How Does CPOE Implementation Longitudinally Impact Physician Perceptions of Job Demand and Process Benefits?

Research-in-Progress

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Abstract

Hospitals are complex organizations where inefficiencies and medical errors are unfortunately all too common. In order to increase both the efficiency and quality of care delivery, hospitals have turned to healthcare information technology (HIT) in general, and computerized provider order entry (CPOE) in particular. CPOE can impact clinical care process in a number of different ways, however, two things that it brings are process standardization and improvements in documentation quality. Our study traces physicians’ response to a CPOE implementation at a large urban Southeastern hospital. Our results reveal an interesting progression over time in how process standardization and documentation quality impact physician perceptions of job demands and process benefits. The progression surfaces the mechanisms through which physicians develop benefit perceptions for turnaround time and medical error reduction quality and how they experience job demands during a CPOE implementation.

Keywords: Computerized Provider Order Entry, IT-enabled processes, cycle time, medical errors, job demand
Introduction

In contrast to healthcare systems in other countries, U.S. physicians are largely independent of hospital management, making it challenging to standardize clinical and operational procedures within a hospital (Cebul et al. 2008; Kohli and Kettinger 2004). Further, U.S. hospitals tend to be more structurally fragmented than their counterparts in other advanced economies and care coordination remains a challenge (Davis et al. 2014). As a result, medical errors in hospitals are common, and, by some estimates, death-rates associated with such errors range between 210,000 and 400,000 annually (James 2013). Against this backdrop, hospitals have turned to healthcare information technology (HIT) in general, and computerized provider order entry (CPOE) in particular to increase both the efficiency and quality of care delivery (Buntin et al. 2011; Hersh 2002). While many advances in HIT adoption have been made in recent years (Audet et al. 2014), the specific benefits of these systems are not yet clear (Berger and Kichak 2004; Holden 2010). Our objective is to investigate the impact of CPOE implementation over time on physician perceptions of key operational characteristics, job demand, and CPOE-enabled process benefits.

Adopted by 50 percent of hospitals so far (Thompson 2014), CPOE is aimed at streamlining clinical operations, providing clinical decision support, and maintaining documented electronic records of the care that a patient receives (Davidson and Chismar 2007; Galanter et al. 2010). The system promotes the use of standard “order sets” and “pre-populates” order information, increasing speed of order processing by auxiliary departments (pharmacy, laboratories, radiology), while assisting physicians with compliance issues as well as avoiding errors such as dosage duplication. CPOE systems are hailed by practitioners for their potential to reduce auxiliary services turnaround times and clinical errors (Edwards and Moczygemba 2004; Serb 2009; Wolf 2003). However, prior research on CPOE has produced conflicting evidence on their impact, with reported findings of positive, neutral and negative outcomes following adoption. For instance, while Kaushal et al. (2003) find CPOE to be associated with reduction in errors, Koppel et al (2005) find CPOE to increase clinical errors in the first two years following adoption. Whereas Skibinski et al. (2007) find automation to improve safety of medication usage, Weant et al. (2007) detect increases in medication errors in the hospital pharmacy following CPOE implementation.

While CPOE systems affect many aspects of hospital operations, they are primarily designed to assist physicians with patient care coordination. Past research shows that physicians are often resistant to new technologies that standardize their work procedures (Bhattacherjee and Hikmet, 2007; Yarbrough and Smith, 2007). As the success or failure of the system is largely dependent on physicians, it is important to understand how they perceive job demand and the benefits associated with the system. If the latter physicians’ perceptions outweigh the former ones over the course of the implementation, the system stands a greater chance to be effectively used. As beliefs about new technology and its benefits evolve over a system’s implementation (Morris and Venkatesh, 2000; Sykes et al. 2011), it is important to distinguish between initial perceptions to an implementation, perceptions during the shakedown period (i.e., early months of use), and perceptions associated with the post shakedown period (Bala and Venkatesh 2013). Initial perceptions often reflect issues associated with education and training, perceptions in the shakedown phase often reflect adjustments to work processes that must be made and the costs that these entail, and it is only after the shakedown period that we can expect stability of beliefs. Accordingly, we integrate the role of time in our theory development and research design to better understand how physicians respond to a CPOE system over the course of its implementation.

Given our research objective, we develop a contextualized model to understand physician response to a CPOE system. We focus on the relationships among physician’s beliefs of operational characteristics that are associated with CPOE (i.e., standardization and documentation quality), job demand, and process benefits that may accrue from the use of CPOE—specifically turnaround time and medical error reduction. Our empirical study involves a longitudinal design to examine the progression in the relationships among these physician perceptions over a period of 6 months at a large public hospital that implemented a CPOE system.

Research Model

Our theory development involves two related steps: (1) leveraging the distinctive contextual aspects of the CPOE technology and clinical care process in which physicians’ beliefs are formed and (2) interrelating
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these beliefs with guidance from the IT implementation and use literature. Through this two-step process, we develop a mid-range model that brings to the foreground physicians’ perceptions of specific, important operational characteristics of a CPOE system, job demand, and process benefits and how these perceptions relate to each other. Our model development does not relegate the contextual characteristics of CPOE to the background as controls; rather, we focus on contextually salient characteristics to develop a mid-range model (e.g., Johns, 2006; Drazin and Van de Ven, 1985).

Our research model (Figure 1) is informed by the process design objectives of a CPOE system to enable two operational characteristics: standardization and documentation quality (Davidson and Chismar 2007; Galanter et al. 2010; Heffner et al. 2004). Drawing on a key premise of the IS Success Model that perceived technology quality affects perceived benefits (DeLone and McLean, 1990; Rai et al., 2002), we look at the impact of physicians’ perceptions of CPOE-enabled operational characteristics on process benefits and job demand. We argue that to the extent physicians’ perceive more favorable operational characteristics to be enabled by a CPOE implementation, they will find the system to deliver process benefits, particularly with respect to decreased turnaround time and reduction in medical errors. We also argue that physicians’ favorable perceptions of CPOE-enabled operations should reduce their job demand. We now elaborate on the constructs in our model and the relationships of interest, but do not develop hypotheses due to space constraints.

**Figure 1. Research Model**

**Physician Beliefs of CPOE-Enabled Clinical Operations**

We identify two physicians’ beliefs about CPOE-enabled operations, which we argue will influence their perceptions of process benefits associated with CPOE (i.e., reduction in turnaround times and medical errors) and job demand.

**Standardization:** Fragmentation of operations into silos is recognized as a weakness hindering clinical care in U.S. hospitals (Kim et al. 2006; Mintzberg 1997). Each department and unit typically focuses on its own task, which results in an imperfect operational alignment with other departments and units. Moreover, physicians are mostly autonomous agents (Kholi and Kettinger 2004) who differ in their practices, care routines, and preference toward equipment and medications. CPOE systems are designed to increase procedural consistency through standardization of care protocols and to facilitate timely ordering of medications and lab tests, all while ensuring compliance with hospital rules as well as external regulations (Davidson Chismar 2007; Heffner et al. 2004). In our longitudinal study, we examine to what extent perceived standardization resulting from CPOE implementation impacts perceived process benefits with respect to turnaround time and medical error reduction over time. As standardization changes physicians’ existing routines, we are also interested in the influence of physicians’ perceived standardization on their job demand over time.

**Documentation quality:** Accurate and up-to-date documentation regarding a patient’s status and the care processes that have been initiated for that patient is important so that care providers have the information they need in order to make good clinical decisions on behalf of the patient. Proper documentation has the potential to reduce medical errors such as dosage duplication, performance of unnecessary procedures, and adverse drug reactions. It helps to reduce fragmentation of care by providing
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easily accessible information to the multiple care givers patients encounter throughout their hospital stay. Whereas the literature recognizes the potential benefits from enhanced documentation quality (Tang et al. 2006), it also shows its adoption to be challenging in many cases. Adjustment to new documentation practices and procedures carries an opportunity cost for physicians in terms of time and energy. Partially for that reason, past rollouts of documentation systems have been received with resistance (Bhattacherjee and Hikmet 2007). In our longitudinal study, we examine to what extent physicians’ beliefs about CPOE-enabled documentation quality impacts their perceived process benefits with respect to turnaround time and medical error reduction. As documentation quality can potentially change how physicians access and use clinical data, we are also interested in the influence of physicians’ perceived documentation quality on their job demand over time.

CPOE Process Benefits

**Medical error reduction:** Providing streamlined laboratory results as well as automatic alerts to prevent adverse drug interactions and dosing duplication, CPOE systems are promoted for their potential to improve clinical processes (Bates et al. 1999). However, empirical evidence is conflicted on the question of their impact on medical errors. Previous research that finds CPOE to reduce medical errors (Bates et al. 1999; Kaushal et al. 2003; Kuperman et al. 2001) is contradicted by more recent findings showing an increase in errors following adoption (Berger and Kichak 2004; Han et al. 2005; Koppel et al. 2012). This ambiguity remains evident when looking at physicians’ perceptions of CPOE in relation to medical errors (Holden 2010). Building on IS research showing assimilation of new technology to change over time (e.g. Bhattacherjee and Premkumar 2004; Morris and Venkatesh 2000), we attempt to reconcile the inconsistency in the literature by longitudinally examining how physicians’ beliefs about CPOE-enabled operations affects their perceptions about CPOE’s impact in terms of reducing medical errors.

**Reduction in turnaround time:** To support optimal decision-making, physicians need the most up-to-date information on the status of their patients. Whereas medical error reduction measures a distinctly clinical process benefit outcome of CPOE, turnaround time is an operational measure examining the extent to which CPOE facilitated standardization and documentation improves the speed of auxiliary services including pharmacy, laboratory and radiology tests. Previous research shows physicians to be generally dissatisfied with the speed of auxiliary services (Jones et al. 2006; Steindel and Howanitz 2001) but also that turnaround times generally improve through automation (Fitzpatrick et al. 2005; Holland et al. 2006). Our model examines to what extent turnaround times are affected by CPOE enabled operations (i.e., process standardization and documentation quality) over time. As faster turnaround times are associated with better clinical outcomes (Menachemi and Brooks 2006), we also look at the evolving association between turnaround time improvement and medical error reduction.

Job Outcomes

**Job demand:** The impact of organizational changes on employees’ job demand is recognized to impact their psychological well-being and performance (Karasek 1979; Van der Doef and Maes 1999). The introduction of a CPOE system brings significant changes in work processes, and these changes may have short or long-term effects on physician job demand for two reasons. First, physicians work under demanding conditions (Rijk et al. 1998) characterized by information overload (Grimshaw et al. 2002) in the absence of CPOE. By redirecting some work associated with order entry that may have previously been done by non-physicians (e.g., unit clerks), and by increasing the volume of work that can be performed without increasing clinical staff, the introduction of CPOE may raise the job demand on physicians. If this is the case, it is important to understand as job demand can lead to burnout, which can negatively impact job performance as well as patient outcomes (Halbesleben and Rathert 2008). Second, physicians are resistant to new technology (Walter and Lopez 2008), sometimes to an extent that it has lead to rebellion against management (Bhattacherjee and Hikmet 2007); hence, it is important to understand the impact of physicians’ beliefs about CPOE-enabled operations on job demand over time.

Control Variables

We control for ease of use as physicians who have an easier time adjusting to the system may be more likely to see its benefits, while physicians who are challenged in using the new system are likely to feel that
it increases their job demand. Past research in IS shows that both gender (Morris and Venkatesh 2000) and age (Elias et al. 2012) are factors in IT adoption; thus, we control for those two variables as well.

Research Design

Our study is based on unique field-study data collected following a new CPOE system implementation in a large 950 bed public hospital. To capture the impact of CPOE changes on outcomes, we followed longitudinal research design principles (e.g., Venkatesh and Davis 2000). A survey was administered in 3 time periods—immediately following implementation (T0), 3 months post-implementation (T1), and then again at 6 months post-implementation (T2). To develop our survey, we used successive stages of literature review, theoretical modeling, and refinement, as suggested by MacKenzie et al. (2011). We reviewed the items with a panel of doctors, nurses, and administrators at the study site and incorporated the feedback. All items were measured on a seven point Likert-type scale ranging from strongly disagree (1) to strongly agree (7). Table 1 presents the study constructs and corresponding items.

<table>
<thead>
<tr>
<th>Construct</th>
<th>Measurement Item</th>
<th>Informing Sources</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>CPOE-Enabled Operations: Documentation Quality</strong></td>
<td>DQ1: The new electronic healthcare system increases compliance with charting. DQ2: The electronic healthcare system makes documenting the care provided to a patient more complete.</td>
<td>Galanter et al. 2010</td>
</tr>
<tr>
<td><strong>Job Outcome: Job Demand</strong></td>
<td>JDE1: I have to work fast. JDE2: I have too much work to do. JDE3: I work under time pressure.</td>
<td>Karasek 1979; Van der Doef and Maes 1999</td>
</tr>
</tbody>
</table>

Data Analysis and Results

**Measurement Model Assessment**

Loadings of measurement items on their constructs ranged from 0.64 to 0.87, and were all above the 0.5 threshold (Teo et al. 2009). The bivariate construct correlations were in the 0.025 to 0.79 range. Measurement items for a construct correlated more strongly with each other than with the measurement items of other constructs. The fit indices for the measurement model suggested a good model fit: $\chi^2 (132df) = 182.1$, $\chi^2/df = 1.338$; NFI= 0.923, CFI= 0.976, and RMSEA = 0.036 (Cheung and Rensvold 2002). Reliability values for all constructs were above the suggested level of 0.70. Collectively, these results suggest that our measures exhibit convergent and discriminant validity and acceptable reliability.
As we have measurements over time, we evaluated measurement invariance across the three time groups (T0, T1, and T2) following recommended procedures (Cheung and Rensvold 2002). We observed the same pattern of item loadings to constructs, indicating configural invariance. Additionally, we did not observe a significant deterioration in model fit when we constrained item loadings to be equal across the three time groups ($\Delta \chi^2 / \Delta df = 15.23 / 12 = 1.27; p = .229; \Delta CFI = 0.001$), indicating metric invariance. These results indicate that our measures exhibit acceptable levels of measurement invariance, enabling a meaningful comparison of structural effects across the time groups. Overall, the model, even with the relatively small sample size, shows promising consistency and robustness.

**Descriptive Statistics**

Table 2 summarizes the means and standard deviations of our construct measures over time.

<table>
<thead>
<tr>
<th>Variable</th>
<th>T0 (n=130)</th>
<th>T1 (n=86)</th>
<th>T2 (n=83)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>SD</td>
<td>Mean</td>
</tr>
<tr>
<td>CPOE-Enabled Operations: Documentation Quality</td>
<td>5.10</td>
<td>1.12</td>
<td>4.77a</td>
</tr>
<tr>
<td>CPOE-Enabled Operations: Standardization</td>
<td>4.67</td>
<td>1.25</td>
<td>4.38</td>
</tr>
<tr>
<td>Process Benefits: Turnaround Time</td>
<td>4.38</td>
<td>1.21</td>
<td>4.01a</td>
</tr>
<tr>
<td>Process Benefits: Medical Error Reduction</td>
<td>5.11</td>
<td>1.23</td>
<td>4.69a</td>
</tr>
<tr>
<td>Job Outcome: Job Demand</td>
<td>5.22</td>
<td>1.27</td>
<td>5.42</td>
</tr>
<tr>
<td>Past Experience with IS</td>
<td>3.87</td>
<td>1.37</td>
<td>3.68</td>
</tr>
<tr>
<td>Ease of Use</td>
<td>4.34</td>
<td>1.45</td>
<td>3.99</td>
</tr>
<tr>
<td>Age (years)</td>
<td>45.87</td>
<td>9.79</td>
<td>46.26</td>
</tr>
<tr>
<td>Female/Male (%)</td>
<td>53/47</td>
<td>54/46</td>
<td>54/46</td>
</tr>
</tbody>
</table>

*Notes:* a Difference between T0 and T1 significant at 0.05 level; b Difference between T0 and T2 significant at 0.05 level; No significant changes detected between T1 and T2.

**Structural Effects Over Time**

The estimated structural effects at T0, T1 and T2 are summarized in Table 3. Figure 2 provides a visual aid illustrating the significant path changes across time.

At T0, shortly after implementation, standardization of processes helps improve turnaround times, whereas documentation quality adversely affects turnaround time. We did not find evidence of standardization or documentation quality significantly impacting medical error reduction at this point. After 3 months of the implementation (T1), we do not find documentation quality to be negatively associated with turnaround times, but we find it, as well as process standardization, to positively impact medical error reduction. We also find process standardization to increase job demand. Finally, we see an additional shift at T2, 6 months post-implementation. Documentation quality further impacts medical error reduction. Standardization no longer increases job demand and no longer directly impacts medical error reduction. Instead, we see that standardization impacts medical error reduction only indirectly through improved turnaround time. A Sobel test indicates that this full mediation is statistically significant ($z = 1.9; p < .05$). We did not find any of the effects on job demand to be mediated.
Table 3. Multi-Group Analysis of Structural Effects Over Time

<table>
<thead>
<tr>
<th></th>
<th>T0 (implementation)</th>
<th>T1 (3 months)</th>
<th>T2 (6 months)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>TTR</td>
<td>MER</td>
<td>JDE</td>
</tr>
<tr>
<td>DQ</td>
<td>-1.625*</td>
<td>-.261</td>
<td>.264</td>
</tr>
<tr>
<td>STN</td>
<td>1.972***</td>
<td>1.302</td>
<td>.125</td>
</tr>
<tr>
<td>TTR</td>
<td>-</td>
<td>-.403</td>
<td>NA</td>
</tr>
<tr>
<td>MER</td>
<td>NA</td>
<td>-</td>
<td>NA</td>
</tr>
</tbody>
</table>

Notes:
1. ***p < 0.001,**p < 0.01, *p < 0.05; N.S.: non-significant
2. One-tailed tests were performed as the direction of differences was hypothesized.
3. $\chi^2 = 300.54; \chi^2/df = 1.38; \text{RMSEA}=0.036; \text{NFI}=0.900; \text{CFI}=0.964$
4. STN = CPOE-Enabled Standardization; DQ = CPOE-Enabled Documentation Quality; TTR = Perceived Turnaround Time Reduction; MER = Perceived Medical Error Reduction; JDE = Perceived Job Demand

Figure 2. Multi-Group Analysis Comparing Structural Effects Over Time

Notes:
1. Path coefficient is significant at: ***p < 0.001,**p < 0.01, *p < 0.05. The circles report variance explained (R²)
2. STN = CPOE-Enabled Standardization; DQ = CPOE-Enabled Documentation Quality; TTR = Perceived Turnaround Time Reduction; MER = Perceived Medical Error Reduction; JDE = Perceived Job Demand
To assess significant differences in path coefficients across time, we performed a series of t-tests (Table 3).

### Table 4. Path Comparisons Over Time of the CPOE Implementation

<table>
<thead>
<tr>
<th>Path</th>
<th>T0 → T1</th>
<th>T0 → T2</th>
<th>T1 → T2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standardization → Turnaround Time</td>
<td>**</td>
<td>***</td>
<td>NS</td>
</tr>
<tr>
<td>Standardization → Medical Error Reduction</td>
<td>NS</td>
<td>**</td>
<td>***</td>
</tr>
<tr>
<td>Standardization → Job Demand</td>
<td>+</td>
<td>NS</td>
<td>**</td>
</tr>
<tr>
<td>Documentation Quality → Turnaround Time</td>
<td>+***</td>
<td>+***</td>
<td>NS</td>
</tr>
<tr>
<td>Documentation Quality → Medical Error Reduction</td>
<td>NS</td>
<td>+**</td>
<td>+**</td>
</tr>
<tr>
<td>Documentation Quality → Job Demand</td>
<td>+***</td>
<td>-***</td>
<td>NS</td>
</tr>
<tr>
<td>Turnaround Time → Medical Error Reduction</td>
<td>+</td>
<td>+***</td>
<td>+***</td>
</tr>
</tbody>
</table>

**Notes:**
1. Path coefficient difference is significant at:***p < 0.001, **p < 0.01, *p < 0.05; N.S.: Path coefficient is not significant.
2. Plus and minus signs indicate the direction of the change.
3. One-tailed tests were performed as the direction of differences is theoretically expected.

### Discussion

Our paper makes three contributions. First, we contribute to our understanding about the mechanisms through which process benefits with respect to turnaround time and medical error reduction develop over time, thereby expanding our understanding about IS success in the context of IT-enabled processes (e.g., Hsieh et al. 2011; Morris and Venkatesh 2000; Rai and Hornyak 2013). Our results reveal that initially after implementation, CPOE-enabled standardization improves turnaround time as standardized order sets—i.e., one-off orders that may be driven by the idiosyncratic preferences of physicians. In contrast, CPOE-enabled documentation quality adversely impinges on turnaround time, likely due to the extra time it initially takes to establish the processes and culture necessary to develop documentation quality. With the passage of more time after implementation, the process benefits of standardization extends from turnaround time to a reduction in medical errors. In addition, the adverse impact of CPOE-enabled documentation quality on turnaround time wanes while the beneficial impact of CPOE-enabled documentation quality on medical error reduction persists. With additional passage of time in which the CPOE-enabled processes and new routines can be expected to stabilize, CPOE-enabled process standardization promotes improvement in turnaround time. Moreover, faster, standardized order processing, promotes medical error reduction above and beyond the influence of CPOE-enabled documentation quality. The temporal-lens uncovers the countervailing effects of CPOE-enabled standardization and documentation quality on process benefits with respect to turnaround time and medical error reduction and the progression of mechanisms through which process benefits develop over time in a CPOE implementation.

Second, we contribute to our understanding about the impacts of an IT-enabled process change on job outcomes of key stakeholders (Bala, 2013; Bala and Venkatesh 2015; Morris and Venkatesh 2000). Our results indicate that CPOE-enabled standardization imposes increased job demands on physicians particularly in the first few months following the implementation. However, these adverse impacts on job demands eventually disappear as the CPOE-enabled processes and new routines stabilize. This finding points to the critical need to manage the implementation so that any increase in perceived job demand among physicians is minimized and does not result in a loss of support or confidence among physicians.

Third, we contribute to the IS success literature by identifying IT-enabled standardization as a predictor of process benefits and job outcomes. The extent to which users perceive a new system and the benefits it produces as valuable, directly predicts its adoption success and subsequent organizational outcomes (DeLone and McLean 1992, Petter and McLean 2009; Rai et al. 2002). After accounting for documentation quality and ease of use (which we incorporated as a control), we found standardization to have a significant effect on the process benefits attributed to the CPOE system. The implication is that for classes of information systems targeted at processes (e.g., clinical processes as with CPOE), we need to
expand the system characteristics from information quality and system quality to consider operations standardization.

For practitioners, our research provides valuable insights into the dynamics of CPOE implementation and how physician perceptions are likely to play out over time. Based on our data, these systems ought not to be oversold to physicians. In fact, expectations should be managed appropriately so that physicians do not expect immediate benefits. Indeed, our data suggest that the benefits are real but that they accrue with time.

References


