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# Managing Patient Health Across Diverse Spaces: Using Activity Theory to Model Pervasive Decision Support

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**Abstract**

Clinical decision support (CDS) systems can offer health care providers and patient data that is intelligently filtered and presented in ways to enhance diagnosis and long-term health care management, both within and outside clinical spaces. Challenges to this information management include diagnostic error and inefficiencies from conflicting, incomplete, or suboptimal clinical systems [3] as well as extending care outside the traditional clinical environment. We propose a Clinical Activity Model (CAM) to understand pervasive CDS system design and use across multiple health care spaces as patients move between critical care, recovery, and long-term home care. We discuss CAM in the context of research findings comparing a novel CDS system with traditional modes of data delivery and by describing use of that system as a mobile diagnostic tool to bridge clinical care and home care.

**Author Keywords**

Activity theory, decision-support, visualization, patient care

**ACM Classification Keywords**

H.4.1 [Information Systems Applications]: Types of Systems -- decision support

**General Terms**

Design, Experimentation, Human Factors, Performance, Theory

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## Research Questions for Discussion

1. How might clinical and home care management be transformed using IV-CDSS as a diagnostic tool, as opposed to traditional methods and tools?
2. As cognitive tool, can IV-CDSS adequately support continuity of patient care across diverse healthcare contexts?
3. Across different settings, how might IV-CDSS support the implicit and explicit rules, structures, and strategies that govern and guide the patient care processes identified in CAM?
4. What conflicts might be observed in different care spaces that IV-CDSS might resolve?
5. Could IV-CDSS help to change clinical behavior and activity in patient care management?
6. Does IV-CDSS have the potential to support a more team-centered patient care environment, including altering organizational workflow?

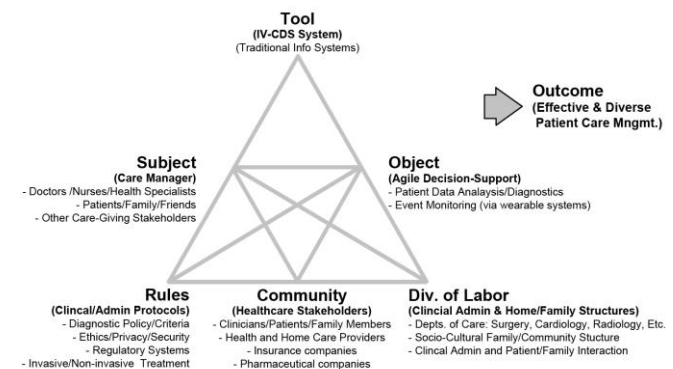
## Introduction

Our research contributes to an activity-centered understanding of pervasive CDS system design, use, and workflow as informed by our developed CAM [10, 7, 4]. This model informs development of an information visualization CDS system (IV-CDSS), a tool for enhancing patient care that initiates in the context of an Intensive Care Unit (ICU), and extends to the mediation of care outside the clinical environment. Trajectory of care includes clinical interventions, recovery (ward monitoring), and long-term home care.

The first goal of IV-CDSS is reduction of diagnostic errors and smaller gaps between knowledge and practice caused by conflicting, incomplete, or suboptimal clinical systems—improving safety and increasing patient longevity [2]. IV-CDSS accomplishes this goal by emphasizing the use of longitudinal real-time events that frame information and the historical development of the knowledge regarding the patient. Through simulation of information-seeking and knowledge-building activities in the ICU, we used CAM to observe IV-CDSS in use by identifying points of interaction and conflict that have potential to cause error (or other negative outcomes) in the patient care management process. See Figure 1 to note the six interacting factors of potential tension that exist within CAM. These six factors are dynamic in nature and can change dramatically relative to the context of implementation and interaction.

The second goal is extending and linking the information-seeking and knowledge-transferring processes of the ICU to the home. We are in the early stages of exploring how CAM can be applied to the design and use of medical information systems across a diversity of health care delivery contexts. Beyond the benefits of continuance of care and patient empowerment, we also recognize that both potential and risk exist in sharing information across these care management environments. We argue, however, that successful transitions between a traditional health care setting and the home (through patient self-care), can improve health in profound ways. Those transitions could be improved with IV-CDSS.

Here, we discuss use of CAM to inform CDS system design and use across multiple health care contexts as patients move between intervention, recovery, long-term home care, and self-management. We further discuss our research comparing use of IV-CDSS to traditional forms of clinical data and identifying potential conflicts that could lead to clinical error. Finally, we discuss the use of IV-CDSS as a mobile diagnostic tool that could link CDS information across clinical and home health care.



**Figure 1:** CAM is a merged model that integrates the clinical as well as the home care environment.

## Applying CAM to IV-CDS

CAM derives from decades of evolutionary research on activity theory (AT), which can be traced back to Vygotsky's [10] research on the "social origins of the mind" and cultural-historical development theory [10, 11]. From this theory, Vygotsky developed his notion of "signs as psychological tools." Zinchenko [12] noted that psychological tools are tools of labor (sign mediators). This concept follows the Marxist thought regarding the role of "tools of labor" in human cognition and their influence on the object of one's activity. Leont'ev [7] extended this research, stressing the importance of tool mediation and goal-directed activities, whereby humans might arrive at renewed structures of behavior beyond their existing state of development, as well as new levels of "culturally-based mental function" [10].

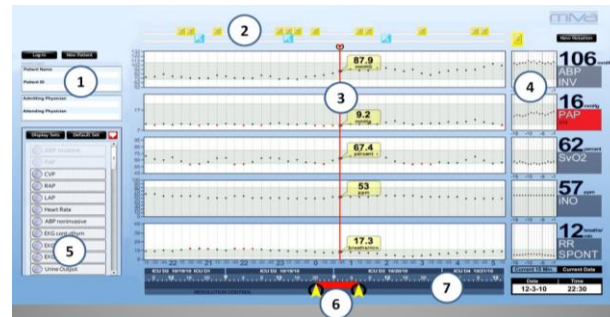
## The IV-CDS System

IV-CDSS delivers multivariate biometric data via a visualization display by transforming and organizing it into temporal resolutions that provide contextual knowledge to clinicians. The result is a spatial organization of multiple datasets allowing rapid analysis and interpretation of trends. IV-CDSS improves diagnosis by allowing a rapid recognition of essential changes to multiple and relational physiological data over a designated time frame. Using selection menus, physicians control necessary data sources, time periods, and time resolutions to narrow down their diagnosis and final assessment of a patient's condition.

Hence, the IV-CDSS interface has been designed to maximize the clinician's ability to control what data is visualized during a specific context-related patient episode or general periodic diagnosis. Key interface tools include the following, as shown in Figure 2:

1. Log-in area
2. Icon Tray
3. Data Point Scrubber
4. Current Data Status
5. Biometric Subcategories
6. Time Resolution Control
7. Timeline

In this research, we apply CAM to IV-CDSS as an extension of AT in the health care domain, in an effort to derive meaning from the impact that mediating technologies might have on health care as clinicians and patients work collaboratively to manage care. In particular, we sought out the "psychological tools" that mediate health care delivery within the context of development and the transformation of knowledge. Both external (behavioral) and internal (cognitive) activities differ across different patient care settings because of the impact of different means of organization, different care managers, and different types of mediation involved. Traditional CDSS are created to improve clinical processes. However, a decade of reporting on the state of health care continues to identify the adverse life-threatening effects caused, at least in part, by poor technology design. Much research has focused on improving health care quality and safety and on reducing cost. However, little actionable knowledge exists relating to contextual user-centered design of CDS technologies or how their potential might be reliably reached.



**Figure 2:** The IV-CDS System interface, also known as the Medical Information Visualization Assistant.

AT was first introduced to the HCI research community in the late 1990s [6]. Since then, scores of HCI researchers have applied AT in many contexts [9]. To a limited degree, AT has been used to describe learning and work in the health care domain. Bardram [1] used AT to study workflow in clinical computer-supported cooperative work, and to

evaluate an early patient scheduler application.

Critical to our discussion is the fact that limited attention has been given to observing cultural practice and socially organized human activity in both clinical and non-clinical patient care settings that support diagnostic processes. Moreover, CAM provides a unique analytical perspective that goes beyond single-clinician-centered task analysis; and seeks to understand the broader context of real-time experiences that are framed by human activity [9]. This model requires researchers to study life-as-it-happens—unfolding in ways that emphasize the historical development of patient care as an evolutionary process in conjunction with mediating technologies that provide decision support across environments.

In CAM, activity is characterized by a "rich social matrix of human activity," [5, p. 10] as first seen within the ICU. In this particular space, CAM aids in emphasizing the construction of goal-centered diagnostics as the object of clinical activity. As framed within CAM, contradictions might include observed tensions between doctors, nurses, patients, other stakeholders, IV-CDSS, and a complex matrix of rules, community, and division of labor [4]. We argue that CAM can more deeply describe the relationships between CDS and the clinician, clinical teams, patient information, clinical processes, and health care organizations involved in the extended circle of ICU patient care and beyond. Our research paradigm uses CAM as a lens through which to extract and describe the nuances of understanding patient diagnosis, while positioning IV-CDSS as a mediating tool.

In sum, a key benefit of CAM for HCI designers is its methodological allowance for tacit knowledge to surface throughout observations of activities in care management, giving insight into human health care work and the intrinsic nature of that work. In particular, it provides the ability to address the daily challenges faced while analyzing large amounts of data. Fulfilling the intentions of health care managers to access and accurately analyze data addresses many problems and potential risks to patients. In our study

### Key Findings

In varying degrees, participants agreed that IV-CDSS:

- Has the potential to provide decision support and speed diagnosis.
- Helps to quickly visualize all available data-points without communication with others or reviewing paper charts.
- Did not perform significantly faster or more accurately than traditional paper records. CAM data suggest these quantitative markers are not necessarily relevant for identifying its impact on care.
- Could be an important part of clinical activity that is consistent with the nature of clinical practice.
- Acts as a workflow tool that visualizes activities, giving clues for coordinating group workflow.
- May be able to resolve some conflicts by acting as a communication mechanism by visualizing a range of actions and events.
- Could support clinicians engaged in various tasks of information gathering and performed those tasks in the context of their standard practice of learning-in-work.

of IV-CDSS, we bring the notions of sociocultural history to the foreground.

### The Problem Space and Methodology

Historically, the health care domain remains one of the most data-rich environments at point-of-care, where physicians must retrieve, organize, and interpret critical data from multiple locations and devices (e.g., paper charts, written notes, conversations, bedside monitors, etc.). The challenges are first to interpret diverse sources of data that do not allow for trends and relationships to be quickly correlated, and then to appropriately, accurately, and legally, transfer data across multiple patient care settings.

Our study took place at the Indiana University Schools of Informatics, Medicine, and Nursing, and consisted of performance testing and interviews of two groups of physicians (8) and nurses (3), comparing IV-CDSS and traditional forms of medical paper records. Both groups performed the same test with different treatments based on the same ICU scenario. Both groups were observed for accuracy and speed in completing questions, and completed questionnaires and interviews related to usability and AT. A summary of findings is noted in the left sidebar and addresses ICU use as well as suggestions for other patient care settings.

### Conclusion

In this workshop, we will present a case for CAM (focused on health care activity) and IV-CDSS (mediating health care activity) as tools to support continuity of care. As people move between care spaces those transitions may lead to adverse events, so designing CDS systems that support multiple aspects of health care activity is imperative to reduce these occurrences. We intend to discuss the impact of our recent findings and the potential of IV-CDSS as a tool to address a wide range of patient care settings and management scenarios.

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