Nurses’ perception of smart IV pump technology characteristics and quality of working life

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Abstract

Technology implementation in health care is increasing. The characteristics of the technology may affect user quality of working life (QWL) which has implications for technology use and job retention. We examined the relationship between technology characteristics of the new Smart intravenous infusion pump and nurse QWL at a U.S. academic hospital. Pump reliability predicted nurse organizational commitment and job satisfaction. The pump’s perceived ability to prevent errors predicted lower stress levels while frustration with pump alarms predicted burnout. The ability to explore new features by trial and error predicted lower satisfaction with quality of care provided. Health care organizations should consider the impact of technology characteristics on user QWL.

Keywords: nurses, smart IV pump, technology characteristics, quality of working life

1. Introduction

Health care organizations are seeing an explosion of new technology to improve the efficiency, quality, and safety of patient care. At the same time, hospitals are struggling with health care staff shortages and providers are experiencing high levels of job discontent. The work system, made up of people, tasks, tools and technologies, environment and the organization, forms the structure of health care leading to patient care processes and patient and worker outcomes [1]. Therefore, a change in one part of the system, e.g. technology implementation, will affect worker outcomes such as quality of working life (QWL). This in turn can affect the worker’s interaction with the technology and their perceptions about its use, including acceptance. Technology characteristics and perceptions of those characteristics can influence the QWL of end users. For instance, technology problems, such as lack of usability and poor performance, can affect attitudes of end users toward their job and their reactions (e.g. stress) [2,3]. The Technology Acceptance Model (TAM) posits that technology acceptance is a proxy for technology use and without technology use, the efficiency, quality and safety benefits of the new technology will not be realized [4]. Many factors influence end-user technology acceptance including technology characteristics and job factors [5,6]. Therefore, technology acceptance, along with other perceptions of technology, may influence worker QWL.

Nurse QWL and retention are important considerations for health care organizations. It is projected that by the year 2020, the US nursing workforce will have a 20% shortage [7]. Nurse QWL has also been linked to the quality of care provided to
hospitalized patients [8]. Medication administration accounts for a large percentage of registered nurse duties [9], and the process itself accounts for half of the medication errors that reach the patient and cause harm [10]. New technologies, such as smart intravenous (IV) infusion pumps and bar coding at the point of care, provide automated medication double checks to prevent errors from reaching the patient [6,11]. In particular, the smart IV pump has built-in software with hospital specific drug libraries that have pre-set upper and lower dose limits for medications. These limits are called ‘guardrails’. When a dose is programmed outside of the limits, an audiovisual alert is presented to the user to provide an opportunity for reprogramming of an erroneous dose.

As smart IV pumps are a relatively new technology in health care, user perceptions of the pump characteristics have been little studied [6,12]. We have previously found that perceptions regarding six technology characteristics were predictive of nurse technology acceptance six weeks after technology implementation [6]. Higher pump acceptance was predicted by perceptions that the pump makes it easier to do the job, enhances job effectiveness, increases the safety of care provided, and functions as expected. Lower pump acceptance was predicted by perceptions that the pump interface was rigid or that alarm messages for pump functioning were frustrating.

In this study, we evaluated nurse perceptions of the IV pump technology characteristics and technology acceptance one year after pump implementation and explored the relationship between technology perceptions and QWL.

2. Methods

The study setting is a 450-bed US Midwest academic tertiary care center. Smart IV pumps were implemented hospital-wide to decrease intravenous medication administration errors. Use of the new IV pump was mandatory for intravenous infusions. Nurses who worked on inpatient units and other areas of the hospital with IV pump use were given a paper survey after training sessions one-week prior to implementation and sent a web-based survey 6 weeks and one year after IV pump implementation. Reminder emails were sent weekly for three weeks to non-responders.

The one-year post implementation survey inquired about user demographics (age, education level, length of time at present job), perceptions of technology characteristics, job characteristics and QWL. Questions about technology characteristics perceptions, in particular regarding usability and technical performance, were modified from a computer user satisfaction survey [13], and the Questionnaire for User Interface Satisfaction version 5.0 [14]. The questions dealt with learnability (6 questions), efficiency (11 questions), memorability (1 question), errors (5 questions), user satisfaction (5 questions), technical performance (6 questions) and technology acceptance (1 question). Questions were scored on a 7- or 10-point negative to positive scale except for seven of the efficiency questions which were scored on a 7-point positive to negative scale (see Table 1). QWL outcomes included organizational commitment, adapted from a 3-item scale [15]; daily life stress, obtained from a 4-item scale [16]; job satisfaction, derived from a 5-item scale [17]; burnout, from an adapted MBI emotional exhaustion scale [18]; and satisfaction with quality of care provided, evaluated on a 5-point scale by the question, “In general, I am satisfied with the quality of care that I provide” [19]. Responses for this question were grouped into three categories for the analyses (low (1-3), med (4) and high (5)). The study was approved by the Institutional Review Board.

The data were analyzed using SPSS© software. Descriptive statistics were performed. Exploratory analyses were performed to identify relationships between perceptions of technology characteristics and the five measures of QWL. Pearson and Spearman correlations identified those technology characteristics that were significantly related to the QWL measures. These characteristics were then entered into a series of stepwise regression analyses to identify the main predictors of QWL. The two rho correlation values were only significantly different for the organizational commitment variable correlations, hence, both are reported and were used in the regression analyses.

3. Results

Three hundred ninety-nine nurses answered the questionnaire for a survey response rate of 38%. Forty-five percent of nurse users were under the age of 34, 26% aged 35-44 and 29% aged 45 and older. The majority had been educated in a bachelor degree program (76%) and 44% had worked in their current job position for 6 years or longer.
Table 1. Correlations between Pump Characteristics and Quality of Working Life*

<table>
<thead>
<tr>
<th>Pump Characteristics</th>
<th>Org Comm</th>
<th>Stress</th>
<th>Job Sat</th>
<th>Burn-out</th>
<th>Qual Care</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acceptance</td>
<td>Acceptance of pump</td>
<td>.12* / .15**</td>
<td>.07</td>
<td>.05</td>
<td>- .02</td>
</tr>
<tr>
<td>Learnability</td>
<td>Learning to operate the pump</td>
<td>- .01 / .05</td>
<td>- .02</td>
<td>.06</td>
<td>- .05</td>
</tr>
<tr>
<td></td>
<td>Exploring new features by trial and error</td>
<td>- .05 / .00</td>
<td>- .02</td>
<td>.04</td>
<td>- .06</td>
</tr>
<tr>
<td></td>
<td>Supplemental training materials</td>
<td>.06 / .06</td>
<td>.06</td>
<td>.12*</td>
<td>- .05</td>
</tr>
<tr>
<td></td>
<td>Designed for all levels of users</td>
<td>.13* / .15**</td>
<td>- .03</td>
<td>.13*</td>
<td>- .09</td>
</tr>
<tr>
<td></td>
<td>Knowing available channel labels</td>
<td>.07 / .09</td>
<td>.05</td>
<td>.08</td>
<td>- .02</td>
</tr>
<tr>
<td></td>
<td>Pump software navigation</td>
<td>.04 / .07</td>
<td>.02</td>
<td>.08</td>
<td>- .06</td>
</tr>
<tr>
<td>Efficiency</td>
<td>Accomplish tasks more quickly</td>
<td>- .12* / - .13*</td>
<td>- .02</td>
<td>- .04</td>
<td>- .03</td>
</tr>
<tr>
<td></td>
<td>Improves quality of care I provide</td>
<td>-.08 / -.12*</td>
<td>-.10*</td>
<td>- .04</td>
<td>- .07</td>
</tr>
<tr>
<td></td>
<td>Improves safety of care I provide</td>
<td>-.09 / -.15**</td>
<td>- .07</td>
<td>- .03</td>
<td>- .04</td>
</tr>
<tr>
<td></td>
<td>Enhances effectiveness on job</td>
<td>-.14** / -.16**</td>
<td>- .06</td>
<td>- .09</td>
<td>- .02</td>
</tr>
<tr>
<td></td>
<td>Makes it easier to do job</td>
<td>-.12*/ -.14**</td>
<td>- .07</td>
<td>- .06</td>
<td>- .04</td>
</tr>
<tr>
<td></td>
<td>Increases safety of care provided to patients</td>
<td>- .09 / -.13**</td>
<td>- .09</td>
<td>- .02</td>
<td>- .04</td>
</tr>
<tr>
<td></td>
<td>Patients feel they receive safer care</td>
<td>- .06 / -.07</td>
<td>- .05</td>
<td>- .04</td>
<td>- .04</td>
</tr>
<tr>
<td></td>
<td>Tasks performed in straightforward manner</td>
<td>.05 / .07</td>
<td>.02</td>
<td>.09</td>
<td>- .03</td>
</tr>
<tr>
<td></td>
<td>Functions as I expect</td>
<td>.14**/ .16**</td>
<td>- .02</td>
<td>.10</td>
<td>- .04</td>
</tr>
<tr>
<td></td>
<td>Easy to use in emergency situations</td>
<td>-.12*/ -.13*</td>
<td>- .04</td>
<td>- .04</td>
<td>.02</td>
</tr>
<tr>
<td></td>
<td>Drug library and guardrails increase safety and quality of care</td>
<td>- .10 / -.13*</td>
<td>- .09</td>
<td>- .03</td>
<td>- .02</td>
</tr>
<tr>
<td>Memorability</td>
<td>Remembering names and use of commands</td>
<td>.05 / .07</td>
<td>.059</td>
<td>.08</td>
<td>- .03</td>
</tr>
<tr>
<td>Errors</td>
<td>Drug library guardrails prevent errors</td>
<td>-.09 / -.12*</td>
<td>-.11*</td>
<td>- .06</td>
<td>- .01</td>
</tr>
<tr>
<td></td>
<td>Pump alarms when appropriate</td>
<td>-.15** / -.17**</td>
<td>- .03</td>
<td>- .06</td>
<td>- .02</td>
</tr>
<tr>
<td></td>
<td>Correcting your mistakes</td>
<td>.12* / .14**</td>
<td>- .02</td>
<td>.08</td>
<td>-.06</td>
</tr>
<tr>
<td></td>
<td>Alert messages for pump functioning</td>
<td>-.01 / .01</td>
<td>- .04</td>
<td>.08</td>
<td>-.11*</td>
</tr>
<tr>
<td></td>
<td>Interface is... difficult–easy</td>
<td>.10 / -.13*</td>
<td>.06</td>
<td>.05</td>
<td>- .03</td>
</tr>
<tr>
<td></td>
<td>Interface is... frustrating–satisfying</td>
<td>.09 / .12*</td>
<td>.03</td>
<td>.05</td>
<td>.00</td>
</tr>
<tr>
<td></td>
<td>Interface is... rigid–flexible</td>
<td>.10 / .13*</td>
<td>.03</td>
<td>.05</td>
<td>.02</td>
</tr>
<tr>
<td></td>
<td>Confidence responding to alerts</td>
<td>.10 / .17**</td>
<td>.11*</td>
<td>.06</td>
<td>.00</td>
</tr>
<tr>
<td></td>
<td>Trust pump working correctly</td>
<td>-.10 / -.12*</td>
<td>- .06</td>
<td>- .00</td>
<td>-.07</td>
</tr>
<tr>
<td>Satisfaction</td>
<td>Speed of programming</td>
<td>.11* / .12*</td>
<td>.00</td>
<td>.09</td>
<td>- .09</td>
</tr>
<tr>
<td></td>
<td>Reliability</td>
<td>.16** / .18**</td>
<td>-.01</td>
<td>.15**</td>
<td>-.04</td>
</tr>
<tr>
<td></td>
<td>Noise</td>
<td>.05 / .06</td>
<td>-.02</td>
<td>.07</td>
<td>- .08</td>
</tr>
<tr>
<td></td>
<td>Drug library alert messages</td>
<td>.07 / .12*</td>
<td>.08</td>
<td>.02</td>
<td>.03</td>
</tr>
<tr>
<td></td>
<td>Air-in-line alarm</td>
<td>.02 / .04</td>
<td>.03</td>
<td>.03</td>
<td>-.01</td>
</tr>
<tr>
<td></td>
<td>Beeps resulting from delay</td>
<td>.11* / .13*</td>
<td>.02</td>
<td>.06</td>
<td>- .08</td>
</tr>
</tbody>
</table>

a QWL measures: organizational commitment, daily life stress, job satisfaction, burnout and satisfaction with quality of care. Pearson correlation rhos are reported except for organizational commitment (Pearson and Spearman correlations reported).
b Characteristics are scored on a negative to positive scale except the first seven measures of efficiency (scored on positive to negative scale). *p<.05, **p<.01

Table 2. Predictors of Quality of Working Life: Results of Stepwise Regression Analyses*

<table>
<thead>
<tr>
<th>Organizational Commitment</th>
<th>Stress</th>
<th>Job Satisfaction</th>
<th>Burnout</th>
<th>Satisfaction quality of care</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total number of variables</td>
<td>13 / 23</td>
<td>3</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>Adjusted r^2 (%)</td>
<td>2.7 / 2.5</td>
<td>1.0</td>
<td>1.8</td>
<td>1.0</td>
</tr>
</tbody>
</table>

Significant predictors (beta coefficient)
- Reliability (.173** / .166**)
- Drug guardrails prevent errors (-.11*)
- Reliability (.113*)
- Alarm messages for functioning (-.106*)
- Exploring new features by trial and error (-.11*)

* p<.05, ** p<.01. Two models were used for organizational commitment. The first was based on the Pearson correlations and the second added the additional measure significant by Spearman correlation.
3.1 Organizational Commitment

Thirteen technology characteristics and nurse technology acceptance were significantly correlated with organizational commitment (Table 1) by Pearson correlation. The technology characteristics included 3 measures of technical performance (speed of programming, reliability and noise resulting from delays in programming), 6 measures of efficiency (accomplish tasks more quickly, enhances job effectiveness, makes job easier, functions as expected, ease of use in emergency situations and drug library and guardrails increase safety and quality of care), 3 error measures (alarm when appropriate, easy of correcting mistakes and acceptable drug library alert messages) and 1 learnability measure (designed for all levels of users). Ten additional characteristics were significant by Spearman correlation including 3 efficiency measures (improves quality and safety of care), 1 error measure (drug library guardrails prevent errors), 4 satisfaction measures (interface flexibility, ease of use, trust pump and confidence responding to alerts) and 1 technical performance measure (drug library alerts acceptable). In stepwise regression analysis, only one variable was significant in both models. Nurses who perceived the pump to be more reliable had higher levels of organizational commitment.

3.2 Stress

Three technology characteristics were significantly related to daily life stress: perceptions that the pump improved the quality of care provided, the drug library guardrails preventing errors and user confidence responding to drug library guardrail alerts. In stepwise regression analysis, only one variable remained; nurses who perceive that the drug library guardrails prevent medication errors have lower levels of daily life stress.

3.3 Job satisfaction

Three characteristics were significantly correlated with job satisfaction: perceptions that the pump was designed for all levels of user, supplemental training materials being clear and high pump reliability. In stepwise regression analysis, only one variable remained; perceptions of pump reliability being high predicted higher nurse job satisfaction.

3.4 Burnout

One technology characteristic was significantly correlated with burnout and remained as a predictor of burnout in stepwise regression analysis: alarm messages for pump functioning. Nurses who perceived that the alarm messages for pump functioning were frustrating were more likely to have symptoms of emotional exhaustion indicating burnout.

3.5 Satisfaction with quality of care provided

One technology characteristic was significantly correlated with nurse satisfaction with quality of care provided and remained as a predictor in the stepwise regression analysis: exploring new pump features by trial and error. Nurses who perceived that the exploration of new features by trial and error was difficult were more likely to be satisfied with quality of care they provide. This unexpected result will be discussed.

4. Discussion

Nurse QWL is an important consideration in health care and can be affected by the introduction and use of technology. One year after smart IV pump implementation, we found relationships with pump technology characteristics and nurse QWL measures. Most notably, perceived pump reliability predicts both nurse organizational commitment and job satisfaction. Interestingly, the main safety feature of the pump, the drug library guardrails, was a predictor of lower daily life stress if nurses perceived that it prevented medication errors. Emotional exhaustion/burnout was predicted by user perception of pump alarm messages being frustrating. This characteristic was also associated with technology acceptance at both 6 weeks and one year post-implementation [6]. An unexpected finding was the relationship between exploring new features on the pump by trial and error and satisfaction with quality of care provided. This may be an artifact from the analysis or may be related to the perception that exploring new pump features by trial and error may lead to inaccurate use of the pump and therefore lower quality of care.

We had expected to find multiple strong relationships between technology characteristics and nurse QWL. One reason that we did not find these relationships may be related to the frequency of pump use, which may differ for nurses across care units in a hospital. Indeed, many of the studies linking technology characteristics and QWL have evaluated...
Table 3. Correlations in Frequent and Low/Moderate Pump Users

<table>
<thead>
<tr>
<th>Pump Characteristics</th>
<th>Org Comm</th>
<th>Job Sat</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Freq</td>
<td>Low/Mod</td>
</tr>
<tr>
<td>Acceptance of pump</td>
<td>.38**</td>
<td>.05</td>
</tr>
<tr>
<td>Supplemental training materials</td>
<td>.25*</td>
<td>.01</td>
</tr>
<tr>
<td>Designed for all levels of users</td>
<td>.33**</td>
<td>.07</td>
</tr>
<tr>
<td>Knowing available channel labels</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Pump software navigation</td>
<td>.22*</td>
<td>-.02</td>
</tr>
<tr>
<td>Achieve tasks more quickly</td>
<td>.43**</td>
<td>-.03</td>
</tr>
<tr>
<td>Improves quality of care I provide</td>
<td>-.27**</td>
<td>-.03</td>
</tr>
<tr>
<td>Improves safety of care I provide</td>
<td>-.28*</td>
<td>-.06</td>
</tr>
<tr>
<td>Enhances effectiveness on job</td>
<td>.43**</td>
<td>-.06</td>
</tr>
<tr>
<td>Makes it easier to do job</td>
<td>.38**</td>
<td>-.05</td>
</tr>
<tr>
<td>Increases safety of care provided to patients</td>
<td>-.27*</td>
<td>-.06</td>
</tr>
<tr>
<td>Patients feel they receive safer care</td>
<td>-.27*</td>
<td>-.02</td>
</tr>
<tr>
<td>Functions as I expect</td>
<td>.30**</td>
<td>.08</td>
</tr>
<tr>
<td>Easy to use in emergency situations</td>
<td>-.27*</td>
<td>-.08</td>
</tr>
<tr>
<td>Drug library &amp; guardrails increase safety and quality of care</td>
<td>-.29*</td>
<td>-.07</td>
</tr>
<tr>
<td>Drug library guardrails prevent errors</td>
<td>-.27*</td>
<td>-.06</td>
</tr>
<tr>
<td>Pump alarms when appropriate</td>
<td>.38**</td>
<td>-.10</td>
</tr>
<tr>
<td>Correcting your mistakes</td>
<td>.24*</td>
<td>.08</td>
</tr>
<tr>
<td>Alert messages for drug library</td>
<td>.32**</td>
<td>.06</td>
</tr>
<tr>
<td>Interface is... difficult–easy</td>
<td>.34**</td>
<td>.01</td>
</tr>
<tr>
<td>Interface is... frustrating–satisfying</td>
<td>.33**</td>
<td>-.01</td>
</tr>
<tr>
<td>Confidence responding to alerts</td>
<td>.33**</td>
<td>.06</td>
</tr>
<tr>
<td>Trust pump working correctly</td>
<td>-.24*</td>
<td>-.04</td>
</tr>
<tr>
<td>Speed of programming</td>
<td>.32**</td>
<td>.05</td>
</tr>
<tr>
<td>Reliability</td>
<td>.20*</td>
<td>.17*</td>
</tr>
<tr>
<td>Noise</td>
<td>-.16*</td>
<td>.12*</td>
</tr>
<tr>
<td>Drug library alert messages</td>
<td>.27*</td>
<td>.03</td>
</tr>
<tr>
<td>Air-in-line alarm</td>
<td>.29*</td>
<td>-.02</td>
</tr>
</tbody>
</table>

*p<.05, ** p<.01

users with intensive use of the technology in their job, e.g. video display terminal clerical workers and computer use [3]. Further analyses of the survey data suggest that frequency of pump use may mediate the effect of technology characteristics on QWL outcomes. Nurse respondents were dichotomized by nursing unit into two groups, those with frequent pump use (n=82) and those with moderate or low pump use (n=305). Correlations between technology characteristics and QWL measures were quite different for nurses with frequent pump use than for nurses with low/moderate use For frequent users, 25 characteristics were correlated with organizational commitment compared with 2 characteristics for low/moderate users (Table 3) and the strength of the association was much higher across the characteristics than what was seen with all users. Job satisfaction also was more likely to be correlated with perceived characteristics in frequent users than low/moderate users (7 characteristics versus 1). In addition, there may be interactions between technology characteristics and frequency of pump use that affect outcome variables. For example, an interaction term of pump acceptance and low/moderate pump use was a significant predictor of organizational commitment (beta coefficient .274, p=.004) in a stepwise regression model. This suggests that nurses with frequent use of the pump have higher organizational commitment. The interaction term was not significant for job satisfaction.

The effects of the technology characteristics on QWL may be mediated through job or technology characteristics [2,3]. The survey also evaluated workload and task control, two job characteristics typically related to stress and burnout [20,21]. In our sample, overall workload levels were high (mean (SD): 4.2 (7) on a 5-point scale) and task control levels were
moderate (mean (SD): 3.2 (.7) on a 5-point scale). Twenty-five of the thirty-four technology characteristics were significantly correlated with task control while none were correlated with workload. This suggests the potential for mediation of technology characteristics effects on QWL through task control. Also, the reliability technology characteristic itself was strongly correlated with many other pump characteristics and hence may serve as an intermediary for other pump characteristics’ effects on QWL. Further analyses should explore the relationships between the technology characteristics and mediation of effects on QWL through job characteristics.

Technology characteristics can significantly contribute to factors relating to user QWL. For smart IV pumps, the error decreasing potential of the drug library guardrails, its reliability, alarm messages, and ease of exploring new features all predict QWL outcomes important for inpatient nurses. Though the technology characteristics’ impact on QWL is small, it may vary based on frequency of pump use. As health care organizations increasingly implement new technologies, the impact on user QWL is an important consideration.

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