Evaluating the Impact of Electronic Health Records on Clinical Reasoning Performance Using Task-Technology Fit Theory

Matthew J. Wills
Dakota State University

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EVALUATING THE IMPACT OF ELECTRONIC HEALTH RECORDS ON CLINICAL REASONING PERFORMANCE USING TASK-TECHNOLOGY FIT THEORY

A dissertation submitted to Dakota State University in partial fulfillment of the requirements for the degree of

Doctor of Science

in

Information Systems

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By

Matthew J. Wills

Dissertation Committee:

Omar F. El-Gayar, Ph.D. (Chair)
Dorine Bennett, Ph.D.
Amit V. Deokar, Ph.D.
Surendra Sarnikar, Ph.D.
Cecelia Wittmayer, Ph.D.
DISSERTATION APPROVAL FORM

We certify that we have read this dissertation and that, in our opinion, it is satisfactory in scope and quality as a dissertation for the degree of Doctorate of Science in Information Systems.

Student Name: Matthew J. Wills

Doctoral Dissertation Title: Evaluating the impact of electronic health records on clinical reasoning performance using task-technology fit theory

Faculty supervisor: __________________________ Date: __________

Committee member: __________________________ Date: __________

Committee member: __________________________ Date: __________

Committee member: __________________________ Date: __________

Committee member: __________________________ Date: __________

Committee member: __________________________ Date: __________
ACKNOWLEDGMENT

The last five years have been some of the most enjoyable and challenging times of my life. From the Master of Science and Doctor of Science programs, there have been times of frustration, joy, sleeplessness and a tremendous sense of accomplishment. I have endeavored to become a better researcher, writer, thinker and contributor to my chosen field of Information Systems. Simultaneously I have come to realize a passion for exploring the many research questions that remain unanswered in this dynamic field of study.

Throughout this journey there have been many people who have made this dissertation possible. I am deeply grateful to my dissertation chair, Dr. Omar El-Gayar for his tireless assistance, patience and willingness to mold not only this project, but me. Also, I offer my sincere thanks to Dr. Amit Deokar who was instrumental during the data analysis process. Special thanks also to my committee - Dr. Surendra Sarnikar, Dr. Dorine Bennett and Dr. Cecelia Wittmayer for reviewing the dissertation proposal and final dissertation and helping to shape it into the work it is today.

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I am forever thankful to my parents, Jim and Kathryn Wills for believing in me and supporting my family during good times and bad. Indeed, this degree, the dissertation and the fire to reach higher rests firmly on the foundation of love and support they have so selflessly given.

To my wife Brenda and my children, Maya, Madelyn and Isaac – You have sacrificed so much throughout this process and supported me so completely during these past years. You have shared in my success and failures, fully understanding that the objective of all of this was to make a better life for all of us. Without your support, none of this would have been possible. Vous et nul Autre...
ABSTRACT

This study established and achieved three objectives which include development of a valid instrument for evaluation clinical reasoning performance with an electronic health record, an extension to TTF theory into the clinical domain and EHR context and confirmation of the on-going viability of TTF theory to explain the factors influencing individual performance.

The motivation and rationale for the study is based on a clear need for a valid instrument that captures user evaluations for research and organizational purposes. The lack of a validated instrument for evaluating the impact of EHR use on clinical reasoning performance is another reason for revisiting the user evaluation construct.

The study took place in a mid-size health system in the mid-western United States. The target population of the study included physicians, certified nurse practitioners and physician assistants with experience using an EHR. Sampling accurately represented the population of clinicians under study in this context. A 62.4% response rate was achieved for the survey.

Semi-structured interviews were conducted to ensure that the theoretical constructs made sense to clinicians, and to identify any additional constructs that might be critical to TTF or task and technology characteristics. The interview process also identified potential problems with the utilization construct, and further suggested that clinicians did not view authorization as an important dimension of TTF. Pre-testing of the instrument assisted with clarification of the wording on survey questions, resulting in eleven changes to survey questions.

Quantitative analysis was accomplished by means of exploratory factor and partial least squares analysis. The survey results suggest that for TTF, data quality, authorization, compatibility, and clinical informatics/IT relationship with users were important dimensions. Data locatability, production timeliness and system reliability all had significant but negative relationships with performance. Analysis of the survey data also suggested that task characteristics (task complexity, task uncertainty and task significance) effectively “moderate” the strength of the link between specific characteristics of EHR’s.
The results give support to many dimensions of the theoretical model and raise some interesting questions of their own. For example, why do locatability and systems reliability not test well, or, are there other dimensions of task and technology characteristics that should be considered? Also, some of the hypothesized relationships between task and technology characteristics did not perform as expected. Indeed, these issues are excellent candidates for future research.
DECLARATION

I hereby certify that this dissertation constitutes my own product, that where the language of others is set forth, quotation marks so indicate, and that appropriate credit is given where I have used the language, ideas, expressions or writings of another.

I declare that the dissertation describes original work that has not previously been presented for the award of any other degree of any institution.

Signed,

_____________________________
Matthew J. Wills
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CHAPTER 1

INTRODUCTION

Background

In the U.S., electronic health records (EHR) have emerged as the foundation of health information technology. Although fewer than 20 percent of physician practices have adopted the technology (DesRoches, 2008), recent directives and incentives from the U.S. federal government call for significant expansion of EHR adoption. Historically the field of medicine has been slow to embrace information technology, relying more on complex diagnostic tools and devices, as well as advances in treatment and surgical techniques (e.g. surgical robotics). So many interesting questions arise as human beings, smart medical devices and information systems become intertwined in support of effective, efficient and safe patient care.

For more than three decades information systems research has explored how and why people accept and use technology. Information systems researchers have also considered how technology impacts individual (Goodhue, D., Thompson, R., 1995) and group (Zigurs, Buckland, B.K., 1998a) decision-making performance. Practitioners who implement and manage EHR’s would benefit from a method of identifying factors that either inhibit, or enhance user performance. In the business world it is essential that performance impacts are identified, understood and accordingly planned for. In health care, where the supply chain is replaced with human patients, understanding performance impact is critical to implementation and operational success, as well as to issues of safety, quality, efficiency and effectiveness and meaningful use. As more clinicians are exposed to health information technologies such as EHR, several questions related to technology-mediated decision-making arise. For example, how do the nature of EHR technology and the clinical task characteristics influence the degree to which task needs are met by the technology, and what role do these constructs play in influencing clinical reasoning performance? Or, which factors contribute to improved performance? Another interesting line of inquiry questions the role of system use; is use a prerequisite for performance achievements? Does thinking about use even matter in a mandatory use environment?
If the mandate to broadly infuse clinician practices with EHR technology is based on the idea that access to better medical/clinical information equates to better, safer and more efficient care for patients, then asking how such technologies will impact decision-makers is paramount. It is critical that we develop systems that meet the information and decision support needs of clinicians without crowding out the clinician. This task is not an easy one to be sure; managing the information and knowledge needs of clinicians is one of the most complex problems researchers and informatics practitioners have encountered.

The practice of medicine is unlike any other vocation. Few other domains combine the complexity and uncertainty of decision-making as clinical medicine does. Clinical decisions are often a matter of life and death, and they are frequently made in a context where best practices, cost control, ethics and bias issues collide on a regular basis. Moreover, the vast volumes of information contained in all the world’s medical journals and libraries is more than one person can reasonably ever know, and the volume of new data, information and knowledge grows exponentially each year. Information systems can make these rich resources available and manageable where it counts: at the point and time of care. Such systems will never replace the human clinician; rather, the purpose is to support them as they make critical decisions that impact real people.

Borrowing from the information systems research tradition, this study uses task-technology fit (TTF) theory as the foundation for an evaluation instrument. TTF provides a theoretically grounded and empirically validated framework for evaluating perceived performance impacts resulting from information system use (Goodhue, D., Thompson, R., 1995). The premise of TTF is that individual performance will be enhanced when the functionality of the technology meets the user’s needs, i.e., fits the task at hand. The original TTF instrument was developed for the evaluation of multiple information systems and focused on managerial decision-making in the transportation and insurance industries (Goodhue, D., Thompson, R., 1995).

Goodhue (Goodhue, 1995) developed the TTF construct and demonstrated that the characteristics of both the task and the technology impact “fit”, which in turn impacts perceived performance. The construct of primary interest is perceived decision performance. This framework is ideal for this study for the following reasons:
1) It provides a comprehensive and detailed account of the factors that influence fit and performance.

2) It incorporates constructs which define task and technology characteristics, and their influence on the capability of the system to meet the needs of its users.

3) It has been adapted to a variety of domains; TTF is a flexible theory which has become cornerstone to the information systems discipline.

4) Preliminary studies by this investigator have demonstrated good results using a reduced TTF model to examine clinical performance.

Despite successful application to a variety of other industries, TTF has not been adequately adapted to healthcare, EHR technology or the clinical reasoning task.

**Research objectives**

Accordingly, the objectives of this research are to: 1) produce a valid instrument with diagnostic and predictive capabilities for evaluation of clinical reasoning performance with electronic health records, 2) extend and validate the TTF model to the clinical domain with an emphasis on specification of the clinical reasoning task and EHR technology characteristics, and 3) assess the on-going viability of TTF theory to explain the factors influencing individual performance.

*Theoretical Significance*

At the heart of this research is the goal of addressing a gap in the literature. This gap is understood as the lack of a tested, validated instrument for evaluating and predicting the impact of EHR use on clinical reasoning performance. While a variety of instruments exist for evaluating a number of important research questions pertaining to EHR, it does not appear as those instruments deal specifically with the important issue of clinical reasoning performance. The research will also shed light into the extent of applicability of TTF to other domains. In essence, the extent of generalizability of the TTF constructs originally proposed by Goodhue (1995).

*Practical Implications*

Practitioners can use the instrument developed here for a variety of purposes. In the case of implementations that are proceeding through the steps leading to advanced CPOE and
decision support capabilities, the instrument can provide a view of the electronic health record and its capacity for clinical reasoning support. The instrument can also be deployed in a pre and post-test manner for use in assessing the success (or lack thereof) of a particular EHR component implementation such as CPOE. Its potential usefulness is not limited to advanced implementations; it can be readily adapted if necessary for the most basic of EHR products. Moreover, the instrument can be used as a diagnostic tool to evaluate possible problems or issues with the technology, fit and performance of the user.

Practically speaking, the instrument may contribute to a fuller understanding of how EHR systems can be used meaningfully. Systems that support the clinical reasoning process may make their use more meaningful, impactful, and safe. At a time when all EHR’s and the institutions using them are coming under review for issues of meaningful use, this instrument may be a significant step in the right direction.

Outline of the Dissertation

Chapter 2 of this study includes a review of the literature on clinical reasoning, health information technology evaluation and information systems performance evaluation research. A task model is proposed and its constructs are presented in Chapter 3 along with the study’s hypotheses. Chapter 4 addresses the research design, while Chapter 5 presents and discusses the results. Chapter 6 concludes with a summary of findings, highlight of limitations and thoughts on future work in this dynamic and exciting field.
CHAPTER 2

LITERATURE REVIEW

Electronic Health Records and Clinical Reasoning

The electronic health record is an aggregate electronic record of health-related information on an individual that is created and gathered cumulatively across more than one health care organization. It is managed and consulted by licensed clinicians and staff involved in the individual's health and care. The EHR is not one specific technology; rather it is often understood as a composite of technologies including computerized provider order entry, clinical decision support plus administrative, laboratory and imaging systems.

Clinical reasoning is the broad term used to describe clinical problem-solving and decision-making. These terms are often used interchangeably, however it is important to note that problem-solving and decision-making represent two unique research paradigms in the cognitive sciences. Clinical decision-making typically refers to diagnostic and therapeutic decision-making while clinical problem-solving is understood as the steps involved in finding a solution to the problem (Croskerry, 2005). Here, the term clinical reasoning is used to describe both paradigms.

Although research on clinical reasoning has a tradition spanning decades, there exists no unified theory or explanation for how clinicians reason. Many of the existing theories differ only in the emphasis or terminology of the strategies used, rather than on the strategies themselves. Despite the theoretical variation of existing decision models, common themes and strategies have emerged from the cognitive literature. For example, present-day models generally agree that clinical reasoning can be understood as being either informal/intuitive or formal/analytical in nature, or some combination of both (Croskerry, 2002; Edwards, Jones, Carr, Braunack-Mayer, & Jensen, 2004; Elstein, S.A., 2002; Elstein, A., Shulman, L.S., Sprafka, S.A., 1978; Norman, 2005).

Informal/intuitive reasoning is enhanced through the use of heuristics and pattern matching; strategies which are largely possible due to the progressive accumulation of domain
knowledge over time and clinical experience (Croskerry, 2005; Elstein, A., 2002). Thus the application of “rules of thumb” and the ability to identify or categorize patterns is dependent on time and clinical practice (Croskerry, 2002). Conversely, the analytical strategies used for clinical reasoning are only possible due to the use of specific learned techniques, such as hypotheses testing or probability estimation (i.e., Bayes theorem). Table 1 summarizes these 2 paradigms and supposes a third, hybrid paradigm.

Table 1. Clinical Reasoning Paradigms

<table>
<thead>
<tr>
<th>Clinical Reasoning Paradigm</th>
<th>Features</th>
</tr>
</thead>
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| Informal/Intuitive         | • Heuristics (rules of thumb)  
|                            | • Pattern matching  
|                            | • Improves with time and experience  
|                            | • Hypothesis testing  
|                            | • Probability Estimation (e.g. Bayes Theorem)  |
| Formal/Analytical          | • must be learned, not dependent on experience  
|                            | • Combination of hypothesis testing and probability estimation during training and early clinical practice, progressively relying on heuristics and pattern matching as time in practice and experience increase.  |
| Hybrid                     |          |

Goodhue (Goodhue, 1995) originally designed TTF around the task of managerial decision-making. To extend this model to the clinical domain and the clinical reasoning task, this question needs to be addressed: How is clinical reasoning different from managerial decision-making? To answer this question, consider three possible types of decisions that might arise during patient care: 1) the evaluation of signs and symptoms to formulate a diagnosis, 2) decisions about further tests needed to refine a diagnosis, and 3) treatment selection.

**Diagnosis formulation:** Clinical diagnosis is similar in many ways to diagnostic problems that arise in business and in everyday life. However, the clinical diagnostic task has a high degree of complexity and uncertainty that makes it unique. First, consider that there are thousands of diseases that can cause signs and symptoms. Second, each of these diseases can cause many different signs and symptoms. Third, the signs and symptoms of these diseases
overlap; that is, most can be caused by more than one disease. Fourth, the relationships between
diseases and signs and symptoms are uncertain. For each disease and every sign or symptom,
there is a probability that each sign or symptom will occur with that disease, thus creating
thousands of probabilistic relationships. To make matters worse, most of these probabilities are
not well known.

**Test selection to refine diagnosis:** The next step in diagnosis is assessing the need for
additional information, choosing which tests or procedures should be done, and interpreting the
results relative to the patient’s diagnosis and management. After evaluating a patient’s signs and
symptoms, the physician may be uncertain about which disease the patient has. The decision to
obtain additional information is complicated by the fact that there are usually several diagnostic
tests and procedures to choose from; their uses overlap; none are likely to be conclusive; and
each has risks, financial impact, and may have negative effects on the patient. Because of this,
the clinician must assess the value of the information each test can provide and compare this to
the procedure’s risks, side effects, and costs. Moreover, the clinician must compare the test’s
expected impact with the expected impact of other tests that could be ordered.

**Treatment selection:** In choosing a treatment, the clinician needs to understand how
each possible treatment can affect each outcome that the patient considers important. Equally
important, the clinician must understand how the patient values each outcome. Treatment
selection is further challenged by considerable uncertainty regarding the effects of treatment on
outcomes. Patients may respond differently to similar treatments or they might have multiple
diseases whose treatments interact.

Finally, each of the above decisions must be made within the context of a massive body
of information and knowledge. For example, the International Classification of Diseases, Ninth
Revision, Clinical Modification (ICD-9-CM) is the official system of assigning codes to
diagnoses and procedures associated with hospital utilization in the United States. This list
contains more than 25,000 codable conditions. There are currently more than 5,400 biomedical
journals in print, and MEDLINE adds between 2,000 and 4,000 completed references each day
Tuesday through Saturday. Over 712,000 references were added in 2009 (NLM, 2009). In no
other field, including managerial decision-making is the decision task so dependent on such vast
subject knowledge.
Real diagnostic problems involve many signs, symptoms, and tests; many diseases; uncertainty about the baseline probabilities of the diseases; uncertainty about the probabilities of the signs, symptoms, and test results; and dependencies between the signs, symptoms, and test results.

While maintaining some similarities to managerial decision-making, clinical reasoning differs in terms of the complexity and uncertainty of the decision task. In all three decision scenarios mentioned above there is complexity with respect to the incredible volume of clinical knowledge that must be accessed to make good decisions at each step of the process. To further compound this complexity is the intricate web of dependencies that results from disease processes and possible diagnosis and treatment options. In terms of uncertainty, the clinical reasoning process is unique from managerial decision-making as a result of the probabilities of disease, signs, symptoms, test results and the dependencies between them. Any IT that seeks to mediate the complexity and uncertainty of clinical reasoning is certain to require the very best of evaluative procedures.

**Health IT Evaluation**

The use of health information technology offers a number of opportunities to improve health care. From reduction of clinical errors to improving efficiency and quality of care, there is mounting evidence to support the notion that information technology plays a critical role in the future of health care (Cantrill, 2010). At the same time, there are potential pitfalls that must be avoided. Health information technology is expensive, and the failure of such systems could have negative effects on patients, staff and organizations. Given what is at stake, evaluation of health information technology is a valuable and necessary activity.

Evaluation studies have focused on a variety of questions. Some studies have questioned the usability of the technology (Beuscart-Zéphir M.C., 1998; Corrao, N.J., 2010; Gräber, 1997; Kushniruk, 2001) while others have asked which technical/system features affect its use (Braccini). Evaluation research has examined how users (Bloom, 2010; Gans, 2005; Miller, 2004; Anderson, 1999; May 2001; Goodhue, 1995) and patients (Gray, 2000; Mair, 2000; Nahm, 2000) adopt and accept information technology, and the impact of information technology on structural and/or process quality has also been studied (de la Torre, 2010;

Evaluation is important for understanding if the implemented knowledge application system is indeed functioning as an effective aid in the diagnosis process, and if so, how effective and useful it is. In that regard, researchers have reported on extensive field studies, which involve comparing the diagnoses provided by the Health IT systems to those suggested by clinicians (Berner and Maisiak, 1999; Berner, 1999; Bonis, 2008; Boonfalleur et al., 1995; Bruning et al., 1997; Edwards, et al., 1995; Hu et al., 2006; Innis, 1997; Korpinnen et al., 1994; Kotzke and Pretschner, 1992; Leitich et al., 2001; Lejbkowicz et al., 2002; Martin, 2001; Moens, 1992; Molino et al., 2000; Ridderikhoff and vanHerk, 1997). Overall, these results indicate that these systems enhance the clinical practitioners’ diagnostic capability, resulting in an improved overall diagnostic accuracy. Additionally, alternative knowledge reasoning algorithms have been compared to determine which technology suits better for the diagnosis problem under consideration. Researchers have reported on such experimental studies, emphasizing the context specific nature of problems and value in conducting such studies (Krusinska et al., 1993; Molino et al., 1996; Todd and Stamper, 1994).

Health information technology has also been evaluated for the investment, operational costs and cost-effectiveness of implementation (Wang, 2003; Miller, 2005; Enning, 1995; van Gennip, 1995; Bryan, 1999; Lock, 1996; Mair, 2000b; Bryan, 2000b), as a vehicle for implementing performance measures (O’Toole, 2005), and implementation best practices (Geibert, 2006; Adler, 2007). It is generally agreed that multiple-method evaluation – quantitative and qualitative methods – offer the best perspective (Yu, 2010). Feasibility (Borbolla, 2010) and pilot studies (Bansler, 2010) are common.

Some evaluation studies have focused on comparing system generated therapy plans with physician generated therapy plans, such as parenteral nutrition plans (Horn et al., 2002), ventilator therapy (Miksch et al., 1996; Shahsavar et al.,1995), and many others (Lau, 1994; Vollebregt et al., 1999). Reduced errors and omissions in resultant plans generated with Knowledge Management Systems (KMS) indicate promise in providing improved patient care. However, in some cases CDSS implementations have shown to introduce errors (Coiera et al., 2006). Other studies have also looked at analyzing the impact of computerized guidelines and decision support on decision quality, reporting positive results on average (Hanzlichek et al.,
2005; Hozo and Djulbegovic, 1999; Sintchenko et al., 2004; Zielstorff et al., 1997). Other patient oriented evaluation metrics have also been used to measure the impact of using HIT systems and applications in the therapeutic process, for example, readability and cultural sensitivity of decision tools (Thomson and Hoffman-Goetz, 2007), improved patient choice (Holmes-Rovner and Rovner, 2000), reduced decisional conflict in patients (Col et al., 2007, Protheroe et al., 2007). It is also suggested that using key performance indicators can be advantageous in understanding the impact of HIT on clinical processes (Berler et al., 2005).

There are a number of challenges to evaluating health information technology. Chief among them is the complexity of the information technology itself, the complexity of the evaluation project, and the motivation for the evaluation (Ammenwerth, 2003). Information systems are defined not only by their hardware and software components, but also by the social and behavioral processes of system use. This socio-technical complexity makes evaluation of information technology difficult on a number of different levels. Because of this complexity, health information technology should be implemented over time. An extended implementation allows clinical processes and workflows to be adjusted for the technology – or alternatively – the technology can be modified to model established processes and workflows. In either case, the object of evaluation (technology and the environment in which it’s used) is dynamically changing. As one would expect, this moving evaluation target is dependent on the point in time where the evaluation took place, making some results obsolete by the time they are obtained.

Another major challenge to evaluation of health information technology is the complexity of the overall evaluation project. Stakeholders in a health information technology project may have different conceptions of what constitutes “successful” information technology. Moreover, evaluation can be done from a variety of perspectives -- from economic, technical, organizational, individual, administrative or clinical views, to name a few (Jorgensen, 1995). As Ammenwerth (Ammenwerth) points out, each perspective brings with it a multitude of choices about evaluation approach (objective v. subjective), methods (quantitative v. qualitative) and study design (randomized controlled trial v. observational).

A third major obstacle to health information technology evaluation is the motivation of stakeholders and participants. It can be difficult to recruit study participants who may already be burdened with learning a new system and for whom the benefits of participation may not be known or appreciated. Support from management is essential to participant recruitment.
The specific challenges addressed in this research include evaluating individual performance with an EHR from a TTF perspective, i.e., taking into consideration the extent of fit between the task characteristics (clinical reasoning) and the underlying technology (EHR). TTF is itself a multi-dimensional construct whose components have been designed from the perspective of managerial decision-making. It will be critical to explore the relevance of Goodhue’s original eight TTF constructs to the clinical decision-making domain, from both theoretical and practical perspectives. Any attempt to clarify the specifics of task and technology constructs should be similarly explored from theoretical and practical perspectives. A final challenge to this research is the inclusion or exclusion of the use construct to the overall model. What role will the evaluation of use play in a mandatory use environment such as this? These challenges and questions will be more fully developed when the theoretical model is more fully developed and addressed in chapter 3.

**Information Systems Utilization and Performance Research**

Technology acceptance and performance research have been impacted by the theories of individual human and social behavior emerging from the disciplines of psychology and sociology. With its origin in the area of Social Learning Theory by Miller and Dollard (1941), Social Cognitive Theory (SCT) is focused on the process of knowledge acquisition through observation (Bandura, 1977). This theory was later expanded, in particular by Bandura (Bandura) and became known as SET, or Self-Efficacy Theory. In the years prior to Bandura’s work on Self-Efficacy, Fishbein and Ajzen (Fishbein, 1975) published their research on the Theory of Reasoned Action (TRA). The theoretical basis for TRA lies in the tenets of social psychology, and has been widely accepted as a foundational theory of human behavior.

A product of TRA and SET, the Theory of Planned Behavior (TPB) emerges as an extension of TRA with perceived behavioral control from SET as an additional determinant of intention (Ajzen and Fishbein, 1980). In 1991, Thompson, Higgins, and Howell (1991) published an alternative to TRA and TPB, the Model of PC Utilization (MPCU). This theory too has its roots in psychology, emanating most distinctly from the Triandis’ (1977) work on human behavioral research.
With respect to the behavioral determinants of use, the Technology Acceptance Model (TAM) represents the first theory specifically established for the information systems (IS) context (Davis, 1989). Other variations followed, including Combined Technology Acceptance Model – Theory of Planned Behavior (TAM-TPB) (Taylor, 1995), Technology Acceptance Model 2 (TAM2) (Venkatesh, V., Davis, F. D., 2000), the Unified Theory of Acceptance and Use of Technology (UTAUT) (Venkatesh, V., Morris, M.G., Davis, G.B., Davis, F.D., 2003) and Technology Acceptance Model 3 (TAM3) (Venkatesh, V., Bala, H., 2008).

Contrasted with models that predict acceptance and use, TTF attempts to explain user performance with information systems. In other words, the focus of TTF is on the outcome of the use-to-performance chain. The theory measures task-technology fit along multiple dimensions. Goodhue also demonstrated the validity of an instrument for information systems user evaluation based on TTF (Goodhue, D.L., 1998b). Later, it was established that user evaluations were effective surrogates for objective performance (Goodhue, D.L., Klein, B.D., March, S.T., 2000).

TTF has been examined in group performance situations (Shirani, 1999; I. Zigurs, Buckland, B. K., 1998b), as intended with the focus on managerial decision-making (Ferrett, 1998), and has been further examined with an emphasis on ease-of-use (Mathieson, 1998). TTF has also been extended with the technology acceptance model (Dishaw, M.T., Strong, D.M., 1999; Klopping, 2004; Pagani, 2006).

More recently, TTF has been the theoretical basis for a number of studies evaluating user performance with information systems. Vlahos et al. (Vlahos, 2004) investigated German managers and their use, perception of value and satisfaction with information technology. These researchers discovered that the TTF model was optimized when it included resource allocation, alternatives evaluation, problem identification and short-term decision making. Another study combined TTF with a cognitive element from Social Cognitive Theory (SCT) (Lin, 2008), investigating knowledge management system (KMS) usage in information technology. Here, perceived TTF, KMS self-efficacy and personal and performance outcome expectations were found to have a significant impact on use. Another study addressed knowledge management (KM), technology usage and performance, this time in the context of a Chinese consulting firm (Teo, 2008). Here, the investigators determined that output quality, data compatibility and knowledge tacitness (an extension of Goodhue’s original model) were positively related to usage. The authors also concluded that utilization and compatibility were positively related to
performance, and TTF was more strongly related to performance than utilization. Other research examined TTF in the context of mobile information systems (Junglas, 2008), where the TTF construct of data locatability was examined in significant detail. Zigurs et. al (Zigurs, I., Khazanchi, D., 2008) applied the theoretical perspective of frames to the challenges of virtual collaboration technologies.

![Task-Technology Fit Model (Goodhue 1995)](image)

Figure 1. Task-Technology Fit Model (Goodhue 1995)

The application of TTF in the healthcare domain has been quite limited to date. With the exception of Kilmon et al. (Kilmon, C., 2008) and Wills et al. (Wills, M., El-Gayar, O., Deokar, A., 2009), there are no studies employing TTF in user evaluation of EHR systems. Kilmon et al. (Kilmon, 2008) utilize the TTF instrument presented in Goodhue (1995b) as a diagnostic tool to evaluate a first-phase implementation of an EHR at a university hospital. While the results indicated that the system implementation was a success in terms of the task-technology fit, the study does not validate the TTF instrument in the healthcare context. Moreover, the study did not attempt to evaluate performance impact or the relationship between TTF and performance impact.

TTF has been and remains a suitable candidate for adaptation to other domains. As a model for evaluating clinical reasoning performance, TTF holds the potential to shed light on the relationships between EHR and clinical reasoning characteristics, their impact on task-technology fit, and the subsequent effects on utilization and performance. Accordingly, and to be able to use a TTF-based instrument to reliably evaluate the impact of EHR on clinical reasoning performance, this study aims to assess the validity of the instrument in the context of
healthcare. The study explicitly defines task and technology characteristics in a healthcare setting. In the next chapter, the theoretical model and research hypotheses are presented and discussed.
CHAPTER 3

THE THEORETICAL MODEL

The Theoretical Model

Whereas past effort (Wills, M., El-Gayar, O., Deokar, A., 2009) in the health care domain have focused on testing reduced TTF models and others have simply used the TTF instrument for evaluation purposes (Kilmon, 2008), this study follows Goodhue (Goodhue, 1995b) in both structure and form, and is adapted to the clinical environment with respect to the task and technology characteristics and performance constructs. The TTF dimensions that comprise the model employed in this study include data quality, data locatability, data compatibility, IS relationship to users, ease-of-use and training, correct level of authorization, systems reliability, and IS production timeliness. Task characteristics include the dimensions of task complexity and task uncertainty. Technology characteristics are defined by the dimensions of information, knowledge and Inferencing support. The relationships between these constructs are depicted in figure 2. The following sub-sections discuss task-technology fit, technology, and task characteristics in the context of the clinical decision making domain. The chapter concludes with a list of the hypotheses emanating from the underlying clinical TTF model.

![Figure 2. Theoretical TTF Performance Model](image-url)
**Task-Technology Fit dimensions**

In building a task-fit process model for managerial decision making, Goodhue established three processes by which managers come to use organizational information: 1) identification of the data, 2) acquisition of the data, and 3) interpretation of the data. In the first step, formulating the structure of the problem leads to identification of the information needed to solve it. Goodhue (1995b) notes that identification may also be interconnected with choices about appropriate decision strategies. Once it has been determined that information is needed, the decision to acquire it is made. Acquisition requires the use of hardware and software to search for and extract the needed data. Interpretation and integration of the acquired data can be facilitated by computer support or other means; however, this third step is also dependent on the accuracy, credibility, presentation and compatibility of the data (Goodhue, D.L., Thompson, R.L., 1995b).

Clinicians pursue and use health information in much the same way as noted by Goodhue (1995b). Once the decision to pursue information is made, the processes of identification, acquisition and interpretation begin. Chapter 2 discussed the three possible types of decisions clinicians may make: diagnostic formulation, diagnostic refinement (test selection) and treatment selection. During diagnostic formulation, the structure of the clinical problem is defined, leading to identification of the information needed to solve it. Following this, the clinician will acquire the information needed to refine the diagnosis. This may involve acquiring specialized information or it may involve the selection and ordering of further diagnostic tests. With the required information identified and acquired, the clinician will integrate and interpret it, leading to the selection of a treatment.

Essential to the identification process is obtaining the right data, the appropriate level of detail, and the correct semantics, or meaning for the data. Acquisition of data is dependent on locatability, ease-of-use, and training – such as effective search techniques or system training – authorization, production timeliness, users’ relationship with clinical informatics and IT staff, and system reliability. Interpretation of the data requires accuracy and compatibility of data between systems.
Table 2. Task-Technology Fit Construct Dimensions and Measurement Items

<table>
<thead>
<tr>
<th>Construct</th>
<th>Construct Dimensions</th>
<th>Measurement Items</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>TTF</strong></td>
<td><strong>Quality</strong>: Quality of the data in the system, including how current it is, how well necessary fields or elements are provided, and the degree to which the right level of detail is provided by the system.</td>
<td><strong>CURRENCY</strong> - Data is current enough for the user’s needs. <strong>RIGHT DATA</strong> - maintaining the necessary fields or elements. <strong>RIGHT LEVEL OF DETAIL</strong> - Maintaining the data at the right level or levels of detail.</td>
</tr>
<tr>
<td><strong>Locatability</strong>: Ease of finding the location and meaning of the data</td>
<td><strong>LOCATABILITY</strong> - Ease of determining what data is available and where. <strong>MEANING</strong> - Ease of determining what a data element on a report or file means, or what is excluded or included in calculating it.</td>
<td></td>
</tr>
<tr>
<td><strong>Authorization</strong></td>
<td><strong>AUTHORIZATION</strong> - Obtaining authorization to access data necessary to do my job</td>
<td></td>
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<tr>
<td><strong>Compatibility</strong></td>
<td><strong>COMPATIBILITY</strong> - Data from different sources can be consolidated or compared without inconsistencies</td>
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</tr>
<tr>
<td><strong>Production Timeliness</strong></td>
<td><strong>TIMELINENESS</strong> - Information Technology (Dept.) meets pre-defined production schedules</td>
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</tr>
<tr>
<td><strong>Systems Reliability</strong></td>
<td><strong>SYSTEMS RELIABILITY</strong> - Dependability and consistency of access and uptime of systems</td>
<td></td>
</tr>
<tr>
<td><strong>Ease-of-Use/Training</strong></td>
<td><strong>EASE OF USE OF HARDWARE &amp; SOFTWARE</strong> - Ease of submitting, accessing and analyzing data using software and hardware.</td>
<td></td>
</tr>
<tr>
<td><strong>CI/IT Relationship with users</strong></td>
<td><strong>1.CLINICAL INFORMATICS &amp; IT UNDERSTANDING OF BUSINESS</strong> - How well does clinical informatics understand my departments’ needs? <strong>2.CI INTEREST AND DEDICATION</strong> - to supporting clinical information needs. <strong>3.RESPONSIVENESS</strong> - Turnaround time for an data/information request. <strong>4.CONSULTING</strong> - Availability and quality of technical assistance and system planning. <strong>5.CI/IT PERFORMANCE</strong> - How well do they keep their agreements?</td>
<td></td>
</tr>
</tbody>
</table>

**EHR Technology Characteristics**

Nolan et al. (Nolan, R. L., 1973) made some of the first characterizations of information technology, based on the concept of information systems maturity (Nolan, 1973; Nolan, 1999). Information systems maturity refers to the condition in which information resources are at their fullest potential (fully developed), totally integrated and interoperable (Raymond, 1992). Additional work in this area has been undertaken with respect to identifying the criteria of information systems maturity or sophistication (Cheney, 1982; Gremillion, 1984; Mahmood, 1985; Saunders, 1984) with Nolan’s work serving as the basis for most of the research that followed.
Unfortunately there is less guidance in the literature regarding the characterization of technology in the TTF model. In many cases, definition of these characteristics is completely omitted in favor of reduced models. The difficulty with respect to assigning such characteristics is more than evident in the literature, most notably Goodhue’s (1995b) seminal paper where technology characteristics were represented with the proxy variables “system used” and “department of the respondent”. Proxy (dummy) variables were used because Goodhue’s study examined TTF for 25 different systems across two companies. Capturing and measuring such a vast array of characteristics was not feasible.

Two TTF studies conducted by Dishaw and Strong (Dishaw, M., Strong, D., 1998; Dishaw, M., Strong, D., 1999) provide some guidance on technology characterization. The characteristics of the technology are defined according to the system functionality. For example, one study describes the technology according to production and coordination functionality (Dishaw, M., Strong, D., 1998). These definitions are a direct reflection of the task activities.

In the medical informatics literature, there is no broad agreement on how to characterize EHR’s. Following the work of Dishaw and Strong (Dishaw, M., Strong, D., 1998), organizations such as the International Organization for Standardization suggest that EHR’s can be defined according to three basic functions: 1) information functions, 2) knowledge functions, and 3) inferencing functions (ISO, 2005). Information function in this context is understood as the provision of raw data, such as the recording and presentation of patient vital statistics. Knowledge function means that the system provides formalized knowledge beyond raw data, such as that contained in clinical guidelines or comparative effectiveness information. Finally inferencing functionality refers to the ability of the system to assist with the clinical reasoning process. The best example of this functionality is represented in the capability of clinical decision support systems.

Selecting representative characteristics for a technology such as an EHR is not done lightly or easily. However, the proposed approach to this characterization is consistent with prior work (see (Dishaw, 1998; 1999). Indeed, there are a variety of ways and dimensions along which EHR’s could be characterized. Table 3 summarizes the EHR characteristics construct.
Table 3. EHR Characteristics and Definitions

<table>
<thead>
<tr>
<th></th>
<th>Construct Dimension</th>
<th>Construct Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Electronic Health Record Characteristics</strong></td>
<td><strong>Information</strong></td>
<td>Information – Data that has been given meaning through a relational connection (e.g. association with a specific patient). Information is differentiated from data in that it is useful. Information is inferred from data in the process of answering interrogative questions (e.g., &quot;who&quot;, &quot;what&quot;, &quot;where&quot;, &quot;how many&quot;, &quot;when&quot;), thereby making the data useful for decisions and/or action. Information is defined as data that are endowed with meaning and purpose.</td>
</tr>
<tr>
<td><strong>Knowledge</strong></td>
<td>Knowledge</td>
<td>Knowledge - knowledge is sometimes described as the synthesis of multiple sources of information over time, and the organization and processing of information to convey understanding, experience and accumulated learning. Knowledge is a mix of contextual information, values, experience and rules. For example, knowledge is contained in clinical practice guidelines.</td>
</tr>
<tr>
<td><strong>Inferencing Support</strong></td>
<td>Inferencing Support</td>
<td>Inferencing Support – Decision support systems combine information and knowledge to provide passive or active support for clinical decision-making.</td>
</tr>
</tbody>
</table>

**Clinical Reasoning Task Characteristics**

Based on the literature for complex systems (Perrow, 1984), complex tasks (Campbell, 1988; Wood, 1986); and information processing (Galbraith, 1973; Daft and Lengel, 1986), two major characteristics of the clinical reasoning task are suggested: structural complexity and dynamic uncertainty. Structural complexity captures the configuration of the components and procedures of the task whereas dynamic uncertainty captures the unpredictable nature of the task.

In the context of patient care, the perceived complexity and uncertainty of the task determine in part the decision strategy used during clinical reasoning (Bianchi, Alexander, & Cash, 2009; Bloom & Bloom, 1999; Charlin et al., 2006; A. S. Elstein, Schwarz, A., 2002; A. S. Elstein, Shulman, L.S., Sprafka, S.A., 1978; Hozo, Schell, & Djulbegovic, 2008; Parmigiani, 2002). Two reasoning paradigms have approached the task in unique ways. The problem-solving research tradition has been largely focused on describing the complexity of clinical reasoning by expert physicians. The psychological decision research tradition has been guided by statistical models of reasoning under uncertainty (Elstein, A.S., Schwarz, A., 2002).

Task complexity refers to the degree of perceived difficulty of making a decision or reasoning through a series of decisions. A patient in the ICU with multi-organ system failure is an example of a complex case; making treatment decisions and solving problems necessitates the delicate balancing of a multitude of inter-dependent considerations. Task complexity is
composed of three dimensions: component complexity, interactive complexity, and procedural rigidity (Becerra-Fernandez, 2008). Component complexity represents the multiplicity of the task components, (e.g., number of people assigned, variety of organizations being represented, computer systems being accessed and used, machines required, and variety of resources required to complete the task). Interactive complexity represents the degree of interactions and interdependencies among the components of the task, (e.g., the inter-connectedness of the people and different organizations involved in a given task). Procedural rigidity represents the lack of flexibility in terms of the sequencing and durations of the task components.

Task uncertainty refers to the perceived level of uncertainty, or ambiguity in decision-making. Uncertainty is characterized as missing information. For example, there is likely to be uncertainty relative to medical decisions for a patient who arrives unconscious in the emergency room, because nothing is known about the patient or how the patient became ill. When that same patient is transferred to the ICU, clinical reasoning is characterized more by complexity than uncertainty. In this scenario, uncertainty is less pronounced because the problem has been appropriately framed (a diagnosis has been made in the ER). The objective is to balance and coordinate the complexities of treatment an array of clinical problems.

Task uncertainty is composed of three dimensions: task novelty, task un-analyzability, and task significance (Becerra-Fernandez, 2008). Task novelty captures the newness (unexpected and novel events that occur in performing the task) and non-routineness (exceptional circumstances requiring flexibility) of the task (R. Daft, MacIntosh, N. , 1981). Task un-analyzability represents the degree to which the task is unstructured and the information required to perform the task is equivocal thus leading to conflicting interpretations (R. Daft, Lengel, R., 1986; Daft, R., MacIntosh, N., 1981). Task significance captures the urgency and impact of the task. While task urgency focuses on the immediate priority and the timeframe in which a task needs to be done, task impact refers to the analysis and assessment of the potential repercussions that need to be prioritized before a task can be completed.

For the construct of task characteristics in a clinical setting, the proposed model borrows from the cognitive science and management literature and utilizes the variables of complexity and uncertainty. In keeping with Goodhue’s suggestion, a simple approach to defining task characteristics is preferred to using a host of variables to describe the construct (Goodhue, D., Thompson, R. L. , 1995b).
### Table 4. Clinical Decision Task Characteristics

<table>
<thead>
<tr>
<th>Construct</th>
<th>Construct Dimensions</th>
<th>Measurement Items</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clinical Decision Task Characteristics</td>
<td><strong>Task Complexity</strong>: (perceived difficulty of making a decision or reasoning through a series of decisions – three dimensions)</td>
<td>1. <strong>COMPONENT COMPLEXITY</strong> - Represents the multiplicity of the task components, (e.g., number of people assigned, variety of organizations being represented, computer systems being accessed and used, machines required, and variety of resources required to complete the task) 2. Task component complexity - the number of distinct and independent actions an individual must process 3. <strong>INTERACTIVE COMPLEXITY</strong> - represents the degree of interactions and interdependencies among the components of the task, (e.g., the inter-connectedness of the people and different organizations involved in a given task). A measure of the degree to which we cannot foresee all the ways things can go wrong. The greater the degree of interactive complexity, the less our capacity to prevent surprises 3. <strong>PROCEDURAL RIGIDITY</strong> - represents the lack of flexibility in terms of the sequencing and durations of the task components</td>
</tr>
</tbody>
</table>
| | **Task Uncertainty**: (the perceived level of uncertainty, or ambiguity in decision-making) | 1. **TASK NOVELTY** – captures the newness (unexpected and novel events that occur in performing the task) 2. **TASK UNANALYZABILITY** - represents the degree to which the task is unstructured and the information required to perform the task is equivocal thus leading to conflicting interpretations 3. **TASK SIGNIFICANCE** – captures the urgency and impact of the task  
  i. **TASK URGENCY** focuses on the immediate priority and the timeframe in which a task needs to be done  
  ii. **TASK IMPACT** – refers to the analysis and assessment of the potential repercussions that need to be prioritized before a task can be completed |

### Utilization

Goodhue (Goodhue, 1995) notes that the ideal measure of utilization is the proportion of times that the users choose to use a system. In the field context, however, this proportion is difficult to measure because EHR use is mandatory. Utilization is measured by asking users to indicate current use and intention for future use. Table 5 summarizes the utilization construct, dimension and measurement items.
Table 5. Utilization Construct

<table>
<thead>
<tr>
<th>Construct</th>
<th>Construct Dimension</th>
<th>Measurement Items</th>
</tr>
</thead>
<tbody>
<tr>
<td>Utilization</td>
<td>Actual System Use</td>
<td>Current use</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Intention for future use</td>
</tr>
</tbody>
</table>

**Performance**

Performance impact is measured by perceived impact, since objective measures of actual decision performance are not available in this field context. Three questions will be used to ask respondents to report on the perceived impact of electronic health record use on clinical reasoning performance. Table 6 highlights the key components of the performance construct.

Table 6. Performance Construct, Dimensions

<table>
<thead>
<tr>
<th>Construct</th>
<th>Construct Dimensions</th>
<th>Measurement Items</th>
</tr>
</thead>
<tbody>
<tr>
<td>Performance</td>
<td><strong>Performance Impact</strong></td>
<td>Performance Impact – positive impact on productivity; importance of assistive technology</td>
</tr>
<tr>
<td></td>
<td><strong>Task Effectiveness</strong></td>
<td>Task Effectiveness - The extent to which the task outcome was satisfactory to all participants</td>
</tr>
<tr>
<td></td>
<td><strong>Task Efficiency</strong></td>
<td>Task Efficiency - The extent to which the task was completed on time</td>
</tr>
</tbody>
</table>

**Research hypotheses**

According to the TTF model, the strength of the link between information systems and performance impacts is a function of the extent system functionality responds to task needs, i.e., task-technology fit. The research hypothesizes the following:

**H1:** User evaluation of task-technology fit will have explanatory power in predicting perceived performance impact. This can be further divided among the 8 TTF dimensions as follows:

**H1a:** Data quality will significantly influence user performance. Data quality is evaluated according to the currency of the data, maintenance of the correct data and the appropriate level of detail.

**H1b:** The locatability of the data will influence user performance. Locatability is assessed by both the ease with which data is located, and the ease with which the meaning of the data can be discovered.
H1c: Data authorization will influence user performance. Authorization measures the degree with which individuals are appropriately authorized to access the data required for the task.

H1d: The compatibility of data from other systems will influence user performance.

H1e: Ease of use and training will significantly influence user performance. The degree to which a person believes a system is easy to use and user training.

H1f: Production timeliness will influence user performance. Production timeliness is evaluated according to the perceived response time for reports and other requested information.

H1g: Systems reliability will influence user performance.

H1h: The IS departments’ relationship with users will influence user performance. This factor includes IS understanding of business, IS interest and user support, IS responsiveness, delivery of agreed-upon solutions, and technical and unit planning support.

The extent of fit between the task and the technology should be adequately explained by the underlying task characteristics, specifically:

H2: The characteristics of the clinical reasoning task, complexity, uncertainty and significance, will have a significant direct influence on the TTF construct.

H2a: Task complexity will influence the fit between EHR technology and the clinical reasoning task.

H2b: Task uncertainty will influence the fit between EHR technology and the clinical reasoning task.

H2c: Task significance will influence the fit between EHR technology and the clinical reasoning task.

Likewise, the extent of fit between the task and the technology should be adequately explained by the underlying technology characteristics, specifically:

H3: The characteristics of EHR technology will have a significant direct influence on the TTF construct.

H3a: Information capability will influence TTF.

H3b: Knowledge capability will influence TTF.
H3c: Inferencing capability will influence TTF.

H4: Utilization (Use) will influence performance.
CHAPTER 4

RESEARCH METHODOLOGY

This chapter describes the efforts required to test the theoretical model and hypotheses presented in chapter three. The setting, context and subjects of the study, data collection procedures, approach to measurement validity and model testing are discussed.

Setting, Context and Subjects

The setting for the proposed study includes a regional medical center in South Dakota, as well as two affiliated primary care and internal medicine outpatient clinics. Participants in the study include physicians (M.D., D.O), advance practice nurses (CNP), and physician assistants (PA) who currently use an EHR system in clinical practice.

Data Collection Procedures

Collection of the qualitative data for semi-structured interviews with clinicians focused on elaboration and refinement of the technology, TTF and task characteristics constructs. Notices were posted in appropriate areas notifying clinicians of the study opportunity a week in advance of the start date. Interviews were conducted over a three-day period. No compensation was offered, and interviews were not video or audio recorded for confidentiality.

Transcripts of the semi-structured interviews were then coded according to emergent themes and keywords and the results extrapolated into actionable changes to the survey instrument. For example each transcript was reviewed for emerging themes relating to EHR satisfaction, dissatisfaction, strong support, little support, no support (the latter three referring to support in the sense of the EHR helping the clinical reasoning task). At the same time we searched for emerging key words such as “use” and “fit”, which refer to TTF constructs.
Following the semi-structured interviews, the survey instrument was pretested with a sample group of 11 clinicians to address the clarity of the questions. Clinicians were sent an email invitation to participate in the online survey. The email originated from the medical center’s clinical informatics department and included an attached letter of endorsement by the Director of Clinical Research. Three additional emails were sent approximately two weeks apart resulting in 42 complete responses.

Simultaneously, paper surveys were collected from the same pool of initial invitees who had not responded to the online invitation. Paper surveys were collected at affiliated clinics, physician offices and the medical center main campus. A total of 137 hours of investigator time was logged to accomplish this response. Both the qualitative and quantitative aspects of the study were approved by an institutional review board (IRB) of the target organization and DSU. Another activity was data exploration. Here the data set was subjected to scrutiny and filtered by columns comparing the response on each question to the response on like-measures. Problematic observations are then identified as candidates for deletion.

**Assessing Measurement Validity**

A variety of techniques are used to analyze the data, from qualitative coding to exploratory factor and partial least square analysis. Following Goodhue (D. L. Goodhue), this research uses the framework for measurement validity of new instruments as suggested by Bagozzi (1979; 1980). The framework identifies six components of construct validity that address each stage of the proposed research, including initial definition of the theoretical constructs, instrument development and testing. Table 7 summarizes the six components of construct validity and compares them with the terminology as described by Straub (1989).

*Theoretical Meaningfulness:* The first step in valid measurement is achieving conceptual clarity on the constructs to be measured. According to Bagozzi (1980) “The theoretical meaningfulness of a concept refers to the nature and internal consistency of the language used to represent the construct. It addresses the formal adequacy of the logical and theoretical terms comprising one’s theory.”

Establishing the theoretical meaningfulness of concepts is the first and possibly the most critical step toward construct validation. At the center of this process is the idea of
construct explication or the procedure of making an abstract word explicit in terms of its observable variables (Nunnally, 1978). As noted by Cook and Campbell (1979, p. 62), "A precise explication of constructs is vital for high construct validity since it permits tailoring the manipulations and measures to whichever definitions emerge from the explication." These emerging definitions should be clear and in accordance with general understanding of the words being used.

Table 7. Six Components of Construct Validity (Bagozzi, 1979; 1980)

<table>
<thead>
<tr>
<th>Concern</th>
<th>Bagozzi, 1979; 1980</th>
<th>Straub, 1989</th>
</tr>
</thead>
<tbody>
<tr>
<td>Well-defined construct that makes theoretical sense</td>
<td>Theoretical meaningfulness</td>
<td>_____</td>
</tr>
<tr>
<td>Measures correspond to theoretical constructs</td>
<td>Observational meaningfulness</td>
<td>Content validity</td>
</tr>
<tr>
<td>Maximally similar measures agree</td>
<td>Internal consistency</td>
<td>Reliability</td>
</tr>
<tr>
<td>Different constructs can be distinguished</td>
<td>Discriminant validity</td>
<td>Discriminant validity</td>
</tr>
<tr>
<td>Maximally dissimilar measures correlate</td>
<td>Convergent validity</td>
<td>Convergent validity</td>
</tr>
<tr>
<td>Makes sense in larger theoretical framework</td>
<td>Nomological validity</td>
<td>_____</td>
</tr>
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</table>

Theoretical meaningfulness is accomplished primarily through the literature review. In this case our goal is to develop measures of user beliefs about the extent to which electronic health records and services meet their task needs. Measures of performance, task-technology fit, and task and technology characteristics are derived directly from the literature. As a result, measures developed and used here have a strong theoretical and empirical foundation.

Observational Meaningfulness: Observational meaningfulness, the second of Bagozzi’s validity concerns, refers to the extent to which a measure represents all facets of a given construct. In developing the questionnaire, the challenge was to devise questions that cover the target domain and are closely linked to the defined theoretical constructs. For each of the constructs (TTF, clinical decision task characteristics, EHR characteristics, utilization and performance), two to three questions have been developed for each indicator. Questions take the form of declarative statements and were measured on a 7-point Likert scale. To further support the goal of observational meaningfulness, the proposed questionnaire was administered in a
pretest to a sample of clinicians. The semi-structured interviews were used to identify problems with the questionnaire and to explore possible omission or inclusion of additional construct dimensions.

*Internal Consistency Reliability:* Internal consistency reliability is a measure of how well a scale addresses different constructs and delivers reliable scores. Internal consistency reliability can be tested by including two versions of the same question within the same test. Since it is presumed that a respondent will give relatively similar answers to both versions of the same question, internal consistency reliability can be measured by comparing a respondent’s answer on two different versions of the same survey question. The survey instrument for this research project was designed with at least two parallel questions for each construct. Internal validity will be measured using Cronbach’s alpha (Cronbach, 1951).

*Discriminant and Convergent Validity:* Discriminant validity addresses the possibility that supposedly distinct constructs may be indistinguishable from each other. Discriminant validity is evaluated through partial least squares by comparing item loadings to variable correlations and by examining the square root of the AVE of each variable to the correlations of this construct to all other variables (Gefen and Straub, 2005).

Convergent validity is used to evaluate the degree to which two or more measures that theoretically should be related to each other are, in fact, observed to be related. Goodhue (Goodhue, 1995) noted that convergent validity of the TTF questionnaire was not explicitly tested. However, Wills et al. (Wills, El-Gayar, Deokar, 2009) did test and was able to confirm the convergent validity of a reduced TTF instrument. Furthermore, Wills (Wills, El-Gayar, Deokar, 2009) was able to test and confirm content validity, reliability, and discriminant validity for a TTF questionnaire. Convergent validity of the variables is assessed by examining the t-values of the outer model loadings (Gefen and Straub, 2005).

*Nomological Validity:* This form of construct validity is the degree to which a construct behaves as expected in a system of related constructs (nomological net). This version of validity is of particular importance in this research project, particularly relative to proposed task and technology characteristics constructs, as these have been adapted to the clinical decision task and EHR technology and are therefore slightly different from previous versions of these measures. Overall, nomological validity will be confirmed by the extent to which theoretically grounded predictions are realized.
**Exploratory Factor Analysis**

The objective of exploratory factor analysis (EFA) was to reduce the number of indicators and explore the theoretical structure of the factors present in the model. Regarding the first objective, the goal is to reduce data to a smaller set of summary variables (constructs), with each construct measured using multiple items which can be combined in a smaller number of factor scores. For the second objective, theoretical questions about the underlying structure of a phenomenon can be explored and empirically tested using factor analysis e.g., is data quality better described as a single, general factor, or as consisting of multiple, independent dimensions?

**Model Testing**

Partial least squares (PLS), a structural equation modeling technique, allows the simultaneous modeling of relationships among multiple independent and dependent constructs (Gefen and Straub, 2000). One main advantage of using SEM techniques like PLS is that it enables the construction of unobservable variables measured by indicators. In addition, it is possible to model measurement error for the observed variables giving the investigator the capacity to test a priori theoretical and measurement assumptions against empirical data, such as the case with confirmatory analysis (Chin, 1998).

PLS can be used for theory confirmation and relationship exploration (Chin, 1996), and uses an iterative estimation technique (Wold, 1992) to formulate a model which includes canonical correlation, multiple regression, redundancy analysis, multivariate analysis of variance and principal components analysis (Chin, 1996). PLS has the advantage that it “involves no assumptions about the population or scale of measurement” (Fornell & Bookstein, 1982, p. 443). As a result it works without distributional assumptions and with nominal, ordinal and interval scaled variables. PLS was chosen as the model testing approach for this study due to its minimal demand on measurement scales, sample size and residual distributions.
CHAPTER 5

RESULTS AND DISCUSSION

This chapter presents the results of the study. The chapter begins with an overview of the data, including sampling characteristics, followed by a detailed view of the results from exploratory factor analysis and PLS. Matters relating to construct and instrument validity are explored.

Sample Characteristics

161 of the 258 eligible participants successfully completed the survey resulting in a 62.4% response rate. During data exploration, 17 observations were omitted as invalid responses resulting in 144 observations or a 55.8% completion rate. Subjects were asked to respond to questions using a 7-point Likert scale, which ranged from 1=strongly disagree to 7=strongly agree. Subjects included 106 physicians, 18 advance practice nurses and 20 physician assistants who currently use an EHR system in clinical practice. Forty-four subjects were between the ages of 55-64, fifty-one subjects were aged 45-54, thirty-eight subjects were aged 35-44 and eleven noted their age in the 25-34 year range. Of the 106 physicians, 69% (73) were male and 31% (33) were female. For nurse practitioners, 95% (17) were female and 1 (5%) were male. Of physician assistants 75% (15) were male, 25% (5) female.

Measurement Validity

In this section, the results are presented in the context of the six components of construct validity presented in chapter 4 (Bagozzi, 1979; 1980; Straub, 1989). The entire survey instrument can be found in Appendix A while detailed results of measurement validity can be found in Appendix B.
**Theoretical and observational meaningfulness**

The first two criteria of validity, theoretical and observational meaningfulness, involve semantic issues as opposed to statistical tests. They refer to the internal consistency of the language used to represent a construct and the conceptual relationship between a theoretical construct and its operationalization (Papoutsakis, 2008). The theoretical foundation upon which this research rests has been derived from previous research on task-technology fit and clinical reasoning, resulting in constructs that are consistent with prior theories. A literature review was conducted and TTF theory was selected as the underlying model for the study. Other constructs such as task and technology characteristics were similarly developed, using the TTF and clinical reasoning literature as a basis for construct explication. Survey pretesting with a representative group of clinicians resulted in minor modifications to nine survey questions (see Appendix B). Clinicians were asked to review questions on the survey for clarity and suggest alternative wording for those that were perceived as unclear. The investigator worked closely with respondents to revise the wording while maintaining the theoretical objectives of the measures. Table 8 summarizes the modifications made to the questions during survey pretesting.

### Table 8. Survey question modification during pretesting

<table>
<thead>
<tr>
<th>Code</th>
<th>Original Question</th>
<th>Modified Question</th>
</tr>
</thead>
<tbody>
<tr>
<td>REL_01</td>
<td>The IS people we deal with understand the day-to-day objectives of my work group and its mission within our company</td>
<td>The people from the clinical informatics and IT departments understand the day-to-day objectives of my department/team</td>
</tr>
<tr>
<td>REL_02</td>
<td>My work group feels that IS personnel can communicate with us in familiar business terms that are consistent</td>
<td>My department feels that clinical informatics and IT personnel communicate with us in familiar, consistent terms.</td>
</tr>
<tr>
<td>REL_03</td>
<td>IS takes my business group’s problems seriously</td>
<td>Clinical informatics (CI) and IT personnel take my departments information problems seriously.</td>
</tr>
<tr>
<td>REL_04</td>
<td>IS takes a real interest in helping me solve my business problems</td>
<td>CI and IT take a real interest in helping solve our clinical information needs.</td>
</tr>
<tr>
<td>REL_08</td>
<td>Based on my previous experience I would IS technical and business planning consulting services in the future if I had a need</td>
<td>Based on my previous experience, I would consult with clinical informatics and hospital IT personnel for assistance with the EHR</td>
</tr>
<tr>
<td>REL_09</td>
<td>I am satisfied with the level of technical and business planning consulting expertise I receive from IS</td>
<td>I am satisfied with the level of assistance I receive for CI/IT.</td>
</tr>
<tr>
<td>REL_10</td>
<td>IS delivers agreed-upon solutions to support my business needs.</td>
<td>CI/IT delivers agreed-upon solutions to support my clinical information needs.</td>
</tr>
<tr>
<td>TSKCMP_05</td>
<td>Unexpected events can complicate clinical decision-making</td>
<td>When making clinical decisions, unplanned or unexpected events can interfere with expected outcomes</td>
</tr>
<tr>
<td>PERF_04</td>
<td>The EHR helps me make more effective decisions</td>
<td>The EHR enhances my clinical decision-making effectiveness.</td>
</tr>
</tbody>
</table>
Internal consistency reliability

Internal consistency reliability is an empirical validity designed to assess the degree of internal consistency. The requirements include more than one observational indicators or variables for each theoretical construct. The most commonly used summary statistic of internal consistency is the Cronbach’s *alpha* coefficient. For attitudinal measurements, Cronbach’s *alphas* above 0.6 are generally considered acceptable. Results are summarized in table 9, where all alphas are above the 0.6 cutoff.

Table 9. Cronbach’s alpha

<table>
<thead>
<tr>
<th>Construct</th>
<th>Cronbach’s Alpha</th>
</tr>
</thead>
<tbody>
<tr>
<td>Data Quality</td>
<td>0.89</td>
</tr>
<tr>
<td>Data Locatability</td>
<td>0.77</td>
</tr>
<tr>
<td>Data Authorization</td>
<td>0.77</td>
</tr>
<tr>
<td>Data Compatibility</td>
<td>0.92</td>
</tr>
<tr>
<td>Systems Reliability</td>
<td>0.75</td>
</tr>
<tr>
<td>EOU/Training</td>
<td>0.61</td>
</tr>
<tr>
<td>Relationship with Users</td>
<td>0.94</td>
</tr>
<tr>
<td>Performance</td>
<td>0.96</td>
</tr>
<tr>
<td>Task Complexity</td>
<td>0.89</td>
</tr>
<tr>
<td>Task Uncertainty</td>
<td>0.71</td>
</tr>
<tr>
<td>Task Significance</td>
<td>0.78</td>
</tr>
<tr>
<td>Information Support</td>
<td>0.75</td>
</tr>
<tr>
<td>Knowledge Support</td>
<td>0.64</td>
</tr>
<tr>
<td>Inferencing Support</td>
<td>0.87</td>
</tr>
</tbody>
</table>

**Discriminate and convergent validity**

One of the criterion for discriminant validity is that outer loadings should be larger than any other loadings (Gefen and Straub, 2005). Table C1 illustrates the outer loadings for each indicator was high (0.7) and is located in Appendix C.

Discriminant validity refers to the degree to which one theoretical construct differs from another. With the outer model loadings confirmed higher than any other loadings, discriminant validity is confirmed according to Gefen & Straub (Gefen and Straub, 2005) as the diagonal elements (representing the square root of AVE) are significantly higher than the off-diagonal values (Chin, 1998) as illustrated in table 10.
Table 10: Square root of AVE scores and correlations of latent variables

<table>
<thead>
<tr>
<th></th>
<th>QUAL</th>
<th>LOCAT</th>
<th>AUTH</th>
<th>CORP</th>
<th>PROD</th>
<th>RELY</th>
<th>RELAT</th>
<th>TSKCOMP</th>
<th>TSKUNC</th>
<th>INFO</th>
<th>EDE</th>
<th>KNOW</th>
<th>INFER</th>
<th>TSKTG</th>
<th>PERF</th>
</tr>
</thead>
<tbody>
<tr>
<td>QUAL</td>
<td>0.948</td>
<td>0.092</td>
<td>0.059</td>
<td>0.219</td>
<td>0.370</td>
<td>0.353</td>
<td>0.331</td>
<td>0.324</td>
<td>0.328</td>
<td>0.353</td>
<td>0.370</td>
<td>0.353</td>
<td>0.331</td>
<td>0.324</td>
<td>0.328</td>
</tr>
<tr>
<td>LOCAT</td>
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<td>0.148</td>
<td>0.003</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
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<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
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<tr>
<td>AUTH</td>
<td>0.000</td>
<td>0.148</td>
<td>0.003</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
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<tr>
<td>CORP</td>
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<tr>
<td>PROD</td>
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<td>0.000</td>
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</tr>
<tr>
<td>RELY</td>
<td>0.370</td>
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<td>0.331</td>
<td>0.324</td>
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<td>0.353</td>
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<td>0.353</td>
<td>0.353</td>
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<tr>
<td>RELAT</td>
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<td>0.331</td>
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<td>0.353</td>
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<td>0.353</td>
<td>0.353</td>
<td>0.353</td>
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</tr>
<tr>
<td>TSKCOMP</td>
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<td>0.353</td>
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<tr>
<td>TSKUNC</td>
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<tr>
<td>INFO</td>
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<td>0.353</td>
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<td>0.353</td>
<td>0.353</td>
<td>0.353</td>
<td>0.353</td>
</tr>
<tr>
<td>EDE</td>
<td>0.353</td>
<td>0.353</td>
<td>0.353</td>
<td>0.353</td>
<td>0.353</td>
<td>0.353</td>
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</tr>
<tr>
<td>KNOW</td>
<td>0.353</td>
<td>0.353</td>
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<td>0.353</td>
</tr>
<tr>
<td>INFER</td>
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<td>0.353</td>
<td>0.353</td>
<td>0.353</td>
<td>0.353</td>
<td>0.353</td>
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<td>0.353</td>
<td>0.353</td>
</tr>
<tr>
<td>TSKTG</td>
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<td>0.353</td>
<td>0.353</td>
<td>0.353</td>
<td>0.353</td>
<td>0.353</td>
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<td>0.353</td>
<td>0.353</td>
<td>0.353</td>
</tr>
<tr>
<td>PERF</td>
<td>0.353</td>
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<td>0.353</td>
<td>0.353</td>
<td>0.353</td>
<td>0.353</td>
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<td>0.353</td>
<td>0.353</td>
<td>0.353</td>
<td>0.353</td>
<td>0.353</td>
</tr>
</tbody>
</table>

Table 11 summarizes the results of the model and illustrates the mean, standard deviation and item loading for each indicator. Composite reliability (CR) and AVE values are shown in bold. The t-value for the outer model loadings is also listed. AVE for each construct is at least 0.50 (Fornell). Composite reliability also measures reliability and carries the assumption that parameter estimates are accurate. For CR, a value exceeding 0.8 is recommended (Straub, 2004; Nunnally, 1978), and realized in the model.
### Table 11. Results summary

<table>
<thead>
<tr>
<th>Construct Dimension</th>
<th>Code</th>
<th>Question</th>
<th>Mean</th>
<th>SD</th>
<th>Item Load</th>
<th>CR</th>
<th>AVE</th>
<th>t-stat</th>
</tr>
</thead>
<tbody>
<tr>
<td>TTF</td>
<td>QUAL_05</td>
<td>Sanford maintains data at an appropriate level of detail for my groups' tasks.</td>
<td>.74</td>
<td>.86</td>
<td>.941</td>
<td>.948</td>
<td>.900</td>
<td>6.322</td>
</tr>
<tr>
<td></td>
<td>QUAL_06</td>
<td>Sufficiently detailed data is maintained by Sanford.</td>
<td>.79</td>
<td>.88</td>
<td>.957</td>
<td>4.348</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Authorization</td>
<td>AUTH_01</td>
<td>Data that would be useful to me is unavailable because I don’t have the right authorization.</td>
<td>.53</td>
<td>.95</td>
<td>.903</td>
<td>.900</td>
<td>.817</td>
<td>6.727</td>
</tr>
<tr>
<td></td>
<td>AUTH_02</td>
<td>Getting authorization to access data that would be useful is difficult and time consuming.</td>
<td>.59</td>
<td>.06</td>
<td>.905</td>
<td>6.893</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Production Timeliness</td>
<td>PROD_01</td>
<td>To my knowledge, the IT department meets its production schedules such as report delivery.</td>
<td>.92</td>
<td>.39</td>
<td>.962</td>
<td>.962</td>
<td>.927</td>
<td>8.880</td>
</tr>
<tr>
<td></td>
<td>PROD_02</td>
<td>Regular IT activities such as report delivery are completed on time.</td>
<td>.85</td>
<td>.31</td>
<td>.964</td>
<td>2.759</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Data Locatability/Data Meaning</td>
<td>LOC_03</td>
<td>The exact definition of data fields relating to my tasks is easy to find out.</td>
<td>.19</td>
<td>.95</td>
<td>.897</td>
<td>.897</td>
<td>.814</td>
<td>1.60</td>
</tr>
<tr>
<td></td>
<td>LOC_04</td>
<td>The exact definition of data fields relating to my tasks is easy to find out.</td>
<td>.45</td>
<td>.00</td>
<td>.907</td>
<td>.520</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Systems Reliability</td>
<td>RELY_01</td>
<td>I can count on the EHR to be up and running when I need it.</td>
<td>.83</td>
<td>.99</td>
<td>.891</td>
<td>.891</td>
<td>.804</td>
<td>0.329</td>
</tr>
<tr>
<td></td>
<td>RELY_02</td>
<td>The EHR is subject to unexpected or inconvenient downtime which makes it harder to do my work.</td>
<td>.24</td>
<td>.85</td>
<td>.903</td>
<td>6.225</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Compatibility</td>
<td>COMP_02</td>
<td>Sometimes it is difficult for me to compare or consolidate data from two different sources because the data is defined differently.</td>
<td>.28</td>
<td>.95</td>
<td>.965</td>
<td>.963</td>
<td>.928</td>
<td>1.733</td>
</tr>
<tr>
<td></td>
<td>COMP_03</td>
<td>When it’s necessary to compare data from different sources, I find that there may be unexpected inconsistencies.</td>
<td>.33</td>
<td>.00</td>
<td>.962</td>
<td>0.123</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ease of Use/Training</td>
<td>EOU_03</td>
<td>There is not enough training for me or my staff on how to find, understand, access or use the EHR effectively.</td>
<td>.85</td>
<td>.86</td>
<td>.813</td>
<td>.845</td>
<td>.732</td>
<td>3.113</td>
</tr>
<tr>
<td></td>
<td>EOU_04</td>
<td>I am getting the training I need to use the EHR effectively.</td>
<td>.26</td>
<td>.28</td>
<td>.895</td>
<td>7.170</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Informatics Relationship with Users</td>
<td>REL_01</td>
<td>The people from the clinical informatics and IT departments understand the day-to-day objectives of my department/team.</td>
<td>.68</td>
<td>.91</td>
<td>.789</td>
<td>.952</td>
<td>.741</td>
<td>.007</td>
</tr>
<tr>
<td></td>
<td>REL_02</td>
<td>My department feels that clinical informatics and IT personnel communicate with us in familiar, consistent terms.</td>
<td>.52</td>
<td>.55</td>
<td>.814</td>
<td>.562</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>REL_03</td>
<td>Clinical informatics (CI) and IT personnel take my departments information problems seriously.</td>
<td>.90</td>
<td>.73</td>
<td>.912</td>
<td>8.894</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>REL_04</td>
<td>CI and IT take a real interest in helping solve our clinical information needs.</td>
<td>.07</td>
<td>.49</td>
<td>.864</td>
<td>4.805</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>REL_08</td>
<td>Based on my previous experience, I would consult with clinical informatics and hospital IT personnel for assistance with the EHR.</td>
<td>.58</td>
<td>.35</td>
<td>.786</td>
<td>3.412</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>REL_09</td>
<td>I am satisfied with the level of assistance I receive for CI/IT.</td>
<td>.71</td>
<td>.94</td>
<td>.918</td>
<td>0.853</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>REL_10</td>
<td>CI/IT delivers agreed-upon solutions to support my clinical information needs.</td>
<td>.85</td>
<td>.74</td>
<td>.929</td>
<td>1.931</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### Reasoning Task Characteristics

**Task Complexity:**

<table>
<thead>
<tr>
<th>Task Complexity</th>
<th>Item</th>
<th>Description</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interactive Complexity</td>
<td>TSKCMP_04</td>
<td>The different activities involved in clinical decision-making frequently interact in unpredictable ways.</td>
<td>.55 .66 .849 .926 .759 3.976</td>
</tr>
<tr>
<td></td>
<td>TSKCMP_05</td>
<td>When making clinical decisions, unplanned or unexpected events can interfere with expected outcomes.</td>
<td>.69 .77 .825 .944 .660 .794</td>
</tr>
<tr>
<td></td>
<td>TSKCMP_06</td>
<td>The various activities involved in diagnostic decision-making are rigid with respect to time or duration.</td>
<td>.46 .68 .923 .634 .825 .930</td>
</tr>
<tr>
<td></td>
<td>TSKCMP_07</td>
<td>The sequence of activities involved in clinical decision-making is rigid.</td>
<td>.47 .68 .885 .694 .869 .826</td>
</tr>
</tbody>
</table>

**Procedural Rigidity**

<table>
<thead>
<tr>
<th>Task Significance – Task Impact</th>
<th>Item</th>
<th>Description</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>TSKSIG_03</td>
<td>During clinical decision-making, analysis and assessment of potential repercussions is common.</td>
<td>.92 .74 .886 .899 .817 .379</td>
</tr>
<tr>
<td></td>
<td>TSKSIG_04</td>
<td>Making good clinical decisions means having a thorough understanding of how a potential intervention or combination of interventions will impact each other and the outcome.</td>
<td>.17 .68 .921 .446</td>
</tr>
</tbody>
</table>

**Task Uncertainty:**

<table>
<thead>
<tr>
<th>Task Uncertainty</th>
<th>Item</th>
<th>Description</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>TSKUNC_01</td>
<td>I often encounter new and unfamiliar challenges when making diagnostic and treatment decisions.</td>
<td>.69 .62 .822 .765</td>
</tr>
<tr>
<td></td>
<td>TSKUNC_04</td>
<td>In my job, I frequently deal with ad-hoc, non-routine clinical problems.</td>
<td>.77 .74 .933 .626</td>
</tr>
</tbody>
</table>

**EHR Technology Characteristics**

**Information**

<table>
<thead>
<tr>
<th>Item</th>
<th>Description</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>EHRINFO_0</td>
<td>The electronic health record makes accessing information about my patients easier</td>
<td>.21 .73 .855 .886 .795 5.234</td>
</tr>
<tr>
<td>EHRINFO_0</td>
<td>The electronic health record provides the information I need to make good clinical decisions.</td>
<td>.95 .73 .927 7.459</td>
</tr>
</tbody>
</table>

**Knowledge**

<table>
<thead>
<tr>
<th>Item</th>
<th>Description</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>EHRKN_0</td>
<td>Best practice knowledge is accessible from the EHR.</td>
<td>.40 .69 .898 .844 .730 1.826</td>
</tr>
<tr>
<td>EHRKN_0</td>
<td>The EHR provides a means for collaboration, thereby enhancing the sharing of knowledge.</td>
<td>.58 .68 .809 2.556</td>
</tr>
</tbody>
</table>

**Inferencing Support**

<table>
<thead>
<tr>
<th>Item</th>
<th>Description</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>EHRINFR_0</td>
<td>The EHR provides passive decision support (user initiates request for decision assistance)</td>
<td>.17 .29 .932 .925 .804 9.189</td>
</tr>
<tr>
<td>EHRINFR_0</td>
<td>The EHR provides active decision support (decision assistance is provided without user request for assistance).</td>
<td>.88 .30 .847 7.551</td>
</tr>
<tr>
<td>EHRKN_0</td>
<td>The EHR provides access to organizational knowledge</td>
<td>.42 .57 .908 3.371</td>
</tr>
</tbody>
</table>

**Reasoning Performance**

<table>
<thead>
<tr>
<th>Item</th>
<th>Description</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>PERF_0</td>
<td>The EHR has a large, positive impact on my job productivity.</td>
<td>.38 .51 .861 0.295</td>
</tr>
<tr>
<td>PERF_0</td>
<td>The EHR is an important and valuable aid to me.</td>
<td>.70 .31 .900 3.464</td>
</tr>
<tr>
<td>PERF_0</td>
<td>The EHR has a strong, positive impact on my effectiveness as a clinician.</td>
<td>.57 .40 .947 1.988</td>
</tr>
<tr>
<td>PERF_0</td>
<td>The EHR enhances my clinical decision-making effectiveness. Overall, the EHR helps me make clinical decisions more efficiently.</td>
<td>.99 .50 .873 7.029</td>
</tr>
</tbody>
</table>
The criterion for convergent validity is that the correlation between measures of the theoretical construct should be different from zero and significantly large to support additional investigation. Two criteria are used to determine convergent validity. In the first approach, convergent validity is assessed by comparing the t-values of the outer model loadings. t-values are estimated using a nonparametric bootstrapping technique of 100 samples. The t-values of the outer model loadings exceed 1.96 (p < 0.05) verifying the convergent validity of the instrument (Gefen & Straub, 2005). Table 12 shows the t-values; those exceeding 1.96 are in bold.

Table 12: Path coefficients table (t-statistic)

<table>
<thead>
<tr>
<th>QUAL</th>
<th>LOCATE</th>
<th>AUTH</th>
<th>COMP</th>
<th>RELY</th>
<th>EOU</th>
<th>RELAT</th>
<th>PROD</th>
<th>PERF</th>
<th>TSKCMP</th>
<th>TSKUC</th>
<th>INFO</th>
<th>KNOW</th>
<th>INFR</th>
<th>TSSIG</th>
</tr>
</thead>
<tbody>
<tr>
<td>QUAL</td>
<td>0.00</td>
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<td>0.00</td>
</tr>
<tr>
<td>LOCATE</td>
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<td>0.00</td>
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<td>0.00</td>
</tr>
<tr>
<td>AUTH</td>
<td>0.00</td>
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<td>0.00</td>
<td>0.00</td>
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</tr>
<tr>
<td>COMP</td>
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<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
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<td>0.00</td>
</tr>
<tr>
<td>RELY</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
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<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>EOU</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
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</tr>
<tr>
<td>RELAT</td>
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<td>0.00</td>
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</tr>
<tr>
<td>PERF</td>
<td>0.362</td>
<td>0.514</td>
<td>0.445</td>
<td>0.982</td>
<td>0.127</td>
<td>0.034</td>
<td>0.642</td>
<td>0.757</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
</tr>
</tbody>
</table>

The items which exhibited loadings of less than 0.7 were removed from the model. Table 13 lists the items removed during PLS analysis. Exploratory factor analysis and PLS was conducted as an iterative process resulting in a reduced number of indicators. For EFA, factors that demonstrated cross-loading on more than one factor were removed beginning with those with the highest degree of cross-loading issues. This process was conducted repeatedly; an indicator was removed and the EFA was run again. This process repeated, and indicators with loadings of 0.70 were also subsequently removed – one by one until the process was complete. Initially 67 indicators were present in the model. EFA resulted in a reduction of 17 indicators – from an initial set of 67 to 52. A similar process was employed for PLS. The initial set of 52
indicators remaining after EFA was summarily reduced to 42 variables. Indicators with loadings less than 0.70 were removed beginning with the lowest and continuing until all indicators loaded at least 0.70. Like EFA, the process for PLS was iterative and repetitive – indicators were removed one by one, the model was executed again and the process repeated.

Table 13: Questions removed during partial least squares analysis

<table>
<thead>
<tr>
<th>Number of Questions Removed by Factor</th>
<th>Question Detail</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>REL_05, REL_06, REL_07</td>
</tr>
<tr>
<td>3</td>
<td>TSKCMP_01, TSKCMP_02, TSKCMP_03</td>
</tr>
<tr>
<td>1</td>
<td>COMP_01</td>
</tr>
<tr>
<td>1</td>
<td>EHRINFO_03</td>
</tr>
<tr>
<td>1</td>
<td>EHRKN_03</td>
</tr>
<tr>
<td>1</td>
<td>TSKUNC_05, TSKUNC_02, TSKUNC_03</td>
</tr>
<tr>
<td>2</td>
<td>TSKSIG_01, TSKSIG_02</td>
</tr>
<tr>
<td>2</td>
<td>UTIL_01, UTIL_02</td>
</tr>
<tr>
<td>1</td>
<td>RELY_03</td>
</tr>
<tr>
<td>1</td>
<td>QUAL_01-QUAL_04</td>
</tr>
<tr>
<td>2</td>
<td>LOC_01, LOC_02</td>
</tr>
<tr>
<td>2</td>
<td>EOU_01, EOU_02</td>
</tr>
</tbody>
</table>

Nomological validity

The last component of Bagozzi’s construct validity is nomological validity. Nomological validity refers to the degree to which predictions from a formal theoretical network containing the concept under scrutiny are confirmed (Papoutsakis, 2008). Nomological validity is interpreted by the consistency with which one’s theory can be confirmed within with a wider body of theory and whether it contributes to that theory. Assessment to nomological validity takes place with reference to related research. The theoretical framework for this research is firmly planted in the domain of task-technology fit and clinical reasoning theory.
**Model Testing Results**

Revisiting the study hypotheses, we find that several relationships are as predicted along with some hypotheses that were not supported by the data. The first hypothesis, H1 predicts that eight TTF dimensions will explain perceived performance impact.

*H1: User evaluation of task-technology fit will have explanatory power in predicting perceived performance impact.*

Figure 4 shows the right-hand side of the model, i.e., hypotheses H1a – H1h with $R^2$ values for the endogenous constructs and path coefficients for the illustrated relationships.

![Diagram of endogenous constructs with R² values and path coefficients]

---

**Figure 4**: Endogenous constructs with $R^2$ values and path coefficients
The results for the individual 8 TTF dimensions are as follows:

**H1a:** *Data quality will significantly influence user performance. Data quality is evaluated according to the currency of the data, maintenance of the correct data and the appropriate level of detail.*

Data Quality significantly influences clinical decision-making performance ($\beta = 0.216$, $p < 0.0005$). This hypothesis is confirmed by the positive and significant relationship from Data Quality to Performance. These findings suggest that as data quality in the EHR increases (or improves), performance increases. It makes sense that clinicians would consider a technology such as EHR to be a better fit if the data it provided were of high quality. It should be noted however, that the study initially defined data quality along Goodhue’s characterization of three dimensions, currency, right data and right level of detail. Convergent and discriminate validity resulted in the final model including items pertaining to the ‘right’ level. The findings here are consistent with Goodhue (Goodhue and Thompson, 1995) and Wills (Wills, El-Gayar, Deokar, 2009)

**H1b:** *The locatability of the data will influence user performance. Locatability is assessed by both the ease with which data is located, and the ease with which the meaning of the data can be discovered.*

Interestingly, locatability is very significant however the path relationship is reversed ($\beta = -0.199$, $p < 0.0028$). Thus hypothesis H1b cannot be confirmed due to an inverse relationship between locatability and performance. Locatability was originally tested with two dimensions: locatability and meaning. The factor analysis and PLS regressions reduced this construct to one dimension – meaning. This inverse relationship runs counter to results documented in Goodhue (1995), as well as the argument that as the ease of discovering the meaning of data increases, performance decreases. Moreover, in a previous study by Wills et al. Wills, El-Gayar, Deokar, 2009), locatability was not a significant predictor of performance. Two possibilities for this inverse relationship come to mind: First, it is possible that the construct failed to measure the intended concept of locatability/meaning. Second, the very act of “discovering” or seeking out
the meaning of data elements may have an overall negative impact on performance. Whatever the case, future work should explore the concept of data locatability.

**H1c:** Data authorization will influence user performance. Authorization measures the degree with which individuals are appropriately authorized to access the data required for the task.

Hypothesis H1c is confirmed. The results indicate a positive, significant relationship from Authorization to Performance ($\beta = 0.218, p < 0.003$), suggesting that as the degree to which individuals are authorized to access data, performance increases with respect to clinical decision-making. The correct authorization for access to a system or data within it makes logical sense from a practical perspective. Although interviews with clinicians revealed some doubt over the necessity of this construct, authorization was included in the model due to its theoretical basis in TTF theory. Interestingly, although studies (Goodhue, Thompson, 1995) and Wills et al (Wills, El-Gayar, Deokar, 2009) did not support authorization as a predictor of performance.

**H1d:** The compatibility of data from other systems will influence user performance.

With respect to compatibility, hypothesis H1d is supported. The results suggest that as data compatibility increases, performance increases as well ($\beta = 0.216, p < 0.0017$). One of the original 8 TTF factors from Goodhue’s (1995) study, compatibility is defined as “data from different sources can be consolidated or compared without inconsistencies.” The issue of compatibility as a relevant construct in the modern EHR marketplace was in question at the outset of the study. In the past, EHR systems often drew data from existing legacy systems, thus the notion of data from different systems meshing properly was a valid idea. Much has changed since in the health care field, as EHR systems are now less likely to draw their input from legacy systems. Of interest here as well is that the original Goodhue (1995) study included more than 20 different systems, thus the issue of compatibility was an important consideration. Despite concerns about the usefulness of this construct, the relationship between compatibility and performance is positive and significant.
**H1e: Ease of use and training will significantly influence user performance. The degree to which a person believes a system is easy to use and user training.**

Regarding H1e, the data suggests that overall the hypothesis is supported. At the construct level, ease-of-use indicators were removed due to cross-loading issues during factor analysis, leaving two questions on training. The positive, significant relationship between this construct and performance indicates that performance will increase as training increases ($\beta = 0.158$, $p < 0.022$). Goodhue (1995) found this construct to be an insignificant predictor of performance, while in Wills et al. (Wills, 2009) it was significant. It is possible that the overall elapsed time (1-2 years) between initially learning to use the system and this study impacted ease-of-use. It is also possible that the effect of on-going system training on performance is the most important dimension to this construct.

**H1f: Production timeliness will influence user performance. Production timeliness is evaluated according to the perceived response time for reports and other requested information.**

Of all of the eight TTF factors, only production timeliness did not significantly impact performance. Accordingly, H1f is not supported by the results. This result is consistent with Goodhue (D. L. Goodhue, Thompson, R. L.) and Wills et al. (2009) suggested that production timeliness should be a hallmark for implementing and using EHR. It is likely, however, that because in some cases report generation is not handled by informatics or IT departments but by clinicians, nurses, case managers and other clinical management personnel, this construct and the questions representing it may need to be redefined for future work.

**H1g: System reliability will influence user performance.**

The relationship between system reliability and performance is significant and negative ($\beta = -0.166$, $p < 0.017$), suggesting that user performance will increase as system reliability decreases. H1g is counter-intuitive and is not supported by the results. Similar to Wills (2009), system reliability in the EHR context did not contribute meaningfully to the theoretical model.
One avenue is to more deeply explore the real issues of reliability. For example, perhaps reliability in the EHR context is less about the system being up and running or suffering crashes, and more about subtle reliability issues such as interfacing with data intensive medical imaging systems or laboratory systems.

*H1h: The IS departments’ relationship with users will influence user performance. This factor includes IS understanding of business, IS interest and user support, IS responsiveness, delivery of agreed-upon solutions, and technical and unit planning support.*

The relationship between the clinical informatics/IT department and performance is strongly positive and significant ($\beta = 0.562, p < 0.0001$). H1h is therefore supported. This multi-dimensional construct evaluates five areas of relationships with users, including understanding of specific department information needs, interest and dedication for addressing clinical information needs, responsiveness (turnaround time for data/information requests, availability and quality of technical assistance or service from CI/IT, and CI/IT performance, for example the extent to which CI/IT keeps its agreements. Of these five, only one area, responsiveness, was not supported. It is possible that an earlier point applies in this situation, that is, clinicians may not always be the persons seeking additional information. A request for additional data or information may go through case or clinic managers, thus bypassing clinicians altogether. From a practical standpoint, it is logical that clinicians would be aware of CI/IT’s understanding of departmental information needs (if they have the info they need this understanding is implied), CI/IT interest and dedication, consulting and performance.

*H2: The characteristics of the clinical reasoning task, complexity, uncertainty and significance will have a significant direct influence on the TTF construct.*

Originally hypothesis H2 included only two characteristics, uncertainty and complexity. Task significance was initially a component of task uncertainty. Results from the factor analysis and subsequent PLS analysis suggested that task significance appears as a distinct task characteristics construct. Consequently H2 has been expanded to include three components.
H2a: Task complexity will influence the fit between EHR technology and the clinical reasoning task.

Task complexity is the perceived difficulty of making a decision or reasoning through a series of decisions. In this study, task complexity has a positive and significant relationship with two of the eight TTF constructs, authorization and system reliability. It should be noted that of the original 3 factors measuring task complexity, two remain after factor analysis and PLS regression. Thus, while three questions for component complexity were dropped, two questions for interactive complexity and two for procedural rigidity remain in the model. These findings suggest interactive complexity and procedural rigidity are predictors of authorization and reliability.

H2b: Task uncertainty will influence the fit between EHR technology and the clinical reasoning task.

Task uncertainty demonstrates positive, significant relationships with data locatability, authorization, compatibility and ease-of-use/training. The path from task uncertainty to CI/IT relationship with users however is significant and negative. The data as yet suggests no explanation for this observation, and the relationship between these two variables would benefit from additional study. When the clinical decision task is uncertain, data locatability, correct authorization, data compatibility and EOU-training becomes critical to establishing fit.

H2c: Task significance will influence the fit between EHR technology and the clinical reasoning task

Task significance is the third part of the task characteristics construct and is comprised of two distinct dimensions, task urgency and task impact. While none of the questions from the task urgency dimension remained in the model following factor analysis and PLS regression, two questions from task impact did. Task significance showed positive and significant relationships with data quality, authorization, compatibility and reliability. The path
from task significance to ease-of-use/training was both significant and negative, suggesting either a possible problem with measurement or an inverse relationship that makes sense. With regard to the latter, recall that the only remaining questions on the EOU construct pertained to training, thus it could be possible that EHR training simply doesn’t matter when the significance of the decision task increases.

**H3: The characteristics of EHR technology will have a significant direct influence on the TTF construct.**

This construct is based on the three dimensions of information, knowledge and inferencing support. Technology characteristics have been defined in various ways, and this study used the functionality of the technology as the defining characteristics

**H3a: Information capability will influence TTF.**

The results showed that the information construct had six significant relationships with TTF constructs, including quality, locatability, authorization, compatibility, system reliability and EOU. Four of these relationships were positive and two, locatability and EOU, were negative. Locatability as a construct was significant with respect to performance, but was negative as well, suggesting perhaps that the construct itself may be flawed. However one would certainly expect a positive, significant with the EOU/training construct, and this was not the case here. It is possible that information itself is not subject to ease-of-use conditions, especially when information is presented in the context of the EHR. The EHR in use during this study often actively presented pertinent information in the context of a predefined workflow. In this case, when presented at the point in workflow where it is deemed most appropriate, ease of use may not be relevant. This is just one possibility for the inverse relationship found in this case, and future research may seek to more fully understand this relationship in the context of EHR.

**H3b: Knowledge capability will influence TTF.**
In the final model, knowledge had four significant paths to the TTF construct, including data quality, locatability, authorization and relationship to users. Of these three were positive and the path from knowledge to authorization was negative. At face value this seems to suggest that as the knowledge capability of the system increases, the need for authorization to access it decreases. What we do know is that access to functional parts of the EHR system is done in a controlled manner, for example lab technicians cannot access a patient’s medical record and input data in a clinician role, just as clinicians are likely not given access to laboratory systems with data editing access.

There are at least two possibilities for this negative relationship. The first is that once clinicians are given access to the clinical part of the EHR, they are automatically granted access to all of the knowledge (medical, organizational) that is contained within the system or accessed externally. As a result, no further authorization is required. In other implementations of EHR, it could be possible that all knowledge, organizational, medical and otherwise, is freely accessible to anyone with access. Such a policy where knowledge is open and freely distributed as opposed to the all-to-common knowledge silos approach is a possibility; however this was not the case in the EHR implementation in this study.

\textit{H3c: Inferencing capability will influence TTF.}

Our test of inferencing support as a component of technology characteristics had positive results. Inference had positive and significant paths to data compatibility, system reliability, EOU/training and relationship to users. As inferencing capability increases, the need for compatible data, reliability, training, and relationship to users increases as well. This perhaps suggests that as the complexity of the EHR grows, the dependence on clinical informatics and IT rises. Another factor may be the process of obtaining information and knowledge external to the EHR and organization, and the data compatibility issues raised by it. Finally, the data suggests that when inference support increases, so too does the need for reliable systems and systems integration.

It is also noteworthy that one of our knowledge indicators loaded with two inferencing questions. Is it possible that organizational knowledge is somehow integrated with decision support? The answer of course is in the affirmative – the organization under study, and
many others like it, certainly do weave organizational knowledge into their EHR’s. These knowledge inputs show up in the form of business rules, which can be customized for each organization. Looking at it in this way may bring some clarity to why the indicator loaded as it did.

Table 14 lists the exogenous path coefficients between task and technology characteristics and TTF dimensions. Statistically significant relationships are denoted with an asterisk indicating $p < 0.05$.

Table 14: Exogenous construct path coefficients

<table>
<thead>
<tr>
<th></th>
<th>TSKCMP</th>
<th>TSKUNC</th>
<th>TSKSIG</th>
<th>INFO</th>
<th>KNOW</th>
<th>INFER</th>
<th>PERF</th>
</tr>
</thead>
<tbody>
<tr>
<td>QUAL</td>
<td>0.126</td>
<td>-0.016</td>
<td>0.261</td>
<td>0.227*</td>
<td>0.245*</td>
<td>0.130</td>
<td>0.216*</td>
</tr>
<tr>
<td>LOCAT</td>
<td>0.134</td>
<td>0.327*</td>
<td>0.129*</td>
<td>0.310*</td>
<td>0.209*</td>
<td>0.059</td>
<td>0.218*</td>
</tr>
<tr>
<td>AUTH</td>
<td>0.305*</td>
<td>0.358*</td>
<td>0.182*</td>
<td>0.451*</td>
<td>0.290*</td>
<td>0.093</td>
<td>0.216*</td>
</tr>
<tr>
<td>COMP</td>
<td>-0.031</td>
<td>0.174*</td>
<td>0.267*</td>
<td>0.309*</td>
<td>0.089</td>
<td>0.218*</td>
<td>-0.199*</td>
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<tr>
<td>PROD</td>
<td>0.127</td>
<td>-0.060</td>
<td>0.154</td>
<td>0.220</td>
<td>0.435</td>
<td>0.131</td>
<td>-0.171</td>
</tr>
<tr>
<td>RELY</td>
<td>0.408*</td>
<td>0.115</td>
<td>-0.215</td>
<td>0.310*</td>
<td>0.130</td>
<td>0.179*</td>
<td>-0.166*</td>
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<tr>
<td>EOU</td>
<td>0.135</td>
<td>0.269*</td>
<td>-0.005*</td>
<td>0.206*</td>
<td>0.072</td>
<td>0.439*</td>
<td>0.158*</td>
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<tr>
<td>RELAT</td>
<td>0.109</td>
<td>-0.141*</td>
<td>0.030*</td>
<td>0.083</td>
<td>0.353*</td>
<td>0.232*</td>
<td>0.562*</td>
</tr>
</tbody>
</table>

In chapter 3 the theoretical model was introduced along with the study hypotheses. Figure 5 illustrates the final model showing each construct and the significant path(s) to TTF factors.
**Figure 5. Model with significant paths**

**H4: Utilization (Use) will influence performance.**

Due to an extremely low $R^2$ and path coefficient values, utilization as a construct was omitted from the final model. Interviews with clinicians support the removal of utilization. Several interview participants noted that use was mandatory and questioned the relevance of it in the theoretical model. H4 is not supported.
CHAPTER 6

CONCLUSION AND FUTURE WORK

This chapter briefly summarizes and reviews the key points of previous chapters and discusses the contributions and implications of this research. The chapter also addresses the limitations of the study and explores opportunities for future research.

Summary

This study established and achieved three objectives which include development of a valid instrument for evaluation clinical reasoning performance with an electronic health record, an extension to TTF theory into the clinical domain and EHR context and confirmation of the ongoing viability of TTF theory to explain the factors influencing individual performance.

The motivation and rationale for the study is based on a clear need for a valid instrument that captures user evaluations for research and organizational purposes. The lack of a validated instrument for evaluating the impact of EHR use on clinical reasoning performance is another reason for revisiting the user evaluation construct and to consider novel instruments that have a strong theoretical foundation and meet measurement validity standards.

The study took place in a mid-size health system in the mid-western United States. The target population of the study included physicians, certified nurse practitioners and physician assistants with experience using an EHR. Sampling accurately represented the population of clinicians under study in this context. A 62.4% response rate was achieved for the survey.

Semi-structured interviews were conducted to ensure that the theoretical constructs made sense to clinicians, and to identify any additional constructs that might be critical to TTF or task and technology characteristics. While no additional TTF constructs were identified, the interviews did assist with the development of the technology characteristics construct. As a result, the focus of this construct changed from data, information and knowledge to information, knowledge and inferencing. The interview process also identified potential problems with the
utilization construct, and further suggested that clinicians did not view authorization as an important dimension of TTF. Pre-testing of the instrument assisted with clarification of the wording on survey questions, resulting in eleven changes to survey questions.

Quantitative analysis of the survey results suggests that for TTF, data quality, authorization, compatibility, and clinical informatics/IT relationship with users were important dimensions. Data locatability, production timeliness and system reliability all had significant but negative relationships with performance. Analysis of the survey data also suggested that task characteristics (task complexity, task uncertainty and task significance) effectively “moderate” the strength of the link between specific characteristics of EHR’s.

The results give support to many dimensions of the theoretical model and raise some interesting questions of their own. For example, why do locatability and systems reliability not test well, or, are there other dimensions of task and technology characteristics that should be considered? Also, some of the hypothesized relationships between task and technology characteristics did not perform as expected. Indeed, these issues are excellent candidates for future research.

**Contribution and implications for research and practice**

Past research on EHR’s and performance (El-Gayar, 2010; Kilmon, 2008; Wills, El-Gayar, Deokar, A., 2009; Wills, 2012) has focused on reduced models of TTF. This study went a step further to develop, test and validate a complete TTF model application to the clinical domain. The results of the study support this model as an appropriate and valid extension of TTF theory, and support the on-going viability of TTF as a means of explaining the factors influencing fit and performance. The study also contributes to theory by establishing the meaningfulness of task and technology characteristics constructs to the overall model. The manner in which adaptation of the model from managerial decision-making to clinical decision-making occurred can be replicated and used to adapt future research to other health care related domains.

This research has both theoretical and practical implications. From a theoretical perspective, the study confirmed the importance of data quality, compatibility, authorization, ease-of-use/training and clinical informatics/IT relationship with users to the fit between the clinical reasoning task and EHR technology. The implication of these findings is that as the
quality and compatibility of EHR data increases performance with respect to clinical reasoning also increases. Similarly, when the correct level of authorization to data exists, and adequate training (the remaining dimension of ease-of-use) increases, performance may increase as well. The findings also support the notion that a good relationship between system users and those who maintain the system (clinical informatics/IT) is an important factor with respect to performance increases.

With TTF now appropriately extended to the clinical domain, practitioners can use the instrument developed here for a variety of purposes. In implementations that are proceeding through the steps leading to advanced CPOE and decision support capabilities, the instrument can provide a view of the electronic health record and its capacity for clinical reasoning support. The instrument can also be deployed in a pre and post-test manner for use in assessing the success (or lack thereof) of a particular EHR component implementation such as CPOE. Moreover, it can be used as a diagnostic tool to evaluate possible problems or issues with the technology, fit and performance of the user.

**Limitations**

This project examined the final eight TTF constructs in Goodhue’s (D. L. Goodhue, Thompson, R. L.) original study without deviation. No other TTF concepts arose during the interview process. Despite these qualitative findings, there is reason to believe that because of the dynamic evolution of EHR products in today’s marketplace and possible changes in the relevant dimensions of TTF, other factors might emerge as essential to the fit between task and technology. When the instrument was designed, basic EHR products were the dominant technology. As EHR’s evolve through incorporation of greater levels of decision/inference support it is possible that the dimensions of TTF will change as well. In a similar fashion, as EHR technologies become increasingly integrated with health information exchange and other external sources of data, the dynamics of the task-technology fit may need updating.

Another limitation exists with respect to sample size and timing. The organization was close to implementation of computerized provider (or physician) order entry (CPOE) enterprise-wide, but had not achieved that by the time the study was undertaken. It is conceivable that the addition of CPOE might exponentially increase the amount of information and knowledge available to clinicians, while simultaneously impacting the presence of active decision support.
Many such systems can be integrated with the EHR to provide active decision support during medication and test ordering. Some departments and sites had computerized order entry and some did not, creating a challenging environment for testing.

While the sample size achieved here is minimally adequate, additional participants for the qualitative (interviews) and quantitative (survey) aspects would be helpful. It is widely known that collecting such data in the health care domain, and particularly on the clinical side, is challenging at best. A larger future study should be able and willing to commit resources and time to additional data gathering.

One must also consider the generalizability of these findings. The study was conducted in a medium-size health system in the Midwest, and focused on one brand of EHR in the context of one of a myriad of possibilities with respect to implementation status. The EHR product used, the degree of implementation (basic EHR, CPOE, and decision support), the overall organizational dynamic – each of these things may contribute to different results in different

**Future Research**

Noted earlier as a limitation to the study, the TTF constructs also represent an opportunity for future research. Although this study did not identify additional new constructs for consideration, other studies should explore the possibilities in this avenue of research. One possible consideration is the concept of trust. Clinicians need to know that the information and knowledge, such as that contained in clinical best practices is of the highest integrity. This might be considered as a dimension of data quality or it could be explored as a standalone TTF construct.

Other areas within the TTF construct worth exploring include data locatability, system reliability and production timeliness. Production timeliness is concerned with the turnaround times for clinical informatics and IT with respect to reports and information requests, and in this study it did not have a significant relationship to performance. This is a interesting result when one considers how vital such service may be to clinicians. Also interesting were the negative, inverse relationships from locatability and systems reliability to performance. Future research should address these constructs in the context of other implementations of EHR and attempt to determine their overall contribution to the model.
While this study examined task characteristics from the perspective of complexity, uncertainty and significance, another consideration may be to look at the construct from the perspective of the clinical reasoning paradigms discussed in chapter 2. The goal in this study was to reduce the clinical reasoning task to its most basic levels such as complexity, uncertainty and significance. However another approach might consider evaluating the clinical reasoning task and the corresponding fit to technology from a higher level, such as informal/intuitive (heuristics, pattern matching) reasoning, formal/analytical (hypotheses testing, probability estimation e.g. Bayes theorem), or some hybrid of the two. It would be interesting to understand the implications to performance if task-technology fit included the specific ways in which clinician’s reason.

Concluding remarks

This research represents both the culmination of a number of recent studies involving electronic health records and task-technology fit (Wills, 2009; El-Gayar, 2009; El-Gayar, 2009; El-Gayar, 2010; Wills, 2012) and one of many likely to come. It has been a progressive and iterative experience, and each study has given us greater insight into how the fit between task and technology – the degree to which the technology supports the task, impacts performance. This study also addressed the impact of task and technology characteristics, an important element of the model that had been missing in previous studies.

A primary objective of this research was to develop and validate an instrument to evaluate EHR particularly in regard to its impact on clinical reasoning performance. This objective situates the study in the context of a dynamic and evolving field of study. At no time in the past has information technology placed so many demands on the health care field and its practitioners. EHR systems are being adopted in the U.S. at ever increasing rates due in no small part to a federal nudge as well as growing support for realized benefits. While there are no doubt countless avenues of research available to the IS or informatics researcher, understanding how to build better systems, capable of supporting the decisions that need to be made during patient care, must be a priority.
REFERENCES


APPENDIX A: SURVEY INSTRUMENT

SURVEY 1: INITIAL INSTRUMENT

Survey 1 represents the initial instrument that was pretested on a group of 11 clinicians. Survey 2 in the next section represents the final survey which was administered to the target group following pretesting. For Survey 1, questions in red indicate those items that were changed for the final instrument. Table 8 also summarizes this information.

INFORMED CONSENT

Sanford Health and Dakota State University are conducting a research project entitled: Evaluating the Impact of Electronic Health Records on Clinical Reasoning Performance. The objectives of the study are to better understand the impact of electronic health record (EHR) use on clinical reasoning, identify new methods of improving EHR functionality and usefulness for clinicians, and produce a validated tool for studying clinical reasoning performance with EHR use.

You as a clinician (MD, DO, CNP, PA-C) are invited to participate in the study by completing the survey online. A paper version of the survey is also available by contacting the project director at the email address or phone listed below. I realize that your time is valuable and I have attempted to keep the survey as brief and concise as possible. It will take approximately 10-12 minutes of your time. Your participation in this study is voluntary and you may withdraw from the study at any time without consequence.

There are no known risks to you for participating in this study. There are no known direct benefits to you for participating in this study. Your responses are strictly confidential. When the data and analysis are presented, you will not be linked to the data by your name, title or any other identifying item. Please assist us in this important research and complete the following survey.

Your consent is implied by the return/submission of the completed questionnaire. If you have any questions, now or later, you may contact me at the number below. Thank you very much for your time and assistance. If you have any questions regarding your rights as a research participant in this study, you may contact the DSU Office of Sponsored Programs 605-256-5100, mickie.kreidler@dsu.edu.

Sincerely,

Matt Wills, M.Sc
Doctor of Science (D.Sc) Candidate
Graduate Research and Teaching Assistant
Dakota State University
820 N. Washington Ave
Madison, SD 57042
(605) 321-0179

1. Agree
2. Disagree

*What is your occupation?
1. Physician (MD/DO)
2. Nurse Practitioner
3. Physician Assistant

*What is your gender?
- Male
- Female

*How old are you?
- 18-24 yrs
- 25-34 yrs
- 35-44 yrs
- 45-54 yrs
- 55-64 yrs
- 65+

*Please select the option which best describes the clinical setting in which you work.
- Clinic/Physician Office
- Ambulatory Surgical Center
- Acute Care Hospital
- Rehabilitation Facility
- Dialysis Unit
Please select the answer on the right which best describes how much you agree or disagree with the statements below

I can’t get clinical data that is current enough for my needs.

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The clinical data is up to date enough for my purposes.

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The clinical data maintained by Sanford or my department is what I need to carry out my tasks.

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The electronic health record is missing critical data that would be useful to me in my job.

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Sanford maintains data at an appropriate level of detail for my groups’ tasks.

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Sufficiently detailed data is maintained by Sanford.
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It is easy to find out what data Sanford maintains on a given subject.

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It is easy to locate system-wide or departmental data on a particular issue, even if I haven’t used that data before.

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The exact definition of data fields relating to my tasks is easy to find out.

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On the reports or systems I deal with, the exact meaning of the data elements is either obvious or easy to find out.

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Data that would be useful to me is unavailable because I don’t have the right authorization.

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Getting authorization to access data that would be useful is difficult and time consuming.

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There are times when I find that supposedly equivalent data from two different sources is inconsistent.

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Sometimes it is difficult for me to compare or consolidate data from two different sources because the data is defined differently.

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When it’s necessary to compare data from different sources, I find that there may be unexpected inconsistencies.

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To my knowledge, the IT department meets its production schedules such as report delivery.

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Regular IT activities such as report delivery are completed on time.

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I can count on the EHR to be up and running when I need it.

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The EHR is subject to unexpected or inconvenient downtime which makes it harder to do my work

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The EHR and other systems I use are subject to frequent crashes and problems.

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It is easy to learn how to use the EHR

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There is not enough training for me or my staff on how to find, understand, access or use the EHR effectively.

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I am getting the training I need to use the EHR effectively.

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The IS people we deal with understand the day-to-day objectives of my work group and its mission within our company.

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My work group feels that IS personnel can communicate with us in familiar business terms that are consistent.

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IS takes my business groups’ problems seriously

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IS takes a real interest in helping me solve my business problems.

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It often takes too long for CI or IT to communicate with me on my requests.

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I generally know what happens to my request for service or assistance or whether it is being acted upon.

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CI/IT responds quickly to a request for assistance or service.

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Based on my previous experience, I would consult with IS technical and business planning services in the future if I had a need.

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I am satisfied with the level of technical and business planning consulting expertise I receive from IS

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IS delivers agreed-upon solutions to support my business needs.

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Making good clinical decisions is sometimes complicated by the number of people involved in a patient’s care.

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Making good clinical decisions is sometimes complicated by the need to access multiple hospital information systems to get the right information.

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Deciding on a course of treatment can be complicated by the number of organizations or individuals (e.g. insurance, care managers, other health facilities, patients, employers) involved.

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The different activities involved in clinical decision-making frequently interact in unpredictable ways.

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Unexpected events can complicate clinical decision-making

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The various activities involved in diagnostic decision-making are rigid with respect to time or duration.

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The sequences of activities involved in clinical decision-making are rigid.

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I often encounter new and unfamiliar challenges when making diagnostic and treatment decisions.

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As a clinician, I frequently see novel and unexpected clinical problems.

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In my job, I frequently deal with poorly understood clinical problems.

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In my job, I frequently deal with ad-hoc, non-routine clinical problems.

Some of the clinical problems I work on involve answering questions that have never been asked in quite that form before.

Diagnostic and/or treatment decisions are sometimes made with a sense of urgency.

Prioritization of clinical decisions is commonplace in my job.

During clinical decision-making, analysis and assessment of potential repercussions is common.

Making good clinical decisions means having a thorough understanding of how a potential intervention or combination of interventions will impact each other and the outcome.

The electronic health record makes accessing information about my patients easier.

The electronic health record provides the information I need to make good clinical decisions.
The electronic health record integrates information from various sources (e.g. other hospital information systems, or the web).

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Best practice knowledge is accessible from the EHR.

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The EHR provides a means for collaboration, thereby enhancing the sharing of knowledge.

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The EHR provides access to organizational knowledge.

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The EHR provides passive decision support (user initiates request for decision assistance).

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The EHR provides active decision support (decision assistance is provided without user request for assistance).

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No decision support is available from the EHR.

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I expect to use the EHR in the future.

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I regularly use the EHR.

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The EHR has a large, positive impact on my job productivity.

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The EHR is an important and valuable aid to me.

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The EHR has a strong, positive impact on my effectiveness as a clinician.

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The EHR helps me make more effective decisions.

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Overall, the EHR helps me make clinical decisions more efficiently.

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The clinical data and information contained in the EHR enable more efficient patient care.

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SURVEY 2: FINAL INSTRUMENT

The final instrument (survey 2) is similar to the initial (survey 1) with the exception of 9 questions that were revised during the instrument pre-test. A group of 11 clinicians were given the survey prior to administration to the target group. As a result of this exercise 9 questions were changed. The objective of the pre-test was to ensure that the questions and wording made sense to clinicians. Questions that were ambiguous, difficult to understand or simply did not make sense from a clinical or technological perspective were re-worded by the participants. The reworded questions were then reviewed by the investigator to ensure that the underlying theoretical construct being measured remained intact. In cases where the re-wording process fundamentally changed the theoretical objective of the question, the investigator and clinician discussed it and restructured the question in a manner that met both clinical sense and theoretical sense.

INFORMED CONSENT

Sanford Health and Dakota State University are conducting a research project entitled: *Evaluating the Impact of Electronic Health Records on Clinical Reasoning Performance*. The objectives of the study are to better understand the impact of electronic health record (EHR) use on clinical reasoning, identify new methods of improving EHR functionality and usefulness for clinicians, and produce a validated tool for studying clinical reasoning performance with EHR use.

You as a clinician (MD, DO, CNP, PA-C) are invited to participate in the study by completing the survey online. A paper version of the survey is also available by contacting the project director at the email address or phone listed below. I realize that your time is valuable and I have attempted to keep the survey as brief and concise as possible. It will take approximately 10-12 minutes of your time. Your participation in this study is voluntary and you may withdraw from the study at any time without consequence.

There are no known risks to you for participating in this study. There are no known direct benefits to you for participating in this study. Your responses are strictly confidential. When the data and analysis are presented, you will not be linked to the data by your name, title or any other identifying item. Please assist us in this important research and complete the following survey.

Your consent is implied by the return/submission of the completed questionnaire. If you have any questions, now or later, you may contact me at the number below. Thank you very much for your time and assistance. If you have any questions regarding your rights as a research participant in this study, you may contact the DSU Office of Sponsored Programs 605-256-5100,
mickie.kreidler@dsu.edu.

Sincerely,

Matt Wills, M.Sc
Doctor of Science (D.Sc) Candidate
Graduate Research and Teaching Assistant
Dakota State University
820 N. Washington Ave
Madison, SD 57042
(605) 321-0179

1. Agree
2. Disagree

*What is your occupation?
1. Physician (MD/DO)
2. Nurse Practitioner
3. Physician Assistant

*What is your gender?
Male
Female

*How old are you?
18-24 yrs
25-34 yrs
35-44 yrs
45-54 yrs
55-64 yrs
65+
*Please select the option which best describes the clinical setting in which you work.

- Clinic/Physician Office
- Ambulatory Surgical Center
- Acute Care Hospital
- Rehabilitation Facility
- Dialysis Unit
- Mental/Behavioral Health
- Home Care
- Hospice
- Long-term Care
- Public Health
- Industrial Health
- School Health
- Other

**Please select the answer on the right which best describes how much you agree or disagree with the statements below**

I can’t get clinical data that is current enough for my needs.

<table>
<thead>
<tr>
<th>Strongly Disagree</th>
<th>Disagree</th>
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The clinical data is up to date enough for my purposes.

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The clinical data maintained by Sanford or my department is what I need to carry out my tasks.

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<th>Strongly Disagree</th>
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The electronic health record is missing critical data that would be useful to me in my job.

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Sanford maintains data at an appropriate level of detail for my groups’ tasks.

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Sufficiently detailed data is maintained by Sanford.

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It is easy to find out what data Sanford maintains on a given subject.

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It is easy to locate system-wide or departmental data on a particular issue, even if I haven’t used that data before.

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The exact definition of data fields relating to my tasks is easy to find out.

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On the reports or systems I deal with, the exact meaning of the data elements is either obvious or easy to find out.

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Data that would be useful to me is unavailable because I don’t have the right authorization.

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Getting authorization to access data that would be useful is difficult and time consuming.

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There are times when I find that supposedly equivalent data from two different sources is inconsistent.

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Sometimes it is difficult for me to compare or consolidate data from two different sources because the data is defined differently.

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When it’s necessary to compare data from different sources, I find that there may be unexpected inconsistencies.

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To my knowledge, the IT department meets its production schedules such as report delivery.

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Regular IT activities such as report delivery are completed on time.

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I can count on the EHR to be up and running when I need it.

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The EHR is subject to unexpected or inconvenient downtime which makes it harder to do my work.

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The EHR and other systems I use are subject to frequent crashes and problems.

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It is easy to learn how to use the EHR

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There is not enough training for me or my staff on how to find, understand, access or use the EHR effectively.

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I am getting the training I need to use the EHR effectively.

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The people from the clinical informatics and IT departments understand the day-to-day objectives of my department/team.

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My team/department feels that clinical informatics and IT personnel communicate with us in familiar, consistent terms.

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Clinical informatics and IT personnel take my departments information problems seriously.

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CI and IT take a real interest in helping solve our clinical information needs.

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It often takes too long for CI or IT to communicate with me on my requests.

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I generally know what happens to my request for service or assistance or whether it is being acted upon.

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CI/IT responds quickly to a request for assistance or service.

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Based on my previous experience, I would consult with clinical informatics and hospital IT personnel for assistance with the EHR

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I am satisfied with the level of assistance I receive for CI/IT.

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CI/IT delivers agreed-upon solutions to support my clinical information needs.

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Making good clinical decisions is sometimes complicated by the number of people involved in a patient’s care.

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Making good clinical decisions is sometimes complicated by the need to access multiple hospital information systems to get the right information.

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Deciding on a course of treatment can be complicated by the number of organizations or individuals (e.g. insurance, care managers, other health facilities, patients, employers) involved.

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The different activities involved in clinical decision-making frequently interact in unpredictable ways.

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When making clinical decisions, unplanned or unexpected events can interfere with expected outcomes.

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The various activities involved in diagnostic decision-making are rigid with respect to time or duration.

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The sequences of activities involved in clinical decision-making are rigid.

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I often encounter new and unfamiliar challenges when making diagnostic and treatment decisions.

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As a clinician, I frequently see novel and unexpected clinical problems.

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<th>Strongly Disagree</th>
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<th>Strongly Agree</th>
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In my job, I frequently deal with poorly understood clinical problems.

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In my job, I frequently deal with ad-hoc, non-routine clinical problems.

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<th>Strongly Disagree</th>
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</table>

Some of the clinical problems I work on involve answering questions that have never been asked in quite that form before.

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<thead>
<tr>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Somewhat Disagree</th>
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Diagnostic and/or treatment decisions are sometimes made with a sense of urgency.

<table>
<thead>
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<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Somewhat Disagree</th>
<th>Neutral</th>
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</table>

Prioritization of clinical decisions is commonplace in my job.

<table>
<thead>
<tr>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Somewhat Disagree</th>
<th>Neutral</th>
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</tbody>
</table>

During clinical decision-making, analysis and assessment of potential repercussions is common.

<table>
<thead>
<tr>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Somewhat Disagree</th>
<th>Neutral</th>
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</table>

Making good clinical decisions means having a thorough understanding of how a potential intervention or combination of interventions will impact each other and the outcome.

<table>
<thead>
<tr>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Somewhat Disagree</th>
<th>Neutral</th>
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</tbody>
</table>

The electronic health record makes accessing information about my patients easier

<table>
<thead>
<tr>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Somewhat Disagree</th>
<th>Neutral</th>
<th>Somewhat Agree</th>
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</tbody>
</table>

The electronic health record provides the information I need to make good clinical decisions.

<table>
<thead>
<tr>
<th>Strongly Disagree</th>
<th>Disagree</th>
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</tbody>
</table>
The electronic health record integrates information from various sources (e.g. other hospital information systems, or the web).

<table>
<thead>
<tr>
<th>Strongly</th>
<th>Disagree</th>
<th>Disagree</th>
<th>Somewhat</th>
<th>Agree</th>
<th>Agree</th>
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<tbody>
<tr>
<td>Disagree</td>
<td>1</td>
<td>2</td>
<td>3</td>
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<td>6</td>
</tr>
</tbody>
</table>

Best practice knowledge is accessible from the EHR.

<table>
<thead>
<tr>
<th>Strongly</th>
<th>Disagree</th>
<th>Disagree</th>
<th>Somewhat</th>
<th>Agree</th>
<th>Agree</th>
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<tbody>
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<td>2</td>
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</tr>
</tbody>
</table>

The EHR provides a means for collaboration, thereby enhancing the sharing of knowledge.

<table>
<thead>
<tr>
<th>Strongly</th>
<th>Disagree</th>
<th>Disagree</th>
<th>Somewhat</th>
<th>Agree</th>
<th>Agree</th>
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<td>3</td>
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<td>6</td>
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</tbody>
</table>

The EHR provides access to organizational knowledge

<table>
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<tr>
<th>Strongly</th>
<th>Disagree</th>
<th>Disagree</th>
<th>Somewhat</th>
<th>Agree</th>
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<td>Disagree</td>
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<td>2</td>
<td>3</td>
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<td>6</td>
</tr>
</tbody>
</table>

The EHR provides passive decision support (user initiates request for decision assistance).

<table>
<thead>
<tr>
<th>Strongly</th>
<th>Disagree</th>
<th>Disagree</th>
<th>Somewhat</th>
<th>Agree</th>
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<tbody>
<tr>
<td>Disagree</td>
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<td>2</td>
<td>3</td>
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<td>6</td>
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The EHR provides active decision support (decision assistance is provided without user request for assistance).

<table>
<thead>
<tr>
<th>Strongly</th>
<th>Disagree</th>
<th>Disagree</th>
<th>Somewhat</th>
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<tbody>
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<td>Disagree</td>
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</table>

No decision support is available from the EHR.

<table>
<thead>
<tr>
<th>Strongly</th>
<th>Disagree</th>
<th>Disagree</th>
<th>Somewhat</th>
<th>Agree</th>
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I expect to use the EHR in the future.

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<tr>
<th>Strongly</th>
<th>Disagree</th>
<th>Disagree</th>
<th>Somewhat</th>
<th>Agree</th>
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I regularly use the EHR.

<table>
<thead>
<tr>
<th>Strongly Disagree</th>
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The EHR has a large, positive impact on my job productivity.

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The EHR is an important and valuable aid to me.

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The EHR has a strong, positive impact on my effectiveness as a clinician.

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The EHR enhances my clinical decision-making effectiveness.

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Overall, the EHR helps me make clinical decisions more efficiently.

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The clinical data and information contained in the EHR enable more efficient patient care.

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APPENDIX B: ASSESSING INSTRUMENT VALIDITY-
QUALITATIVE STUDY

Appendix B includes the summary transcripts from the semi-structured interviews. The objective of the interview was to assess whether or not the theoretical model made “sense” to clinicians, that is, is it both theoretically and practically meaningful? The transcripts highlight several important findings, such as a lack of support for the utilization (use) construct, authorization, data compatibility and locatability. It is interesting to note that utilization was dropped from the final model as not contributing to the overall model, and locatability, although significant, demonstrated an inverse relationship to performance. Furthermore, there was support for the idea of the technology characteristics knowledge and information. Assessment of workflow and throughput were also recurrent themes, although the evaluation of these constructs was beyond the scope of this study.

<table>
<thead>
<tr>
<th>Question</th>
<th>Interviewee</th>
<th>Comments</th>
<th>Summary</th>
</tr>
</thead>
<tbody>
<tr>
<td>According to the model as I’ve described it, are there any constructs or relationships that do not make sense to you?</td>
<td>2 - MD</td>
<td>[The] Use [construct] does not really make sense to me. I understand how use of the EMR is required for any level of performance, however we have to use it. I think that performance would be affected more by the nature of the decision tasks and the capabilities of the system than by use. Toss use.</td>
<td>Discard Use construct</td>
</tr>
<tr>
<td></td>
<td>3 –PA-C</td>
<td>I think the TTF construct has some things [indicators] that will not be useful. Authorization, for example should not be an issue for docs or mid-levels; data</td>
<td>Authorization not useful, also data locatability and compatibility</td>
</tr>
</tbody>
</table>
Locatability is a non-issue because everything (usually...) is right there on the screen - it’s not like we have to go searching for the information we need. Also, compatibility should not matter, as we are usually not dealing with more than one system at a time.

<table>
<thead>
<tr>
<th>11 - DO</th>
<th>It makes sense that you would break technology characteristics down by capability [information, knowledge, inference support], however it’s important to know that we are not there yet [pointing at inference support]. I can’t enter a bunch of symptoms and have the thing spit out a top five list of likely candidates (though that would be nice). I think we do get knowledge, probably from the built-in guidelines that we have to document on, and certainly we get information like lab results that exceed normal values. The EMR will even warn us when there’s a problem, such as a high lab value. In a way these active alerts do help me make decisions, but it does not go so far as to make them for me.</th>
</tr>
</thead>
<tbody>
<tr>
<td>15 - MD</td>
<td>If by inference support [meaning the technology considered dropping Inference support, chose to test this construct indicator. Knowledge and Information supported as construct indicators. No decision support yet</td>
</tr>
</tbody>
</table>
As a clinician, what are your primary concerns about the EMR?

<p>| 19 - CNP | What about throughput or workflow? I don’t see anything about these. Throughput is very important to me in the clinic. The more patients I see the better the bottom line for the clinic, and I see that as job security. However seeing a new patient every 15 minutes is taxing as hell, and the EMR needs to be able to support that pace. I see it as a workflow issue as well, for the same reasons. | EMR support for throughput and workflow will be considered as components of TTF in future research. |
| 1 - PA-C | Being able to use it at the pace I’m used to. | *Workflow |
| 4 - MD | None. I have no concerns. Yes, it can be a bear in the beginning, be it starting with a new system or transitioning from one EMR to another, but overall I’m very enthusiastic about how better information will help me take better care of my patients. | *Challenge is learning the system, not using it. |
| 6 - CNP | I don’t like it; I have always used paper records. I understand the need, and I’m getting better at it, but I’m not a techy person and I think it sometimes reduces the quality time I get to | *Reduces patient care time *Prefer paper |</p>
<table>
<thead>
<tr>
<th>Question</th>
<th>Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>What roles do uncertainty and complexity play in clinical reasoning?</td>
<td>Should clinical reasoning be defined by these components, or should clinical reasoning be understood by the mechanisms of reasoning (e.g. probabilistic, heuristic, pattern matching, intuition, etc.)?</td>
</tr>
<tr>
<td>In some cases, there is a high degree of uncertainty, others not so much. Same for complexity. High amounts of uncertainty and complexity define the “tough” cases. At the same time, a case can be quite simple, yet still quite uncertain in terms of outcome or prognosis. Obviously the more complex the problem, the greater the difficulty in making good decisions. It makes more sense to define clinical reasoning has having characteristics of uncertainty and complexity, rather than by the mechanism used to make the decision.</td>
<td></td>
</tr>
<tr>
<td>Uncertainty is a bugger. There are times when decision-making is based on probabilities, in</td>
<td></td>
</tr>
<tr>
<td>That it doesn't go far enough...though I know more features are coming online all the time. Decision support would be interesting, I see it coming but I’m not sure how to react to it.</td>
<td><em>DSS</em> <em>Complexity/Uncertainty</em> <em>Better to define by complexity and uncertainty than by mechanism(s) used to make decision.</em></td>
</tr>
<tr>
<td>That it will slow me down</td>
<td><em>Workflow</em> <em>Negative impact on production, better care</em></td>
</tr>
<tr>
<td>It definitely has an impact on production, and not always a good one, but overall I think the tradeoff is better care.</td>
<td></td>
</tr>
</tbody>
</table>
addition to other things. The challenge also lies in the complexity of the case. The more complex, the less useful probabilistic reasoning becomes; one cannot simply do the math in her head.

6 – CNP These do play a role because the degree of uncertainty and complexity will inevitably determine the ease and accuracy of my decisions. Personally, I think it makes more sense to talk about mechanisms as elements of the technology...the technology should support the way reasoning happens.

7 – DO My practice sees very little complexity, and the only uncertainty is whether or not my patients will follow my advice.

13 -MD It makes sense to think of the decisions I make in terms of the degree to which they are complex and uncertain. Easy decisions are marked by low complexity and uncertainty. I can't think of any other way to better state that. At the same time though, I do use the mechanisms you described, or some combination of them, but I see these as...
<table>
<thead>
<tr>
<th>Can EMR technology improve clinical reasoning performance?</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Fit = solve complexity, ease of access to information, timeliness of information, currency and relevance</em></td>
</tr>
<tr>
<td><strong>Describe in your words what would determine a good fit between task (clinical reasoning) and technology (EMR).</strong></td>
</tr>
<tr>
<td><strong>Can EMR technology improve clinical reasoning performance?</strong></td>
</tr>
<tr>
<td><strong>9 – PA-C</strong></td>
</tr>
<tr>
<td><strong>10 - MD</strong></td>
</tr>
<tr>
<td><strong>14 - MD</strong></td>
</tr>
<tr>
<td><strong>11 – MD</strong></td>
</tr>
</tbody>
</table>

Mechanisms for decision-making, not characteristics of decision-making.
**17 – MD**

*Fit = support for task; ease-of-use, support decision mechanisms.*

**A good fit means that the nature of the task is supported by the technology. The technology should be easy to use, and should help support the way I think (which is probably very difficult to do).*

**7 – DO**

*Control information overload, easy access to supplemental knowledge, currency, accuracy*

*The EMR should have no more information than I need at any given time, meaning there’s still some screen real estate left, and there should be an easy mechanism for requesting additional information, such as journal articles. The information I do get should be current and accurate. Also, good support from informatics and IT is critical.*

**18 – PA-C**

*mediate complexity, uncertainty via DSS*

*A good fit would mean that the technology somehow mediates the complex and uncertain nature of decisions; I think we’ll see that as more decision support comes online.*
Table C.1: Factor Loadings

<table>
<thead>
<tr>
<th>Factor</th>
<th>REL_01</th>
<th>REL_02</th>
<th>REL_03</th>
<th>REL_04</th>
<th>REL_05</th>
<th>REL_06</th>
<th>REL_07</th>
<th>REL_08</th>
<th>REL_09</th>
<th>REL_10</th>
<th>REL_11</th>
<th>REL_12</th>
<th>REL_13</th>
<th>REL_14</th>
</tr>
</thead>
<tbody>
<tr>
<td>Factor2</td>
<td>0.92188</td>
<td>0.12604</td>
<td>0.03038</td>
<td>-0.09371</td>
<td>-0.16628</td>
<td>0.26231</td>
<td>-0.27589</td>
<td>0.22083</td>
<td>-0.03294</td>
<td>-0.15794</td>
<td>-0.0832</td>
<td>0.11054</td>
<td>0.01854</td>
<td>-0.06299</td>
</tr>
<tr>
<td>Factor3</td>
<td>0.86914</td>
<td>0.15706</td>
<td>-0.32930</td>
<td>-0.11088</td>
<td>-0.02803</td>
<td>0.04052</td>
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<td>-0.23934</td>
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<td>0.08971</td>
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<tr>
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