and physical capabilities. These constraints are adjusted to accommodate and challenge the capabilities of the learner during training.

Kirlik (1995) suggested his version of ETA in response to a perceived shortage of models supporting environmental design, and it appeared in the domain of cognitive engineering. The main criticism of existing models was that few models adequately included and accounted for the environment’s contribution to behavior. The suggested solution was to change the basic unit of analysis from person to the person-environment because the environment places important constraints on behavior. Specifically, Kirlik asked for a model of skilled behavior to account for the environment’s becoming more structured and meaningful for the person over time.

Fundamental is creating two surface structures: the perceptual surface structure (i.e., information available in the environment) and the action surface structure (i.e., possible actions). The two structures are then examined in terms of their congruence. If the structures match, the environment allows fluent, perceptually guided activity. A mismatch indicates that the environment requires cognition to overcome a perceptual nonspecification of action (Kirlik, 1995).

The product of Kirlik’s (1995) ETA is a description of the mismatch (if applicable) between the perceptual and action-oriented surface structures. For the example of the short-order cooks, the perceptual surface structure would contain visual information from the stove and preparation areas as well as auditory information as servers state the orders aloud. The action surface structure may be constrained by visual accessibility of the space and signal-to-noise ratio for the relevant sounds.

**RECOMMENDATIONS**

As this brief overview of the methods, general process, required expertise, and resulting products shows, there are clear differences between types of task analysis methods. In practice, these methods can be ordered from general to specific according to the three levels of analysis mentioned earlier to guide an overall understanding of a task, its goals, and the environment (see also Figure 3). This also shows how complementary these methods are.

**HTA.** HTA is a valuable first step in an overall task analysis, illustrated by the fact that other analyses build on the results of HTA. The question addressed by HTA foremost is at the computational level; that is, focusing on the goal the task is trying to accomplish and redescribing it into subgoals. A high-order HTA provides a useful overview of the hierarchy of goals and subgoals of a task. Because the redesign occurs in terms of goals and not actions, an HTA of a task can be more easily validated. An HTA can also be reused when considering different methods and implementations for accomplishing the goals. Furthermore, validated HTAs of individual tasks may facilitate design of convergent products; that is, uniting functionalities of separate technologies into one technology.

**ETA (Kirlik, 1995).** ETA as defined by Kirlik (1995) would also be completed at a higher level of analysis because it focuses on functionality, specifically addressing how experts include and structure their environment. Goal-related questions as well as method-related questions are addressed, with an overall request for more attention to the environmental variable, the situational contributions to meaning and skillful behavior in general, and, specifically, the acquisition of situated skills.

**CTA (ACTA).** CTA adds a framework for addressing cognitive elements in a task that are largely left undefined by GOMS. HTA does not preclude cognition but also does not provide guidance about which cognitive goals to consider and include in the analysis. Although CTA somewhat addresses the goals of a task, the main focus of the analysis lies in gathering information about the methods and algorithms used to

![Figure 3. Suggested flow of task analysis methods based on level of analysis.](image-url)
accomplish a task. In general, the decision to perform a CTA requires the analyst to prejudge a task as mainly cognitive. However, some authors argue that all tasks require information processing and rely on cognition to some degree and that it would be more beneficial if understanding cognition were part of the overall task analysis process (e.g., Shepherd, 2001).

GOMS. A GOMS analysis is specific to a particular system design, which suggests that it is better situated at a later stage in the overall task analysis process. GOMS addresses questions at the algorithmic and implementational levels, focusing on specifying how a task is accomplished given a particular architecture. A GOMS analysis can be especially useful for estimating the extent of transfer of knowledge between different architectures, to run simulations, and to predict performance and errors.

ETA (Davis & Burton, 1991). ETA as defined by Davis and Burton (1991) introduces an additional perspective into using task analysis. ETA is directly applied during training and allows one to adjust variables to account for trainees’ interindividual variability.

CONCLUSION

In sum, task analysis methods vary in their processes, the expertise required to implement them, the products they yield, and the nature of the questions they can best answer. Our goal was to elucidate how the variety of task analysis methods can provide answers to questions posed at different levels of analysis (computational, algorithmic, implementational). A top-down approach as outlined in this article can guide HF/E professionals to a systematic understanding of a task and allow recycling of higher-level task analyses to determine new lower-level implementations. The interested reader is referred to Table 3 for additional readings.

REFERENCES


Table 3. Recommended Readings

<table>
<thead>
<tr>
<th>Task Analysis Method</th>
<th>Reference</th>
</tr>
</thead>
</table>

Note. HTA = hierarchical task analysis; GOMS = goals, operators, methods, and selection rules; ACTA = applied cognitive task analysis; ETA = ecological task analysis.
Choosing the Right Task Analysis Tool


Anne E. Adams is an independent human factors consultant. She received her PhD in the Engineering Psychology Program from the Georgia Institute of Technology in 2010.

Wendy A. Rogers is a professor in the Engineering Psychology and Cognitive Aging Programs at the Georgia Institute of Technology. She received her PhD in psychology from the Georgia Institute of Technology in 1991.

Arthur D. Fisk is a professor in the Engineering Psychology Program at the Georgia Institute of Technology. He received his PhD in psychology from the University of Illinois in 1982.

This research was supported in part by contributions from Deere & Company as well as a grant from the National Institutes of Health (National Institute on Aging) Grant P01 AG17211 under the auspices of the Center for Research and Education on Aging and Technology Enhancement (CREATE; www.create-center.org).

Copyright 2011 by Human Factors and Ergonomics Society. All rights reserved. DOI: 10.1177/1064804611428925