

## 1 Introduction

The value of experience and of understanding how to apply knowledge is described in a wonderful story, a story shared so often it has become one of those enduring urban legends. The story has many different versions,<sup>1</sup> involving various professions and famous people. In one version of the story the scientist and inventor Nikola Tesla visited Henry Ford at his automobile factory. The factory was having some kind of difficulty with its systems, and Ford asked Tesla if he could help identify the problem area. Tesla walked up to a wall of boilerplates, scanned them briefly, and then made an "X" in chalk on one of the plates. Examination of the boilerplate showed that it was indeed faulty. Ford was impressed, and told Tesla to send an invoice. The bill arrived, for \$10,000. Ford, never known for his generosity, was astonished at the cost of writing an "X" on the boilerplate, and asked for a breakdown. Tesla sent another invoice, which read:

Marking wall:	\$1
Knowing where to mark:	\$9,999

This story speaks directly to the purposes and goals of this book in two respects.

First, the story illustrates the "why" of Cognitive Task Analysis (CTA). What is it that Tesla knows, and how does he know it? What tells him what to do, with Henry Ford (not the most patient of men, by many accounts) looking over his shoulder? Capturing that knowledge and reasoning is one of the things CTA can do.

Second, the story illustrates the "how" of CTA. Cognitive Task Analysis can be thought of as a set of tools in a toolkit. Like any tool, CTA can be employed well and wisely, or it can be employed poorly or inappropriately. What tool would you use if you wanted to understand how Tesla was able to grasp the nature of the problem so quickly?

This book is about having the tools and the toolkit to understand how people think: how their minds work, what they struggle with, and how they manage to perform

complex work adeptly and pluck inventive solutions out of difficult, sometimes dangerous, situations. Our purpose in writing the book is to help people learn how to do CTA—how to collect data about cognitive processes and events, how to analyze it, and how to communicate it effectively.

### What CTA Offers

All CTA procedures have the general goal of helping researchers understand how cognition makes it possible for humans to get things done and then turning that understanding into aids—low or high tech—for helping people get things done better. The “work” may be that of a consumer who is using a product for the first time, or that of a weather forecaster who is trying to cope with data overload during a thunderstorm, or that of a firefighter who must figure out in seconds or minutes what to do about a dangerous situation. In all these cases, performance depends on what people know, what they perceive, what they believe, and how they think.

In many applications of CTA, the work is conducted in what are called “complex cognitive systems” (Hoffman and Woods 2000). These are work settings in which the knowledge and reasoning of individuals play a role (of course), but so do the cognition and reasoning of larger groups of people, including teams and even entire organizations. In addition, these complex cognitive systems often involve people interacting with computers and also interacting with each other via computers in intricate networks of humans and technology. Cognitive Task Analysis can show what makes the workplace work and what keeps it from working as well as it might.

Over the past several years an unusually broad population of individuals has become interested in CTA. People want to know how to do it, how to use it, and how to make it work for their organizations. Systems analysts need CTA methods to develop user specifications for new computer technologies. Trainers and instructional systems designers imagine applying CTA in order to describe the cognitive processes that need to be trained and how best to train them. Market researchers clearly understand the benefit of a lens into the minds of consumers and are discovering that CTA can offer ways to expose the thought processes involved in purchase decisions and product use. Program managers tasked with building new or improved technologies for military clients are embracing the notion that front-end analyses of the operators can help ensure that their systems work effectively. They look to CTA as a tool for understanding the cognitive requirements of those operators and the most effective combinations of humans and technology. Employers faced with a range of personnel issues wonder whether CTA could provide insights into selecting and retaining personnel. Healthcare pro-

viders and medical technology developers have begun to look to CTA to assist with enhancing patient safety and to identify and apply lessons learned from errors and accidents. Military commanders, faced with increasingly complex and dangerous missions, seek ways to best support planning and decision making in the field.

Across these many different types of work, there is recognition that CTA yields information people need. It provides leverage on deeply challenging problems, and when done well it provides solutions that can make a difference.

In writing this book, we hope to increase greatly the number of people with the skills and knowledge to conduct high-quality CTA. There are individuals and organizations with problems they cannot solve and opportunities they want to take advantage of. They need CTA tools and methods, and people who know how to apply them skillfully, across a range of problems and issues.

### Unpacking Cognitive Task Analysis

A good place to begin is with some definitions.

**Cognitive** When the tasks that people are doing are complex, it is not enough to simply observe people's actions and behaviors—what they do. It is also important to find out how they think and what they know, how they organize and structure information, and what they seek to understand better. This is a principal reason why the word “cognitive” begins the phrase Cognitive Task Analysis. Cognitive Task Analysis is a family of methods used for studying and describing reasoning and knowledge. These studies include the activities of perceiving and attending that underlie performance of tasks, the cognitive skills and strategies needed to respond adeptly to complex situations, and the purposes, goals, and motivations for cognitive work.

**Task** What about the second word in CTA, the notion of a “task?” It may seem straightforward to think about “task” as people engaged in discrete activities or sequences of activities aimed at achieving some particular goal. This is a traditional notion of “task.” But in complex cognitive systems, it is not always the literal action sequences—the steps—that matter as much as the fact that practitioners are trying to get things done; they are not simply performing sets of procedures. Therefore, we define task in this broader sense as the outcomes people are trying to achieve.

**Analysis** We use the term “analysis” deliberately. Literally, to analyze something is to break it into parts in order to understand both the component parts and their relationship in making up the whole. Cognitive Task Analysis methods provide procedures for systematic, scientific examination to support description and understanding. For scientists interested in pursuing research questions, we believe CTA presents a number



of opportunities and challenges (Klein, Phillips et al. 2003). For practitioners who are interested in CTA primarily to develop tools and technologies, the “analysis” component of CTA is particularly important. Cognitive Task Analysis provides a process for systematically identifying key cognitive drivers in many types of applications.

### Topics and Focus

This book is about both the “why” and the “how” of methods for studying thinking and reasoning in the course of performing real-world tasks in complex and dynamic work settings.

We primarily study adults in the workplace, and the methods described here have been developed within the world of adult work. The tasks that make up the working life of firefighters, nurses, military commanders, weather forecasters, or pilots may seem far from commonplace to you and me, but they are what fill the work lives of people in each of these occupations. Everyday tasks can also mean decisions and choices about products that face consumers on a daily basis.

Much of what we have written about here focuses on people’s reports about their own, lived experience—their stories and examples and their understanding of the work they do. As we will show, CTA study can reveal the risks, time elements, opportunities, and mistakes that confront people as they work. It can help us understand the workplace: the technologies, tools, work conditions, stressors, and team interaction modes that all contribute to cognitive performance. Cognitive Task Analysis can help us consider hypothetical conditions, such as the influence of system X or technology Y, or a work practice that increases tempo by a factor of two. These are all questions that have been posed by people using CTA.

We also share some of our own stories and experiences as CTA practitioners, including what we have learned about how to apply CTA methods and how to get them to work well. What factors make the difference between a great interview and a folder full of notes that don’t really say much? What techniques can determine whether data analysis yields an elegant Concept Map that conveys crucial knowledge about a domain or a bewildering mass of lines and arrows? How do seasoned CTA practitioners use a given set of methodologies to investigate problems and issues?

We have several goals in writing this book. First, the book is intended to help people learn how to do a CTA: how to collect data about cognitive work, how to analyze it, and how to use and communicate it effectively. We offer examples, guidance, and our

own experiences using CTA to investigate a wide range of problems, questions, issues, and domains. Our express purpose is to give people knowledge and tools that will allow them to conduct CTA studies.

Second, the book is intended to convey the reasons to do CTA: What is CTA good for? What sorts of questions can it answer? What problems can it address?

We offer a look at how experienced practitioners apply CTA in such arenas as aviation, the military, national security, health care, firefighting, emergency response, manufacturing, nuclear power, consumer research, and many others. We hope to give readers an understanding of why CTA matters and how it can make a difference. Details of methods do not mean much if the reasons for using the methods are not clear.

We chose to write about CTA methods that we have found useful for understanding cognitive aspects of work in order to share the expertise we have gained in performing CTA and provide an insider's perspective on the process of CTA data collection. These methods are the tools we use in our own work to pursue certain types of questions and to explore the cognitive landscape. For us, core questions concern how people think and reason in complex, dynamic settings that characterize real-world tasks. That said, every method carries particular assumptions with it. Every method opens some doors and leaves others tightly shut. Knowing the strengths and limitations of a particular method is critical to using it well.

We also believe that skilled and effective use of CTA methods means understanding something about the cognitive issues they have been designed to illuminate. Our experience helping people learn to use CTA methods has left us convinced that skilled CTA practice has to combine knowledge of specific methods and techniques with some conceptual grounding in cognitive theory and research. It simply isn't sufficient to pick up a tool and place it in your toolbox. To use it well, you have to also understand why the tool was fashioned in a particular way and how the tool came to be. Doing CTA well requires knowing what a cognitive perspective can offer for understanding problems and issues of work. With that in mind, we provide an overview of current work on cognition—of how people think, reason, and make decisions—in the real world.

If we are successful in meeting these two goals, we will satisfy a third one: to expand the circle of CTA practitioners. We hope to foster a community of research practitioners who have the necessary skills and knowledge to conduct CTA, who can provide useful information and effective application to individuals and organizations, and who can advocate for its use. Although learning to do CTA can be a demanding experience, the insights and perspective to be gained make the challenges of learning to do it

worth the investment. One primary reason for writing this book is to present the details of the CTA process, to provide a road map for how to conduct a CTA. We want to make the methodology more accessible and the skills involved in CTA practice more attainable.

In terms of coverage of the types of CTA methods and applications, the book is selective rather than inclusive. We chose not to write a survey volume with brief summaries of many different methods. There are some excellent survey volumes and review articles available, and we recommend that you spend some time with them in order to gain an overview of the breadth of methodologies available (Bonaceto and Burns 2003; Cooke 1994; Hoffman 1987; Jonassen, Tessmer, and Hannum 1999; Patrick 1992; Schraagen, Chipman, and Shalin 2000). Instead, we have presented an overview of the field and then homed in on a smaller number of methods to provide detailed descriptions of the CTA process, offer specific guidance, describe examples from our own work, and supply practical tips. We believe the narrower focus and specificity of detail will be particularly helpful for people who are new to CTA. We also expect that people who are experienced with other forms of behavioral task analysis, or who are seasoned interviewers, will find this book interesting and useful for expanding their skills to encompass cognitive components of performance.

### Talking to the Reader

Across the pages of this book we present many suggestions. Some are pretty firm guidance about the "how to" of CTA. Some convey lessons learned or cautionary tales. Some are specific descriptions of steps in procedures and may seem rather prescriptive. Others are best regarded as advice.

In our efforts to present advice and guidance, we occasionally speak directly to you, the reader, as an individual who is interested in learning about and possibly conducting CTA. Thus, for example, we say in chapter 2:

The three primary aspects of CTA are knowledge elicitation, data analysis, and knowledge representation. Each of these aspects is critical to a successful CTA study. Many people equate CTA with the first aspect, eliciting the knowledge, because traditionally that has received the most attention. But if you don't do a good job of analyzing your data, why bother collecting them? And if you don't represent your findings so that others can understand them and why they matter, what have you accomplished?

It is our hope that this style of directly addressing the reader is not perceived as overly familiar or informal. We are simply trying to communicate clearly and in a way that is meaningful to you, the reader, as we present the concepts covered in this book.



## Organization of the Book

The book is organized into three major sections:

Part I, "Tools for Exploring Cognition in Context," provides detailed guidance for planning and carrying out CTA. It includes chapters on capturing knowledge and on capturing the way people reason. We rely on this distinction throughout the book: CTA investigates what people know and how they think.

Part II, "Finding Cognition," provides a perspective on studying cognition in real-world settings and what an expanded view of cognition—a macrocognitive framework—offers. We describe some of the issues that surround CTA and what it means to study cognition in context. We end the section by exploring the challenges of rapidly changing technology.

Part III, "Putting CTA Findings to Use," describes key issues in applying CTA findings to several applications areas: technology development, training and instructional design, and market research. We also present a chapter on the role of CTA in the development of measures for evaluating cognitive work.

Our intent in writing this book is to share what we have learned about CTA, from our experience in the field to the concepts and models we draw on. We have offered examples and suggested ways to apply CTA findings to real-world problems and issues. We hope this book provides you with some tools you can use in your own practice and that the CTA methods can help you discover how people like Tesla know where to put their chalk marks.