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CHALLENGES SUPPORTING COGNITIVE ACTIVITIES IN DYNAMIC WORK ENVIRONMENTS:

APPLICATION TO POLICING

A Thesis in
Information Sciences and Technology

by

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ABSTRACT

Municipal police officers perform cognitive activities, such as decision making, judgment and problem solving, while facing real world constraints that include large, socially distributed problem spaces with potential for high risk outcomes.

As such, the goal of this dissertation is to improve cognitive effectiveness in the policing domain by integrating Cognitive Systems Engineering methodologies to achieve three objectives:

1) Developing an understanding of the police domain and its constraints on the cognitive activities of officers,

2) Analyzing sources of complexity and needs in the cognitive activities of officers, and

3) Exploring technology interventions to reduce officer task complexity and accommodate domain constraints.

The results include eight findings with implications for cognitive system design. The findings suggest it is possible to improve the use of technology to enhance cognitive effectiveness, and that there are strengths in combining methodologies to explore the feasibility of cognitive interventions.
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I dedicate this dissertation in memory of my father, Dr. Paul J. Glantz, Sr. Above, Dr. Glantz shares his new PhD diploma (Penn State – 1958) in Microbiology with (from left) nephews Michael and Eddie Seibel, sons Louis and Paul, wife Norma Mae, and sons Thomas and John. Dr. Glantz overcame early obstacles when, at the age of 15, he permanently lost his hearing while seriously ill with spinal meningitis. During the illness, both of his parents passed away. Dr. Glantz published numerous scholarly articles and created an internationally recognized E.Coli research center at Penn State that continues to this day. He retired Professor Emeritus in 1979. Dr. and Mrs. Glantz raised 7 children: Kathryn, Paul Jr., John, Thomas, Louis, Edward and Frank.
Chapter 1

Introduction
As it gets close to bar closing time, Officer Stevens finds herself behind a suspicious car. As they slow to a traffic light, she decides to reach over and enter the car’s license into her mobile data terminal. Although her attention was only diverted for a moment, she still ran into the car she was looking up.

Officer Corl is responding to a silent bank alarm. Unfortunately, there are so many new banks in that part of town that he went to the wrong one. The second bank was not right either. Frustrated and delayed, he finds the bank on the third try.

Officer Walker approaches a house to serve a warrant. He wishes he had more information from the caseworker. As the door opens, his fears are confirmed – it is now a barricaded gunman situation.

In their performance of duties, police officers need to make effective decisions, show good judgment, remember details and react quickly to evolving situations. This is not always accomplished, however, as illustrated above. The officers in these and other scenarios were observed and interviewed as they worked in an effort to understand and improve the cognitive aspects of their work. This chapter introduces the challenges to achieving effective cognitive work in policing and discusses reasons why this is an important dissertation topic to investigate. This is followed by a discussion that examines two perspectives of problem analysis: domain practitioner and cognitive engineer. Next, the goals and objectives of this research are discussed and key contributions are summarized. This chapter concludes with a roadmap of the rest of the dissertation.

Police work involves uncertainty, evolving scenarios, collaboration with other officers and agencies, and information derived or mediated by information systems. This combination of complex work, officers and system dependence often results in suboptimal results. In several situations, the information systems that were intended to
support officer cognitive activities, such as judgment and decision-making, actually had an opposite effect. For example, poorly designed interfaces, partial system access or limited system availability resulted in cognitive breakdowns that could distract officers in the performance of their duties. In other situations, support tools that could have helped were noticeably missing, also creating an unnecessary cognitive burden on officers.

An understanding of this problem is important to domain practitioners, cognitive engineers and researchers. Effective cognition and collaboration is important to police who are faced with increasingly high stakes and risks that result from the outcomes of their decisions. Cognitive engineers are challenged with evaluating, designing and implementing systems that support the cognitive needs of their users in the context of the user’s work. Researchers seek to better understand the cognitive processes of workers in dynamic settings where time constraints, uncertainty, changing scenarios and risks to life and property create challenges for decision makers.

The goal of this dissertation is to improve cognitive effectiveness in the policing domain. This goal is accomplished through three objectives:

1. Develop an understanding of the police domain, and the effect domain constraints place on the cognitive activities of officers,

2. Analyze the cognitive tasks undertaken by police officers to identify sources of complexity and specific officer needs, and

3. Explore technology interventions to reduce task complexity and accommodate domain constraints.

Objectives one and two reflect analytical efforts, while objective three extends this analysis into design intervention.
There are five contributions from this dissertation:

1. Development of the MAKADAM methodology that facilitates identification of cognitive support interventions by integrating ethnography, knowledge elicitation and active participatory design,
2. Design of a prototype that supports the cognitive activities of police officers during critical incidents,
3. Extensive collection of policing data over a 2 year period,
4. Analysis of policing data and 8 analytical findings, and
5. Integration of findings and prototype into a series of design and research recommendations.

These contributions are presented in more detail at the end of this dissertation.

The remainder of this dissertation is arranged in five chapters (Figure 1). Chapter 2 reviews the literature that informed this dissertation, including types of cognitive work and investigation frameworks. Chapter 3 describes the ethnography and knowledge elicitation methods used to analyze the cognitive domain and tasks of police officers, as well as the participatory design methods used to develop the prototype. The analytical results (ethnography and knowledge elicitation) are presented in Chapter 4, while Chapter 5 presents the intervention results in the form of a prototype. In addition to contributions, chapter 6 presents the conclusions from this dissertation as well as future research.
Figure 1 Dissertation Storyboard
Chapter 2

Literature Review
The goal of this dissertation is to improve cognitive effectiveness in the policing domain by accomplishing two analytical and one intervention objectives. The first analytical objective is to develop an understanding of cognitive constraints within the police domain, and the second is to develop insight into the complexity of cognitive police tasks. These understandings can then be used to explore a technology intervention objective to reduce task complexity while accommodating domain constraints. This chapter begins by introducing Cognitive Systems Engineering (CSE), the research specialization that provides the foundation for this investigation. After introducing CSE, types of work are discussed including gaps in effective work that have been identified in the literature. This is followed by a discussion of the methods and frameworks used by cognitive engineers to understand work in its context. The analytical methods that will be used to understand the domain and the task complexity (objectives one and two) are then presented. Finally, this chapter describes the approaches to intervention that will be used to explore objective three.

2.1 Cognitive Systems Engineering (CSE)

There are several methodological and theoretical foundations available to study the design of digital artifacts used in work, including Cognitive Systems Engineering (CSE)\(^1\), Human Computer Interaction (HCI), and Computer-Supported Cooperative

\(^1\) The terms Cognitive Systems Engineering (McNeese, 2002), Cognitive Engineering (Vicente, 1999) and Cognitive Systems (Woods, 1998) may be used interchangeably. All focus on the design of artifacts that do cognitive work or that change the cognitive work of practitioners. This research uses the term Cognitive Systems Engineering.
Work (CSCW). This section describes differences in the method, level of analysis and scope of these three approaches.

CSE is a multidisciplinary field with scientific conceptual foundations originating in the 1980’s (Hollnagel & Woods, 1983; Norman, 1986; Rasmussen, Pejtersen, & Goodstein, 1994; Woods & Roth, 1998). Since then it has evolved from a scientific endeavor to also include tools and methods to inform engineering design (Dowell & Long, 1998; Eggleston, 2002). CSE now represents both a theoretical science and practical engineering within the context of system design for complex systems (Figure 2). Furthermore, CSE “toolkits” or frameworks have been developed for the analysis of work domains (McNeese, Zaff, Citera, Brown, & Whitaker, 1995; Potter, Roth, Woods, & Elm, 2000; Vicente, 1999). Each framework represents multiple techniques, methods and approaches for knowledge elicitation, knowledge capture and design support.

---

Figure 2 CSE links design with conceptual foundations (Eggleston, 2001, p. 6)
CSE is useful to study work environments that find “users in an information-rich world with little time to make sense out of events surrounding them, make decisions, or perform timely activities” (McNeese, 2002, p. 80). CSE takes a user-centered and problem-based focus to designs that support users in complex settings. This means creating designs that are not just usable, but also useful in supporting decisions and other cognitive activities within time constraints at varying levels of information richness.

The relevance of information technology, and the information it processes, is highly dependent on the user’s ability to use and understand the technology (McNeese, 2002; Woods, 1998). Cognitive systems engineering expands the level of analysis beyond the user or the computer-user dyad. The unit of analysis in CSE is a cognitive system (Roth, Patterson, & Mumaw, 2002; Woods & Roth, 1998). This is a triad consisting of the user, the system and the work context. As such, CSE is a method suitable for analysis of collaborative activities and represents a significant strength relative to traditional human-computer research which tends to focus on either the user (i.e. solitary cognition, problem-solving, sensemaking) or the user with the user’s machine (i.e. human-computer interface issues and key stroke models). A major benefit of CSE is insight into relationships between the social and material world and their influences on the cognitive processes of the human actor. A CSE approach emphasizes environment and context and allows for a distributed unit of analysis that measures the complex interdependencies between the user and the user’s artifact, and in socially

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2 To enhance readability in this dissertation, the first appearance of a critical term will appear in bold. To enhance navigation, references to figures, tables chapters and appendices will also be in bold. Italics will be used for emphasis.
distributed work, the other users and their artifacts. This distributed unit of analysis integrates the user, technology (digital artifacts) and environment and provides theory, methods and analysis that support identification of system design principles, issues, and tradeoffs. These studies are useful in answering questions such as:

- Who needs to communicate with whom, when and how? (Workspace Design),
- What information needs to be shared? (Artifact Features), and
- Who has what information and when? (System Design).

In its origins, CSE distinguished itself from other human-computer design approaches by being more applied and grounded in contextual constraints.

2.1.1 Other Design Approaches

Other human factor approaches for the analysis and design of digital artifacts and work include Human Computer Interface (HCI) and Computer-Supported Cooperative Work (CSCW).

2.1.1.1 Human Computer Interaction (HCI)

HC1 emphasizes usability, and as such has been a focal area for computer science research and development as well as applied social and behavioral science. This interdisciplinary research program congealed and grew rapidly in the 1980’s along four independent research threads (Carroll, 2002):
The focus on “user interface software and tools is concerned with user interface concepts and metaphors, display and interaction techniques, and software development methods [have been the] most visibly successful area of HCI” (Carroll, 2002, p. xii).

Cognitive perspectives influenced traditional or “mainstream” HCI. Early HCI work focused on replacing human skill (or lack thereof) with systems comprised of software agents that would operate around the user. In some cases, the user was viewed as a weak link in the system. Terms such as “naïve user” and “idiot-proof system design” support this by implying an inept user. In addition, the small, controlled laboratory experiments favored by HCI researchers had difficulty generalizing to the social nature of work in real world settings. Some researchers felt that not incorporating a use-setting was a major problem for HCI work based in cognitive science (Bannon, 2001; Hollnagel & Woods, 1983; Sutcliffe, 2000; Sutcliffe, Carroll, Young, & Long, 1991).

Perhaps as a result, recent efforts have proposed using sociologically derived methods such as ethnography to refocus HCI to studies of work in the workplace, (Button, 2003). Others have proposed reformulating HCI with a distributed cognition perspective, as opposed to human information processing models that were common during HCI’s inception (Hollan, Hutchins, & Kirsh, 2000). Either way, it is encouraging to see the increasing recognition by HCI practitioners of the importance of the work context and the elements of social cognition in human-machine studies.
2.1.1.2 Computer-Supported Cooperative Work (CSCW)

CSCW developed as a sub-community of HCI around 1986 to emphasize the social context of groupware systems that began to evolve in the 1970’s (i.e. ARPA Net email and Usenet groups) (Carroll, 2002). This is important, since work frequently requires the cooperative efforts of a team (Kraut, 2003; McNeese, Zaff, & Brown, 1992), and groupware plays a critical role in facilitating situated and distributed teamwork. As a result, CSCW’s focus has been on groupware systems and the resulting cooperative activity within varied communities of workers and collaborators (Carroll, 2002; Grudin, 1994). CSCW research varies in terms of focus (i.e. technical infrastructure, architecture, application, task, and people) and group size (i.e. individual, dyad, small group/ team, organization, society). Engineering oriented disciplines focus on building systems, while social science disciplines focus on identifying social phenomenon and causal mechanisms (Kraut, 2003). Just as interpretations of “interaction” within HCI have allowed that field to evolve, so have interpretations of “cooperative” within CSCW allowed this field to evolve (Bannon, 2001; Grudin, 1994).

2.2 Types of Work

The intent of CSE is to design artifacts that are user-centric so that the artifact becomes part of and even improves the cognitive work to which it is attached (Woods, 1998). Therefore, to achieve productive error-free work it is important that designs carefully consider work in its various forms, as well as new relationships resulting from the introduction of design interventions.
2.2.1 Intrinsic Constraints and Current Work Practices

In order to analyze work and design complex systems to support work (in ways to emphasize safety, productivity and health), it is useful to distinguish between intrinsic work constraints and current work practices. **Intrinsic work constraints** are independent of any artifacts currently in use. Intrinsic constraints “delimit the actions that are required to get the job done, not the actions that are required to get the job done with a particular device” (Vicente, 1999, p. 96). Intrinsic constraints originate in the environment, the organization, with the workers and with the system itself to impact each other and shape the work context. Examples of environmental constraints include mountain location in air traffic control and laws of physics for a power plant, while organization constraints include training and technology adoption practices. Worker constraints include cognitive and ecological elements such as goals and context, while system constraints include issues of usability and usefulness, among others.

**Current work practices** are dependent on current artifacts and represent actions used by workers to complete tasks with the tools at their disposal. As shown in **Figure 3**, **Functional actions** occur at the intersection between intrinsic work constraints and current work practices, and represent work that is effectively supported. **Workaround**

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3 In some cases, organizational constraints stem from a view of end users as a source of error. An alternative view suggests that users should be seen as a system resource capable of actively resolving uncertainties, conflicts, and competing demands. This latter view rejects the term “human error” since it masks the constraining influences that led to a system user being in a situation where error could occur. This view recognizes that all stakeholders (i.e. regulatory bodies, administrative entities, economic policies and technology design and development organizations), and not just the end user, contribute to both the conflicts that confront users and the ability to manage those conflicts (Woods, Johannesen, Cook, & Sarter, 1994). For example, managers set safety policies by which end users must abide. The ability of end users to succeed is often influenced by such constraints (Reason, 1998; Woods et al., 1994).
activities highlight current system inefficiencies. These are “overhead” actions that
workers must perform to compensate for poor system design. Currently unexplored
possibilities represent another form of inefficiency resulting from intrinsic work
constraints which are not currently part of the system design. Although they may
represent very productive ways to complete a job, they are not exploited. The
identification of these functional actions, workaround activities and currently unexplored
possibilities represents an important reason to conduct field studies of work under
naturalistic conditions (Hutchins, 1995; Vicente, 1999; Xiao & Milgram, 2003). This is
important since new designs should not necessarily support work in its currently
articulated form, but rather should attempt to overcome current system inefficiencies and
exploit new opportunities.
This dissertation focuses on cognitive activities supported by complex sociotechnical systems in dynamic work environments specifically for police activities. Complex systems are those where machines mediate cooperation between people or collaborative control of some technical system (Vicente, 1999). The nature of complexity in dynamic environments stems from the presence of characteristics that increase cognitive demands on workers, such as the amount of information needed and whether this information must be shared and processed by others, as well as risks to the worker and environment (Vicente, 1999). Examples of unsuccessful sociotechnical systems in dynamic environments include reactor destruction at Three Mile Island and
Chernobyl, onboard Apollo 13 explosion, the space shuttle Challenger disaster, and grounding of the tanker Exxon Valdez (Woods et al., 1994).

According to Rasmussen et al. (1994) normative, descriptive and formative techniques may be used to analyze current work environments. Each is discussed below.

2.2.2 Normative (Legislating) Work

A diverse set of normative methods exists for the analysis of work, including input-output, sequential flow and timeline task analysis (Vicente, 1999). In general, normative methods are used for task analysis (as opposed to work domain analysis which is discussed in the next section). Normative methods for task analysis have their roots in Taylor’s scientific management methods (Taylor, 1947), and include the GOMS (Goals, Operators, Methods, Selection Rules) method in HCI (Vicente, 1999).

Task analysis is associated with normative methods that are based on the belief that there is one best way to perform a task. This means, for example, that if we identify and analyze an expert performing a certain task (bricklaying, for example), then those results could be replicated by legislating that other workers mimic the expert’s activities and use of tools. The shortcomings of this approach are twofold. First, even the expert’s performance is constrained by current artifacts. A better approach would recognize the potential to enhance the expert’s performance with new tools that reduce workarounds and/ or address unexplored opportunities. Second, it is not assured that what works for
one expert will be appropriate for others, especially if they do not share the same mental model\textsuperscript{4} regarding work.

Normative methods of task analysis have been used to evaluate work for half a century and as such they represent a very common form of work analysis (Taylor, 1947; Vicente, 1999). Although suitable for some interventions, normative methods are not sufficient for analysis of sociotechnical systems in dynamic environments, primarily due to the non-routine nature of these work environments.

2.2.3 Descriptive (Portraying) Work

Descriptive work analysis improves upon normative techniques in open-systems\textsuperscript{5} by analyzing actual work and seeking to portray what workers do and would like to do. In particular, descriptive techniques do not assume one best way to perform tasks. By studying work as it actually evolves in naturalistic settings, these techniques also disclose the clever adaptations of workers to the dynamic challenges of work (Hutchins, 1995; Suchman, 1995; Vicente, 1999).

Work dependent on complex systems and open to disruptions from the environment needs to facilitate worker adaptation to unanticipated events. Vicente (1999) states that successful descriptive studies have already led to significant theoretical

\textsuperscript{4} A mental model is an “explanation in someone's thought process for how something works in the real world. It is a kind of internal symbol or representation of external reality, hypothesized to play a major part in cognition.” (downloaded 5 May 2006 from http://en.wikipedia.org/wiki/Mental_model).

\textsuperscript{5} Open systems interact with the environment and thus can incur unanticipated disturbances. Closed systems do not interact with the environment (i.e. lab settings) and have fewer possible outcomes and less need for operators to adapt.

Although descriptive analysis provides a basis for designing interventions needed to resolve shortcomings, a problem may occur if the new artifact leads to new limitations. Depending on perspective, this is called the task-artifact cycle (Carroll, Kellogg, & Rosson, 1991) or envisioned world problem (Woods, 1998). Resolution of this problem may be addressed in whole or in part by using participatory design methods (McNeese et al., 1995; Woods, 1998). In these cases the cognitive engineer works with the user to generate mutually acceptable findings, build new designs based on them, and cycle new ideas and feedback. The researcher as designer needs to base judgments on the interconnections of use, user, and artifact which congeal in the work practice/context (McNeese et al., 1995; Woods, 1998).

2.2.4 Formative (Idealized) Work

To further reduce envisioned world problems, descriptive work analysis may be supplemented with formative (predictive) techniques (Vicente, 1999). For example, data collection of current work practices can inform descriptive analysis, which can then be used to create generalized models of intrinsic work constraints. Identification of these critical constraints can be used in the formative process of designing new idealized systems that hopefully get it right the first time. This is especially important in dynamic environments where sociotechnical systems affect safety, productivity and health.
CSE frameworks recognize intrinsic constraints allowing designers to overcome task-artifact or envisioned world problems and create formative interventions that treat workers as flexible, adaptive problem solvers.

2.3 Frameworks for Analyzing Cognitive Work

Cognitive Systems Engineering is a participatory approach to design that is represented by various frameworks consisting of techniques, methods and approaches for eliciting and capturing domain expert knowledge for design innovation support. **Cognitive Work Analysis** is an example of the Rasmussen system design framework (Rasmussen et al., 1994; Vicente, 1999), while **AKADAM** (Advanced Knowledge and Design Acquisition Methodology) is an example of the McNeese framework (McNeese et al., 1995; Zaff, McNeese, & Snyder, 1993).

Frameworks combine sets of knowledge elicitation techniques to help designers understand various aspects of cognitive work and systems. The results could lead to design interventions that allow workers to adapt to the unexpected and changing demands of their jobs. These frameworks represent different combinations of knowledge elicitation tools for the analysis of cognitive activity. This dissertation uses a modified form of AKADAM.
2.3.1 Cognitive Work Analysis

The Cognitive Work Analysis (CWA) framework is an example of a designer-centric CSE approach to design based on the work of Jens Rasmussen and his colleagues at Risø National Laboratory (Rasmussen et al., 1994; Sanderson, 2003; Vicente, 1999). The CWA motivation came from a recognition of the need for a new approach to inform system design, organize and integrate design data derived from different instruments, create a unique framework to design systems for complex (cognitive and social) work environments, and reduce impressionistic and ad hoc research and design of computer-based work. The result is a framework that can be adapted and modified to fit the particular needs of a research and/or design team.

The overarching goal of CWA is to develop systems that are inherently safe, productive and healthy. The framework seeks to accomplish this by satisfying the following subgoals (Vicente, 1999):

- Support workers adapting to and coping with unfamiliar events that have not been anticipated by system designers,
- Identify functionality required to accomplish intellectual tasks requiring discretionary decision-making (usefulness),
- Understand human capabilities and limitations (usability), and
- Improve decision latitude by providing workers with the autonomy to make decisions and the opportunity to exercise and develop skill.
To accomplish these goals, Vicente (1999) a tiered investigation was developed to explore ecological and cognitive constraints of workers (Figure 4). The CWA framework incorporates ecological constraints in contrast to exclusively cognitive viewpoints popular with psychology and HCI. Although CWA considers both viewpoints important, this framework suggests not considering cognitive constraints until after ecological compatibility has been determined (Rasmussen et al., 1994; Vicente, 1999).

Figure 4 Cognitive Work Analysis (CWA) framework
(Adapted from Vicente, 1999, p. 115)

Figure 5 expands the five constraint levels of the CWA framework with examples of questions that are addressed at each level along with possible design interventions.

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6 Ecological constraints originate in the surroundings and work environment of the user, as opposed to cognitive constraints that originate in the thinking processes of the user (Vicente, 1999).
Researchers have suggested that not all design cases warrant the cost and time required to carry out a full Cognitive Work Analysis, especially since any given knowledge elicitation technique often generates insight into more than one constraint level. This can effectively reduce the number of techniques actually required for an investigation (Sanderson, 2003; Vicente, 1999).

Further, knowledge elicitation techniques not specifically prescribed by the CWA framework might also be considered appropriate (or more appropriate, in some cases) for the different constraint levels. Thus, researchers often select combinations of techniques based on their needs, skills and the situation (McNeese et al., 1995; Potter et al., 2000; Vicente, 1999). Other techniques include, for example, structured interviews, critical

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**Figure 5** Complete CWA framework  
(Vicente, 1999, p. 301)
incident analysis methods, field study methodologies and methods based on scaled world simulations.

### 2.3.2 AKADAM

AKADAM (Advanced Knowledge and Design Acquisition Methodology) is an example of a user-centric CSE toolkit that has been used successfully in the design of complex systems for military and aviation use. It features the user in a participatory design approach that begins by gathering knowledge regarding users, tasks, and their environment (McNeese et al., 1995; Zaff et al., 1993). Its primary focus is to overcome conventional human factors engineering limitations including:

- Segregate the user, task and environment (social, technological, and organizational) into discrete units of study that overlook interactions between the constraints,
- Treat the user as a passive rather than active source of knowledge in the task domain,
- Suffer from functional isolation that separates those performing analysis, design and evaluation, and
- Suffer from temporal isolation from a sequential process that leads to bottlenecks and dead ends.

To offset these shortcomings, AKADAM’s participatory approach promotes active design participation by users in a collaborative process with the designer that features an understanding of constraints and their interactions.
AKADAM researchers believe designs should be user-centric, rather than technology (or designer or cognitive engineer) centric. Existing technology-centric designs resulted from a history of specialization leading to a separation of artifact designer and end user. Performance improvements result from either extending the user’s capacities (effectivities) relative to the environment, or changing the environment to increase the user’s capacities (affordances). User-centric design seeks to accomplish this by involving user-experts in the design process, as well as immersing designers in the work processes. Technology-centric approaches may result in artifacts that produce patterns of errors by failing to address user capabilities within design limitations (McNeese et al., 1995).

User-centric, participatory design encourages a mutual learning process between domain-experts and knowledge elicitors. This can be accomplished by using knowledge elicitation tools that depict knowledge in a way that allows both parties to check and confirm mutual understanding, thus reducing errors or omissions. The AKADAM toolkit, for example, includes a functional task decomposition tool (IDEF), design storyboarding, and concept mapping. IDEF\(^7\) (Integrated computer-aided manufacturing DEFinition) is a functional task decomposition tool used to identify key task decisions and information requirements. Design storyboarding and scenarios (from film and theatre production) are used to brainstorm design solutions with the domain expert in a

\(^7\) IDEF was initiated and developed at Wright-Patterson Air Force Base Materials Laboratory during the 1970’s and 1980’s as part of the efforts to modernize technology by specifically focusing on Computers in Manufacturing (CIM) initiatives. (downloaded 12 April 2006 from http://en.wikipedia.org/wiki/IDEF).
participatory-design manner. Concept maps are used interactively to share knowledge about the expert’s task domain.

2.3.3 Modified-AKADAM (MAKADAM)

This dissertation uses a modified version of AKADAM (MAKADAM) to explore the ability of a user-centric aid to support the cognitive needs of police officers in dynamic environments. This begins with an artifact-independent analysis of the cognitive work domain resulting in an abstraction hierarchy diagram, followed by a task analysis resulting in scenarios and concept maps. The substitution of functional decomposition methods should not change the outcome, although domain experts may find it easier to work with the abstraction hierarchy. This provides an opportunity to explore decomposition techniques within the participatory AKADAM framework.

Both MAKADAM and AKADAM attempt to link cognitive analysis to cognitive engineering. They use different techniques to model the cognitive domain (the former uses abstraction hierarchy, while the latter uses IDEF). In addition, MAKADAM precedes knowledge elicitation with extensive use of ethnography. Finally, MAKADAM emphasizes an active participatory design environment where users manipulate design artifacts to refine the prototype.  

The order of methods in MAKADAM is important. Beginning with ethnography allows the researcher to identify ecological constraints in the work domain prior to 

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8 In this dissertation, end-users actively manipulated actual elements of the prototype in an iterative design and development process. The added realism represents a positive benefit for effective design understanding.
addressing cognitive constraints during knowledge elicitation. Ethnography allows the researcher to become more familiar with the domain while also developing important relationships with participants. Both provide a solid foundation for subsequent knowledge elicitation and participatory design stages.

2.4 Knowledge Elicitation (KE) and Representation Methods

Design interventions based on descriptive and formative work analysis enhances design acceptance and worker satisfaction. This user-centered approach is based on knowledge elicited from domain practitioners (McNeese et al., 1995).

The objective of knowledge elicitation has expanded beyond simple knowledge capture to also include insight into cognitive activities dependent on expert knowledge. These include decision-making, perception, planning and diverse applications such as intelligent tutoring systems, adaptive computer interfaces, intelligent agents, training and selection for human resources, human-computer interaction, human factors and cognitive engineering (Cooke, 1994; Potter et al., 2000).

Several researchers have summarized elicitation techniques (Cooke, 1994; Hoffman, Coffey, Carnot, & Novak, 2002; Potter et al., 2000). Cooke, for example, grouped techniques into three areas by mechanics: observation and interviews, process tracing, and conceptual techniques. These are described below with emphasis on those techniques specific to this dissertation including abstraction hierarchy, critical decision method, decision ladder templates and concept mapping.
2.4.1 Observation and Interview

These methods include ethnographic techniques such as direct observations and interviews with domain workers (Cooke, 1994; Potter et al., 2000). The focus of the observations can be real or simulated tasks, limited information tasks, constrained processing tasks, and tough cases. A benefit of observation is the ability to discern task strategies that are not conscious to the worker, as well as domain limitations and constraints. Observation is also useful to verify an expert’s description of work. Problems with observation include influence from the presence of the observer, difficulty interpreting collected data, and environment constraints precluding direct observations such as a single seat aircraft.

Interviews (specifically unstructured interviews) are a common method of task analysis and knowledge elicitation. Since they require little interviewer experience within the domain, they are especially useful for early elicitation sessions. The downside is that volumes of data can be generated that must be processed through extensive transcribing and coding. Task analysis methods based on observation focus more on a behavioral level such as understanding what a worker does, rather than what is known (Cooke, 1994; Vicente, 1999). Combining observation and interview provides an opportunity for the researcher to understand why a worker performs a task a certain way, in addition to the how.
2.4.1.1 Abstraction Hierarchy

Rasmussen (1985) developed abstraction hierarchy diagrams as a technique for researchers to model the work domain with knowledge elicited during field ethnographies. The diagrams include means-ends data plotted vertically to represent the goals, priorities, functions, processes and objects within the domain. In some cases, whole-part decomposition data is then plotted horizontally to represent systems, subsystems and components within the domain. As shown in Figure 6, each strata of the hierarchy represents “what” is being done at that level within the work domain. The strata immediately above will explain the ends or “why” those things are done while the strata below will explain the means or “how” these things are accomplished. Modeling the work domain as such allows researchers to capture the environment within which work is done, independent of any specific tasks, artifacts or current work practices.

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9 When means-ends or abstraction hierarchy data is plotted with whole-part decomposition data, the resulting diagram is referred to as an “abstraction decomposition” diagram.
Abstraction hierarchy diagrams also attempt to provide context to the motivation behind tasks which can become masked by institutionalized processes and behaviors, or in some cases, forgotten. Currently unexplored possibilities within work environments may also be disclosed, benefiting design interventions.

2.4.2 Process Tracing

Process tracing techniques (Cooke, 1994; Potter et al., 2000) are useful for cognitive task analysis since they focus on the performance and thinking behind activities. They can be applied with little practice and thus have been frequently used. Unlike the family of interview and observations techniques, process tracing techniques...
typically specify both the knowledge elicitation and analysis methods. Examples include thinking aloud techniques, observation of nonverbal behaviors, protocol analysis and critical decision methods.

2.4.2.1 The Critical Decision Method (CDM)

The critical decision method is a retrospective interview strategy involving a series of cognitive probes to progressively uncover perceptual cues and information used by experts to make decisions during non-routine events. Klein, Calderwood and MacGregor developed the CDM based on J. C. Flanagan’s Critical Incident Technique (Flanagan, 1954; Klein, Calderwood, & MacGregor, 1989).

The probe questions used to perform the CDM are based on Klein's Recognition-Primed Decision (RPD) model (Klein, 1989; Klein, Calderwood, & Clinton-Cirocco, 1986). The RPD is a naturalistic decision-making theory focusing on worker judgments and decisions in dynamic environments consisting of high stakes and time pressures involving multiple players and ill-defined goals. The RPD model suggests that during critical incidents, domain experts use knowledge, training, and experience to quickly recognize and develop a course of action. This is in contrast to decision-making processes requiring time to deliberate and to methodically evaluate alternatives against a common set of abstract evaluation dimensions.

The CDM is conducted in several iterations. In an interview setting, the researcher asks the domain expert to recall a past non-routine incident. The person describes the incident including a general description of the incident as well as his or her
role, actions, thoughts, and observations during the incident. Next, the expert is guided to develop a more detailed chronology of the incident based on the recollections. To assist the expert’s recall, the researcher asks questions to help fill in gaps or develop details in the chronology. Finally, the researcher asks questions regarding decisions that were made, the cues and knowledge required to make those decisions, and possible decision differences based on the expert’s experience level.

Focusing on non-routine or critical incidents provides insight into the expert’s unique skills and knowledge. The CDM is an effective method for indirectly accessing expertise and cognitive skills not otherwise available for conscious retrieval. The representation of knowledge elicited by CDM can be in the form of a table or a Decision Ladder. The Situational Assessment Record (SAR) table (Table 1) outlines the expert’s cues, knowledge and decisions while the Decision Ladder which is discussed in the next section documents the expert’s perception, decision-making and action processes.

<table>
<thead>
<tr>
<th>SAR</th>
<th>Tanker Incident</th>
</tr>
</thead>
<tbody>
<tr>
<td>Knowledge</td>
<td>Potential explosion; life hazard.</td>
</tr>
<tr>
<td>Cues</td>
<td>Overturned truck on highway; ruptured fuel tank; engulfed in flames; intense heat (highway signs melted); another truck 50 feet away; citizen rescuing driver.</td>
</tr>
<tr>
<td>Goals</td>
<td>Complete the rescue; extinguish fire; block traffic</td>
</tr>
<tr>
<td>Decision Point - 1</td>
<td>Aid in driver rescue.</td>
</tr>
<tr>
<td>Decision Point - 2</td>
<td>Call for additional units: rescue, police, foam</td>
</tr>
</tbody>
</table>

Table 1 Sample Situational Assessment Record (SAR) (Klein et al., 1989, p.469)
2.4.2.2 Decision Ladder Templates

Decision ladders are formalized models derived from linear human information-processing models (Figure 7) found in human factors, HCI and psychology (Rasmussen et al., 1994; Vicente, 1999).

Figure 7 Linear information processing
(Adapted from Vicente, 1999, p.184)

Decision ladders can be used to analyze and model cognitive activities. The linear sequence is redrawn in Figure 8 as an inverted ladder, allowing the analyst to more readily document decision heuristics or shortcuts (leaps and shunts\(^{10}\)) between elements, as well as recognize starting points other than “activation.” For example, a novice may proceed through every element in sequence, beginning with “activation” while an expert may enter the process at a different point and use experience to take shortcuts between stages.

\[^{10}\text{In Decision Ladders, shunts are used to connect boxes (activities) to circles (states) while leaps are used to connect two circles (states). Shunts are frequently used by experts processing information resulting in non-sequential knowledge states. Leaps are changes in states resulting from familiarity with the significance of a state and its relation to another state. Experts process leaps by direct association and without further information processing. Identifying the shunts and leaps used by experts can help analysts develop and support shortcuts for novices.}\]
2.4.3 Conceptual

Conceptual techniques are used to elicit knowledge and generate representations of work domains, including concepts, structures and interrelations. Since the representations are graphical, they can be used to jointly confirm researcher understanding with respondent intentions. These methods tend to be indirect (as opposed to interview and observation), but are the best for aggregating input from multiple experts. Use of these techniques requires a higher degree of elicitor familiarity with the work domain. Benefits include less data to manage (as opposed to interview and
observation) as well as less reliance on verbal reports. In some ways, these methods are somewhat restrictive in scope in that they may not cover the full range of knowledge for task performance. However, they are able to focus on important concepts which are otherwise difficult to articulate. Cooke (1994) suggests combining conceptual techniques with the other families. In this dissertation, concept maps and other conceptualizations are combined with the critical decision method.

2.4.3.1 Concept Maps

Concept maps (Novak & Gowin, 1984) are a popular conceptual knowledge elicitation technique which are also used to capture and analyze data. Concept maps are part of the AKADAM (McNeese et al., 1995) and MAKADAM frameworks. They have also been successfully used by CSE researchers in military and aviation domains, among others. For example, researchers strengthened the user-centered, participatory design feature of AKADAM by generating concept maps in conjunction with the pilots in the investigation (Brewer & McNeese, 2004).

Concept maps enable data collection regarding a person’s mental model for given situations. After collecting these knowledge representations, researchers may manipulate the maps to represent analysis. These manipulations are part of the process used by researchers who use coloring, counting, and tagging to make sense of the maps and to organize and aggregate the concepts.

Creating a standard concept map involves a series of steps that begins by defining a focused topic or question, listing high level concepts associated with that topic and then
subdividing each high level concept from most general and inclusive, to the most specific. “Linking phrases” are used to connect and describe relationships between concepts. Cross links can be added to show interrelatedness between concepts falling in different domains on the map (Coffey, Carnot, Feltovich, Feltovich, Hoffman, Cañas, & Novak, 2003; Novak & Gowin, 1984). Figure 9 is an example of a concept map created to share knowledge about concept maps. It is read by following a branch beginning at the high level node, such as “concept maps represent organized knowledge [which] is context dependent.”

![Figure 9 Concept map example](http://cmap.coginst.uwf.edu/info/cmap.gif)
2.5 Using Domain Knowledge and Task Complexity Assessment to Inform Design

Increased organizational use of information systems has created new and useful opportunities to conduct studies of workers and their tools in both natural and controlled settings. Of particular interest in this dissertation is improving the use of complex sociotechnical systems supporting cognitive activities, such as decision-making, perception and judgment. When these tools are developed by happenstance or without consideration of dynamic work environments, the outcomes may result in what has been described as *clumsy automation* (Wiener, 1989, in Woods et al., 1994, p. 114).

Improving cognitive effectiveness within the policing domain requires a progressive deepening of understanding using a combination of methods that begins with ethnography and knowledge elicitation (Brewer & McNeese, 2004; McNeese, Zaff, Peio, Snyder, Duncan, & McFarren, 1990; Potter et al., 2000). As shown in Figure 10, these methods form a basis leading to designs capable of supporting effective cognitive activity. In particular, the opportunity to reveal hidden rationales and overlooked opportunities is a primary reason that the ethnography techniques of CSE were selected for this dissertation.
Figure 10 Linking cognitive analysis to design
(McNeese et al., 1995; Roth, Gualtieri, Easter, Potter, & Elm, 2001)

MAKADAM combines domain experts in an active participatory setting with designers. AKADAM, upon which MAKADAM is based, is one of the few CSE methodologies that actually includes “design” in its title. These methodologies promote active participation and collaboration throughout the design process while being sensitive to a broad range of domain and cognitive constraints (McNeese et al., 1995). To develop the prototype, MAKADAM elicits and represents information and decision needs using concept maps, decision ladders and scenarios.
The next chapter will detail the methods and approach used in this dissertation to identify and represent expert knowledge leading to improved designs supporting cognitive police work.
Chapter 3

Approach and Methods
This chapter describes the methods used in this dissertation to accomplish the analytical and intervention objectives to improve the cognitive effectiveness of police information systems. First, the research setting is described. Next, the approach and methods are described for the three research stages. The method employed extends existing AKADAM by emphasizing ethnography prior to knowledge elicitation and the use of an active participatory design. In this method, which is illustrated in Figure 11, information from the analytical stages of ethnography (1) and knowledge elicitation (2) informs the scaled world intervention stage (participatory design (3)). A scaled world is a model or simulation of the real world where components in the scaled world have meaning in the real world.

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**Figure 11** Model to improve cognitive effectiveness of police systems
3.1 Research Setting

Insight into design of cognitive systems can be obtained by studying municipal police officers and the environment within which they work. Similar to emergency medical and fire responders, municipal police officers exemplify experts facing dynamic work environments. Situations include large problem spaces, ill-defined problems and high risk outcomes. Police information systems should support making sense of these situations thereby improving decision-making, judgment, problem-solving and perception.

Three Pennsylvania municipal police departments are included in this dissertation. As shown in Figure 12, the headquarters (represented by solid circles) of the three police departments are located within close proximity of each other. Although managed by different municipalities, the police departments in this dissertation participate in a county-based law enforcement consortium. They work closely together, are dispatched by a common 911 center and share radio frequencies and computing technology. The townships and borough that they serve are located in the same county along with a state university.11 Municipal police department A (MPD-A) includes a borough with retail and student housing, as well as two residential townships. MPD-B and MPD-C provide police support for neighboring townships that include residences, student housing, rural farmland and developed commercial sectors. Approximately 130 square miles are covered by the three police departments, with a total population served of 81,183.

11 The university property in the northern part of the borough and its police department were not included in this dissertation. University police perform a unique combination of police and security services.
Pennsylvania police statistics track crime based on seriousness of offense, which can be used to compare these departments. More serious Part I offenses include murder, rape, aggravated assault and arson. Part II offenses include lesser assaults, forgery, drug abuse, drunkenness, and disorderly conduct. **Table 2** reveals that the three departments are consistent with state averages for the more serious Part I Incidents per officer. An active student population in the area covered contributes to an above average rate of Part II Incidents per officer, especially in the central and southern borough area of MPD-A.
Table 2 Crime statistics for the three municipal police departments ("Pennsylvania state police uniform crime report", 2004)

<table>
<thead>
<tr>
<th></th>
<th>Officers</th>
<th>Part I Incidents</th>
<th>Part I Incidents / Officer</th>
<th>Part II Incidents</th>
<th>Part II Incidents / Officer</th>
</tr>
</thead>
<tbody>
<tr>
<td>MPD-A</td>
<td>63</td>
<td>1,008</td>
<td>16</td>
<td>5,680</td>
<td>90</td>
</tr>
<tr>
<td>MPD-B</td>
<td>18</td>
<td>186</td>
<td>10</td>
<td>733</td>
<td>41</td>
</tr>
<tr>
<td>MPD-C</td>
<td>15</td>
<td>230</td>
<td>15</td>
<td>528</td>
<td>35</td>
</tr>
<tr>
<td>Pennsylvania</td>
<td>24,646</td>
<td>326,961</td>
<td>13</td>
<td>625,008</td>
<td>25</td>
</tr>
</tbody>
</table>

The three departments can also be compared to statewide averages by number of full time officers per department. Department size relates to the type and complexity of work, as well as workload (as reflected in crime statistics). Figure 13 shows that the majority of the approximately 1,200 police departments in Pennsylvania have fewer than 30 officers, including MPD-B (18 officers) and MPD-C (15 officers).
3.1.1 Gaining Access to the police domain

The population of interest in this dissertation is mobile police officers. Access to personnel in these police departments was initiated through a senior municipal police department administrator who has participated in local and state committees investigating initiatives and standards for mobile police systems. Lieutenant Stevens\textsuperscript{12} was responsible for implementing a county database to track crime, install mobile data terminals in the police cars and implement field reporting by mobile officers. Because of this, he was particularly sensitive to challenges in implementing and using police information systems.

\textsuperscript{12} An alias.
as well as the need for improvements to existing systems. Gaining access included meeting senior police administrators and successfully passing criminal background checks. The result was authorization to ride with officers, observe them in the performance of their duties and to conduct interviews.

3.2 Methods to Address Analytical Objectives

The first analytical stage uses ethnographic methods to identify cognitive domain constraints of officers in naturalistic settings. The second analytical stage uses knowledge elicitation techniques with police experts to reveal cognitive task complexity in the performance of critical incidents.

3.2.1 Ethnography Stage

In this stage, ethnographic techniques reveal the backdrop or landscape within which officers perform their cognitive activities. This landscape includes ecological and cognitive constraints that impact the effectiveness of cognitive police work. Methods began with domain training and secondary data analysis, followed by 46 hours of immersive fieldwork that included 35 hours observing and interviewing police officers during ridealongs (Figure 14). Video was used to supplement analysis of officer use of current police information systems.

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13 Research hours represent actual hours in the field. Total research hours are substantially higher, and include time to record and compile the interviews and observations as well as analyze and evaluate the data.
Both semi-structured and unstructured discussions occurred between the researcher and the officers during these ridealongs. The ridealong probe questions used to initiate the unstructured interviews are listed in Appendix A. To better understand the cognitive domain, the probes focused on the use and manipulation of information by officers to make decisions and solve problems.

![Officer completing an incident report using a mobile data terminal (MDT) with a full keyboard and touch screen](Image1)

![Screen shot from the field reporting application](Image2)

**Figure 14** Police officer completing a field report during a ridealong

The ridealongs were conducted between March and October 2004 with 11 police officers during different shifts and events. The schedule of interviews and participant information is provided in Appendix B. Several ridealongs lasted approximately 4 to 5 hours, with an average length of 2 hours. Since incidents frequently begin with a 911 call to dispatchers, and may require more than one shift to complete, most of the ridealongs were conducted in overlapping research segments. These segments sequenced ridealong
observation and interviews\textsuperscript{14} from the county-911 call center and police briefings. Three segments are particularly noteworthy due to both their length and the richness of sequencing (Table 3).

<table>
<thead>
<tr>
<th>Segment 1</th>
<th>Segment 2</th>
<th>Segment 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>8AM – 11AM county-911</td>
<td>4AM – 6AM ridealong</td>
<td>3PM – 8PM ridealong</td>
</tr>
<tr>
<td>11AM – 1PM ridealong</td>
<td>6AM – 7AM briefing</td>
<td>8PM – 10PM ridealong</td>
</tr>
<tr>
<td>1PM – 2PM briefing</td>
<td>7AM – 9AM ridealong</td>
<td>10PM – Midnight county-911</td>
</tr>
<tr>
<td>2PM – 4PM ridealong</td>
<td>9AM – 11AM ridealong</td>
<td></td>
</tr>
<tr>
<td>8 hour segment</td>
<td>7 hour segment</td>
<td>9 hour segment</td>
</tr>
</tbody>
</table>

Cognitive domain analysis outcomes include evaluation of intrinsic work constraints and current work practices, with an emphasis on currently unexplored possibilities and workaround activities. This includes identification of cognitive design leverage points, or generalized areas of cognitive police work not effectively supported by current systems. Design leverage points from the ethnography stage focus the identification of cognitive design seeds in the second analytical stage (knowledge elicitation). Design seeds represent specific cognitive tasks not effectively supported by current artifacts. Design seeds then form the basis for prototype development during the intervention part of this dissertation.\textsuperscript{15}

\textsuperscript{14} The participants did not seem to alter their behavior due to my presence and as such my presence should not impact findings. Observation was frequently used including video and audio taping. During interviews, the participants were quite frank and open in their responses.

\textsuperscript{15} Other researchers conducting cognitive task analysis have used design seeds as well. Patterson, Woods, Tinapple and Roth (2001) triggered development of modular design concepts to assist intelligence analysts
As the largest and most active\textsuperscript{16} department, MPD-A is the primary police department used for the field ethnography stage since the focus of this stage is the domain. Working three full shifts every day of the week, MPD-A provides an opportunity for observing a wide variety of cognitive police work during varying shifts, workloads and activities.

3.2.2 Knowledge Elicitation Stage

The second analytical stage uses the critical decision method (CDM) (Klein et al., 1989) as a cognitive task analysis technique to elicit cues, knowledge requirements and decision points used in solving real world problems by police experts. Between August and November 2005, sessions combining semi-structured interview and graphing techniques were conducted with 10 officers from MPD-B and MPD-C using the probes listed in Appendix C.

The primary difference between the ridealong questions and those developed for the cognitive task analysis is the level of focus and specificity. Whereas the ridealongs were intended to explore the richness of the domain, the cognitive task analysis targets specific activities within this domain, and requires the respondent to both describe the activity and his/ her actions, thought processes, and decision-making approach. The first four questions ask the respondent to describe a critical incident, its timeline, the decision-

\textsuperscript{16}Most activity per officer based on Part II crime statistics. MPD-A also provided opportunities to observe diverse police activities during special community events such as parades and football games.
making heuristics, and a post hoc analysis of decision-making effectiveness. A fifth question was then posed asking the officer to consider system support and possible enhancements that might have improved the decision-making effectiveness. This fifth question helped to focus the intervention stage.

Officers were selected for interview based on their work experience and specialized training (summarized in Appendix D). Training included years of experience and diversity of experience. The ten officers all had twelve or more years of experience and had held multiple positions or had highly skilled backgrounds such as an observation-sniper. The elicitation and follow-up sessions totaled 59 field hours of field research and generated 26 situation assessment records (SAR) that included 61 decision points during a variety of critical events.

The CDM is adapted in this dissertation to take advantage of the knowledge elicitation and representation benefits of concept mapping as well as to facilitate expert exploration of leverage points identified in the first analytical stage to identify design seeds. Figure 15 illustrates a typical concept map developed by the officer through discussion with the researcher. Concept mapping by officers eliminates the need for transcribing interview notes. In addition, the researcher and expert simultaneously share in the representation of knowledge with immediate benefits of interpretation and discussion. Using this technique, the police expert represents his or her perspective directly without interpretive bias by the researcher.
3.3 Methods to Address Intervention Objective

The third and final stage in this dissertation applies knowledge gained in the analytical stages by using participatory design methods to develop a prototype capable of enhancing cognitive police work.

Using the MAKADAM methodology which links cognitive analysis to cognitive design (Figure 16), interventions based on design seeds improve cognitive police work by both complying with domain constraints and reducing task complexity. In the third research stage, one of the identified design seeds is developed into a prototype using participatory design methods.
3.3.1 Participatory Design Stage

This stage applies cognitive domain and task knowledge in a scaled world to explore a design intervention capable of improving cognitive work in dynamic police environments. This scaled world includes a command center scenario derived from police experiences with a real world barricaded gunman. The complete scenario is presented in chapter 5. The researcher and domain experts work together using participatory design methods to develop a prototype. The prototype is based on a design seed identified in the knowledge elicitation stage and is developed in an iterative
bootstrapping process\textsuperscript{17} that includes mapping information and decision needs with visual concepts. Scenarios are then created to supplement the use of the prototype as a police training tool in a scaled world setting.

The participatory design methods used in this dissertation are similar to those associated with Scandinavian participatory design (Greenbaum & Kyng, 1991; Kyng, 1994).

\textsuperscript{17} Bootstrapping is the use of multiple, converging techniques where each step provides knowledge and insight used to guide the next step (Potter et al., 2000).
Chapter 4

Analytical Results
This chapter describes the results from the two analytical stages in this dissertation. First, results from ethnographic methods, including domain training, secondary data analysis and observation of officers working in the field, provide insight into the domain and its constraints for cognitive work. Major outcomes of the ethnography stage include identification of workaround activities, unexplored possibilities and design leverage points. Second, knowledge elicitation methods based on the critical decision method (CDM) provide insight into the complexity of cognitive tasks. Major outcomes of the knowledge elicitation stage include insight into cognitive task complexity, cues, knowledge and decision points used by police experts during critical incidents, and design seeds. Analytical outcomes are used in the intervention stage (Chapter 5) to explore technologies to reduce cognitive complexity and accommodate domain and task constraints.

4.1 Analytical Results: Ethnography Stage to Develop Domain Understanding

The objective of the first analytical stage is to develop a practical understanding of decision-makers in the context of their work domain. Understanding decision-making within the context of police work begins with understanding the cognitive work domain of the patrol officer. First, the skill set required for police work is described, highlighting the training that police officers undergo. As part of this discussion, I describe my participation in some of this training to further familiarize myself with the demands of the domain. This is augmented by an extensive summary of secondary data tracing the evolution of modern policing and its impact of police workers. This is followed by a
description of my fieldwork to explore the cognitive work domain, the findings of my participant observation activities, and responses to my probes. The ethnography results conclude with an analysis of the cognitive work domain and its implications for the second analytical stage of the research. The second stage uses knowledge elicitation to focus on cognitive tasks occurring in the police work domain.

4.1.1 Skills Required in this Domain

There are two primary training programs that prepare full-time police officers and non-full-time officers working in other fields. Act 120 certification provides the knowledge and skill set required for full time police work in Pennsylvania. Act 235 certification, with a reduced set of requirements, must be achieved to carry a lethal weapon as part of employment. As part of my preparation for this research, I completed Act 235 certification, and this section includes a description of that training. Results from this section include insight into the diverse skill sets needed to perform police work and the importance of post hoc analysis and review for police officers.

4.1.1.1 Municipal Police Officer Certification

To work in Pennsylvania, a police officer must complete a certified Act 120 program from one of 16 Commonwealth Academies. Typically this is completed after an individual has been hired as a police officer by a city, borough, township or municipality, although it is not uncommon for individuals wishing to become police officer to undergo
certification training. Completion of the required 700 hours requires five months in a full time program or one year in a part time program. Acceptance into a program is conditional upon the outcome of a cardiac stress test, physical conditioning assessment, psychological evaluation, reading comprehension and personal interviews.

Act 120 applicants must be at least 18 years of age, possess a high school diploma or GED equivalency, a driver’s license, and meet Pennsylvania State Police criminal history requirements. Applicant testing also includes physical performance evaluation in a 1.5 mile run, 300 meter run, bench press and sit-ups. Psychological evaluation includes a Minnesota Multiphasic Personality Inventory (MMPI) Test, Nelson-Denny reading test and personal interviews.

Training covers a broad array of topics including physical and emotional readiness, laws and procedures, defensive tactics, principles of criminal investigation, crisis management, arrest procedures and basic firearms.

After completing certification, departments will typically assign their new hires to a field training officer for several months of additional training in the processes specific to that agency. It is during this time that new officers develop critical skills such as radio ear, or the ability to monitor and process information from the police radio while also performing other tasks such as driving a car or talking with someone.

Thus, the complete process to recruit, screen, hire and retain a police officer is lengthy and crosses a broad spectrum including physical and mental health criteria, formal training in law and police tactics and field experience in an apprentice role.
4.1.1.2 Lethal Weapons Training Act

Pennsylvania’s Act 235 or “lethal weapons training act” is a lesser set of requirements for non-full-time police officers to carry and use lethal weapons in their employment, such as detectives, security guards and criminal investigators. “Lethal weapons” include any weapon designed to produce serious bodily harm or death such as a firearm, nightstick, or billy club.

This certification requires 40 hours to complete, including 22 hours in the classroom, four hours of skills training and 14 hours on the firing range. Classroom training covers crimes code, incident investigation and reporting and testifying in court. Skills’ training includes armed and unarmed defense procedures.

Physical and psychological examinations are similar to the Act 120 requirements and attempt to determine the appropriateness for an individual to be vested with a position of public and private trust and have the ability to exercise significant physical strength and undergo high emotional stress.

4.1.1.2.1 Participation in Lethal Weapons Training

My familiarity with the policing domain and its practitioners began with lethal weapons certification. During this training, I was able to meet and get to know several current and former municipal officers. Most of the instructors were current officers, and the participants were either individuals interested in becoming police officers or retiring police officers requiring certification for some type of future employment. During my training, I attended classroom lectures, participated in skills training and practiced at the
firing range. In addition to the weapons skills, I also gained valuable insights into the domain.

Initial insight into policing and contextual situations was provided by being in the classroom and field with these officers and having them talk to me and hearing them talk to each other. There were two recurring themes in many of these conversations. The first was a bias toward non-lethal decisions. For example, although the criminal code may justify a decision to use lethal force, the officers were aware of the personal liabilities resulting from civil cases. The second was an emphasis on developing decision-making skills and tactics from relating and studying incidents through story telling. To an outsider it may appear that police share a somewhat macabre curiosity. My observations suggest that these shared stories and discussions are really a form of post hoc analysis and review.

4.1.2 The Context of Policing

Police reform leading to community policing and preventative patrol has had a significant impact on police work. It has created a stronger presence in the community, but in doing so has resulted in a nearly virtual organization, where actors work in the field independent of each other using technology (radio and computer) to support decisions while maintaining contact and awareness. Successive technology funding from community policing initiatives has led to an ad hoc implementation of technology, which frequently has resulted in awkward solutions. Of particular interest here is the impact
that the awkward nature of some solutions has had on organizational structure, roles and activities, particularly field reporting activities.

To understand the complex sociotechnical systems used to support decision-making in police work it is important to understand the domain of policing itself, including the history, environment and context of policing. In general, modern policing is a relatively young profession that is still evolving. At the municipal level it is highly fragmented, with over 13,000 local police departments in the U.S. (Hickman & Reaves, 2003). This section draws on an extensive review of secondary data sources which are summarized in Appendix E. Results from this section include insight into changes in policing as a result of social reforms, problems with police technology, as well as additional insight into the diverse skill sets needed in police work.

4.1.2.1 Historical Roots and Implications of Preventative Patrol

According to Klockars (1985), the roots of modern policing, or policing conducted by state-salaried, full-time professionals, can be traced to London in 1829, and New York City in 1845. Prior to this, the right, obligation, and inducement to police were the responsibility of private citizens acting as unpaid volunteers. Policing is work, and as such requires a certain level of competence to complete. Unlike most work, however, it is possible to be either too aggressive or too passive. Police are very much influenced by the social and political system in which they operate. Examples of this influence include the transition from private citizens to state-paid professionals,
legislative acts that specify that police should be drawn from the community that they serve, and the adoption of “preventative patrol” as a major police activity.

Of these influences, the institutional emphasis on preventative patrol as the dominant method has shaped policing in several ways. Preventative patrol has made the domain of police work the streets. This expanded police work from the prevention of crime to include duties such as parking enforcement, monitoring the opening and closing times of bars, completing detailed accident reports, monitoring road conditions, giving directions and quite frequently unlocking cars on behalf of citizens (a “keys” call).

A preventive patrol focus also increases the staffing needs for field officers to cover various shifts. This leads to a very flat organizational hierarchy, with the majority (over 85%) of American police department line employees in uniformed patrol. For many officers, not only will their job be the same from the first day to the last, but hazy performance metrics make it difficult to discern good police work (did they write too many/ few tickets, did they settle the domestic dispute the “right” way). Further, because of the flat organization, few openings exist to reward good work with promotion (Manning, 1997).

4.1.2.2 Community Policing Initiatives Extend the Domain

Over the years police work has changed in response to changing social and political influences. Bureaucratic (paramilitary) police work was the major theme for the past 75 years. It included limited public interaction, limited community service and a focus on crime as centrally directed, cool detached professionals (Hickman & Reaves,
2003; Manning, 1997). **Community policing** had its origins in the economic recession of the early 1980’s, and was elevated to a funded program with the Crime Control Act of 1994. The crime act provided community policing the funding to hire 100,000 officers, and support for many technology innovations to support police work. The reforms suggested in the crime control act were expropriated from programs and innovations from many countries and departments (Manning, 1997). These elements include:

- Use of media for education and crime control,
- Team policing,
- Foot patrol,
- Mini-stations,
- Crime analysis, and
- Crime prevention and problem-solving.

Community policing sees officers as knowledgeable, visible, available, working watches in a nominal area and leading to an improved quality of life by maintaining order and preventing crime. Unfortunately, this has come at a cost to officers loaded with additional responsibility but without tangible rewards. Officers receive no special training or rewards, perks or promotional opportunities from community policing (Manning, 1997). Perhaps as a result of this reform, it has been said that police must be ‘lawyers, scientists, medics, psychologists, athletes, and public servants.’
4.1.2.3 Police Work and Supporting Technology

Police work relies on a diverse set of technologies, including complex systems in dynamic work environments. The nature of complexity in dynamic environments stems from the presence of characteristics that increase cognitive demands on workers, such as challenges in accessing information, the quality (timeliness, completeness and accuracy) of information, and whether this information must be shared and processed by others, as well as risks to the worker and environment (Vicente, 1999).

4.1.2.3.1 Police Technology

Police are information workers interacting with their environment in occasional states of information overload or absence. They transform “facts” (naturally occurring information) into organizationally preferred and actionable processed messages. Information technologies alter (move, broaden, make permeable) the relationship of the police organization to the environment. Modern policing depends on the operation of diverse technologies such as radar, photographic equipment, digital fingerprinting and booking, electronic listening devices, office machines, devices to analyze evidence, radio, television, and airplanes. In a sense, federal grants have had the net effect of linking policing to the very powerful symbol of science (Manning, 1997).

Many technology enhancements have been made available to the police in the last 30 years including forensic technologies (including DNA databases), biochemical assays, accident reconstruction, weapon refinements, force-application techniques, and non-coercive persuasion training. Computer technologies have also led to important changes
during this timeframe. Systems include data gathering technologies, management
information systems, computer-assisted dispatch (CAD) systems and enhanced-911
technologies that reveal the caller ID and number. Regional and national databases
automate records and database access (i.e. motor vehicle registration, drivers’ licenses,
state and local criminal records, and the FBI’s National Criminal Information Center).
Mobile technologies available in the car include data terminals, video systems, fax
systems (warrant approvals), mapping and location applications, fingerprint files, and
photo IDs (mug shots, driver license photos) (Manning, 1996).

To gain insight into the multivariate ways that technology implementation can
impact police work, consider an earlier study of the impact from cellular phones (Table
4). The cell phone was introduced to officers in response to community policing
initiatives enabling direct communication with citizens throughout the shift. Since then
cell phone use has evolved to include multiple official and unofficial uses.
Table 4 Changes from police agency cellular phone implementation  
(Adapted from Manning, 1997)

<table>
<thead>
<tr>
<th>Physical settings</th>
<th>Phone occupies space and displaces other material objects (rearrangement of standard radio equipment, shotguns, writing surface, note pads, flashlight, nightstick and other work tools).</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sociotechnical interactions</td>
<td>Officers can communicate on-duty with other officers and friends without being monitored.</td>
</tr>
<tr>
<td>Organizational authority patterns</td>
<td>Technology reduces face-to-face supervision by permitting direct, unmonitored communication with the public.</td>
</tr>
<tr>
<td>Work process uncertainty</td>
<td>Provides an additional communication channel that, unlike the radio, cannot be monitored by other officers. Colleagues cannot anticipate actions resulting from cell communications. Additionally, new technology reliability needs to be determined (i.e. weak signal areas, heavy cell tower usage).</td>
</tr>
<tr>
<td>Status symbol</td>
<td>Introduction of a cell phone, depending on who gets them and what they imply, may enhance or reduce status.</td>
</tr>
<tr>
<td>Patterns of trust</td>
<td>New communication channel raises issues of trust in sender, receiver, and message as well as channel privacy concerns.</td>
</tr>
<tr>
<td>Work routines</td>
<td>Routine traffic stop routine, for example, is now changed allowing officer to directly call a tow truck, ambulance, emergency medical services, fire services or record checks.</td>
</tr>
</tbody>
</table>

Changes from the introduction of new technologies do not always meet expectations. A significant problem results from the introduction of new equipment without a clear purpose for its use, training for its operators, or repair and maintenance agreements (Chan, 2001; Manning, 2003; Schwabe, Davis, & Jackson, 2001). Additionally, technologies may be introduced too little/ too late or too much/ too soon. For example, San Diego police officers recently reported that in emergency situations they could not use their new field computer to request assistance. The keyboard sequence was too complex to perform during stressful field situations (Hafner, 2004).

The White House Office of Science and Technology Policy commissioned RAND’s Science and Technology Policy Institute to conduct a national survey of some 200 law enforcement agencies to summarize needed technology at the state and local
level. Table 5 lists technologies that survey respondents considered potentially necessary, but not available. From the table it is interesting to note the wide range of technologies used in policing. Note also that “computers in patrol cars” is listed as one technology, although it really represents a wide variety of technologies depending on software and network access. For example, a terminal could be used to type a follow-up narrative, route dispatch requests, look up operator and vehicle license information, and send email or chat, among other uses.

<table>
<thead>
<tr>
<th>Technology</th>
<th>% Not Available</th>
<th>Technology</th>
<th>% Not Available</th>
</tr>
</thead>
<tbody>
<tr>
<td>Detection and analysis of cyber attacks</td>
<td>79</td>
<td>Computers in patrol cars</td>
<td>58</td>
</tr>
<tr>
<td>Blister/nerve agent protective clothing</td>
<td>79</td>
<td>Electronic listening</td>
<td>57</td>
</tr>
<tr>
<td>Video conferencing equipment</td>
<td>75</td>
<td>Night vision devices</td>
<td>57</td>
</tr>
<tr>
<td>Kinetic energy projectiles</td>
<td>75</td>
<td>Vehicles-special purpose</td>
<td>45</td>
</tr>
<tr>
<td>Chemical agent detection</td>
<td>71</td>
<td>Crowd or riot control</td>
<td>44</td>
</tr>
<tr>
<td>Long-range video monitoring</td>
<td>69</td>
<td>Computer-based training</td>
<td>41</td>
</tr>
<tr>
<td>Stun devices/projectiles</td>
<td>68</td>
<td>Conference call equipment</td>
<td>36</td>
</tr>
<tr>
<td>Radioactive agent detection</td>
<td>66</td>
<td>Computer assisted dispatching (CAD)</td>
<td>35</td>
</tr>
<tr>
<td>Explosives detection</td>
<td>64</td>
<td>Integrated data bases</td>
<td>34</td>
</tr>
<tr>
<td>Polygraph equipment</td>
<td>64</td>
<td>Protective gloves, helmets and shields</td>
<td>34</td>
</tr>
<tr>
<td>Fleeing vehicle interdiction equipment</td>
<td>63</td>
<td>Audio-visual equipment to obtain evidence</td>
<td>30</td>
</tr>
<tr>
<td>Concealed weapon detection devices</td>
<td>62</td>
<td>Training equipment</td>
<td>28</td>
</tr>
<tr>
<td>Bomb containment/disablement equipment</td>
<td>60</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The U.S. Department of Justice’s Bureau of Justice Statistics (BJS) surveyed 13,000 local police departments operating in the United States in terms of their personnel, expenditures and pay, operations, community policing initiatives, equipment, computers
and information systems, and written policies. Their results included insight into the wide range of computer uses supporting police work (Table 6). Unfortunately, these functions are non-specific regarding the location of the application, although the trend is for officers to perform a wider variety of duties and spend more time in the field. Of all the computer uses, records management is the most common (used by 60% of all departments and representing 85% of all officers).

While most departments used a computer-aided dispatch system at their 911 centers, only a third of local police departments dispatched the calls for service to mobile-data terminals in the police cars. This implies that most police departments still dispatch the calls using radios.

Table 6 Computer functions in local police departments (Hickman & Reaves, 2003, p. 23)

<table>
<thead>
<tr>
<th>Population served</th>
<th>Records management</th>
<th>Internet access</th>
<th>Crime investigations</th>
<th>Personnel records</th>
<th>Dispatch</th>
<th>Crime analysis</th>
<th>Inter-agency information sharing</th>
<th>Automated booking</th>
<th>Fleet management</th>
<th>Crime mapping</th>
<th>Resource allocation</th>
</tr>
</thead>
<tbody>
<tr>
<td>All sizes</td>
<td>60%</td>
<td>56%</td>
<td>44%</td>
<td>40%</td>
<td>32%</td>
<td>30%</td>
<td>26%</td>
<td>16%</td>
<td>15%</td>
<td>10%</td>
<td>15%</td>
</tr>
<tr>
<td>1,000,000 or more</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>500,000-999,999</td>
<td>88</td>
<td>94</td>
<td>93%</td>
<td>93%</td>
<td>100%</td>
<td>93%</td>
<td>93%</td>
<td>100%</td>
<td>86%</td>
<td>85%</td>
<td>85%</td>
</tr>
<tr>
<td>250,000-499,999</td>
<td>98</td>
<td>98</td>
<td>90%</td>
<td>90%</td>
<td>90%</td>
<td>90%</td>
<td>90%</td>
<td>90%</td>
<td>85%</td>
<td>85%</td>
<td>85%</td>
</tr>
<tr>
<td>100,000-249,999</td>
<td>89</td>
<td>89</td>
<td>88%</td>
<td>88%</td>
<td>88%</td>
<td>88%</td>
<td>88%</td>
<td>88%</td>
<td>85%</td>
<td>85%</td>
<td>85%</td>
</tr>
<tr>
<td>50,000-99,999</td>
<td>89</td>
<td>88</td>
<td>75%</td>
<td>75%</td>
<td>75%</td>
<td>75%</td>
<td>75%</td>
<td>75%</td>
<td>75%</td>
<td>75%</td>
<td>75%</td>
</tr>
<tr>
<td>25,000-49,999</td>
<td>86</td>
<td>80</td>
<td>72%</td>
<td>72%</td>
<td>72%</td>
<td>72%</td>
<td>72%</td>
<td>72%</td>
<td>72%</td>
<td>72%</td>
<td>72%</td>
</tr>
<tr>
<td>10,000-24,999</td>
<td>81</td>
<td>72</td>
<td>65%</td>
<td>65%</td>
<td>65%</td>
<td>65%</td>
<td>65%</td>
<td>65%</td>
<td>65%</td>
<td>65%</td>
<td>65%</td>
</tr>
<tr>
<td>Under 2,500</td>
<td>60</td>
<td>57</td>
<td>50%</td>
<td>50%</td>
<td>50%</td>
<td>50%</td>
<td>50%</td>
<td>50%</td>
<td>50%</td>
<td>50%</td>
<td>50%</td>
</tr>
</tbody>
</table>

The BJS study also noted that in-field computer use grew from 5% to 40% between 1990 and 2000 (Table 7). The departments using in-field computers represented 75% of all officers in 2000 (up from 30% in 1990). This is relevant for several reasons. First, putting terminals in the cars means that the new systems may somehow impact
cognitive activities such as police decision-making. Second, applications such as mobile dispatch and field reporting facilitate community policing objectives by allowing officers to stay in the field and out of the station. Third, the role of policing now includes data entry jobs previously performed by clerks. And finally, these technological and organizational changes will impact policing with possible unintended consequences as the deployments may take place with minimal study on the impact or implications.

Of all the mobile computing devices, portable laptops were the most common field device (21% of all departments), while a few agencies have begun experimenting with portable digital/data terminals and computers (1%). Laptops tether the officer to the vehicle, while PDAs allow data access away from the vehicle.

Table 7 In-field computer use by local police
(Hickman & Reaves, 2003, p. 25)

<table>
<thead>
<tr>
<th>Population served</th>
<th>Percent of agencies using in-field computers or terminals</th>
<th>Portable (not vehicle-mounted)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Any in-field computer or terminal</td>
<td>Vehicle-mounted</td>
</tr>
<tr>
<td>All sizes</td>
<td>40%</td>
<td>27%</td>
</tr>
<tr>
<td>1,000,000 or more</td>
<td>66%</td>
<td>80%</td>
</tr>
<tr>
<td>500,000-999.999</td>
<td>97</td>
<td>91</td>
</tr>
<tr>
<td>250,000-499.999</td>
<td>83</td>
<td>68</td>
</tr>
<tr>
<td>100,000-249.999</td>
<td>82</td>
<td>70</td>
</tr>
<tr>
<td>50,000-99,999</td>
<td>81</td>
<td>70</td>
</tr>
<tr>
<td>25,000-49,999</td>
<td>70</td>
<td>59</td>
</tr>
<tr>
<td>10,000-24,999</td>
<td>59</td>
<td>45</td>
</tr>
<tr>
<td>2,500-9,999</td>
<td>39</td>
<td>27</td>
</tr>
<tr>
<td>Under 2,500</td>
<td>24</td>
<td>12</td>
</tr>
</tbody>
</table>

In summary, police officers work with and depend on multiple technologies representing various levels of performance and many of which need upgrades or replacement. The trend is toward increased access to computers in the field.
4.1.2.3.2 Police Work

Computer support of police work takes a variety of forms. Table 8 shows a range of police activities from straightforward “repetitive manipulation and inquiry of prescribed data, often by definite procedure” to more complex “decision-making, strategic planning, and personal technology interaction” (Colton, 1979, p. 12). In addition, this dissertation recognizes that police work is also contextual and not just application based. For example, a straightforward patrol inquiry could quickly escalate to a more complex felony stop if additional information determines that the vehicle is stolen or used in a crime.

Table 8 Computer support of police activities
(Adapted from Colton, 1979)

<table>
<thead>
<tr>
<th>Police Activity</th>
<th>Computer Support</th>
</tr>
</thead>
<tbody>
<tr>
<td>Traffic</td>
<td>Automated traffic records and statistics (accidents, citations, and parking violations)</td>
</tr>
<tr>
<td>Police Patrol &amp; Inquiry</td>
<td>Rapid real time inquiry identifying people (outstanding warrants) and property (stolen items, vehicle registrations)</td>
</tr>
<tr>
<td>Miscellaneous operations</td>
<td>Files related to jail arrests and intelligence records</td>
</tr>
<tr>
<td>Police administration</td>
<td>Personal records, payroll, budget analysis, forecasting, inventory control, fleet management.</td>
</tr>
<tr>
<td>Statistical crime files</td>
<td>Type and number of criminal offenses and arrests, and juvenile activity (compatible with FBI Uniform Crime Report and general law enforcement database)</td>
</tr>
<tr>
<td>Criminal investigation</td>
<td>Crime patterns, modus operandi, field interview reports, aliases, and fingerprint databases</td>
</tr>
<tr>
<td>Command &amp; control</td>
<td>Computer-aided dispatch (CAD) and automatic vehicle tracking (AVM)</td>
</tr>
<tr>
<td>Resource allocation</td>
<td>Analysis of police service and traffic resource allocation</td>
</tr>
</tbody>
</table>
4.1.2.3.3 Field Reporting as an Example of Technology Supported Police Work

In a sense, the car is a modern office for the patrol officer who is becoming increasingly dependent on technology. Cars equipped with mobile data terminals and field reporting systems allow an officer to work independently or collaborate, enabling elements of command, control, communication, intelligence, reconnaissance, sensing, situation assessment, situation awareness, contextual awareness, decision support, and geographical support.

Additional technologies include a range of communicational and coercive artifacts available to the officer in the form of additional lights and sirens, more powerful personal and car radios, personal and departmental cell phones, video units, wireless microphones and wireless field reporting using mobile data terminal, (Manning, 2003; Schwabe et al., 2001). Field reporting systems may also connect to databases including:

- Direct access to department of motor vehicles, including driver photos,
- Call patterns by time, neighborhood, address, and unit,
- List of warrants or local data on crimes, arrests and the jail, and
- Regional networks of wanted and arrests.

The artifacts used by the officer tend toward being more diverse, lighter and computerized. In the last few years, mobile data terminals with wireless access to dispatch have been installed in police cars to support (Williams & Aasheim, 2005):

- Administrative and personnel functions (statistical tracking of work),
- Dispatching and 911 emergency services, and
- Incident reporting, case management, arrest, investigative, and crime analysis.

In particular, field reporting is an important police activity to understand due to its growing popularity and role in supporting police decision-making. Field reporting is described as the process used by officers to receive, act on and complete incident reports in the vehicles, and includes the directly related actions involved in the execution of these tasks. The sequence of steps involved in field reporting by an officer includes receiving, accepting, investigating, documenting and closing an incident report. In some cases, the incident is actually not closed but becomes part of an ongoing investigation requiring cooperation with other officers and citizens. For example, a study of field reporting implementation by the Charlotte-Mecklenburg Police Department was recently completed. Table 9 compares workflow changes resulting from the implementation (Williams & Aasheim, 2005).

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18 Charlotte-Mecklenburg Police Department has 2,000 employees and serves 700,000 citizens in North Carolina.
Table 9 Workflow changes resulting from field reporting (Williams & Aasheim, 2005)

<table>
<thead>
<tr>
<th>Event</th>
<th>Before Field Reporting</th>
<th>After Field Reporting</th>
</tr>
</thead>
<tbody>
<tr>
<td>Incident is reported</td>
<td>Officer dispatch to scene (no change)</td>
<td>(no change)</td>
</tr>
<tr>
<td>Initial investigation</td>
<td>Officer interviews witnesses and records information in paper notebook (no change)</td>
<td>(no change)</td>
</tr>
<tr>
<td>Incident report submission</td>
<td>Officer writes and submits paper report to on-duty officer-in-charge (OIC) after returning to headquarters</td>
<td>Officer types and transmits text-based online report to on-duty OIC from car immediately (or shortly after) investigation Note: some reports may not be submitted electronically (i.e. traffic accidents)</td>
</tr>
<tr>
<td>Supervisor report approval</td>
<td>On-duty OIC may return report for correction Revision completed and submitted to current on-duty OIC (this OIC may be different and may not be aware of other OIC comments)</td>
<td>System alerts OIC of new report Report may be rejected for revision OIC comments saved by system</td>
</tr>
<tr>
<td>Storing/archiving reports</td>
<td>Paper report sent to records department clerks for data entry into database and archiving</td>
<td>Report is automatically stored in database and archived w/ o records dept. intervention</td>
</tr>
<tr>
<td>Assign to investigation unit (IU)</td>
<td>Records dept. sends paper copy to IU IU supervisor assigns report to a detective Time elapsed from incident to IU assignment 4-5 days</td>
<td>System alerts investigative unit (IU) of report IU supervisor electronically assigns case to detective Time elapsed from incident to IU assignment &lt; 24 hours</td>
</tr>
<tr>
<td>Case investigation</td>
<td>Detective updates paper case file Access to paper file needed to see updates Similar cases manually identified and pulled for analysis</td>
<td>Detective updates case electronically All versions maintained by system System alerts involved officers of updates Similar cases electronically identified (search) and pulled for analysis</td>
</tr>
</tbody>
</table>

Field reporting changes include the elimination of some steps and a generally faster cycle time to process data and make it available to other officers and administrators. In addition, the role of the police officer now includes data entry duties.
4.1.3 Exploring the Cognitive Demands of the Police Domain

With a foundation in law enforcement skills and training from the ACT 235 certification and after extensive review of the literature concerning the history and context of policing, including sociotechnical issues, I began immersive data collection techniques including participant observation and interviews during ridealongs with police officers. To better understand domain constraints, the ridealongs were supplemented by interviews with local police and county 911 dispatch administrators, as well as observation of the dispatch center operations. During this time further insight into the police domain was gained while solidifying access and relationships. Results from this section include insight into workaround activities in current work practices as well as currently unexplored possibilities.

4.1.3.1 Participant Observation and Interviews

Officers were observed patrolling, interacting with each other and the public, and using various technologies (i.e. cell phone, car radio, personal radio, mobile data terminal, field reporting system, car video, VASCAR, chat and email). These observations included issuance of citations, response to silent alarms, and response to a fraternity party brawl. A shoplifting arrest was followed through the booking process, including photographing and fingerprinting. Officers were observed working autonomously while maintaining awareness of each other at all times by monitoring radio traffic. When necessary, such as the fraternity fight, I saw how officers patrolling
individually used information gleaned from radio traffic to make decisions to quickly converge into a team.

Also, perhaps to illustrate that police work has evolved to include the domain of almost anything occurring in the streets, I observed officers search a neighborhood for a bear that had been sighted. The officer mentioned to me that he really was not sure what was expected should they find the bear.

For another perspective of policing, I spent several hours at the dispatch center observing how call information is gathered, interpreted and distributed to police officers. This resulted in observation of an interagency response to a report that a student had climbed on a roof. This call required three dispatchers to coordinate a response by police, fire and EMTs. In addition, to further enhance observation of information sharing, several interviews sequenced police and dispatch shifts in research segments.

Except for a few special assignments (such as traffic or DUI), most officers that were observed had been given a district to patrol. During these patrols, officers could be assigned specific incidents by the county 911 dispatch center. The incidents were assigned by police jurisdiction and based on officer availability, proximity and experience. Ridealongs were conducted in Dodge Intrepid sedans, or similar vehicles. Each was marked and similarly equipped with a mobile data terminal and police radio. Most cars had VASCAR (speed timing device), while only a few had VCR taping capability. Because of the space and heat generated by the police technology in the cars, the ridealongs were cramped and hot.
4.1.3.2 Police Information Systems

Technology has changed how officers interact with the public and each other. Prior to the county-based 911 call center, police calls went directly to the local police department instead of a remote, windowless, bunker-like dispatch center. Figure 17 illustrates the new flow of information from a caller to the inbound 911 operator. The inbound operator makes sense out of the call and creates an incident file. The file is routed to an outbound dispatcher for assignment to a first responder (police, fire, emergency medical, etc.). Thus, several layers of mediation have occurred before the caller’s information reaches the field officer.
The information flow in Figure 17 involves both voice communications over police radio frequencies as well as the routing of incident files to mobile data terminals installed in the police car. Since multiple officers and dispatchers shared the same frequency, minimizing radio traffic is necessary to keep the radio available. The primary
means for officers to track each other is by monitoring the radio transmissions. Police regularly reported their status (location, on-scene, completed on-scene, available to take another call, etc.) using 10-codes\textsuperscript{19} over the radio. Instead of names, 4 digit badge numbers are used on the radio to identify officers, and “county” to refer to any dispatcher at the county 911 center. For example, several transmissions are required to report an officer clear to take another call:

1. \textit{County – thirty-two,thirty-two} (officer with badge #3232 radios to county dispatchers),

2. \textit{Thirty-two,thirty-two – County} (county dispatchers acknowledges the call),

3. \textit{Thirty-two,thirty-two – ten-eight} (officer with badge #3232 is 10-8 or “clear and available to take other incidents”), and

4. \textit{Ten-four - thirty-two,thirty-two} (county dispatchers have noted the officer is available for assignment in their CAD system).

In addition to radio confirmation, officers assigned an incident are also sent a computer aided dispatch (CAD) file from the county 911 center to the mobile data terminals in the police cars. These files help reduce radio traffic by including information needed by the officer such as caller information, incident type and location. This file also includes the basic information needed by officers to complete incident reports in the field. Officers currently complete incident reports by entering data into terminals installed in their police cars. Interview data reveal strengths and weaknesses of

\textsuperscript{19} Another technique to minimize radio traffic is 10-codes. For example, “10-4” means “understood.”
the mobile data terminals and applications as described by several comments made by officers:

Officer 1: Our computer works like a cell phone, so sometimes the signal is stronger and weaker. Sometimes it would be hard to get the calls, or send stuff. That is why the other officer called me to ask how my signal was.

Officer 2: The mobile data terminals (MDTs) were deployed shortly after I came. The MDTs were great – I could look up a driver’s license and registration plate info in the car. I can also check the address since it is sent by the dispatcher.

Officer 3: Cars and dispatch have limited database access. For example, only the first seven of 14 name matches for warrants or police contacts are shown.

Officer 4: Our field reporting system doesn’t work with county 911 software – we are trying to make the best of it.

Officer 5: Police are now more clerical with computer field reporting to help administration make justifications and run reports.

Officer 6: Has the field reporting system achieved the goal of saving officer time? No!

What surfaced during these and other conversations is that officers value some applications enabled by the data terminal, such as looking up driver information, but not others such as field reporting. Field reporting seems to require extra work that can be compounded by system limitations including signal loss and partial data access (Figure 18). Also apparent is officer displeasure resulting from the addition of field reporting duties.
Figure 18 Data access limitations

4.1.3.3 Field Reporting Issues

The field reporting system of the departments in this dissertation consists of a mobile data terminal in the police car, a wireless network, a county incident and contact police database (called “CRIMES”) and software modules. Incident modules allow the terminal to receive dispatches electronically from the county 911 call center. This is not a smooth transfer, since the police use a different system than the county, and middleware is required. Department of transportation modules allow limited access to state databases to check vehicle registration and driver licenses. A field reporting module allows officers to complete incident reports from the car and then route them to a supervisor for approval. After supervisor approval, the reports are forwarded for eventual integration into the CRIMES database.
The current field reporting system impacts cognitive police work in two ways. First, the data entered through the field reports may eventually be used for decision-making. For example, in responding to a domestic disturbance, this database could provide information on previous police contact with the residents. Second, the system interface and structure may create usability problems for officers. For example, officers using the system at night feel vulnerable due to a loss of night vision. This is not only due to screen glare, but also to the car’s dome light which must be on to read the notes that officers are transcribing.

4.1.3.3.1 Workarounds

Workarounds and effort duplication consume human and system resources and can lead to human error (Vicente, 1999; Woods et al., 1994). Workarounds can be thought of as cognitive breakdowns that distract workers and cloud decisions. Workarounds during data entry may even reduce the accuracy and completeness of the data. For example, mergers and acquisitions among cellular telecommunications providers created a situation in which driving into one part of the municipality resulted in the car’s computer being dropped from the wireless network frequently resulting in transmission problems during data entry. When cell coverage was dropped while an officer was not using the system, the mobile data terminal appeared to still be working (i.e. the screen still showed icons). This situation would persist until the officer noticed the problem and rebooted the computer (after returning to the networked part of the municipality). In the meantime, any CAD files that had been routed from dispatch were
lost. This problem persisted for a year until the installation of a more compatible cellular antenna on the vehicles.

Officer issues with the field reporting system include unused screen icons and confusing icons. Only four or so of the more than 50 icons in the system are actually used. Also, when asked about the difference between the two “delete” icons in Figure 19, for example, an officer replied ‘I don’t know – I won’t use either of them since I don’t know what will happen if I do.’ When asked about the many other icons, he replied ‘I don’t know what any of the other icons are for. I only use the ones that I am sure about.’ Even though officers receive annual training, I did not find any that used more than a few icons.

Figure 19 Field reporting screen with two “delete” icons
Sometimes even the workarounds were duplicated. After responding to an incident, an officer has to duplicate data entry (including workarounds) by completing similar incident and case files. **Figure 20** shows the duplication between the two reports.

![Figure 20 Incident and case report duplication](image)

Officers must duplicate data entry first as an incident report (above left), and then as a case (above right). Data entry workarounds must be repeated each time. This duplication of effort is also repeated by the supervisor, who must check both reports.

**Figure 20** Incident and case report duplication

The first time the data is entered as an “incident” which includes a brief one-line narrative (used for daily police briefings and media reports). After completing the incident report, the officer reenters the data as a “case.” The case includes a more
complete narrative (used internally by the police). Narratives for incident and case reports are illustrated in Figure 21.

The above incident report ends with a brief narrative. This narrative is used in a daily bulletin for police briefings and press updates.

The above case report ends with a more complete narrative to be used internal to the police.

Figure 21 Incident and case narrative comparison

Workarounds exist for various reasons, including system and protocol differences between the police and county 911 dispatch systems. For example, the county 911 center transmits an incident file with “Research Drive” in the Street Name field. The officer
edits this field by first deleting “Drive” and then typing “Drive” into the Type field (Figure 22). This conversion is required for other fields including incident type (which actually requires table look ups by the officer to find correct code numbers). Further, these workarounds are again repeated in the case file which the officer must also create.

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**Figure 22 Field incompatibility example**

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### 4.1.3.3.2 Field Reporting Workaround Impact on Data Entry Quality

The end of the case report narrative in Figure 21 shows that the officer took 15 minutes (“2300 – 2315 hours”) to complete the reports. This means that 15 minutes of field reporting overhead is added to every incident processed by an officer, one hour with every four incidents, and so on. Adding ‘data entry clerk’ to ‘lawyer, scientist, medic, psychologist, athlete, and public servant’ may lead to cognitive overloading ultimately impacting all tasks, but especially data entry. This raises a further concern regarding the quality of the data captured by the current field reporting system.

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20 Officers had just begun tracking the time needed to complete reports. This time is consistent, however, with my observations for simple incident and case reports. I attribute the lengthy time primarily to workarounds and duplication of data entry.
An example of data entry quality involving redundancy was mentioned in an interview with an officer who had worked as a criminal investigator and depended on field reporting data. He said that when officers are rushed to complete the reports they found it is easier to create a new contact record than to do the research needed to determine whether a record already existed. This is especially true with names that have various spellings, or first, middle and last name combinations.

Officers also had to detect and fix, when possible, data entry problems that originated at the county 911 dispatch center. Some of these problems included incident files with incorrect contact, time, incident type, and jurisdiction data.

### 4.1.3.4 Other System Workarounds

The wide variety of technology deployed to officers and lack of vendor coordination has resulted in issues with other systems in the police cars. These systems may take up too much space due to redundant power supplies and user interfaces, may interfere electronically with each other, and may not be very ergonomic to use. Examples include the VASCAR system used to enforce speed limits, the car’s light-bar controls, and the mobile data terminal itself. I had the opportunity to observe all of these on my first ridealong.

The VASCAR controls are between the front seats. This consists of pushing a button each time a car being observed passes two measured street markers. The speed is calculated by how much time the car takes to pass between the markers. To view the results, the officer has to twist and look down between the seats to see the calculated
speed display. Fortunately officers have become good at recognizing which cars seemed to be speeding. They do not waste time twisting and looking down at the display for every car, just the ones they suspect of speeding.

The light-bar controls consist of toggle switches also located between the front seats (along with the VASCAR and the police radio). Officers now have to remember to turn the lights off, since only the position of the toggle between the seats indicates the light status. By comparison, one officer reported that older light-bars at least made a “whirring” noise that served as a reminder that they were still on.

The mobile data terminal also requires officers to twist to use the screen. Although it does not look comfortable for extensive data entry, the system shown in Figure 23 is actually a second generation system preferred by officers. The full keyboard on the lap requires less twisting than the original system, which was a laptop computer mounted in place of the console mounted touch screen.
4.1.3.5 Currently Unexplored Possibilities

The workarounds described in the previous section suggest exploitable opportunities for system improvement. Additional opportunities for system support were identified during participant observation and interviews.

During a daylight shift ridealong, an officer responded to an illegally parked car complaint. Since the car had neither a license plate nor a legible vehicle identification number through the front windshield, the officer began to process the incident as an abandoned vehicle. Abandoned vehicles require completion of separate electronic and paper forms that contain duplicate information. Fortunately, a neighbor saw the officer and let him know that the police had already been there. After some calls, the officer determined that a night shift officer had stopped the car and removed its license plate (either the tags had expired or did not match the car’s registration). The night shift officer had the owner park the car (illegally) on a side street until the owner could legally collect it. Without a license plate, however, day shift could not readily investigate the car and determine its status. This incident reveals problems in tracking vehicles without license plates and incidents that occur across different shifts.

This incident also revealed related situations that require duplicate electronic and paper reporting. Reasons include department policies, the inability to export data to partner systems, and the need to create a copy that can be attached to a car or property. Examples include:

- State Department of Transportation accident (reportable and non-reportable) forms,
- Ridealong consent form,
• Abandoned vehicle form,
• Photo evidence,
• Stolen property,
• Found property,
• Citations, and
• Daily log report.

Although this officer expressed dissatisfaction with all incidents that require duplicate electronic and paper reporting, he singled out the eight page reportable accident form that officers must complete for the state department of transportation:

Now, when you have one of those [reportable accidents], PennDot (Pennsylvania Department of Transportation) has to be notified. They don't like it in the computer. They take the handwritten report and scan it into their system. I don't know why they can't take the report from the computer. That is one question I have always had since I started, why we can't type that.

During follow-up research, another officer explained that it is possible to complete accident reports through the web for the Department of Transportation. This is still duplication, however, since officers need to complete incident and case files for the police department in addition to the web report.

Access to the Internet as well as mapping and positioning technology is unavailable in the cars. Several incidents, however, revealed opportunities to use these systems.

1. An officer writing a citation (by hand) had to retrieve a diagram from his car to find the correct magistrate for the address he was at.
2. An officer showed me thick notebooks he personally kept in his police car with photocopies of maps and guides to apartment numbering systems. Since this community regularly adds new developments with new streets, it is hard for officers to stay current.

3. During a traffic stop, an officer discovered he could not give dispatch his location - the street signs had been removed.

4. The officer I was with could not find the bank during a silent alarm - six new banks had opened along the same short stretch of road. We had already gone to two other banks before noticing a police car at the correct bank.

5. An officer described a situation in which a bicyclist had been injured on a rural road. By driving around, police eventually located the bicyclist. Unfortunately they then had trouble describing the location to EMTs.

Although several opportunities exist to improve technology in the cars, such as web access and positioning software, it is important that they be considered within the work domain under consideration. During many dynamic situations, police have limited opportunity for traditional computing in the cars. One officer pointed this out:

I would say in a crisis situation - not a normal situation you are used to going to, like a domestic assault where you would use the computer to check on things - it is such a hostile environment and you are cognizant of your safety and everyone else's safety (example, a barricaded gunmen with a hostage), that you really don't have time to jump into the car and start typing on computer.

You tend to forget about the computer system and just radio dispatch and have them do everything on their computer system which is basically the
same thing we have. We don't have to sit in the car and try to look things up - just let dispatch do it. We can take care of our primary responsibility. It frees up our hands and eyes. I've been called into situations like this and I just get on the radio and let dispatch handle the computer.

This suggests situations where officers need access to technology indirectly, such as by radio to dispatchers. Officers may not want direct access to computers, especially once they are outside their vehicles. Though research has considered handheld devices for first responders, (Sawyer, Tapia, Pesheck, & Davenport, 2004), these may be restricted to certain scenarios. The other point this brings out is dispatcher-police cooperation. Even though the officer is too busy to directly access the system in some circumstances, system support is still an important issue. Some systems could be developed at the dispatcher level\textsuperscript{21} to better support the officer in the field.

In addition, officers felt that some information should continue to be reported to dispatch by radio, such as officer status, even though mobile data terminals could automate these updates. Their concern is twofold. First, officers use the radio to monitor each other. Status updates by current mobile data terminal applications would only be relayed to dispatchers and not “heard” by the other officers. Second, officers feel more comfortable operating a radio in an emergency than a computer.

\textsuperscript{21} Sawyer et al. (2004) refer to this as a “proxy query” by the dispatcher in parallel with the officer’s on-scene incident management. For example, while observing dispatchers an officer could not locate a rural accident that a caller had “heard” from their home. Without prompting, the dispatcher brought up a detailed map of homes and identified an overlooked road close enough to the caller to be a probable location. In doing so, the dispatcher successfully guided the officer to the accident.
4.1.4 Implications for Second Analytical Stage - Knowledge Elicitation

The ethnography stage provided valuable insights into the policing domain. It also helped guide planning for the knowledge elicitation stage. During the ridealongs it was clear that knowledge elicitation would best be done during weekday daylight working hours, a time of reduced police activity. Also, the constrained space of the police car and the not much larger office space reduce the concept mapping activities from the traditional poster board to a more manageable ledger-sized office pad.

Another ethnography implication for knowledge elicitation was identification of design leverage points. In this dissertation, design leverage points represent commonly occurring themes where the cognitive activities of the officers might benefit from the intervention of a cognitive support tool. For reasons described below, the design leverage points include situation awareness and post hoc analysis and review of police incidents.

4.1.4.1 Design Leverage Point - Situation Awareness

Decision-making in the wild (Hutchins, 1995) frequently depends on situation awareness (SA). Evaluating situations and courses of actions involves three levels. First, the expert must perceive critical factors in the environment. Second, the expert must understand what those factors mean particularly within the context of a goal state. Third, the expert must understand what will happen with the system in the near future (Endsley, 1988).
SA can be generalized in this dissertation to begin with awareness of surrounding events as well as recognition of the importance of those events. This is particularly true in the police domain where officers work independently while monitoring the situation of other officers. It was observed that this awareness was suboptimal during several ridealongs. For example, improved SA would have helped during an incident to search an apartment complex in an attempt to serve a warrant. The suspect had been seen leaving a school and heading to a nearby apartment. Several officers responded, including a vehicle from the sheriff’s department. However, it was difficult for the officers to develop or share an awareness of the scene and to coordinate movement between them.

SA shortcomings have also been noted in secondary data analysis of other domains, including emergency response during the World Trade Center attacks as well as Hurricane Katrina ("The 9/11 commission report: Final report of the national commission on terrorist attacks upon the United States", 2004; Gage & McCormick, 2002, "McKinsey report / increasing FDNY’s preparedness", 2002; Walsh, 2006).

4.1.4.2 Design Leverage Point – Post Hoc Analysis and Review

During a ridealong, I observed two officers stop beside each other during their patrol to discuss an officer that had been assaulted the night before. While exchanging news, it also seemed that they were exchanging ideas on how to think and act in similar situations. The importance of post hoc analysis and review of incidents such as this was also observed during the skills training described earlier.
Community policing reforms and field reporting systems have made police work more autonomous, making it more difficult to find opportunities for officers to discuss incidents and share knowledge. For example, one officer mentioned that prior to field reporting he would meet with his supervisor to submit reports during the last hour of his shift. This also provided an occasion to meet and discuss incidents with other officers in the work group also turning in their reports.

In general, storytelling has been cited as an important example of learning that needs to be retained in process and system designs (Schank, 1995). Thus, a system could be envisioned to manage and share the learning that takes place through storytelling. This is important since shared lessons from past experiences help officers approach and manage new situations encountered in the future. In addition, processes and systems could be designed to share experiential learning even beyond an officer’s immediate work group.

4.2 Analytical Results: Knowledge Elicitation Stage to Develop Task Understanding

The objective of the second analytical stage is analysis of decision-making during critical incidents using knowledge elicitation methods. This stage builds on the ethnography analysis of the cognitive work domain. Whereas the objective of the domain analysis was to develop understanding of domain-based constraints on cognitive work, the goal of the cognitive task analysis is to provide insight into specific cognitive activities situated within this domain. Whereas, the domain analysis provides insight into
the cognitive environment of the worker, task analysis provides insight into specific
cognitive activities in performing tasks.

The task analysis is conducted using cognitive knowledge elicitation techniques
including concept mapping and analysis of decision-making during critical incidents.
Results from this section include insight into real world problem-solving by police
experts, as well as specific design seeds that will be used in the intervention stage to
create a prototype and related training scenarios to enhance cognitive effectiveness in the
policing domain.

4.2.1 Exploring Cognitive Complexity of Critical Police Tasks

The critical decision method is used to elicit explicit and tacit knowledge used by
domain experts to assess situations and make decisions. Modifications are made to the
method to seed design and training based interventions to support and improve officer
decision-making in dynamic work environments. The data was collected through semi-
structured interviews based on the critical decision method and graphing techniques.

4.2.1.1 Participant Interviews

The semi-structured critical incident interviews with ten police experts generated
28 Situation Assessment Records and 61 decision points. This process presented rich
insight into officer decision-making, including expert use of cues, knowledge and goals
to make decisions. The records captured easily identifiable knowledge (explicit) such as
protocols, less visible knowledge (tacit) such as hunches, cues and goal states, and system support opportunities (mostly within the design leverage areas of situation awareness and post hoc analysis and review). Appendix F describes the ten critical incidents and identifies the title of associated Situation Assessment Records. It also includes a conceptual assessment of one of the Situation Assessment Records.

4.2.2 Analysis of Themes

Colored markers were used on printouts of the Situation Assessment Records (SAR) to flag themes. The themes continue to be refined through the data analysis spiral (Appendix G), including member checking. The themes that emerged were cognitive shaping processes developed before arriving on-scene (prior cognitive shaping processes), after arriving on-scene (situated cognitive shaping processes), and through direct and indirect use of system support tools (system shaping cognitive processes). Each of these cognitive shaping processes include elements of visible and less visible knowledge and cues used to guide the focus of decision-making process during non-routine events.

In this section, two assessments (SAR 1.1 and SAR 1.2) from the “Shots Fired” incident are presented both as an illustration of the task analysis process as well as to help present findings. In this incident, a sergeant and patrol officer from MPD-B were called at 2:30AM to investigate a man under the influence, waiving a gun and making threats in his apartment. The caller told the dispatcher to expect the gunman as well as a woman in the apartment. These two assessment records were created prior to shots being fired at
the officers. The first record (Table 10) ends after arriving on-scene, positioning the vehicles and approaching the apartment.

Table 10 Situation Assessment Record 1.1 Approach (Shots Fired Incident)

<table>
<thead>
<tr>
<th>SAR 1.1</th>
<th>Approach</th>
</tr>
</thead>
<tbody>
<tr>
<td>Description</td>
<td>Upon arriving the officers followed protocol to position cars away from the scene and arrive on foot. Almost as an afterthought, the sergeant grabs his black police jacket as he leaves the car. Other than the jacket, each officer is similarly equipped including a handgun and portable police radio.</td>
</tr>
<tr>
<td></td>
<td>As the offices approach the apartments, they find the numbering somewhat confusing. The apartment building has two levels. Each apartment has its own door to the outside at ground level. Some doors enter directly into ground floor apartments, while others enter to a stairway that then goes up to a landing and finally through another door to the 2nd floor apartments.</td>
</tr>
<tr>
<td></td>
<td>It is late and the officers are almost at the end of their shift. It is very dark and the air is cool. The officers find the correct door and position themselves to the sides and knock. The door has side window panels through which they observe a female come out of the apartment to the top of the landing. It is at this point that they realize the apartment is actually above them on the 2nd floor.</td>
</tr>
<tr>
<td>Cues/ Knowledge</td>
<td>Dispatch reports a call claiming a man in an apartment is drunk and waiving gun.</td>
</tr>
<tr>
<td>Goals</td>
<td>Arrive safely on-scene.</td>
</tr>
<tr>
<td>Decision Point -1</td>
<td>Position cars and approach apartment on foot.</td>
</tr>
<tr>
<td>Decision Point -2</td>
<td>Grab Jacket when leaving car.</td>
</tr>
</tbody>
</table>

The second record (Table 11) begins after assuming positions at the apartment doorway and ends with removing the woman from the apartment. Note that changes in goal state are used to decide when to create a new assessment during an incident. In this incident, the first goal state was to arrive safely on-scene, and the second goal state was to safely investigate claims and not to allow the woman to reenter apartment.
Table 11 Situation Assessment Record 1.2 Door Tactics (Shots Fired Incident)

<table>
<thead>
<tr>
<th>SAR 1.2</th>
<th>Door Tactics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Description</td>
<td>The female comes down the stairs and opens the door. Behind her, the door to the apartment at the top of the landing is open. She appears uncomfortable and not sure what to do after realizing it is the police. It appears her first instinct will be to just turn and return to the apartment. The sergeant, who had been on the left side of the door, crosses in front of the doorway to take the woman’s arm and escort her outside and to the officer on the right-side of the doorway.</td>
</tr>
<tr>
<td>Cues/ Knowledge</td>
<td>Officers position below balcony creates exposure; movement of woman to reenter apartment.</td>
</tr>
<tr>
<td>Goals</td>
<td>Safely investigate claims; do not allow woman to reenter apartment.</td>
</tr>
<tr>
<td>Decision Point -1</td>
<td>Cautiously maintain position by doorway, below balcony.</td>
</tr>
<tr>
<td>Decision Point -2</td>
<td>Do not allow female to return upstairs to apartment.</td>
</tr>
<tr>
<td>Decision Point -3</td>
<td>Do not re-cross doorway; go around building to get officers back into position on both sides of door.</td>
</tr>
</tbody>
</table>

Officer cues, knowledge and decision points are discussed relative to three cognitive shaping processes: prior cognitive shaping processes, situated cognitive shaping processes, and system shaping cognitive processes.

4.2.2.1 Cognitive Shaping Processes Prior to Arriving On-Scene

In SAR 1.1, the cues came largely in the form of a dispatch report based on a call from a woman that had left the apartment earlier. However, this includes more than the visible information included in a police incident report such as caller, time, location, and incident type. It also involves cognitive shaping processes developed over time by officer knowledge of the dispatchers, experience with similar incidents, and in some cases, the caller themselves. At this point it is useful to consider the sequence of events leading up to dispatching an officer.
A call to the 911 dispatch center is usually from a victim or witness untrained in reporting emergencies and often under duress. The inbound dispatcher who takes the call is trained to follow certain protocols to determine the identity and location of the caller, the safety of the caller and enough details to route the call to the appropriate outbound dispatcher. In this jurisdiction dispatch is managed and run by the county. Peak dispatch staffing typically includes one supervisor, one inbound dispatcher (to take 911 calls) and four outbound dispatchers. Dispatchers are typically cross-trained and during peak call time, any (including the supervisor) may take calls.

As one inbound dispatcher related, understanding the caller can be a challenge. If a caller says “I’ve been hit by a car” this could mean very different things depending on if the caller was walking, driving or riding a bike, for example. Figuring out the location of the incident can also be difficult. At the dispatch center I observed a cell phone caller report a “fight outside a bar.” The dispatcher could not send an officer because the person could not describe the location. In this particular situation, the dispatch center was receiving heavy call volume. Calls such as this were common and began frustrating the dispatchers, adding to their stress of the call volume. Also, some calls require multiple responses. I observed a call reporting that a drunk had climbed out on a roof. This call required the inbound dispatcher to coordinate with three outbound dispatchers to get police, fire and EMT to the scene.

During peak hours, outbound dispatchers are assigned a specific function. The first will dispatch MPD-A, the second will dispatch non-MPD-A police, the third will dispatch fire and the fourth will dispatch EMTs.
The net effect is that the incident details finally presented to the officer may have passed through several individuals in various states of understanding and compounded by distance, duress and stress. This leaves the officer to also interpret the information. Thus, the process of identifying cues begins before arriving on-scene and extends beyond the few details announced over the radio or routed by computer. Part of this includes analysis about the dispatchers handling the call, and in some cases, knowledge about the caller themselves.23

Officer knowledge (including confidence, attitudes and opinions) regarding dispatchers develops over time. Since dispatchers refer to themselves as “county” on the radio and do not identify themselves individually, officer knowledge of dispatchers is largely gained by associating past experiences with a dispatcher voice. This is an example of using meta-cognitive cues to interpret priorities and responses. Similarly, since officers identify themselves by badge numbers, dispatchers also begin associating their voice with a number. The relationship is virtual and anonymous, since officers and dispatchers rarely meet face-to-face.

The knowledge and confidence that officers associate with the dispatcher carries over from previous experiences. This influences officer decisions based on what support the officer can expect from the dispatcher, since experienced dispatchers anticipate officer needs and requests. This, in turn, guides where the officer can plan to focus his or her attention, actions, and decision-making after arriving on-scene. Experienced officers

23 As an example of the latter, an officer was observed to receive a second incident before he had responded to the first incident. He suspected from previous experience with the callers in the first incident that given time, the situation would resolve itself. He used this knowledge to prioritize the incidents and respond to the second incident. He used his cell phone from the scene of the second incident to verify with the first caller that, in fact, the situation had resolved itself.
know that with minimal direction, tasks can be offloaded to an experienced dispatcher. In doing so, the officer can focus decisions and actions to more immediate tasks (such as escorting the woman from the doorway which was previously described in the Shots Fired incident). Other decisions, such as requesting back up, EMTs, fire, traffic control, etc., can be offloaded by simply reporting “gun” or “shots fired” or “10-13” (officer in distress) to an experienced dispatcher.

Thus, the cues and knowledge used to guide decision-making in critical incidents begin to be shaped in the context of the situation even before the officer is on-scene, are developed over time, and influence the focus and decision-making abilities of the officer once on-scene.

4.2.2.2 Cognitive Shaping Processes after Arriving On-Scene

The officer has an opportunity, once on-scene, to directly evaluate the situation as a professional trained in assessing critical incidents, prioritizing responses, and making decisions. Upon arriving, officers are trained to treat every incident as unique. This is important to prevent officers from becoming desensitized to incidents resulting in poor judgment. For example, an officer must respond to silent alarms with caution, even after responding to many false alarms.

In the Shots Fired incident, the sergeant was a supervisor with over 20 years of experience, while his partner had less experience. In SAR 1.1, the sergeant grabbed his jacket, while his partner did not. In SAR 1.2, the less experienced partner was observed shivering from the cold. Although the sergeant and officer were both tired and coming to
the end of their shift, the sergeant knew from experience that any incident involving a
gunman could become lengthy and that protection from the elements might be
important.\textsuperscript{24} This was the case here as the standoff continued until almost noon the next
day.

The first cue in SAR 1.2 begins with the discovery that the apartment is on the
second floor, followed by a second cue in movement of the woman to retreat from the
door. Recognizing that the apartment was above them made the officers realize that their
approach path and current position could expose them to the gunman above. Despite this
knowledge, they decided in SAR 1.2 to maintain the doorway position. Doing so now,
however, meant dividing attention between the doorway, the woman and the balcony
above.

The second cue in SAR 1.2 was subtle. It required the sergeant to interpret the
woman’s movement as an attempt to return back to the apartment. In response to this
cue, the sergeant decided to risk exposure in the doorway while quickly guiding the
woman out of the entrance and to the other side with his partner. At this point the goal
shifted from maintaining safety to not allowing the woman to return to the apartment.
Allowing the woman to return would have compounded the situation by providing the
gunman either a hostage or an accomplice.\textsuperscript{25} This situation could not have been
anticipated until the officers were in place and the woman came down the stairs just

\textsuperscript{24} Phetteplace (2000) reports that cold weather can negatively impact physical, cognitive, and emotional
capabilities.

\textsuperscript{25} After encountering a gunman, officers switch into a defensive mode where decisions focus on containing
the gunman, protecting themselves and removing civilians from danger. The only exception to this is when
an officer decides that hostages are in eminent danger. This exception is a recent policing development
following the 1999 Columbine High School Shooting. In either scenario, however, officers are still
motivated to isolate and contain gunmen from others.
moments earlier. Again, it was the more experienced sergeant that interpreted and reacted to the woman’s movement.

SAR 1.1 and 1.2 in the Shots Fired incident help illustrate that cues developed in real world contexts are interpreted to the best of an officer’s ability at the time and within the context of prior experiences. Officers can enhance this ability by suppressing previous experiences (such as frequently responding to false alarms), grabbing a jacket or recognizing implications from subtle movements.

4.2.2.3 Systems Shaping Cognitive Processes

Systems can also shape decision-making. In doing so, however, officers consider the perceived decision-making value with the cognitive resources required to operate the systems.

The technologies in the Shots Fired incident included the initial phone call to dispatch, the dispatch CAD system, the dispatch radio call to the responding officers and the mobile data terminal in the car. Once onsite and out of the cars, though, the officers’ preferred device is the radio. The radio is easy to operate and consumes minimal physical and cognitive resources. In fact, the common personal radio is almost embedded into the uniform. The microphone is frequently clipped to a shoulder epaulet allowing the officer to speak into the microphone by reaching up with one hand to key the mike along with a slight head movement. Eyes can focus on their surroundings, the gun hand is free, and all other movement (walking, running, etc.) is unconstrained. At any time an officer
can let go of the microphone, if needed, and quickly move about without worry of loss of the device for later use.

The cell phone is a relatively recent support tool that is gaining in popularity with police, but is still second to the personal radio. The cell phone is versatile and allows officers in the field to communicate directly without having to return to the station or go through dispatch. Officers can also use the cell phone to hold extended conversations with other officers or dispatchers. This is important since, as described earlier, radio communications are intentionally minimized. In many cases, the cell phone is the only way for officers on duty to talk to each other for more than a few moments (other than pulling cars next to each other). The reason the cell phone is still second to the radio is because it can not be monitored by other officers. Monitoring radio traffic results in a dynamic awareness of other officers. In the Code 1 Search incident, for example, a supervisor even treated the lack of radio communication as a cue to identify which officer was in need of assistance.26

The radio is the primary support device used by on-scene officers during the Shots Fired incident. The sergeant focused on keeping the gunman talking while his partner maintained radio communication with dispatch directly. In doing so, communication was also shared with all officers monitoring the shared channel.

The dispatcher, on the other hand, had computer access to maps, dwelling photographs and several law enforcement databases. Dispatchers also have access to

26 The Code 1 Search incident is described in Appendix F. An officer wrestling with a gunman only had time to radio “10-13” (officer in distress). He did not have time to identify himself or his location.
Design interventions to support officers in the field should provide situation-relevant information at the lowest cognitively distracting cost possible. The current arrangement of using an embedded portable radio to connect to a dispatcher with extensive access to computing is the standard upon which future system support should be evaluated.

Possibilities do exist and should be investigated for system improvement from a cognitive perspective. For example, the ability to send images and documents to officers in the field is limited, even using their car computer. In some cases, attaching building photographs and aerial maps to incident reports could be helpful. In the Shots Fired incident, for example, officers might have altered their approach to the apartment had such site location and configuration information been available. Support officers assigned to perimeter positions would benefit by having a photograph of the suspect routed to a PDA, for example. In any case, the pursuit of system innovation for policing needs to preserve the cognitively shaping role of current systems by balancing cognitive load with situational benefits.

4.2.3 Assessment Record Results Using Conceptual Techniques

The ninth incident (Road Rage Part II) was elicited using conceptual techniques. SAR 9.3 (“Standoff”) from this incident is discussed below to illustrate conceptual benefits as well as to reinforce the three cognitive shaping results described above. The
Road Rage Part II incident began with two officers attempting to serve a search warrant to look for a gun that had been used in a road rage incident. This assessment begins in a standoff with officers outside a home, communicating with the gunman. The goal at this point is to end the standoff without injury, disarm the individual and have him surrender. In this assessment, the cues and knowledge are displayed in a concept map generated by an officer in response to the CDM prompts.27

The officer began by mapping the situated cognitive shaping processes (Figure 24). From left to right, the sequence begins with what the officer sees (man with a gun and the direction the gun is pointed), what the officer hears (the man wants police to leave) and what the officer is told (command is notified and additional officers including the chief are on the way). In a sense, the officer is telling us that he processed the information based first on what he saw, then on what he heard and then finally on what he was told.

27 The complete 9.3 assessment map is presented in Appendix F.
The bolded items in Figure 24 indicate the system shaping cognitive processes. In this incident, the officer used his “radio ear” to monitor police communications. Knowledge of the police response (including deployment of additional officers and creation of a command center) allowed him to focus decisions on maintaining a calming conversation with the gunman.

The situated and system shaped cognitive processes described above were used to develop decisions on-scene and shaped by knowledge from prior experiences. The officer mapped the cognitively shaping prior experiences on the right side of the concept map which is continued in Figure 25.
In the above map, the expert developed knowledge and cues from prior experience as a negotiator and member of the O/S (observation-sniping) team to shape on-scene decision processes. This enabled the officer in this incident to focus on decisions to appear ‘less intimidating and more personable.’ The officer kept the situation from escalating by developing trust with the gunman.

4.2.4 Seeding Design Interventions

The process to develop design seeds began with the identification of two design leverage points in the ethnography stage: situation awareness, and post hoc analysis and
review. These two leverage points are used at the conclusion of each critical incident analysis session to identify specific design seeds capable of improving cognitive effectiveness.

4.2.4.1 Situation Awareness

Critical decisions involve recognition of world cues and other elements of situation awareness that reveal level of threat and needed response. Experts making decisions in dynamic work environments are faced with problems that involve multiple players and may be time constrained, ill-structured, ill-defined, and shifting. The stakes of the decision may also be high (Klein, 1989; McNeese, Bautsch, & Narayanan, 1999; Rasmussen, 1985).

To identify design interventions, the critical decision sessions in the second analytic stage included an opportunity for the expert to evaluate situation awareness gaps or opportunities. The knowledge elicitation sessions generated 36 such ideas (Appendix H), ranging from monitoring the radio to determine officer status to using case files to determine an individual’s recent history to knowing the layout of an apartment complex, for example.

4.2.4.2 Post Hoc Analysis and Review

Experts are able to see events differently than novices, allowing them to make better decisions under the pressure of non-routine incidents. This visibility includes
world cues, patterns, missing information, the past, the future and methods to process this information (Klein, 1998). It became apparent as I observed officers during the domain analysis and interviewed them during the task analysis that their experiences could help novices. Currently many of these experiences are not captured and if shared, only reach a few officers in an immediate circle. After conducting the knowledge elicitation session with the officers, I asked them to analyze their experiences. In contrast with the situation awareness initiative, which is to identify system support gaps, this effort is to conduct post hoc analysis and review of their experiences to identify useful information for future incidents. This exercise generated 32 ideas (*Appendix I*), ranging from selection of approach paths to evening uniform selection to interviewing rescued family members, for example.

### 4.2.5 Implications for Intervention Stage – Participatory Design

Insight developed from the domain and task analysis in this chapter is used in the intervention stage (*Chapter 5*) to create a prototype intended to improve cognitive effectiveness. This begins with the selection of a design seed for prototype development. This is followed by domain and task modeling that includes representations of the work domain structure, work activity processes, information flows and decision-ladders used in decision-making. In addition to guiding prototype development, these models are used to create scaled world training scenarios. The scenarios can be used to train officers in real world decision-making.
Chapter 5

Intervention Results
This chapter describes the results from the intervention stage, beginning with the selection of the incident and design seed upon which the prototype is based. Next, the prototype planning processes are described, including modeling of the cognitive domain and task, as well as information needs. Then, participatory design used to develop the prototype is described. Finally, training scenarios based on the prototype are presented.

5.1 Design Seed Selection for Participatory Design

Critical incident knowledge elicitation sessions identified cues, knowledge and decision points by officers of various levels of expertise during critical incidents. These sessions were modified to also include an analysis of opportunities to improve incident-related situation awareness and post hoc analysis and review. The critical incidents were then evaluated to select one to develop in the scaled world. The criteria used to select the incident for further development included expert availability to participate in design and evaluation of a prototype, the ability to create useful scenarios to accompany the prototype, and the likelihood that the prototype could be adapted in the police domain.

The critical incident that best met all these criteria came from the knowledge elicitation session with Sergeant Johnson\(^\text{28}\), the research liaison at MPD-C. The liaison had 25 years of law enforcement experience both as an officer and a supervisor, and also had the interest, experience and availability to further develop the scenario and prototype. The original critical incident centered on the creation of a unified incident command center in response to a barricaded gunman (Critical Incidents 3 and 4 in Appendix F).

\(^{28}\) An alias
As senior officer, Sergeant Johnson was incident commander and experienced first hand the difficulties in assessing situation information needed for decision-making. This incident is reviewed in the next section.

5.1.1 Unified Incident Command for Barricaded Gunman Incident

Police events that may not be resolved quickly and may need the integration and deployment of first responders from different jurisdictions require the creation of a command center. Thus, in the police domain, command centers are developed spontaneously and evolve in response to certain incidents. Command centers follow the unified incident command originally developed in the 1970’s by emergency managers responding to rapidly moving wildfires ("History of incident command system", 1994).

Wildfire emergency managers were faced with several issues including too many people reporting to one supervisor, different organizational structures of the responding agencies, lack of structure to coordinate planning between agencies, and unclear lines of authority. In response to these issues, an interagency task force involving local, state and federal agencies created a response structure that could be organizationally flexible to handle incidents of different sizes and types and allow diverse agencies to meld into a common management structure. The command center structure is now used in several domains, including law enforcement, to manage incidents that occur with no advance notice, can develop rapidly, represent risk for life and property, are expensive to mitigate, and involve several agencies and jurisdictions.
Police command centers are created with temporary structures and organizations (including managers and participants) in response to diverse incident types. The location and focus of the command center varies in response to the incident that caused its creation, and may need to change over time.

During the knowledge elicitation sessions to investigate decision-making during a critical incident, Sergeant Johnson described a barricaded gunman situation. The situation began when Officer Simpson and another officer attempted to serve an involuntary commitment warrant to an individual with a history of mental health and alcohol abuse issues. The two officers arrived mid-morning during a pleasant August day. In response to their knock, the man’s mother and two friends came fleeing out past the officers yelling “He has a gun.” The situation became more complicated because the gun was actually an assault rifle and the home was located near other homes, a major shopping area and heavily traveled roads. Officer Simpson and his partner switched into containment mode and notified dispatch of the situation. Dispatch directed available officers from other jurisdictions to the scene, off duty officers from MPD-C, and an MPD-C supervisor (Sergeant Johnson). As senior officer in the jurisdiction, Sergeant Johnson assumed the role of incident commander upon arrival. This incident lasted 18 hours and included shots fired by the suspect, one of which actually hit the command center. Table 12 summarizes the major event timetable for this scenario.

29 An alias
Table 12 Barricaded gunman major event timetable

<table>
<thead>
<tr>
<th>Time</th>
<th>SAR</th>
<th>Event</th>
</tr>
</thead>
<tbody>
<tr>
<td>9:30</td>
<td>3.1 Warrant</td>
<td>Officer Simpson and a partner serve a 302 involuntary commitment warrant.</td>
</tr>
<tr>
<td>10:00</td>
<td>3.2 Barricaded Gunman</td>
<td>Response to police knock on door is family members fleeing, saying “He has a gun.” Man appears briefly with an assault rifle before returning into home.</td>
</tr>
<tr>
<td>10:05</td>
<td></td>
<td>Officer Simpson retreats to safety to observe and contain the gunman barricaded in his home. Simpson requests family members stay nearby in safety and wait to be interviewed to gather information to be used in a negotiation.</td>
</tr>
<tr>
<td>10:15</td>
<td>3.3 Preliminary Staging</td>
<td>Officer Simpson acts as initial incident commander and creates first staging area to brief and deploy arriving officers. To continue observation, Simpson creates staging area in close proximity to incident.</td>
</tr>
<tr>
<td>10:30</td>
<td>4.1 Unified Incident</td>
<td>Off-duty Sergeant Johnson called in by dispatch to create and manage a unified incident command center.</td>
</tr>
<tr>
<td></td>
<td>Command Center</td>
<td></td>
</tr>
<tr>
<td>11:00</td>
<td></td>
<td>Sergeant Johnson arrives and assumes incident command from Simpson. Second staging area and command center created across the street from first staging area (more room for arriving police cars).</td>
</tr>
<tr>
<td>11:05</td>
<td></td>
<td>Officer Simpson assumes role of negotiator and begins interviewing family members.</td>
</tr>
<tr>
<td>15:35</td>
<td></td>
<td>Sergeant Johnson moves incident command to third location after it is observed that the second location is in the line-of-fire from gunman’s home.</td>
</tr>
<tr>
<td>16:14</td>
<td></td>
<td>Nearby store advised to voluntarily close garden shop (also in line-of-fire).</td>
</tr>
<tr>
<td>16:45</td>
<td>4.2 Intruder</td>
<td>Through the outer police perimeter, a male intruder charges from a wooded area toward the gunman’s home. Intruder believes his girlfriend is held hostage by the gunman and is attempting a rescue (although gunman is actually alone). A perimeter officer with a less-than-lethal shotgun fires three sandbag rounds at intruder, knocking the intruder down. Intruder is arrested. Police detail is assigned to gather evidence regarding intruder arrest (i.e. witnesses, video, etc.).</td>
</tr>
<tr>
<td>20:00</td>
<td></td>
<td>Photo of barricaded gunman, flashlights, food and dark shirts distributed to perimeter officers.</td>
</tr>
<tr>
<td>03:09</td>
<td>4.3 Flash-Bang</td>
<td>Sert (state police high risk entry team) detonates flash-bang grenades and tear gas into gunman home. Gunman believes police are attacking and fires toward explosions (one round strikes incident command center).</td>
</tr>
<tr>
<td>03:55</td>
<td></td>
<td>Gunman surrenders.</td>
</tr>
</tbody>
</table>
Analysis of the critical incident during knowledge elicitation focused on decisions that were made and the cues and knowledge used in making those decisions. The critical incident sessions also included evaluation of situation awareness and post hoc analysis and review. Several comments by Sergeant Johnson in response to these probes revealed opportunities to improve cognitive activity within the command center (Table 13).

Table 13 Opportunities to improve incident command cognitive activity

<table>
<thead>
<tr>
<th>Situation</th>
<th>Opportunity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Staging command center moved 2 times (initially to provide more space for arriving officers, and then to remove the command from line-of-fire).</td>
<td>Planning tool to determine command center location meeting space and security needs.</td>
</tr>
<tr>
<td>As incident continued into the evening, task managers needed an illuminated meeting area for field communications and planning (a DUI van, which included lights, was improvised).</td>
<td>Mobile command center with communication and planning capabilities, as well as shelter from the elements.</td>
</tr>
<tr>
<td>Police force during an incident can include less-than-lethal and flash bangs, for example. In these cases, perimeter officers with lethal weapons need to be aware so as to refrain from using their weapons.</td>
<td>Procedures to notify perimeter officers of force being used.</td>
</tr>
<tr>
<td>Lengthy incidents require replacement of officers, including negotiators and command staff. Event history and situational information needed for continuity.</td>
<td>Orientation capability for replacements.</td>
</tr>
<tr>
<td>Other agency officers arrived with white uniform shirts (stood out too much when incident continued into evening).</td>
<td>Ability to replace equipment, including uniforms, of arriving officers.</td>
</tr>
<tr>
<td>SERT (state police SWAT team) decided to use flash-bang grenades to bring incident to an end. Gunman, thinking he was being invaded, fired his gun at the noises.</td>
<td>Track experience for future incidents.</td>
</tr>
</tbody>
</table>
Continuation of Table 13 Opportunities to improve incident command cognitive activity

<table>
<thead>
<tr>
<th>Situation</th>
<th>Opportunity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Negotiator has specialized needs, including a team with a scribe (track discussions) and criminal investigator (conduct research). Also needs access to family members to provide insight into gunman background and state-of-mind.</td>
<td>Develop negotiation team capabilities and instruct officers not to allow evacuated family members to leave scene without being interviewed.</td>
</tr>
<tr>
<td>Command had trouble understanding aspects of scene based on descriptions (such as proximity and position of possible escape vehicles).</td>
<td>Capability for video and/ or photography access into scene.</td>
</tr>
<tr>
<td>Perimeter officers did not get a picture of gunman until several hours after start of incident.</td>
<td>Capability to acquire and share information with officers in the field.</td>
</tr>
</tbody>
</table>

Consistent with the MAKADAM methodology, the interview sessions use concept maps to provide an interactive basis to share and check information, as well as enable unconstrained expression of knowledge (McNeese et al., 1995). In follow-up sessions with Sergeant Johnson, a concept map was created to explore aspects of the unified command center (Figure 26). During this interview, it became apparent that cognitive challenges in managing the command included locating the center, understanding the scene, and tracking and managing resources. These activities are important because they have ripple effects on subsequent cognitive processes during an incident.
The map in Figure 26 indicates solutions to several problems in managing the command, such as assigning and tracking resources. For example, as officers present themselves they are assigned to a deployment detail, including inner and outer perimeters, observation-sniper positions, negotiation, traffic control and evacuation. If possible, an officer’s deployment should consider specialized skills and weapons (i.e. less-than-lethal, long gun and shotgun). In addition, officers arriving from other jurisdictions have special needs in developing common familiarity with the scene, the incident and other officers.
Besides officer deployment, other command decisions include command location, officer tracking, road closures, and business and residential evacuations. During prolonged deployments, officers need food, water, breaks and eventually relief. In some cases, special clothing or other equipment is needed.

5.2 Planning the Prototype

To continue this development of a cognitive aid for command centers, it is necessary to consider domain constraints identified during the field ethnography. Analysis of the work domain helps frame the landscape within which all cognitive tasks takes place.

5.2.1 Command Center Task Analysis

Means-ends diagrams (Rasmussen et al., 1994) are useful to model domains because they identify the resources (“means”) by which actors achieve their goals (“ends”). These diagrams attempt to make explicit the goals, constraints and processes available within a particular work domain. When combined with task analysis, this approach is particularly valuable in the current effort to develop a prototype intervention. For the unified command center, the means-ends hierarchy can be combined with a whole-part decomposition to show how the command fits into the overall goals of regional law enforcement. Using this combined technique, tasks that are performed at the
physical command center level can be understood within the context of the greater system goals (Figure 27).

![Figure 27 Unified command center relationship to general law enforcement (Adapted from Chin et al., 1999)](image)

The means-ends command center hierarchy presented in Figure 28 was elicited from interviews with domain experts, as well as domain readings (Klockars, 1985; Manning, 1997). The overarching goal for all tasks performed within this domain is inherited from regional police goals to prevent and investigate crime. Within the context of the unified incident command center created in SAR 4.1, this translates into preventing a barricaded gunman from harming himself or others, and attempting to safely take him into custody. The priorities that stem from these goals include making good decisions, processing information, and keeping clear lines of authority. This is accomplished by assessing the incident, managing resources and sharing information. These are further subdivided into the needed physical processes (i.e. moving information, deploying officers, etc.) and objects (i.e. first responders, radios, and the command center itself).
This information can also be presented in a diagram that shows the why and how relationship between each of the strata (Figure 29). Later in this chapter, the designed means-ends hierarchy will be compared to an information needs map developed for the barricaded gunman scenario.
The ends strata in Figure 29 (goal and priorities) were identified during the field ethnography and domain analysis. The means strata (functions, processes and objects) for the command center were identified during knowledge elicitation sessions with Sergeant Johnson, including one that resulted in the concept map presented in Figure 30. The results presented here and from interview discussions suggest that the decision types performed by police incident commanders fall into three groups: situation monitoring, planning and control. These findings are consistent with other studies (Potter, Elm, Roth, Gualtieri, & Easter, 2002; Roth et al., 2002).
Figure 30 Command center task analysis map for barricaded gunman scenario

Situation monitoring includes tracking elements related to goal status and the processes supporting those goals. As this situation began, the goals included containing the gunman and protecting the public (i.e. prevent crime by preventing injury to officers, civilians and the gunman). The processes supporting the goal are also monitored including officer details that are tracked. Information from the officers is reported back and processed. This information includes what officers see and hear at the scene with respect to the gunman, civilians and each other.
Planning includes setting priorities, tracking resource availability and supporting needs for those resources. Planning begins with the location of the command center itself. It needs to be close enough to the incident and have space to stage and manage resources. However, it should not be too close to be compromised should the incident escalate. In this case, although the command had been relocated several times, it still ended up being shot. Tracking resources includes providing officers breaks and sustenance and, at some point, relief. Planning also includes identification of actions and alternatives as well as the outcomes of those activities. After 18 hours, for example, it was decided that flash-bang grenades would be used by the state police high risk entry (SERT) team to scare the gunman into surrendering and bring the incident to a close. Unfortunately this action actually scared the man into firing his assault weapon at the noise.

Controlling the process includes using information to make decisions to optimize the performance of the various elements ultimately leading to the termination of the incident and command. Follow-up investigations are used to review police actions and gather evidence for prosecution.

Each of the situation monitoring, planning and control decision groups can be evaluated within the context of the information needed at the command center.
5.2.2 Visualizing Command Center Information Needs

The next step in this iterative bootstrapping\textsuperscript{30} process is to identify informational needs of incident commanders with respect to the above decision groups. This was done in a knowledge elicitation session using concept mapping to graphically capture and represent the results. A probe question was used to develop this map: “As incident commander, identify information that would be needed or desired in an idealized screen.” Mapping allowed the expert to focus on informational concepts unencumbered by specific artifact constraints.

\textsuperscript{30} Bootstrapping is the use of multiple, converging techniques where each step provides knowledge and insight used to guide the next step (Potter et al., 2000).
Figure 31 Information needs in the command center barricaded gunman scenario

The map includes useful information for situation monitoring, planning and control decisions. It includes aerial maps to place the command center and staging area, and place officers. This information could also be used to plan evacuations and close roads. Specific officer resources could be tracked by location, weapon and skills allowing for support and replacement decisions. A whiteboard component could be used to track notes and evaluate alternative plans. In addition, the information could be used to brief new officers and partner agencies in a rather quick and consistent manner.
As a process check, Figure 32 compares information needs (presented at the bottom half of Figure 32) with the previously designed means-ends hierarchy (presented at the top half of Figure 32). It reveals a close relationship between command decision-making and the mid-level priority and functions stratum. Priority strata are important to establish the intention behind the design and operations, such as developing the command relative to the incident and information quality (speed, accuracy and cost effectiveness). The functions strata connect the higher level priorities to the lower level processes, such as assessing the incident, tracking and managing resources and sharing information. This close relationship adds consistency to the mapping sessions.
5.3 Prototype Development Based On Participatory Design

Based on the group’s decision-making tasks and the information needed to support them, the next step in the intervention was to create an artifact through
participatory design that increases cognitive effectiveness within the command center. Ideally, the cognitive aid should meet as many informational needs (Figure 31) as possible, while also being easy to use and maintain.

A meeting was scheduled with Sergeant Johnson, Officer Simpson and the chief of MPD-C to conduct a participatory design session. To facilitate the participatory design session, I decided to simulate the desired experience by projecting an aerial map onto an actual whiteboard. By combining the computer with the whiteboard, the benefits of both media (map and whiteboard) could be exploited. System materials included a 4’ x 5’ magnetic white board and easel, a laptop and portable projector, aerial photo jpg files, and dry-erase markers and magnets of different colors and widths. This session also included a flip chart and digital and video cameras to document the session (Figure 33).
The design session first considered map details, then icons, and finally system feasibility from police domain and cognitive engineering perspectives. These represent initial attempts to mitigate task-artifact/envisioned world problems (Carroll et al., 1991; Carroll & Rosson, 1992).

First, the maps used in the design session were evaluated. The maps were readily generated using a publicly available web-based GIS viewer accessible over the Internet. The GIS viewer uses county and state data to create custom maps. Users select map “layers” or map details to display from a list using checkboxes. The layers are grouped by boundaries, development, environment and infrastructure categories. Examples include streets, township boundaries, streams, land use, parcels, soils, schools, hospitals, game lands, parks, and aerial photography. In addition, specialized GIS training and computers are not needed to create the maps. A user begins by generating a custom map in a browser (using the GIS viewer). The custom map is then converted into a jpg file for display on a whiteboard in the command center using a projector connected to a laptop computer.  

Officers indicated a preference to personally create and customize maps for use in the command center. Depending on the incident, they valued the ability to select detail level, roads and intersections, businesses and residences. Figure 34 presents the map created by officers for the command center barricaded gunman incident along with the selected layers. The preferred map detail is approximately 1 square mile, although

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31 The jpg file is created by pressing the computer print-screen key, and then pasting the image into MS Paint. From MS Paint, the map can be saved as a jpg file.
32 In subsequent sessions, officers enjoyed learning the GIS system by generating views of known locations such as their own homes.
officers might, based on incident location, vary this to include major roads or shopping districts. Control of map detail is one reason officers preferred managing this process. Another was elimination of potential delays.\textsuperscript{33}

Another feature of the GIS viewer is a “measure tool” option that allows officers to add a reference line on the map. Although the maps include a scale at the bottom, officers found it beneficial to apply the measure tool with respect to the incident itself (i.e. the series of red dots in Figure 34). For example, officers had not realized the distance from the main road to the back of this apartment complex was over 1,200 feet.

\textbf{Figure 34} Accepted map detail and selected layers

After agreeing on map detail, the design session next focused on icons. The officers spent a great deal of time refining the icons to convey necessary information

\textsuperscript{33} For example, dispatchers at the county 911 center also have access to mapping software. Besides lacking the police expertise to create the maps, the dispatchers did not have the technology to electronically route a jpg file to police, resulting in delays.
while minimizing complexity. Officers wanted to keep the screen uncluttered. They also wanted to simplify operation and maintenance of the map as the scenario evolved. This was consistent with knowledge elicitation findings that officers carefully balance cognitive load with benefits. The iterative process officers used to refine the icons is part of the user-centered design initiatives in MAKADAM (McNeese et al., 1995; Zaff et al., 1993).

Figure 35 presents a close-up of the finalized icon set for the unified command center. Deployed officers are represented by badge number on the whiteboard using a thin, dry erase marker. The position of the barricaded gunman is represented with a red rectangle. Road closures points were marked with a red line. The staging and command center is marked by the word “Stage” written on a white rectangular magnet. Colored magnetic circles are used to represent police with special weapons or skills:

- Blue - state police (high risk entry team),
- Red - local police with long gun (“S” added to badge number to indicate shotgun), and
- Green - local police with less-than-lethal weapon (these are typically shotguns that shoot a sandbag).\(^{34}\)

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\(^{34}\) The less-than-lethal shotguns used by officers are painted green.
Finally, the prototype was evaluated from police domain and cognitive engineering perspectives. Beginning with the police domain perspective, the three officers in the participatory design session indicated that they considered the prototype valuable and planned to purchase a portable laptop, projector and magnetic whiteboard for use in the mobile command center shown in Figure 36.
The officers indicated that the prototype facilitated decisions in locating the command center and tracking officer deployment. The prototype also provides an opportunity to improve interagency coordination. For example, the state police SERT team currently maintains a separate command center during critical incidents. At one point during the participatory design, an officer commented that he felt the state police would also use this center, if this system were in place.

From a cognitive engineering perspective, the prototype can be evaluated based on previously identified informational needs. These needs are presented again in Figure 36 County mobile command center (Vehicle purchased following the incident described in SAR 4.1)
this time with the realized concepts in bold. Many of these information needs are addressed in this prototype.

![Diagram](image)

**Figure 37** Implemented prototype information objectives
(Implemented information needs in bold)

Next, this chapter continues development and evaluation of the prototype through the creation of training scenarios. These scenarios may be used in a scaled world to continually refine the prototype, as well as to train and evaluate officers.
5.4 Command Center Training Scenarios

The process of creating a scaled world follows formalized cognitive models of the work domain structure and the processing of cognitive activities within that domain. Developing a prototype for scaled world use not only provides researchers further understanding into cognitive systems, but also leads to an effective intervention capable of supporting cognitive activities in the field.

5.4.1 Sample Training Scenarios

In this section, several training scenarios (TS) are created to enable police experts to use the command center prototype in a scaled world environment. The use of these scenarios is primarily for officer training. Experiencing a command center in a scaled world environment can help prepare officers for real world incidents. Thus, a possible benefit of training is preparing experts for future thinking (Endsley, 1988).

Designers could use this opportunity to increase design acceptance and worker satisfaction by incorporating the worker’s use of the prototype in ongoing design refinements (McNeese et al., 1995). Scenario-based design is seen as one way to reduce envisioned world/ task-artifact problems (Potter et al., 2000; Rosson & Carroll, 2002; Schoenwald, Trent, Title, & Woods, 2005).

Although scenarios can take several forms, they should include a description of the actors, background information on the actors and assumptions about their environment, the goals of the actors, and sequences of actions and events (Go & Carroll, 2004). The training scenarios in this dissertation are derived from the barricaded gunman
part I and part II critical incident sessions conducted during the second analytical stage (knowledge elicitation) with police officers.

5.4.1.1 Barricaded Gunman Incident Foundation for Training Scenarios

A barricaded gunman incident is the foundation upon which the following training scenarios build. The barricaded gunman incident assumes that two officers serving a warrant during the middle of the day in August are confronted by a man with an assault rifle demanding that the officers leave. The two officers withdraw and take positions to contain and observe the gunman. Witnesses inform police that the gunman is alone, and that he is skilled with the rifle. The training scenarios build on this and include situation monitoring, planning and control decisions.

5.4.1.2 Unified Incident Command Training Scenario

The unified incident command training scenario TS-1 (Table 14) is based on SAR 4.1. In this scenario, an incident commander must create a unified command center to manage the barricaded gunman incident. Initial decisions include configuration of the prototype and aerial map (similar to Figure 34). Decisions must then be made on the location of the command center, as well as officer deployments, evacuations and closings.
Table 14 Unified incident command training scenario (TS-1)
(Derived from SAR 4.1)

<table>
<thead>
<tr>
<th>TS-1</th>
<th>Unified Incident Command</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Description</strong></td>
<td>An officer is assigned incident command and must create and manage a command center in response to a barricaded gunman incident. Gunman is in a home near major roads and shopping areas.</td>
</tr>
<tr>
<td><strong>Knowledge</strong></td>
<td>Expect the situation to be resolved peaceably. Know that the man is alone in the home. Two officers are in containment positions.</td>
</tr>
<tr>
<td><strong>Cues</strong></td>
<td>Several houses are very close to the gunman</td>
</tr>
<tr>
<td><strong>Goals</strong></td>
<td>Contain the suspect and protect/isolate the public from the incident.</td>
</tr>
</tbody>
</table>
| **Decision Points** | • What map details to include?  
• Where to locate the command center?  
• What staffing assignments for the command center?  
• What roads to close?  
• What stores to close?  
• How to brief officers?  
• Where to position officers?  
• Who to evacuate? |

5.4.1.3 Intruder Training Scenario

Table 15 presents the intruder training scenario TS-2, based on SAR 4.2. This presents decision-makers with a scenario within a scenario. Several hours have now passed since the barricaded incident began. The unified incident command center, including prototype configuration and staffing, has been established and officers have been deployed to inner and outer perimeters.

Suddenly, perimeter officers are surprised when an intruder charges out of a wooded area heading toward the suspect’s home. Perimeter officers need to subdue the intruder using less-than-lethal force and take him into custody while minimizing
exposure to the gunman. A police detail is created to gather evidence to be used in charging the intruder.

Table 15 Intruder training scenario (TS-2)
(Derived from SAR 4.2)

<table>
<thead>
<tr>
<th>TS-2</th>
<th>Intruder</th>
</tr>
</thead>
<tbody>
<tr>
<td>Description</td>
<td>An intruder charges through the outer police perimeter towards the home of the barricaded gunman.</td>
</tr>
<tr>
<td>Knowledge</td>
<td>The intruder refuses orders to stop. An officer with a less-than-lethal weapon shoots him with a bean bag to stop him from getting closer to the suspect’s house.</td>
</tr>
<tr>
<td>Cues</td>
<td>Gun shots, radio call “bean bag, bean bag” (radio call is to alert other officers that less-than-lethal force is being used so officers with lethal weapons do not also shoot).</td>
</tr>
<tr>
<td>Goals</td>
<td>Continue containing the suspect (barricaded gunman) and isolating the public. In addition, arrest and treat intruder.</td>
</tr>
</tbody>
</table>
| Decision Points | • What changes are needed to improve perimeter?  
• How to safely take intruder into custody and transport for medical treatment?  
• How to gather evidence to be used in charging intruder? |

5.4.1.4 Flash-Bang Training Scenario

The flash-bang training scenario TS-3 (Table 16) is based on SAR 4.3, and also represents a scenario within a scenario. The time is now after midnight. The barricaded gunman has become uncooperative and unresponsive with negotiators. In an effort to bring the standoff to an end, the state police high risk entry team plans to use flash-bang grenades and tear gas to scare the gunman into surrendering. Perimeter units need to be notified to be on alert. Also, arrest teams need to be established and assigned to front and rear exits of the home.
Table 16 Flash-bang training scenario
(Derived from SAR 4.3)

<table>
<thead>
<tr>
<th>TS-3</th>
<th>Flash-Bang</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Description</strong></td>
<td>Barricaded gunman scenario has continued over 18 hours. Police wish to bring the incident to an end.</td>
</tr>
<tr>
<td><strong>Knowledge</strong></td>
<td>State police have notified command that officers will be using flash-bang grenades.</td>
</tr>
<tr>
<td><strong>Cues</strong></td>
<td>Gunman has stopped communicating with negotiators - no indication that he will surrender.</td>
</tr>
<tr>
<td><strong>Goals</strong></td>
<td>Contain the gunman, isolate the public from the gunman; attempt to bring situation to an end.</td>
</tr>
</tbody>
</table>
| **Decision Points** | • Who will comprise arrest teams outside gunman’s home?  
| | • How will state police action need to be coordinated with perimeter officers?  
| | • What alternate plans should be considered if he doesn’t come out?  
| | • What other outcomes could result from the flash bangs? |

5.4.2 Evaluating Cognitive Activity in Scaled Worlds

There are several ways to evaluate officer decision-making in the training scenarios, including monitoring activities and progress on the white board. The scenarios can also be combined with decision ladders to model the cognitive activities used by officers of different experience levels.

As an example, three decision ladders have been created for the intruder training scenario TS-2. Figure 38 shows two first two decision ladders (initial notification and command center part I). The initial notification ladder begins when an officer is assigned incident command and must create a unified incident command. Decisions include assistance requests for EMTs, neighboring officers, and fire police\(^{35}\) for traffic control. Decisions also include assignment of a negotiation detail.

\(^{35}\) Fire police are voluntary firefighters that specialize in traffic control.
Figure 38 Initial unified incident command training scenario TS-1 decision ladders

Next, the command center part II ladder (Figure 39) begins after the incident commander is on the scene and other officers begin arriving for deployment. Decisions begin with assigning police resources to the perimeters and shutting off utilities. Inner perimeter deployments are made immediately, while other deployments require additional situational information.

As the perimeters are established, additional decisions include road closings and evacuations of homes and businesses. These are presented in the decision ladder shown in Figure 39. Some neighbors need immediate evacuation, for example, based on proximity to the incident. Additional information is needed to plan road closings and
traffic detours, as well as subsequent evacuations. Also, evacuations can either be encouraged or mandated, and may require assistance or force. The ability to view and track this information using the prototype should improve the effectiveness of these decisions.

Figure 39 Subsequent unified incident command training scenario TS-1 decision ladders

It should be noted that additional training scenarios and related decision ladders can be created by changing location, time and type of incident. This provides an opportunity to refine the prototype as well as train and evaluate police decision-makers.
An outcome of this dissertation is an evaluation of the effectiveness of this prototype in real world settings. As mentioned, the three officers in the participatory design session plan to implement the prototype in the mobile command center shown earlier in Figure 36. Plans were made to train officers representing six county-based municipal police departments in the use of the prototype during field exercises conducted June 2006.\textsuperscript{36}

\textsuperscript{36} The six county police department training and use of this prototype occurred outside the original scope of this dissertation. Evaluation of the prototype’s effectiveness as a cognitive aid is an opportunity for future research.
Chapter 6

Discussion and Conclusions
This dissertation is driven by a general desire to understand challenges supporting cognitive activities in dynamic work environments. Figure 40 presents the process used to develop this understanding by conducting research improving the effectiveness of cognitive activities in the policing domain. Figure 40 highlights the way that the dissertation’s goal is broken down into three objectives which are each addressed by different methods. Recent events, including the 2001 World Trade Center attacks and the 2005 Hurricane Katrina, have made clear the need to support the cognitive activities of emergency planners and responders. The development of useful cognitive aids to support emergency personnel could have a tremendous impact on the ability to handle these and other critical incidents. Findings suggest it is possible to improve the use of technology to enhance cognitive effectiveness, and that strengths exist in combining methodologies to explore the feasibility of cognitive interventions.

Figure 40 Dissertation Storyboard
This chapter begins by presenting the eight critical dissertation findings. Next, the linked methodologies used in the dissertation are discussed. This is followed by an assessment of the research findings using concepts of reliability, validity and generalizability. The chapter concludes with a discussion of the role of an interdisciplinary doctoral program in completing this dissertation, final thoughts and future research opportunities.

6.1 Dissertation Findings

Police officers working in dynamic environments make decisions that involve large problem spaces, time constraints, uncertainty, ill defined situations, conflicting goals and socially distributed responses. The identification of challenges to enhance the cognitive effectiveness of police officers began during the literature review. The findings continued to evolve during the subsequent analytical and intervention research stages that include ethnography, knowledge elicitation and participatory design. Eight findings were identified and substantiated during this process. These findings are summarized in Table 17 and each is presented below, including implications for cognitive system design and integrative research based on intersections between information, technology and people (ITP).
Table 17 System design and ITP research implications from findings

<table>
<thead>
<tr>
<th>Findings</th>
<th>Cognitive Design Implication</th>
<th>ITP Research Implication</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Cognitive demands are increasing as police scope increases</td>
<td>Implications for resource allocation and prioritization, training, etc.</td>
<td>Worker performance issues from too little or too much information</td>
</tr>
<tr>
<td>2. Police officer autonomy creates challenges of information sharing and</td>
<td>Implications for virtual and distributed work create new system requirements along with unanticipated results</td>
<td>Technology-mediation may lead to new organizational forms (i.e. distributed) that inadvertently impact information flows between workers</td>
</tr>
<tr>
<td>coordination/ monitoring</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Current system solutions encourage workarounds</td>
<td>Workarounds result from system inefficiency not only consume resources but may impact data quality</td>
<td>People, information and technology are tightly coupled in a work context; understanding one requires an understanding of the others</td>
</tr>
<tr>
<td>4. Current system interoperability reduces effectiveness and results in</td>
<td>Issues in system interoperability have been cited in recent critical incidents as significant; but are difficult to address due to conflicting organizational goals and interests</td>
<td>Researchers should focus on the handoffs in communication &amp; data, as well as version control and data maintenance</td>
</tr>
<tr>
<td>unexplored possibilities</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. Police officers consciously weigh benefits and costs of use before</td>
<td>Possible benefits from different communication paths suggest maintaining existing channels even as new technologies become available</td>
<td>Technology needs to meet performance efficiency of different users in different work contexts</td>
</tr>
<tr>
<td>adopting technology solutions</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6. Active participatory design by officers highlights best application of</td>
<td>Achieving benefits of user-centered design requires design insight from users as tool is used/conceived</td>
<td>The more effective designers are at soliciting real and verifiable input from users (sometimes conflicts with thought or belief), the better the design</td>
</tr>
<tr>
<td>technology</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7. Not all solutions require high tech approach (must balance high</td>
<td>Best design need not be the most technical (opportunities for appliance-like interventions)</td>
<td>Balance user preferences with actual tool use to reduce features to a useful level</td>
</tr>
<tr>
<td>cognitive load with anticipatory information provision)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8. Historical roots of policing that emphasizes cases, learning through</td>
<td>Use process modeling to identify non-obvious information exchanges and values</td>
<td>Recognize that information technology can enhance as well as limit people-to-people information sharing</td>
</tr>
<tr>
<td>storytelling and experiential development of decision-making capabilities</td>
<td></td>
<td></td>
</tr>
<tr>
<td>cannot be fully replaced by fully integrated/ automated solution</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
6.1.1 Increasing Cognitive Demands in Scope of Policing

Legal, social, and technological change has contributed to an increase in the cognitive requirements associated with policing. Police are expected to show good judgment and quick response under challenging circumstances. In addition to mastery of a diverse set of skills, police are also expected to be active users of information systems both to record and support their activities. This is important for cognitive design decisions involving both the allocation and prioritization of systems, and related maintenance and training. The practical implication for ITP research suggests considering performance issues from systems that provide too much or too little information.

6.1.2 Cognitive Challenges from Increasing Police Autonomy

Autonomy in field officer policing creates challenges for information sharing, coordination and monitoring. The autonomy stems from a combination of policing reforms and the introduction of mobile technologies. Reforms that require a more visible community police presence support administrative decisions to distribute officers in the field for patrol and report writing. Cell phones, wireless networks and mobile computing help keep these officers in the field while they perform office-type duties that otherwise would require a return to the station. However, even though police work autonomously, they still need to monitor each other and be ready to provide support when needed. This creates new system design challenges for information sharing and situation monitoring.
The practical ITP implication from the new technology-mediated organizational form is a potential disruption in the free exchange of information between workers.

6.1.3 Workarounds from Current Work Practices

Current system solutions encourage workarounds by officers. Gaps in the support of current work practices are an outcome from present police information system planning, use, maintenance and training. Since so many technologies are becoming available for police use, the importance of workarounds cannot be underestimated. From a design perspective, the workarounds that result from system inefficiency not only consume resources, but may impact the quality of the data needed for cognitive actions. This reveals, from an ITP perspective, the tight coupling of people, information and technology in a work context, and the need for researchers to understand all three.

6.1.4 Currently Unexplored Interoperability Possibilities

System interoperability represents a currently unexplored possibility to increase cognitive policing effectiveness. Gaps in the sharing of information between agencies reduce decision-making quality. These gaps are visible during daily police operations, but have also become quite visible during recent national disasters. Potential interoperability exists between first responders, dispatch, and other groups including health services. Since a shared commitment from several organizations may be required, design opportunities to close this gap may prove more difficult than others. From an ITP
perspective, the implications of this finding suggest researchers focus on handoffs in communications and data between people from different groups, as well as issues of version control and data maintenance.

6.1.5 Efficiency of System Performance

Police officers consciously weigh benefits and costs of use before adopting technology solutions. Officers will choose the technology that best accomplishes the task while consuming the least amount of cognitive resources. From a system design perspective, this suggests that an intervention with lesser capabilities may be preferred in different contexts due to the user’s perceived efficiency of performance. There are benefits, then, for maintaining the multiple communication opportunities currently available to police (i.e. chat, radio, cell, email, and face-to-face), as long as each has a demonstrated effectiveness during certain tasks. Researchers need to contrast technology performance with user performance in different work contexts.

6.1.6 Participatory Design in User-Centered Solutions

Participatory design by officers highlights the best application of technology. For system designers, this suggests that achieving the benefits of user-centered interventions requires design insight as the tool is both conceived and used. For example, videotape was used in this dissertation to evaluate users during tool design as well as interacting with current systems. This method was important to disclose multiple workarounds in
the current field reporting system. In addition, there are benefits of actively involving the users in the design conception, as opposed to just surveys, for example. Active participation can be facilitated by combining users and artifact components in a scaled world setting. For ITP researchers, this implies that designers need to be more effective at soliciting the real and verifiable user needs and system features which may be at odds with a longer wish list of possible features.

6.1.7 Anticipatory Value of Technology Levels

Not all solutions require a high tech approach. Designers must balance the high cognitive loads associated with situations and tools against anticipated information provision and needs. This suggests that the best design may not be the most technical. In some contexts, targeted, simple appliance-like solutions have great potential. ITP researchers need to reevaluate initial user preferences with actual tool use to reduce features to a useful level.

6.1.8 Face-to-Face Exchange of Expertise

Historical roots of policing that emphasizes cases, learning through storytelling and experiential development of decision-making capabilities cannot be fully replaced by integrated, automated solutions. To this end, cognitive designers may use process modeling to highlight non-obvious information exchanges and value. ITP researchers
should recognize that while information and technology can enhance people to people exchanges, they may inadvertently limit them as well.

6.2 Methodological Complementarity

The MAKADAM methodology of this dissertation relies on a multimodal approach to gathering data. This consists of linking analytical methods, ethnography and knowledge elicitation, with an intervention method consisting of participatory design. As shown in Table 18, these methods triangulate findings by eliciting similar information from different perspectives. This demonstrates a consistency of findings across different groups while increasing depth of understanding.

6.2.1 Discussion of Dissertation Findings

The multimodal methodology facilitated the identification and substantiation of the findings in Table 18. The process of linking the stages through design data points tightly integrated the process. Design leverage points from the ethnography are developed during knowledge elicitation into design seeds, which are then linked to prototype development during participatory design.

For example, the secondary data analysis, interview and observation in the ethnography stage reinforced the notion that police “generally work alone” and that the

37 The linking of methods is not uncommon in the CSE community, as evidenced by AKADAM (McNeese et al., 1995) and Cognitive Work Analysis (Vicente, 1999), as well as converging bootstrapping methods (Potter et al., 2000; Roth et al., 2001).
practice of police is “shaped by information technology” (Manning, 2003, p.13). These observations formed into the situation awareness leverage point. Continuing the process through knowledge elicitation and participatory design allowed these observations to further develop into the second finding of this dissertation: police autonomy creates challenges of information sharing, coordination and monitoring. Similarly, the complementarity of the methodology and the tight coupling of the stages led to the other findings.

<table>
<thead>
<tr>
<th>Findings</th>
<th>Literature</th>
<th>Ethnography</th>
<th>Knowledge Elicitation</th>
<th>Participatory Design</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Cognitive demands are increasing as police scope increases</td>
<td>Social, political and technical reforms have made policing more complex and demanding (Klockars, 1985; Manning, 2003); Nuclear power plant operators face increased cognitive demand (Rasmussen et al., 1994; Vicente, 1999)</td>
<td>Police observed performing a variety of cognitive tasks including field reporting, data entry and lookup, navigating new streets and complex apartment numbering, and determining magistrate jurisdiction for citations</td>
<td>The value of expertise is seen in the differences between novices and experts as they handle critical incidents, including the reliance on hunches</td>
<td>Situational uncertainty increases decision-making complexity and action alternatives for officers</td>
</tr>
<tr>
<td>2. Police officer autonomy creates challenges of information sharing and coordination / monitoring</td>
<td>Communication and coordination failures hindered firefighter and EMS response on September 11 (&quot;McKinsey report / increasing FDNY’s preparedness&quot;, 2002)</td>
<td>Police observed relying on their “radio ear” to monitor each other, meeting in parking lots for face-to-face information exchanges, and using storytelling to develop expertise</td>
<td>Police rely on different feedback loops depending on the task</td>
<td>Uncertainty increases the need for coordination and requires targeted delivery of focused information (i.e. need to know)</td>
</tr>
</tbody>
</table>
### Continuation of Table 18 Dissertation findings across methods

<table>
<thead>
<tr>
<th>Findings</th>
<th>Literature</th>
<th>Ethnography</th>
<th>Knowledge Elicitation</th>
<th>Participatory Design</th>
</tr>
</thead>
<tbody>
<tr>
<td>3. Current system solutions encourage workarounds</td>
<td>Survey respondents feel information systems require police to follow unnecessary steps to get things done (Chan, 2001); Even well planned systems may result in unforeseen limitations (Carroll et al., 1991; Dekker &amp; Woods, 1999; Hoffman &amp; Woods, 2000)</td>
<td>Police observed fixing field reporting data entry problems and loss of network connectivity, as well as relying on dispatchers to innovate solutions to find accident scene</td>
<td>Officers had delays in getting needed photos of barricaded gunman to perimeter officers; Investigation officers had to create strategies to find incident information in CRIMES database</td>
<td>Lack of workarounds is the intended result of participatory design</td>
</tr>
<tr>
<td>4. Current system interoperability reduces effectiveness and results in unexplored possibilities</td>
<td>First responders could not talk to each other, and in some cases resorted to waving signs (Walsh, 2006); Consolidation of records systems has hardly begun in U.S. policing (Manning, 1997, p. 245)</td>
<td>County 911 dispatch center and MPD use different database fields; Officers have limited federal, state and county database access, especially from their cars; State police and MPD use different radio frequencies</td>
<td>Unavailable caseworker background data increases challenges to officers serving warrant; State police and MPD can not communicate directly and monitor each other during critical incidents</td>
<td>Single magnetic whiteboard/projection “pallet” approach brings together information across systems</td>
</tr>
<tr>
<td>5. Police officers consciously weigh benefits and costs of use before adopting technology solutions</td>
<td>Officers find ‘Call for assistance’ command too complicated (Hafner, 2004); “Officers do not equate information technology with useful and valued knowledge.” (Manning, 2003, p. 161)</td>
<td>Police radio information processing requests to county 911 dispatchers to generate reports and fax to MPD; Officers indicated they have little time for any system other than their radio during critical incidents</td>
<td>Officers value ability to look up driver information, but not field reporting; Police defer computing to dispatchers during critical incidents</td>
<td>Expert suggestions of what and how to automate implies conscious choices about adoption and value</td>
</tr>
</tbody>
</table>
Continuation of **Table 18** Dissertation findings across methods

<table>
<thead>
<tr>
<th>Findings</th>
<th>Literature</th>
<th>Ethnography</th>
<th>Knowledge Elicitation</th>
<th>Participatory Design</th>
</tr>
</thead>
<tbody>
<tr>
<td>6. Active participatory design by officers highlights best application of technology</td>
<td>Officers not involved in design of new system prefer old system (Chan, 2001; Hafner, 2004); Fighter pilot input helps design pilot aid (McNeese et al., 1995)</td>
<td>Systems overlook story telling and learning needed to develop expertise and instincts; Officers feel the field reporting system they were given did not improve their jobs, resulting in friction with the administration</td>
<td>Approaches to problems, including perception, decision-making and action, are related to experience level</td>
<td>Officers create an icon set that meets their information needs, reveal map detail and layer preferences, and emphasize prototype simplicity</td>
</tr>
<tr>
<td>7. Not all solutions require a high tech approach (must balance high cognitive load with anticipatory information provision)</td>
<td>“Some officers were not entirely comfortable with the heavy reliance on information technology for information” (Chan, 2001, p. 254)</td>
<td>Critical police expertise is developed through story telling and face-to-face communication; Police effectively combine a shared radio frequency and their radio ear to monitor each other</td>
<td>Police compute by “proxy” through dispatchers; During critical incidents, police rely primarily on their radio, not their computers</td>
<td>Increases in uncertainty and complexity requires flexibility to reflect and share information</td>
</tr>
<tr>
<td>8. Historical roots of policing that emphasizes cases, learning through storytelling and experiential development of decision-making capabilities cannot be fully replaced by integrated/automated solution</td>
<td>“Even though intelligence is extremely good, these officers felt that it will never take the place of basic hands-on traditional intelligence gathering—getting out on the street, talking to people, finding out what is going on” (Chan, 2001, p. 154)</td>
<td>Police develop expertise through story telling and share incident-handling information in parking lot exchange</td>
<td>Critical expertise for incidents (cues, knowledge and decision points) learned by experience and shared informally</td>
<td>Choices about what cognitive activities to support and what requires face-to-face communication</td>
</tr>
</tbody>
</table>
6.2.2 Implications for Future Research Methods and Designs

The findings suggest strengths in combining methodologies to explore the feasibility of cognitive interventions, such as linking analytical and intervention methodologies using MAKADAM. The linked MAKADAM methodologies provide a progressive deepening of understanding in the development and refinement of cognitive support tools.

The development and application of the MAKADAM methodology provides researchers and designers an additional problem-based toolkit for knowledge elicitation, analysis and synthesis. MAKADAM integrates concept mapping, means-ends diagrams, decision tree modeling and storyboarding for work domain and task analysis, as well as participatory design.

6.2.3 Discussion of Methodological Limitations

There are few limitations with the MAKADAM methodology, interviewer bias and research sample. First, the MAKADAM methodology represents multimodal data collection that generated consistent findings across methods and groups. As such, MAKADAM has few limitations.

Second, interviewer bias limitations are reduced by having the respondents use their own words to describe the data, minimizing transcription and interpretation. For example, video documentation techniques were used in the ethnography and participatory design stages. During knowledge elicitation, officers used concept mapping techniques
to describe cues, knowledge and decision points. In addition, open ended interview questions do not impose limitations on answers.

Third, research sample limitations are minimized by using a multi-group respondent pool. Despite this, the groups do represent a sample of convenience with possible unique attributes. The officers interviewed within the groups were selected by the municipal police departments. Although an effort was made to interview officers of different ages and experience levels, this non-random sampling could not be controlled for diversity in gender and race. The results of this dissertation may still be true for a more heterogeneous group, however, since nationally 91 percent of sworn police are male and 81 percent are white (Manning, 2003, p. 55).

6.3 Design Implications for Cognitive Effectiveness

The eight findings described earlier (and presented in Table 18) include implications for the design of cognitive systems. These findings combine to suggest that it is possible to improve cognitive design to enhance effectiveness of cognitive activities. These implications can be considered from the context of routine\textsuperscript{38} and dynamic work environments.

---

\textsuperscript{38} Straightforward “repetitive manipulation and inquiry of prescribed data, often by definite procedure” (Colton, 1979, p. 12).
6.3.1 Discussion of Technology Implications from Dissertation Findings

Table 19 presents implications for cognitive design with respect to the work context. For example, several findings suggest periodic reviews are needed to improve systems used for routine work. What might be less obvious are specialized technology requirements for dynamic work environments. Also, improperly designed systems for routine work eventually impact dynamic work. This is illustrated in the last finding, for example, where the importance of sharing tacit knowledge and expertise during routine work prepares officers for dynamic work environments.
<table>
<thead>
<tr>
<th>Finding</th>
<th>Routine Work Environment</th>
<th>Dynamic Work Environment</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Cognitive demands are increasing as police scope increases</td>
<td>Post hoc analysis is essential to capture nuances of dynamic work environments</td>
</tr>
<tr>
<td></td>
<td>A periodic review of workers in naturalistic settings using linked methods identifies</td>
<td></td>
</tr>
<tr>
<td></td>
<td>new constraints and cognitive demands</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Current workarounds are inadequate to meet the fast paced communication needs of dynamic environments</td>
</tr>
<tr>
<td>2.</td>
<td>Police officer autonomy creates challenges of information sharing and coordination/</td>
<td></td>
</tr>
<tr>
<td></td>
<td>monitoring</td>
<td></td>
</tr>
<tr>
<td></td>
<td>High officer dependence on technology for routine data is inconsistent with systems</td>
<td>Workarounds compromise data availability and accuracy and cannot accommodate the</td>
</tr>
<tr>
<td></td>
<td>availability</td>
<td>unanticipated communication needs associated with dynamic work environments</td>
</tr>
<tr>
<td>3.</td>
<td>Current system solutions encourage workarounds</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Periodic review leading to system refinements should be planned to reduce workarounds</td>
<td></td>
</tr>
<tr>
<td>4.</td>
<td>Current system interoperability reduces effectiveness and results in unexplored</td>
<td></td>
</tr>
<tr>
<td></td>
<td>possibilities</td>
<td>Partner interoperability enhances critical information sharing and coordination of</td>
</tr>
<tr>
<td></td>
<td></td>
<td>response in dynamic environments</td>
</tr>
<tr>
<td>5.</td>
<td>Police officers consciously weigh benefits and costs of use before adopting technology</td>
<td></td>
</tr>
<tr>
<td></td>
<td>solutions</td>
<td>Complex technological systems/solutions do not automatically translate into enhanced</td>
</tr>
<tr>
<td></td>
<td></td>
<td>cognition.</td>
</tr>
<tr>
<td>6.</td>
<td>Active participatory design by officers highlights best application of technology</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>A deep functional understanding through participatory design is essential to anticipate</td>
</tr>
<tr>
<td>7.</td>
<td>Not all solutions require high tech approach (must balance high cognitive load with</td>
<td>potentially useful or detrimental system features</td>
</tr>
<tr>
<td></td>
<td>anticipatory information provision)</td>
<td></td>
</tr>
<tr>
<td>8.</td>
<td>Historical roots of policing that emphasizes cases, learning through storytelling and</td>
<td>Sharing of tacit knowledge and expertise needed in dynamic environments can be facilitated</td>
</tr>
<tr>
<td></td>
<td>experiential development of decision-making capabilities cannot be fully replaced by</td>
<td>by information exchange during routine work</td>
</tr>
<tr>
<td></td>
<td>integrated/ automated solution</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Regardless of organizational and technology changes, maintain opportunities for informal</td>
<td></td>
</tr>
<tr>
<td></td>
<td>information exchange needed to develop and share tacit knowledge and expertise</td>
<td></td>
</tr>
</tbody>
</table>

Table 19 Technology implications from dissertation findings
6.3.2 Overall Recommendations for Cognitive Designers

The process to develop specific interventions should be grounded in the constraints of the domain and the complexity of the task using cognitive analysis. In general, a user-centered process identifies unexplored possibilities as well as workarounds from current artifacts. Particularly in dynamic work environments, designers need to be sensitive to the cognitive load of the interventions relative to the information need. In some situations, simpler, targeted solutions are preferred over more robust and complicated solutions. In some cases, the best solution is not technical at all, such as processes and procedures allowing face-to-face information exchange.

6.4 Reliability, Validity and Generalizability

Actions are taken to evaluate this dissertation by applying standards to evaluate the quality or rigor\(^\text{39}\) of the research. These standards include reliability, validity and generalizability.

6.4.1 Meaning of Reliability, Validity and Generalizability in Qualitative Research

Reliability evaluates the consistency of research results with the research population, while validity evaluates the accuracy of the results to achieve the research objective (Golafshani, 2003; Morse et al., 2002). Results need to be reliable (i.e.

\(^{39}\) Some qualitative researchers also refer to rigor as “trustworthiness” (Golafshani, 2003; Morse, Barrett, Mayan, Olson, & Spiers, 2002).
representative of the research population under study) and valid (i.e. accurately reflect the research objective). Generalizability is a qualitative assessment of the appropriateness of applying the research results to other settings.

6.4.2 Reliability

Reliability refers to the consistency of the research results. The results should be both repeatable and precisely represent the population under study. In this dissertation, reliability can be evaluated by considering the consistency of the results across data collection methods and respondent groups.

6.4.2.1 Consistency across Data Collection Methods

The ethnography, knowledge elicitation and participatory design data presented in Table 18 reflect the consistency of the eight findings across the different data collection methods. For example, finding 7 suggests that not all solutions require a high tech approach. During the ethnography, officers disclosed the importance of simple storytelling to develop expertise, and the benefits of a shared radio frequency for communicating status. During participatory design, officers echoed this finding when they indicated a preference for the flexibility of a simple whiteboard when dealing with complex and uncertain situations.
6.4.2.2 Consistency across Respondents

The multimodal data in Table 18 also reflect consistency across respondents and respondent groups. The ethnography data is primarily from MPD-A officers, while knowledge elicitation data is from MPD-B and MPD-C officers. Participatory design data is primarily from officers with MPD-C. Despite differences between the departments and officers, the findings are consistent.

6.4.3 Validity

Although research can be reliable by consistently generating the same results, the results also need to be valid. Validity implies that the results accurately reflect the research objective. In this dissertation, validity can be demonstrated by comparing the results with similar research from other studies and domains.

6.4.3.1 Consistency with other Studies and Domains

The literature column in Table 18 presents consistency between the findings of this dissertation with other studies and domains. For example, finding 1 suggests that cognitive demands are increasing as the scope of policing increases. Changes in scope stem from social, political and technical reforms. Technology reforms change work substantially, especially when not well planned. Manning describes police technology advances as “unplanned, politically driven, and centered around an imagined efficient force” (Manning, 2003, p. 129). In the forward to Kim Vicente’s book Cognitive Work
Analysis, Jens Rasmussen states that the “fast pace of technological change has influenced work conditions in all application domains” (Vicente, 1999, p. ix). Similar cognitive challenges stem from social and political reforms, requiring police to have a stronger presence in the community while capturing data needed for administrative reports. Manning writes that challenges to the police role include “changes in routines; altered socialization; confused supervision; confused evaluation; weakened teamwork; new patterns of job control; and eroded loyalties” (Manning, 2003, p. 192). In a similar fashion, the other findings in this dissertation can be shown to be consistent with other studies and domains.

6.4.4 Generalizability

Generalizability refers to the utility or usefulness of the research by describing the ability to extend the results from the sample population to a setting different than the study (Lee & Baskerville, 2003). This can be accomplished in qualitative research by summarizing the characteristics of the research sample and suggesting domains with similar characteristics.

The decision-makers in this dissertation were subject to five attributes. Thus, the findings could be generalized to other settings where these attributes are found, including domains with:

1. Dynamic environments,
2. Task interdependence,
3. Time critical and sensitive information,
4. Coordinated responses, and

5. Unpredictable outcomes with potentially high negative impact.

Applicable domains include other first responders (fire, police, hazmat and emergency medical services), military and hospital triage units.

6.4.4.1 Policing Domain Limitations

Most police departments have fewer than thirty officers (Manning, 2003, p. 44). The findings in this dissertation should be applicable to these departments since they are similar in size. Even very large police departments may share aspects of these findings, especially those resulting from distributed and autonomous policing and impacts from technology, for example.

The declining face-to-face exchange finding is related to the implementation of field reporting by the departments in this dissertation. Field reporting enables officers to stay in the field for both patrol and report writing. Officers in departments that have not implemented field reporting still need to return to the station to complete report writing, providing opportunities for informal face-to-face information exchanges.

6.4.4.2 Limitations of Findings

The findings would not be applicable to decision-makers working exclusively in routine environments or those without task interdependence requiring coordinated responses with potentially high negative impacts. A typical business setting lacks many
of these attributes, for example. Similarly, settings with data interdependence as opposed to task interdependence, such as intelligence analysts, would also be excluded.

6.5 Conclusions

Findings suggest it is possible to improve the use of technology to enhance cognitive effectiveness, and that there are strengths in combining methodologies to explore the feasibility of cognitive interventions. Researchers have already suggested the importance of considering cognitive design issues when developing systems. In a sense, this is similar to calls in the 1980’s to incorporate ergonomic features into system design. At some point, the issues will be well known and the consideration will become a natural course of system design. Until then, it is important to call attention to the design of systems capable of enhancing cognitive activities.

The critical incidents described in this dissertation make real the importance of supporting cognitive activities of police officers. The design of the information flows and systems leading up to the critical incident have a substantial impact on the ability to successfully navigate the task complexities. While in the midst of a critical incident, the sharing and coordination of information continues to impact successful outcomes. Understanding and responding to these challenges requires immersion of researchers in the naturalistic settings of the worker. As Manning suggests for the police domain, “A close look at the impact of technology must move beyond attitudinal studies – bleak surveys with low response rates and ambiguous results – and observe the actual context of use” (Manning, 2003, p. 136, including italics).
6.5.1 Final Thoughts on Findings

The findings in this dissertation contradict some popular notions with respect to change in policing, the benefits of high technology solutions and mediated communication, and a current request for proposal (RFP) for a police information system.

In the his book *Policing Contingencies*, Manning states that “the structure and function of policing have changed little in the last thirty years” (Manning, 2003, p. 32). This is somewhat at odds with the findings in this dissertation that suggest reforms and mobile technologies have combined to make policing more decentralized and expanded the role to include more data entry responsibilities. In addition, field reporting reduces face-to-face information exchanges. The resulting technology-mediated organization impacts the free exchange of expertise. Perhaps the contradiction with Manning can be attributed to changes observed in the smaller police department of this dissertation.

Manning states that “much of what is known about Anglo-American policing comes from studies of urban patrolmen policing in large urban centers” (Manning, 2003, p.43).

This dissertation also challenges the notion that high technology solutions are preferable. In several instances police were observed seeking out simple alternatives to meet their cognitive support needs. The magnetic whiteboard for command center use is very easy to configure and maintain, yet met police requirements to plan, track and share information in a unified command center. From their cars, officers report their status by using a shared radio frequency rather than using the screen icons on the mobile data terminals. The high technology alternatives were either too complicated to use in dynamic work environments or did not support critical information needs.
The findings also suggest unanticipated detrimental impacts from the introduction of mediated communications. Opportunities for informal face-to-face information exchange become more difficult as officers work more autonomously. The technology-mediated communications do not afford the same level of information exchange needed to develop and share expertise.

Finally, a cursory evaluation of an RFP for a next generation police information system by the departments in this dissertation suggests that identified issues will go unresolved. For example, an RFP requirement to “minimize [the] need for multiple screens for input” still allows for multiple input screens. Officers felt very strongly that only one screen should be required, similar to the paper forms used prior to field reporting. Also, report requirements will not integrate incident and case reports, despite the observed duplication of effort. Last, the opportunity to resolve interoperability issues between the police and the county 911 center will go unresolved. The proposal states that it is “extremely unlikely that the dispatching system will be replaced.”

6.5.2 Future Research

Future research opportunities include evaluation of the command center prototype and comparison of cognitive performance with varying degrees of automation.
6.5.2.1 Evaluation of Artifact Cognitive Effectiveness

This dissertation developed a prototype that attempts to improve the effectiveness of cognitive activities during command center scenarios. However, the evaluation of the cognitive effectiveness of this prototype in real world settings is not an outcome of this dissertation. The use of this prototype in real world settings is expected to begin the summer of 2006, and represents an opportunity for researchers to evaluate its effectiveness.

Depending on those findings, there is an opportunity to expand the prototype for use on the mobile data terminals in the police cars. This could, for example, coordinate officers searching for a suspect in an unfamiliar setting. Refining and expanding the prototype can also include varying the scenarios and contexts used to evaluate the prototype. Changing situations and contexts would be appropriate to further understand the prototype, its limitations and cognitive effectiveness.

6.5.2.2 Comparison of Cognitive Performance from Varying Degrees of Support Automation

One of the findings in this dissertation is that not all solutions require a high tech approach. Officers balance the high cognitive load of artifacts with the anticipated value of the information provided by the artifact. For example, officers only minimally used the sophisticated mobile data terminal in the car. During the ethnography officers described how they developed expertise through face-to-face storytelling, and used shared radio frequencies and their radio ear to monitor each other. Future research could
develop this finding by comparing the cognitive performance of a range of artifacts with varying degrees of support automation.
References


Appendix A

Ethnography Probes

The first analytical stage of this dissertation includes ridealongs to observe and interview officers in the performance of their duties. Participant observation during different shifts and events are combined with unstructured interviews to provide additional understanding of the cognitive work domain. Interview probe questions from Table 20 are used to initiate officer interviews.

Table 20 Ridealong probe questions

<table>
<thead>
<tr>
<th>Information Focus</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Describe the flow of information from the moment a call is first received until action and wrap-up (indicate information flows between individuals and agencies)?</td>
</tr>
<tr>
<td>• What is documented, when and why (for whom)?</td>
</tr>
<tr>
<td>• Does information have to be interpreted, evaluated or otherwise filtered/manipulated by individuals? Examples?</td>
</tr>
<tr>
<td>• What channels (face-to-face, cell, radio, chat, email, etc.) do you use to exchange information? When several channels exist, how do you decide which to use?</td>
</tr>
<tr>
<td>• How do the police information systems support/impede the information flow?</td>
</tr>
<tr>
<td>• Describe the use of police information systems when making decisions and solving problems.</td>
</tr>
</tbody>
</table>
Appendix B

Ethnography Interview Schedule

Police ridealongs were conducted between March and October 2004 with 11 officers of different seniority from MPD-A. The ridealongs took place during different shifts and events (Table 21). Since incidents frequently begin with a 911 call and may require more than one shift to complete, ridealongs were conducted in overlapping research segments (RS) that sequenced observation and interviews from the county-911 call center with police briefings and ridealongs. Three segments (RS1, RS2, and RS3) averaged eight hours each.
Table 21 Ethnography schedule and informant information

<table>
<thead>
<tr>
<th>Date</th>
<th>Research Segment</th>
<th>Weekday (Mon.-Thur.)</th>
<th>Weekend (Fri.-Sat.)</th>
<th>Day Field</th>
<th>6A-6P</th>
<th>6P-6A</th>
<th>Field Hours</th>
<th>Ridealong (Officer Seniority)</th>
<th>Police Administrator</th>
<th>County-911 Dispatch</th>
</tr>
</thead>
<tbody>
<tr>
<td>3/24</td>
<td></td>
<td>🍃 🌿</td>
<td>🍃 🌿</td>
<td></td>
<td></td>
<td></td>
<td>4</td>
<td>Senior &lt; Senior Administrator</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4/24</td>
<td></td>
<td>🍃 🌿</td>
<td></td>
<td>3</td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>5/17</td>
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<td>🍃</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>5/18</td>
<td>RS1</td>
<td>🍃</td>
<td>🍃</td>
<td>3</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>5/18</td>
<td>RS1</td>
<td>🍃</td>
<td>🍃</td>
<td>2</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>5/18</td>
<td>RS1</td>
<td>🍃</td>
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<tr>
<td>5/19</td>
<td>RS2</td>
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<td>2</td>
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<tr>
<td>5/19</td>
<td>RS2</td>
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<tr>
<td>5/19</td>
<td>RS2</td>
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<tr>
<td>5/19</td>
<td>RS2</td>
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</tr>
<tr>
<td>5/21</td>
<td>RS3</td>
<td>🍃</td>
<td>🌿</td>
<td>1</td>
<td></td>
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<td></td>
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</tr>
<tr>
<td>5/21</td>
<td>RS3</td>
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<td>🌿</td>
<td>5</td>
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</tr>
<tr>
<td>5/21</td>
<td>RS3</td>
<td>🍃</td>
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<td>2</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5/21</td>
<td>RS3</td>
<td>🍃</td>
<td></td>
<td>2</td>
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<td></td>
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<tr>
<td>9/17</td>
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<td>🍃</td>
<td>🌿</td>
<td>2</td>
<td></td>
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<td></td>
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<td></td>
<td></td>
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<tr>
<td>10/22</td>
<td></td>
<td>🍃</td>
<td>🌿</td>
<td>4</td>
<td></td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

A typical ridealong session began by notifying my police liaison that I was coming. The liaison would check the schedule and select an officer for me to accompany. During office hours, I would present myself at the front desk and they would either call the officer by cell or use a police radio. If the interview began after the office closed, I would arrive at the station and call county-911 on a non-emergency line. County-911 would notify the officer by radio that I was ready. When the officer arrived,
I would sign his waiver and he would sign my informed consent form for social science research. After completing the forms, I would then accompany the officer on his patrol.
Appendix C

Knowledge Elicitation Probes

Knowledge elicitation and follow-up sessions totaled 59 field hours of field research. Ten sessions elicited expert knowledge in critical decisions using the Critical Decision Method (CDM). The sessions were conducted using a combination of semi-structured interview and graphing techniques based on the probes in Table 22.

Table 22 Critical Decision Method probes adapted to identify design seeds

| Sweep 1 | Describe a critical incident that you were in, where you had to make decisions. The decisions should be ones that you might not have made earlier in your career, that another officer might not have made, or that you would do differently now. |
| Sweep 2 | Describe the timeline for this incident. When did it start, and how long did each stage take? Also, what time of day was it, and what time of year? |
| Sweep 3 | What decisions did you make? What were your goals and expectations? What cues or knowledge did you use to make the decisions? |
| Sweep 4 | How would you make that decision differently? How would another officer have made that decision? Would you make the decision differently now? |
| Sweep 5<sup>40</sup> | Let’s look at the incident for opportunities for systems support. What additional information about the situation would have been helpful? What systems did you use? Regarding lessons learned, what would have been important to share from this situation with other officers? |

<sup>40</sup>The CDM is adapted in this dissertation to include sweep 5 (identification of design seeds).
Appendix D

Knowledge Elicitation Participants

Experienced officers from MPD-B and MPD-C were interviewed using the Critical Decision Method. In addition to substantial work experience, each possessed at least one type of special training as supervisors, negotiators, criminal investigators and observation-snipers (Table 23).

<table>
<thead>
<tr>
<th>Expert ID</th>
<th>Current MPD</th>
<th>Years Current MPD</th>
<th>Years Total Police</th>
<th>Supervisor</th>
<th>Negotiator</th>
<th>CI 41</th>
<th>OS 42</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>B</td>
<td>15</td>
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<td>2</td>
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<td>4</td>
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<td>5</td>
<td>C</td>
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<tr>
<td>8</td>
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<td>10</td>
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<td>8</td>
<td>16</td>
<td></td>
<td></td>
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<td>16</td>
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<td>12</td>
<td>12</td>
<td></td>
<td></td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>

Similar to the ethnography stage, a typical session began by scheduling an interview by contacting the police liaison from either MPD-B or MPD-C. The liaison would check the schedule and select a new officer to be interviewed. During office hours

41 “CI” stands for Criminal Investigator. This is the title given to detectives.
42 “OS” stands for Observation-Sniper. These officers receive tactical training to observe and contain a suspect, but not to perform high-risk entries.
I could present myself at the front desk and a receptionist would notify the officer by cell or police radio. If the interview began after the office closed, I would arrive at the station and call county-911 on a non-emergency line. County-911 would then notify the officer that I was ready.

When the officer arrived, I signed his waiver and the officer signed my informed consent form for social science research. The informed consent form included a check box to give permission to record the interview. Unlike the domain analysis study with MPD-A officers, MPD-B and MPD-C officers could be interviewed in the station, depending on the current workload. To minimize interruption, I intentionally avoided scheduling interviews during busy weekends and rush hours. To access a variety of experience levels, some interview sessions started as early as 8AM while others ended as late as midnight.
Appendix E

Secondary Data Sources

Below is a representative list of the secondary data sources used in this study.

They ranged from books on policing, government reported police statistics, and research publications. The selected research publications emphasize police use of technology.

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Ioimo, R. E., & Aronson, J. E. The benefits of police field mobile computing realized by non-patrol sections of a police department. 5(3), 195-206.


Appendix F

Knowledge Elicitation Situations

Table 24 is a list of the ten knowledge elicitation situations researched in this dissertation. The table includes a brief description of the incident as well as a list of the related Situation Assessment Records (SAR). Figure 41 is the complete conceptual assessment record for SAR 9.3, Standoff.

<table>
<thead>
<tr>
<th>Critical Incident</th>
<th>Description/ Situation Assessment Record</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 SHOTS FIRED (2:30AM, Saturday)</td>
<td>Sergeant and patrol officer investigate a man under the influence, waiving a gun and making threats in his apartment. SAR – 1.1 Approach SAR – 1.2 Door Tactics SAR – 1.3 Shots Fired SAR – 1.4 Evacuation/ Containment/ Command SAR – 1.5 Resolution</td>
</tr>
<tr>
<td>2 FELONY STOP</td>
<td>Officer investigates a silent alarm at a residence in the west-end of the township. West end is rather rural and at that time did not have wireless network capabilities for police computers SAR-2.1 Approach SAR-2.2 Search SAR-2.3 Felony Stop</td>
</tr>
<tr>
<td>3 BARRICADED GUNMAN PART I (10AM, Hot August, 1998)</td>
<td>Officer serves a 302 (involuntary mental commitment health warrant) where individual must be taken into custody for observation. Instead of complying, the man appears with an assault rifle. SAR-3.1 Warrant SAR-3.2 Barricaded Gunman SAR-3.3 Preliminary Staging</td>
</tr>
</tbody>
</table>
Continuation of Table 24 Knowledge elicitation situations

<table>
<thead>
<tr>
<th>Critical Incident</th>
<th>Description/ Situation Assessment Record</th>
</tr>
</thead>
<tbody>
<tr>
<td>4 BARRICADED GUNMAN PART II (noon, Hot August, 1998)</td>
<td>Off-duty officer is called in to create and manage a command center in response to a barricaded gunman. Gunman is near major roads and shopping areas. Incident begins where 1st Staging Area (SAR 3.3) ends. SAR-4.1 Unified Incident Command Center SAR-4.2 Intruder SAR-4.3 Flash-Bang (‘too close’).</td>
</tr>
<tr>
<td>5 STEAK KNIFE (Sat. noon, Summer 1999)</td>
<td>Officer responds to investigate a 911 call for a domestic disturbance. Arrives to find older man with steak knife chasing 15 people. SAR-5.1 Domestic with Knife SAR-5.2 Suspect Flees Inside SAR-5.3 Barricaded Man</td>
</tr>
<tr>
<td>6 CODE 1 SEARCH (7PM Sept. 2005, dark, warm evening)</td>
<td>Multi-agency search to support officer in distress. Begins when an officer investigating a retail theft recognizes a gun in suspect’s pocket. During ensuing struggle for the gun, officer only has time to radio “10-13” (officer in distress), but not his badge number or location. SAR-6.1 “10-13” SAR-6.2 Search</td>
</tr>
<tr>
<td>7 INEBRIATED GUNMAN (2000, decent weather, ~1AM)</td>
<td>Officer decides to take a different approach during second response to a disorderly conduct call. Arrives on foot to find a man loading his rifle. SAR-7.1 Trailer Park Party</td>
</tr>
<tr>
<td>8 ROAD RAGE PART I (1:30 AM, Oct. 2003)</td>
<td>Argument at gas station evolves into a road rage incident. Subsequent investigation leads to an encounter with a gunman. SAR-8.1 Initiate Investigation (29 October) SAR-8.2 Anonymous Tips (4 Nov.) SAR-8.3 Gunman (5 Nov.)</td>
</tr>
</tbody>
</table>
Continuation of Table 24 Knowledge elicitation situations

<table>
<thead>
<tr>
<th>Critical Incident</th>
<th>Description/ Situation Assessment Record</th>
</tr>
</thead>
<tbody>
<tr>
<td>9 ROAD RAGE PART II (1:30 AM, Oct. 2003)</td>
<td>Serving search warrant to look for gun used in road rage incident leads to an encounter with a gunman.</td>
</tr>
<tr>
<td></td>
<td>SAR-9.1 Preparation</td>
</tr>
<tr>
<td></td>
<td>SAR-9.2 Serving warrant</td>
</tr>
<tr>
<td></td>
<td>SAR-9.3 Standoff</td>
</tr>
<tr>
<td></td>
<td>SAR-9.4 After Action Review</td>
</tr>
<tr>
<td>10 DOMESTIC KNIFE (Thursday evening, September 2005)</td>
<td>Officer responds to a domestic dispute call at a residence with frequent police contact. Arrives to find a man threatening his wife with a knife. Husband and wife were both under the influence of alcohol.</td>
</tr>
<tr>
<td></td>
<td>SAR-10.1 Domestic</td>
</tr>
</tbody>
</table>
Figure 41 Conceptual assessment record 9.3
Appendix G

Data Analysis Spiral

Although there are several strategies available to analyze ethnographic data (Creswell, 1998; Miles & Huberman, 1994; Wolcott, 1994), the stages can be generalized in what Creswell calls the data analysis spiral:

**Data Management** – Analysis actually begins with the organization and conversion of field notes. For example, converting field observations and notes into typed outlines (described above) begins the process.

**Reading and Memoing** – Develop a broad sense of the collected data by using short phrases to denote ideas and concepts in the notes.

**Interpretation Loop** – Researcher uses multiple passes through the data to describe and classify it into categories and themes. As I identified themes in the data, I used the opportunity to check my findings in subsequent interviews with domain experts.

**Data Presentation** – Output the findings in narrative form supplemented by tables and figures.
Appendix H

Design Seeds – Situation Awareness

In the last stage of the critical incident knowledge elicitation sessions, the participants were asked to describe how awareness of the situation was developed in the incident or how it could be improved by technology. This is a summary of the raw data from those sessions.

<table>
<thead>
<tr>
<th>Table 25 Situation awareness design seeds</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Dispatch assigns 2 units from MPD-A; MPD-B monitors activity on radio</td>
</tr>
<tr>
<td>2. On-site team, SO talks to residents while JO is operates radio with dispatch and acts as backup</td>
</tr>
<tr>
<td>3. JO radios dispatch “Shots fired.” SOP 2 MPD-B units arrive. Dispatch knows to ask if more backup needed (yes) and if fire police needed for blocking traffic (yes)</td>
</tr>
<tr>
<td>4. “Pound” on adjacent apartment unit doors to evacuate residents</td>
</tr>
<tr>
<td>5. All units and command in place</td>
</tr>
<tr>
<td>6. Detectives need case narrative to book suspect</td>
</tr>
<tr>
<td>7. Partner location and coordinate paths to residence.</td>
</tr>
<tr>
<td>8. O1 and O2 arrive and inform each other of findings</td>
</tr>
<tr>
<td>9. Awareness of other officers to assist in felony arrest roles (Comm/ Contact/ Cover)</td>
</tr>
<tr>
<td>10. Off duty MPD-B officers notified by pager; on duty officers of different departments by radio.</td>
</tr>
<tr>
<td>11. Began making decisions on way in to scene by telephone to dispatch.</td>
</tr>
<tr>
<td>12. Experienced dispatcher will suggest information by checking CRIMES database on suspect and guns in home and decisions such as need EMS?)</td>
</tr>
<tr>
<td>13. Officers need to be on same page as to what force can be used and IS BEING USED (history of suspect is needed; ability to distinguish bullets and bean bags)</td>
</tr>
<tr>
<td>14. State (SERT) and municipal police had separate command vehicles; no common area for meeting.</td>
</tr>
<tr>
<td>15. Negotiator needed a scribe and CI working as a team to find hooks (and provide continuity to relieve negotiator)</td>
</tr>
<tr>
<td>16. OIC would like video into scene</td>
</tr>
<tr>
<td>17. Perimeter officers did not get a picture of gunman until several hours after starting (no JNet in the field)</td>
</tr>
<tr>
<td>18. Knowledge from caseworker on individual’s recent history and mental health.</td>
</tr>
<tr>
<td>19. Call on duty backup from MPD-C, MPD-D, MPD-E; EMS, OS, and Fire Police. Page off duty from MPD-B.</td>
</tr>
<tr>
<td>20. Specify 1st of 3 staging areas or command posts (to deploy arriving officers, based on time of arrival and weapon-types)</td>
</tr>
<tr>
<td>21. Dispatch 2 incidents from previous evening:</td>
</tr>
</tbody>
</table>
Continuation of Table 25 Situation awareness design seeds

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
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</thead>
<tbody>
<tr>
<td>22.</td>
<td>Caller reported altercation began at convenience store; was chased and fired upon; believed he knew car type &amp; color</td>
</tr>
<tr>
<td>23.</td>
<td>MPD-A officer reported following 2 speeding cars</td>
</tr>
<tr>
<td>24.</td>
<td>MPD-A needed to know of investigation by MPD-B’s CI.</td>
</tr>
<tr>
<td>25.</td>
<td>Officers at primary and secondary residences needed to be aware of each other (Action at secondary residence was driven by findings at primary residence).</td>
</tr>
<tr>
<td>26.</td>
<td>Dispatch 2 incidents from previous evening:</td>
</tr>
<tr>
<td>27.</td>
<td>Caller reported altercation began at convenience store; was chased and fired upon; believed he knew car type &amp; color</td>
</tr>
<tr>
<td>28.</td>
<td>MPD-A officer reported following 2 speeding cars</td>
</tr>
<tr>
<td>29.</td>
<td>MPD-A needed to know of investigation by MPD-B’s CI.</td>
</tr>
<tr>
<td>30.</td>
<td>Officers at primary and secondary residences needed to be aware of each other (Action at secondary residence was driven by findings at primary residence).</td>
</tr>
<tr>
<td>31.</td>
<td>Who made 10-13? Not sure where all officers are at given time (if they can’t radio). Cars have GPS. Rely on officers reporting by radio arrival on scene. Could poll by radio officers to reply if ok (knew to begin with officer 2, who did not reply); not replying, in this case, was important information regarding officer situation</td>
</tr>
<tr>
<td>32.</td>
<td>7 now on scene included 5 arriving backups with 2 more on way from other MPD’s - did not know complex apartment geography. Hard to describe (maps in cars would help). Had rough description of suspect (again, file sharing 1 mi. x 1 mi. aerial photo in cars would help) – suspect had changed clothes.</td>
</tr>
<tr>
<td>33.</td>
<td>“Where is everyone” (hard for sweep search)</td>
</tr>
<tr>
<td>34.</td>
<td>Instructions given by radio</td>
</tr>
<tr>
<td>35.</td>
<td>Even though trainee, and female, male officer 1 was comfortable with officer 2 as backup; “Gut” told officer 1 that they should arrive on foot – felt this decision saved them from being shot at with .270 rifle.</td>
</tr>
<tr>
<td>36.</td>
<td>Share awareness of husband/ wife history, geography, approaches, roles in approach</td>
</tr>
</tbody>
</table>

43 Did know one arriving officer had military sweep search training – assigned that officer to meet others at staging area and take charge of a mini-sweep search
Appendix I

Design Seeds – Post Hoc Analysis and Review

In the last stage of the critical incident knowledge elicitation sessions, the participants were asked to also describe the important lessons they learned from the incident or what information they felt would be important to analyze and review with other officers. This is a summary of the raw data from those sessions.

Table 26 Post hoc analysis and review design seeds

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
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</thead>
<tbody>
<tr>
<td>1.</td>
<td>Approach path to apartment was very risky – passed right below window; did not know apartment unit specific location or that it was upstairs.</td>
</tr>
<tr>
<td>2.</td>
<td>Position was too near the door opening and immediately underneath apartment deck</td>
</tr>
<tr>
<td>3.</td>
<td>JO should have grabbed jacket (shivering)</td>
</tr>
<tr>
<td>4.</td>
<td>Prevent female from trying to reenter</td>
</tr>
<tr>
<td>5.</td>
<td>12 gauge blast hits floor 18” from SO (too close)</td>
</tr>
<tr>
<td>6.</td>
<td>Black jackets and pounding on apartment doors at night startles residents (show patch on sleeve).</td>
</tr>
<tr>
<td>7.</td>
<td>Desire to stay to resolution greater than fatigue awareness</td>
</tr>
<tr>
<td>8.</td>
<td>Take different paths to scene.</td>
</tr>
<tr>
<td>9.</td>
<td>West end problem with police data computers.</td>
</tr>
<tr>
<td>10.</td>
<td>Driver could not follow orders to exit car (with hands raised) because seatbelt was on (other impairments such as hearing?)</td>
</tr>
<tr>
<td>11.</td>
<td>Staging command center moved 2 times (1st time was when planners asked where scene was and looked up and it was right there). Needed a better F2F meeting area for task managers – brought in DUI van (also had lights).</td>
</tr>
<tr>
<td>12.</td>
<td>Officer shooting bean bag needs another officer to radio “bean bag”</td>
</tr>
<tr>
<td>13.</td>
<td>Lengthy events: Issues of batteries in cell phones needs to get resolved; meeting area needed to get resolved. Tracking events (notes) for negotiator and command is needed for bringing replacements up to speed.</td>
</tr>
<tr>
<td>14.</td>
<td>MPD-D officers arrived with white shirts – stood out too much at night.</td>
</tr>
<tr>
<td>15.</td>
<td>Flash bang without announcement led gunman to think he was under attack and he fired towards noises</td>
</tr>
<tr>
<td>16.</td>
<td>Caseworker photo when serving 302 warrant?</td>
</tr>
<tr>
<td>17.</td>
<td>302’s are wildly unpredictable</td>
</tr>
<tr>
<td>18.</td>
<td>Needed mother to learn about individual’s immediate history and mental health as well as trailer floor plan, guns he had access to, experience with guns, likes (hooks)/ dislikes, etc.</td>
</tr>
<tr>
<td>19.</td>
<td>Need to act dual-role as OIC and containment (until relieved)</td>
</tr>
<tr>
<td>20.</td>
<td>Selection of staging area should not be too close to scene.</td>
</tr>
<tr>
<td>21.</td>
<td>Convenience store surveillance video could not help with incident</td>
</tr>
</tbody>
</table>
Continuation of Table 26 Post hoc analysis and review design seeds

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
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</thead>
<tbody>
<tr>
<td>22.</td>
<td>Investigation priorities:</td>
</tr>
<tr>
<td></td>
<td>o Find handgun</td>
</tr>
<tr>
<td></td>
<td>o Match gun to casings</td>
</tr>
<tr>
<td></td>
<td>o Match gun to suspect</td>
</tr>
<tr>
<td>23.</td>
<td>Process to handle multiple tips and time to follow-up leads</td>
</tr>
<tr>
<td>24.</td>
<td>Public assumes police information integration (called MPD-A instead of MPD-B).</td>
</tr>
<tr>
<td>25.</td>
<td>Didn’t expect too much trouble since suspect though he had got away with it and they were not coming to take him into custody but search for handgun.</td>
</tr>
<tr>
<td>26.</td>
<td>Situation made worse because suspect was intoxicated and believed he could get 20—40 years (had talked to an attorney)</td>
</tr>
<tr>
<td>27.</td>
<td>Suspect had disposed of gun, but thought he was safe and had retrieved it (investigation time elapsing helped case)</td>
</tr>
<tr>
<td>28.</td>
<td>Could have called assault team</td>
</tr>
<tr>
<td>29.</td>
<td>Importance of communicating with backup officer of situation; importance of communicating with dispatch of scene arrival; importance of identifying threat (gun) in pocket. Importance of radioing situation (when milliseconds count); value of team piecing together who is in trouble.</td>
</tr>
<tr>
<td>30.</td>
<td>Good to be lucky sometimes – ready to give up search for night when suspect observed leaving woods. Found gun next day on apartment roof.</td>
</tr>
<tr>
<td>31.</td>
<td>Gut is a good thing to “hear.” Good idea to change arrival methods, especially when same call later in evening.</td>
</tr>
<tr>
<td>32.</td>
<td>Younger officer might have charged into incident alone. Now realized the few minutes to stage backup officers was important.</td>
</tr>
</tbody>
</table>
VITA

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Education

Pennsylvania State University (University Park, PA)
Ph.D., Information Sciences & Technology, December 2006
Dissertation: Challenges Supporting Cognitive Activities in Dynamic Work
Environments: Application to Policing, Advisor: Dr. Michael D. McNeese

Wharton School of Business (Philadelphia, PA)
M.B.A., Strategic Management, May 1988
ASP: Design for Manufacturability, Advisor: Dr. Paul R. Kleindorfer

Pennsylvania State University (University Park, PA)
B.S., Mechanical Engineering, February 1982
B.A., General Arts and Science, February 1982

Teaching Experience

Pennsylvania State University (University Park, PA)
1999 – Present: Instructor of Management Information Systems,
Department of Supply Chain & Information Systems, Smeal
College of Business

2002: Instructor, College of Information Sciences & Technology,
Pennsylvania Governor’s School

Awards

The Pennsylvania State University
Smeal Teaching Innovation and Excellence Grants
2006: Incorporating Computing Skills Course Component within a Business Context
into MIS 204 ($10,300)
2005: Implementing Web-Based Delivery for "By Appointment" Component of MIS
204 ($4,000)

The Pennsylvania State University
Eighteenth Annual Graduate Exhibition March 28 & 30, 2003
2nd Place: Evaluating the Effectiveness of Moderated Chat Rooms for Student Exam
Reviews: Preliminary Results

Certifications

Registered Professional Engineer
Pennsylvania #PE035703E