HARVARD | BUSINESS | SCHOOL

Work Design Drivers of Organizational Learning about Operational Failures: A Laboratory Experiment on Medication Administration

Anita L. Tucker

Working Paper

13-044

September 4, 2013

Work Design Drivers of Organizational Learning about Operational Failures: A Laboratory Experiment on Medication Administration

September 4, 2013

Anita L. Tucker

Associate Professor

Technology and Operations Management

Harvard Business School

Morgan Hall 413

Boston, MA 02163

atucker@hbs.edu

Abstract

Operational failures persist in hospitals, in part because employees work around them rather than attempt to prevent recurrence. Drawing on a process improvement tool—the Andon cord—we examine three work design components that may foster improvement-oriented behaviors: 1) blockages to prevent workarounds; 2) a support person to assist with problem-solving; and 3) education portraying operational failures as "waste" to be removed from the system. Using laboratory experiments, we test each component's impact on whether hospital nurses speak up about medication administration problems and contribute improvement ideas. We find that each component provides its own contribution to organizational performance. Blockages encourage people to suggest improvement ideas, while education sparks improvement suggestions even when there are no blockages. Blockages can backfire, however, if they are difficult to work around in a policy-compliant manner and problem-solving support is unavailable. Under these conditions, blockages led to a risky workaround associated with a 10X overdose of insulin. Risky workarounds can be mitigated with a readily-available support person, whose presence also elicits higher levels of speaking up about operational failures.

1. Introduction

Hospitals face an imperative to reduce medical errors, improve patient experience, and increase operational efficiency. However, operational failures—defined as instances when caregivers are unable to provide care due to missing information, equipment, supplies, or human resources—interfere with these goals by delaying patient care, wasting employee time, and contributing to poor quality of care. Workarounds, which are informal, temporary practices that achieve a work goal that otherwise would have been blocked by an operational failure, are common compensative responses (Halbesleben et al., 2008, Kobayashi et al., 2005). These workarounds can circumvent standard procedures, introducing variability and errors into processes.

Hospitals' frontline employees play a key role in improving organizational performance by identifying and helping to remove operational failures. However, most hospitals have a workaround culture in which nurses work around failures rather than voicing concerns and contributing improvement ideas (Ash et al., 2004, Koppel et al., 2008, Spear and Schmidhofer, 2005). We call this workaround behavior "first-order problem solving" (FOPS). Frontline employees in general tend to remain silent about problems (Burris, 2012, Detert and Treviño, 2010, Kish-Gephart et al., 2009). In contrast, second-order problem solving (SOPS) occurs when employees work around operational failures so that care can continue, but also speak up about the failure or offer suggestions to prevent recurrence (Tucker and Edmondson, 2003). We define SOPS as speaking up about an operational failure or contributing improvement ideas.

SOPS is one type of proactive employee behavior – specifically, employees' discretionary, anticipatory actions that attempt to bring about change (Crant, 2000, Grant and Ashford, 2008, Parker et al., 2006). These positive, discretionary behaviors in response to operational failures have also been referred to in the literature as improvement-oriented behaviors (Burris et al., 2012, Detert and Burris, 2007), pro-social behaviors (Brief and Motowidlo, 1986, McNeely and Meglino, 1994), initiative-taking (Frese et al., 1996), and voice (Ashford et al., 2009, Detert and Edmondson, 2011, LePine and Van Dyne, 1998). In the search for antecedents of proactive behaviors, scholars have focused on individual differences (Crant, 2000, Frese, et al., 1996, Pearce and Gregersen, 1991) and interpersonal dynamics of the work, such as trust, support, and autonomy (Edmondson, 2003, Grant and Parker, 2009, Parker, et al., 2006). These findings suggest that developing an improvement-oriented culture requires hiring employees with proactive personality traits. However, the nursing shortage (Buerhaus et al., 2000) makes it unlikely that hospitals can restrict themselves to hiring only proactive nurses. Furthermore, creating positive organizational culture and supportive managerial relationships can be difficult and may take a long time (Kotter, 1995). Thus, we join the set of researchers who examine job-design related drivers of speaking up about operational failures and contributing improvement ideas (Grant and Parker, 2009, Parker, 1998).

In particular, we turn to the Toyota Production System (TPS) for inspiration because it has been extremely successful at predisposing employees to speak up about operational failures that interfere with work (Imai, 1986, Liker, 2004, Robinson and Schroeder, 2009, Spear, 2004, Womack et al., 1990). To illustrate, in 1990, the average Toyota employee contributed nearly 62 suggestions, compared to only 0.4 suggestions per employee in U.S. and European car companies (Robinson and Schroeder, 2009, Womack, et al., 1990). In addition to offering improvement suggestions, Toyota employees also pull the "Andon cord" an average of 12 times per shift to signal to their manager that they have encountered a problem.[1] Pulling the cord stops the production line, which prevents defective products from leaving the plant (Mishina, 1992). Similarly, to prevent medical errors from reaching patients, hospitals have empowered frontline staff to "stop the line" when they have a safety concern (Bush, 2007, Connolly, 2005, Furman and Caplan, 2007, Jimmerson et al., 2005, Shannon et al., 2007, Wysocki, 2004).

In a series of laboratory experiments, we investigate three key components of Toyota's Andon cord: 1) *blockages* to prevent workarounds and "stop work" when an operational failure is encountered; 2) a readily available person who can provide problem-solving assistance (*"support person"*); and 3) *education* describing operational failures as "waste" – the removal of which is part of employees' routine work. We examine the impact of these components on hospital nurses' willingness to speak up about operational failures and suggest improvement ideas. To test for unanticipated negative consequences associated with blockages or the lack of a support person, we also consider the impact of the three components on workarounds and medication errors. This research thus advances understanding of employees' responses to operational failures by disaggregating individual work design components of a process improvement tool to test each component's influence on workarounds that could inadvertently harm patients (FOPS) and improvement-oriented behaviors that could improve performance (SOPS).

We find that participants were more likely to contribute improvement suggestions when blockages made it difficult to work around operational failures. However, participants who encountered the most severe blockage were also more likely to use against-policy ("risky") workarounds associated with a serious medication error (a 10X overdose of insulin). A readily available support person was associated with higher probability of speaking up and lower probability of risky workarounds. Thus, our findings suggest that work blockages and a support person should be used in combination with each other. . Finally, participants who watched an education video that portrayed operational failures as waste were significantly more likely to contribute improvement ideas than nurses who were not assigned to watch the

[1] The Andon cord is a thin cord that runs above a production line. Workers pull the cord when they encounter a problem that prevents them from completing their work correctly or within the allotted cycle time. Pulling the cord lights up their workstation number on an overhead board, which signals the worker's manager to go to that station to help remedy the situation. Mishina, K. 1992. *Toyota Motor Manufacturing, U.S.A., Inc.* Harvard Business Publishing, Boston, MA.

video. Therefore, our study suggests that the three Andon cord components each make their own contribution to increasing SOPS in hospitals.

2. Literature on the Impact of Work Design on Second-Order Problem Solving

2.1. Work Blockages

We first investigate blockages, which—at the extreme—make it impossible to work around operational failures. The lean production literature refers to this design principle as "poka-yoke" (Liker, 2004). A poka-yoke device stops the production line when an employee encounters an operational failure, which secures managerial attention to help address the situation so that production can continue (Kobayashi, et al., 2005, Nakajo and Kume, 1985, Vogelsmeier et al., 2008). The immediate goal of work flow blockages is to prevent defective products from continuing down the line (Stewart and Grout, 2001). It also records the occurrence of the operational failure, which aids improvement efforts.

Empirical research suggests that creating blockages to prevent workarounds and force communication about operational failures may be necessary because if permitted, employees tend to silently work around operational failures instead (Halbesleben et al., 2010, Halbesleben, et al., 2008, Jimmerson, et al., 2005, Kobayashi, et al., 2005, Spear and Schmidhofer, 2005, Tucker and Edmondson, 2003). There are several reasons for this kind of behavior. Workers do not want to be the cause of a production slow-down, and therefore they will elect to engage in a work around to avoid stopping the line (Schultz et al., 1998). In addition, workers are reluctant to take time away from production to communicate about operational failures (Tucker and Edmondson, 2003).

However, nurses may be more likely to speak up about operational failures when they encounter a blockage that increases the cost of the workaround. We consider two things that increase the cost of working around a blockage: violating organizational policy (risky workarounds) and increased time to complete the task. When nurses have to go against policy to work around an operational failure, they experience an uncomfortable dilemma: do they try to work around it, thus enabling them to provide care, but also requiring that they violate policy; or do they obey policy, but delay care to the patient? Research suggests that employees will feel this tension when they agree with the values that underlie the organizational policy prohibiting the workaround (Galanter, 1980, Tyler and Blader, 2005). Nurses are likely to agree with policies designed to protect patients from common medication errors as well as themselves from medical malpractice. For example, using insulin syringes, as opposed to tuberculin syringes, to administer insulin significantly reduces the chance of a ten-time (10x) overdose of insulin (Pennsylvania Patient Safety Authority, 2004). As a result, many hospitals have stipulated in their policies that insulin can only be administered with an insulin syringe. Thus, nurses who encounter a shortage of insulin syringes when they are required to administer insulin will face the difficult choice of either not administering the insulin in a timely fashion or dispensing it with a non-compliant tuberculin syringe.

Furthermore, deliberate work blockages can make it time-consuming to work around operational failures. For example, studies of barcodes in medication administration have found that information technology (IT) system blockages, such as a poorly scan-able barcode on a medication, increase the time required to administer medications (Holden et al., 2012, Koppel, et al., 2008). Problems that take longer to work around are more "difficult," increasing the burden the operational failure places on the nurses. Theory suggests that workarounds that take a long time to perform or require nurses to break policy will spur nurses to speak up about them and contribute improvement ideas to remove them. This is because the potential benefit of removing the underlying operational failure is greater than the cost of doing so (Grant and Ashford, 2008). Thus, we hypothesize:

Hypothesis 1a (H1a): Workers are more likely to speak up about operational failures when it is more difficult to work around them in a policy-compliant manner.

In addition to the reasons outlined above, research on pro-social behaviors also supports the hypothesis that difficult workarounds should increase employee efforts to contribute ideas on how the underlying operational failure could be removed. A prior study has found that people who involuntarily paid to engage in an initial round of pro-social behavior were more likely to voluntarily engage in future pro-social behaviors than individuals who were able to engage in the initial pro-social behavior at no cost to themselves (Gneezy et al., 2012). The authors theorized that because the worker paid to signal his altruism by investing in the common good, he wanted to leverage his payment by continuing to engage in pro-social behaviors. Similarly, nurses who demonstrate pro-social behavior by engaging in a time-consuming, difficult, but policy-compliant workaround will be more likely to engage in the pro-social task of improving work systems. We therefore hypothesize:

Hypothesis 1b (H1b): Workers are more likely to contribute improvement ideas related to operational failures when it is more difficult to work around them in a policy-compliant manner.

Despite the potential benefit of work blockages that increase employee willingness to try to prevent recurrence of operational failures, they may also encourage some employees to engage in risky workarounds. Risky workarounds are workarounds that are against organizational policy because they increase the chance that patients will experience harm because safety precautions are bypassed. For example, a risky workaround in barcode medication administration systems is placing duplicates of a patient's barcoded identification label on a piece of paper and using them for medication administration rather than scanning the actual label on the patient's wrist as dictated by policy (Holden, et al., 2012, Koppel, et al., 2008). This workaround makes it faster for nurses to withdraw and administer medications, but increases the chance of giving a medication to the wrong patient. Research has found that when employees encounter blockages that make it difficult to work around operational failures in a policy-compliant manner, they will engage in risky workarounds to complete their tasks (Ash, et al., 2004, Halbesleben, et al., 2008, Holden, et al., 2012, Koppel, et al., 2008). Thus, we hypothesize,

> *Hypothesis 1c (H1c): Workers are more likely to engage in risky workarounds when it is more difficult to work around operational failures in a policy-compliant manner.*

2.2. Support Person

The second factor that we examine is the physical presence of an official support person who can provide assistance when frontline employees encounter operational failures ("support person"). Prior research suggests that the physical presence of a problem-solving support person could encourage frontline employees to speak up about operational failures that they encounter. Specifically, manager availability and openness to communication is associated with higher levels of speaking up (Detert and Burris, 2007, Edmondson, 2003). Furthermore, an observational study of hospital nurses found that when managers were on their units, nurses were more likely to communicate about operational failures (Tucker and Edmondson, 2003). The physical presence of a manager reduced the time required to communicate about the operational failure, lowering the cost to the nurse of speaking up. Similarly, Halbesleben's study (2010) found that when a pharmacist was physically present on the nursing unit, the nurses reported their medication administration problems to that person rather than working around it on their own. Studies of help-seeking behavior show that accessibility of the help-provider is a key driver of whether or not the person in need of assistance speaks up (Borgatti and Cross, 2003, Hofmann et al., 2009). Thus, we hypothesize that having a problem-solving support person physically present and available on the frontlines will be associated with higher levels of speaking up about operational failures.

> *Hypothesis 2a (H2a): Workers are more likely to speak up about operational failures when a support person is physically present to help with problem solving.*

A problem-solving support person can also spur the frontline staff to contribute improvement suggestions. The physical presence of an authority figure helps generate nurses' commitment to the organization's goals (McGuire and Kennerly, 2006), which is a necessary condition for engagement in process improvement efforts, such as contributing suggestions for improvement (Lukas et al., 2007, Repenning, 2000, Zohar and Luria, 2007). In addition, being physically present on the frontlines will enable him or her to see operational failures in context, allowing a deeper understanding of the underlying causes, which can lead to more successful problem-solving efforts (Spear, 2004, von Hippel, 1994). Such problem-solving efficacy can increase employees' willingness to provide suggestions for improvement (Tucker, 2007). Thus, the presence of a support person is an important signal to employees that it is worth their time to contribute improvement ideas. We therefore hypothesize that when a problem-solving support person is readily available, workers will be more likely to contribute improvement ideas.

Hypothesis 2b (H2b): Workers are more likely to contribute improvement ideas related to operational failures when a support person is physically present to help with problem solving.

In addition, the physical presence of a problem-solving support person may minimize risky workarounds. Research has found that the physical presence of a pharmacist on a nursing unit was associated with lower medication errors, in part because nurses were less likely to engage in workarounds (Halbesleben, et al., 2010). Easy access to an expert might encourage people to seek help rather than trying to solve operational failures on their own (Borgatti and Cross, 2003, Hofmann, et al., 2009). Halbesleben (2010) speculated that the reduction in error rates was driven in part by the pharmacist's oversight of the nurses' actions, which dampened policy-violating behaviors. Other studies have also found that oversight from a figure of authority reduces deviant behaviors that violate organizational policies (Bernstein, 2012). For these reasons, we hypothesize:

Hypothesis 2c (H2c): Workers are less likely to engage in risky workarounds when a person is available to help with problem solving.

2.3. Education on Operational failures as Waste

The final component of Toyota's Andon cord procedure that we investigate is education that depicts operational failures as waste, which should be a part of the daily work of frontline staff to remove from the system. Toyota's employees are taught to detect opportunities for improving work processes and are expected to contribute improvement ideas on a daily basis (Spear, 2004). Research suggests that Toyota's success at improvement might be because it is part of employees' regular work rather than a discretionary, extra-role behavior (Liker, 2004, Plsek, 1999, Spear, 2005, Toussaint et al., 2010, Victor et al., 2000). Making process improvement part of the regular job of employees may lead to more speaking up and contributing improvement ideas for three reasons. First, employees should be able to identify more opportunities for improvement. When employees learn that managers want them to reduce the time that they spend working around operational failures, employees will begin to "see" process inefficiencies that they previously ignored or considered unchangeable (Spear, 2004). Second, studies have found that when employees define their job role broadly, they are more likely to engage in proactive behaviors which are essential to process improvement programs (Parker, 2000, Parker et al., 1997, Parker, et al., 2006). Employees are more likely to have a broad job definition when supervisors expect them to participate in improvement activities (Coyle-Shapiro et al., 2004, Morrison, 1994). Third, employees may be more likely to believe that it is worth their effort to communicate about operational failures if they know managers will want to hear about and help resolve them. This removes a major obstacle to speaking up and contributing improvement ideas, namely, employees' reluctance to spend time raising issues that they think the organization will disregard (Tucker, 2007). Thus, we hypothesize that employees will be more likely to engage in SOPS when they receive education that delineates what is considered waste and also shows their daily work routine to include speaking up about operational failures and suggesting ways in which their occurrence can be reduced. The rationale for this is that participating in such behavior is not an optional investment, but rather is a current job requirement (Coyle-Shapiro, et al., 2004, Morrison, 1994). We thus hypothesize,

Hypothesis 3a (H3a): Workers are more likely to speak up about operational failures when they receive education portraying operational failures as waste and showing process improvement activities to remove waste as part of their daily work.

Hypothesis 3b (H3b): Workers are more likely to contribute improvement ideas related to operational failures when they receive education portraying operational failures as waste and showing process improvement activities to remove waste as part of their daily work.

We also hypothesize that when employees receive such education, they will be less likely to engage in risky workarounds. Research on process improvement programs has found that when employees engage in SOPS activities, such as contributing improvement ideas, they have greater group cohesion (Wech et al., 1998). Group cohesion is associated with greater organizational commitment (Steel et al., 1990, Steel and Lloyd, 1988), which is an antecedent to compliance with policies (Angle and Perry, 1981, O'Reilly and Chatman, 1986). Thus, receiving education that removing waste from the system is part of one's expected daily work, nurses should be more likely to comply with organizational policies when working around operational failures. We hypothesize:

Hypothesis 3c (H3c): Workers are less likely to engage in risky workarounds when they receive education portraying operational failures as waste and showing process improvement activities to remove waste as part of their daily work.

3. Overview of our Research Methods

3.1. Method and Sample

We report on a series of laboratory experiments that tested conditions under which nurses were more likely to engage in SOPS in response to operational failures encountered during medication administration. We chose to use hospital nurses as participants because research has found that they have low levels of SOPS (Halbesleben, et al., 2010, Jimmerson, et al., 2005, Spear and Schmidhofer, 2005, Tucker and Edmondson, 2003, Vogelsmeier, et al., 2008). Medication administration is a fruitful context for studying SOPS because operational failures, such as missing medications or supplies, occur frequently (Halbesleben, et al., 2010) and can lead to inefficiency, errors, and frustration (Gurses and Carayon, 2007, Hall et al., 2010), which should motivate nurses to speak up. We conducted our experiments at national nursing conventions by renting exhibitor space and using the designated exhibitor hours to recruit participants and run the experiments. The experiments enabled us to isolate the impact of our variables of interest while removing the influence of other factors, such as time pressure and organizational culture, which impede SOPS in organizations (Tucker and Edmondson, 2002). Furthermore, we used laboratory experiments as opposed to field experiments because to incite SOPS among the nurses, we deliberately created medication-related operational failures. In a real hospital context, this could have posed significant health risks to actual patients.

We only recruited nurses who used needles in their daily work – as per the requirements of our IRB – because one of the ordered medications was insulin, putting participants at risk of an accidental needle stick. The experiment ran for roughly 20 minutes and participants received $10 after completion.

3.2. Overview of the Experiment

The experiment task was to dispense the 11:00 am medications for three fictitious patients—Smith, Wheeler and Lopez. In total, five medications were to be administered. Unknown to the nurses, we deliberately implanted two operational failures (described in detail below) in their medication system. Our main outcome variable was whether they engaged in SOPS in response to either operational failure.

3.2.1. Participant Instructions. Multiple nurses participated in the experiment at the same time, with one person at each experiment station. After recruiting four participants, the experimenter gave an overview of the instructions to the group. The experimenter explained that after answering a few questions about how they were currently feeling, they would administer medications to three fictitious patients, and then answer a few more questions about how they felt during the medication administration process. If asked, the experimenter explained the purpose of the experiment was to study the thoughts and feelings of nurses during medication administration. Participants were told that they were co-workers and could ask each other to double check their medications just like they would on their nursing units. The experimenter used one of the stations to demonstrate where supplies and medications were located.

3.2.2. Experiment Set Up. An experiment “cell” consisted of either one (Study 1) or two (Studies 2 and 3) long tables in an exhibitor’s 10’ X 10’ space at the conference. For every table, we had two medication administration stations that were positioned as far apart as possible to allow for enough space in between. Each station accommodated one participant and had a unique identifying color, which matched the color of an identification card contained within an envelope that we randomly distributed to participants to assign them to a station. Tables were arranged at opposite sides of the exhibitor booth facing away from each other, such that participants had their backs to other participants in the same cell.

Each station had a computer, which was preloaded with a web-based survey (Qualtrics) that provided the participant with the clinical information needed for the 11 a.m. medication administration tasks, as well as other survey questions, which we used to check the efficacy of our manipulation and to gather our control variables (described later in the paper in Study 1’s variable section). An example of a patient’s medication administration script is shown in **Figure 1**. In addition to the information shown on the computer, all nurses were also provided with a binder that contained each patient’s complete medication administration record and order, diagnosis, allergies, and other personal information such as birthdate. Nurses could use this additional information to verify that there were no inadvertent medication interactions, patient vital signs, or patient allergies that warranted withholding medication. There were no reasons to withhold any of the patients’ medications so nurses should have administered all of the 11 o’clock medications.

Figure 1. Experiment Script for the Insulin Patient’s Medication Administration Task

Patient #3: Martina Lopez
Date of Birth: 5/2/1961
Diagnosis: Diabetic Ketoacidosis/ Type I diabetes
Physician: Victor Peacock

11:00 medications
Practi-Regular Insulin (U-100)

Martina Lopez is a 50-year old, newly-diagnosed, insulin dependent diabetic. Her blood glucoses have been ranging from 150mg/dl to 350mg/dl.

The lunch tray for Martina Lopez has arrived on the floor and is the correct diet. She is hungry and wants to eat lunch and can eat within the next 15 minutes.

You just checked her blood glucose level it was 270 mg/ dL. Please use the standardized sliding scale provided below to draw up the correct dose.

Standardized Sliding Scale (for Practi-Regular Insulin U-100)

0-60	Initiate Hypoglycemic Protocol
61-150	No Insulin
151-200	3 units SQ
201-250	5 units SQ
251-300	8 units SQ
301-350	10 units SQ
351-400	12 units SQ
>400	15 units SQ and call MD

Write your ID number in the box below to signify that you gave the ordered dose, or enter the letter "W" if you would like to withhold the medication dose.

We used a small, plastic chest of 16 drawers to simulate the type of medication cabinets used in hospitals that have a manual medication administration system rather than automated dispensing devices. We designed the medication system to resemble as closely as possible the system that nurses actually use in practice. For example, each of the three patients had a drawer labeled with his or her name and the drawer was stocked with the patient's remaining medications for that day. In addition, to simulate the medication preparation room, we stocked each station with a bin of general supplies used in medication administration, including tuberculin syringes (marked in milliliters "mLs"), needles, alcohol swabs, and insulin vials. Furthermore, to make the medications themselves as realistic and safe as possible, we purchased fake medication from a company that sold training supplies to nursing schools. The medications had dosages, packaging, shapes, colors, and names that were nearly identical to actual medications (Practi-Digox^{TM} instead of digoxin). Patients were represented by see-through, plastic, zippered pencil pouches labeled with the patient's name and date of birth. This provided two forms of identification as required by policy to administer medications. Participants put the medication into the pouch to signify that they gave the medication to that patient. After each nurse completed the experiment, we recorded the medications and dosages he or she administered as well as the medical supplies used, and then emptied the pouches, disposed of trash, and restocked the medications for the next participant.

3.2.3. Description of the Operational Failures. To create opportunities for SOPS, we deliberately embedded two operational failures into the medication workstation. One operational failure was that one of the patients (Wheeler) was missing an ordered oral medication pill (digoxin) used to treat her heart condition. Participants did not have to speak to the experimenter to obtain the pill, however, because one was in the drawer of another patient (Smith), who came before Wheeler. While preparing Smith's medications, they could notice that Smith's drawer had a digoxin tablet, which was not due until much later that evening. Therefore, nurses could borrow the medication from Smith to give to Wheeler. They also could take a digoxin from the drawer of a fourth patient (Keegan). Participants had no information about Keegan and were not required to treat him. Borrowing a medication from one patient to give to another is a common workaround, although it is against most hospitals' policies (Holden, et al., 2012). The second operational failure we created in the medication administration system was a lack of an insulin syringes at the individual workstations. Patient Lopez required eight units of insulin. Insulin is typically only administered with insulin syringes because they are marked in units. However, the supply bins at the experiment stations were stocked with tuberculin syringes, which are marked in milliliters (mLs). Participants could workaround the missing insulin syringes by converting the 8-unit dose into a 0.08 mL dose. The conversion was done by dividing the number of units ordered (8 units) by the insulin concentration marked on the insulin vial (100 units/ mL) to arrive at the 0.08 mL dose. We also provided a conversion chart in the medication binder. However, using a mL syringe to administer insulin violates most hospitals' policies due to the well-documented risk of the medication error associated with administering insulin with a mL syringe (Cohen, 2003).

4. Pilot Test: Methods, Sample, and Procedures

We pilot tested the experiment set-up at the American Association of Critical Care Nurses annual conference, which was held in Chicago in 2011. In this experiment, there were no insulin syringes available at all, and the digoxin was available in the other patients' drawer as described above or from the experimenter if participants asked the experimenter for digoxin. We recorded whether the participant spoke to the experimenter about the missing medication or syringe. Our outcome variable, "speaking up," was coded as a "1" if the participant spoke to the experimenter about at least one of the two operational failures and "0" if he or she did not.

4.1. Pilot Test Results

A total of 25 participants completed the experiment. Based on prior field research, we had anticipated that few participants would speak up about the operational failures and would instead work around them. However, 92% (n=23) of the participants spoke up by asking for an insulin syringe or a digoxin pill and 28% (n=7) refused to work around the missing insulin syringe by using the mL syringe. Many of the participants were visibly unhappy to be in a situation where they had to choose between potentially making a medication error as a result of an against-policy workaround ("risky workaround") or withholding a needed medication. A surprising finding was that of the 18 (72%) participants who used an mL syringe, one in four (27.7%, n=5) drew up a 10X overdose (.8 mL rather than .08 mL). In fact, only 36% of the participants (n=9) were able to successfully work around the no insulin syringe operational failure. We concluded that work blockages forced speaking up, but also led to risky workarounds associated with medication errors. In subsequent experiments, therefore, we looked closer at the relationships between blockages, speaking up, workarounds that either complied with or violated standard hospital policy, and medication errors.

5. Study 1: Blockages that Make Workarounds Difficult

5.1. Methods

To test H1, which predicted that work blockages would foster SOPS and risky workarounds, we rented exhibitor booths at the Academy of Medical-Surgical Nurses national nursing conference in Salt Lake City in 2012. Over 900 nurses attended the conference. We operationalized work blockages by manipulating the difficulty of engaging in a policy-compliant workaround. The experiment set-up consisted of two separate experiment cells, each with two workstations. The "easy workaround" cell had a "pharmacy" set up on a small table in the exhibitor booth. The pharmacy contained the missing supplies that participants needed to work around the two operational failures in a policy-compliant manner. The pharmacy had a bin with ten insulin syringes and several tuberculin syringes. There was also a stack of 20 labeled medication boxes, one of which was digoxin. Thus, unlike the pilot test, participants could obtain an insulin syringe and digoxin from the pharmacy without having to talk to the experimenter. Half of the participants were randomly assigned to the easy workaround condition. The other booth was the "difficult workaround" cell because it did not have a pharmacy and was located in an adjacent row in the convention center exhibit space, about 80 feet from the pharmacy cell. Participants in this cell could not see the experimenter or the cell with the pharmacy. All participants were recruited and instructed from a third booth that was adjacent to the easy cell. During the instructions, participants in both cells were told about the pharmacy. The experimenter pointed to where it was and told participants that they should feel free to look there if they needed something, such as gloves. The difficult station participants were then walked over to their stations while the experimenter explained that we needed multiple stations to get the required sample size, but were unable to rent three adjacent booths due to late registration.

5.2. Variables

5.2.1. Outcome variables. In addition to the speaking up outcome measure described in the pilot study, we also measured whether the nurse contributed an improvement idea. At the end of the medication tasks, the computer survey script stated, "If you have any ideas about changes to improve the efficiency of the medication dispensing process in this experiment, please write them on the 'Improvement Opportunity' slips located in your unit supply bin." Pens and a stack of papers labeled "Improvement Opportunity" were placed between the two workstations at each table. Participants could also enter free text into the computer under the question prompt. We read through all of the improvement ideas to verify that they were valid suggestions. The dependent variable, "*improvement idea*" was coded 1 if the participant wrote an improvement slip and 0 if he or she did not.

Our third outcome was "*risky workaround,*" which was created based on the data collected by the experimenter after each participant completed the experiment. This variable was coded as "1" if the participant had used a tuberculin (mL) syringe to administer the insulin or if the participant used a digoxin pill from another patient's drawer, which could be deduced by checking the drawers of other patients. If it had been taken from another patient's drawer, we returned the digoxin to the appropriate drawer for the next participant. Administering one patient's medication to a different patient and using a tuberculin syringe to administer insulin are considered risky workarounds because they are unsafe medication practices and violate most hospitals' policies (Cohen, 2003, Holden, et al., 2012). "Safe" workarounds involved using an insulin syringe and digoxin from the pharmacy. If participants used only safe workarounds, they received a "0" for risky workarounds.

We also recorded the amount of insulin in the syringe. Participants who drew up an amount other than 8 units (.08 mL) received a "1" on *insulin error* and a "0" if they drew up 8 units (.08 mL). Participants who drew up 80 units received a "1" on the variable, *10x overdose*, and a "0" otherwise.

5.2.2. Independent Variables. We coded participants who were in the experiment cell that was a long distance from the pharmacy with a "1" on "*difficult workaround,*" while those who were in the cell with the pharmacy received a "0."

5.2.3. Control Variables. We controlled for individual differences related to self-assurance, problem-solving efficacy and felt responsibility because prior research has theorized that these traits make it more likely that employees will determine that the benefits from engaging in proactive behaviors outweigh the costs (Ashford, et al., 2009, Morrison and Milliken, 2003). We also controlled for attentiveness to account for participants who were not particularly alert before the medication administration tasks. We measured participant's *self-assurance* and *attentiveness* at the beginning of the experiment—before administering any medication—by asking questions from the Positive and Negative Aspect Scale (PANAS) (Watson et al., 1988). This statement preceded the questions: "This scale consists of a number of words and phrases that describe different feelings and emotions. Indicate to what extent you feel this way right now (that is, at the present moment)." The 5-point response scale was "very slightly or not at all", "a little", "moderately", "quite a bit", and "extremely". The self-assurance construct consisted of the following adjectives: proud, strong, confident, bold, daring, and fearless (Watson, et al., 1988). Cronbach's alpha was 0.80 (n=44). We used the mean of these six items to calculate a self-assurance score for each person. The attentiveness construct was calculated in a similar fashion and included the following adjectives: alert, attentive, determined, concentrating (Cronbach's alpha = .91).

After completing the medication administration tasks and filling out the improvement suggestion slips, but before answering any questions about the operational failures, participants answered questions measuring felt responsibility (Pearce and Gregersen, 1991) and problem-solving efficacy (Kasouf et al., 2006, Tucker, 2007). We asked the felt responsibility and problem-solving efficacy questions at this point in the experiment so that the questions would not influence participant behavior during the medication administration task or their contribution of improvement ideas. For both felt responsibility and problem solving efficacy, we used a 5-point response scale ranging from strongly disagree to strongly agree, with the midpoint being neither agree nor disagree. We used the mean of three items to create *felt responsibility*: "It is up to me to bring about improvement in processes I use for work." "I feel a personal sense of responsibility to bring about change." "I feel responsible to introduce new procedures to complete my work more efficiently." Cronbach's alpha for felt responsibility was 0.91. *Problem-solving efficacy* measured the extent to which employees felt that raising concerns to their managers would lead to positive change (Tucker, 2007). We took the mean of three items: "It was worth my time to communicate about problems I experienced during this experiment." "Bringing problems to the experimenter's attention resulted in the problem being resolved." "It was worth my effort to resolve problems with this experiment." Cronbach's alpha for this construct was 0.66.

5.3. Sample

Forty-six nurses participated in the experiment, 22 in the difficult and 24 in the easy workaround condition. However, two participants in the easy workaround conditions had missing control variables and were dropped from the analysis, leaving a final sample size of 44. The majority of participants were non-manager nursing staff (91%) on medical-surgical units (89%). There was no difference between participants randomly assigned to the difficult workaround and easy workaround stations for the control variables of self-assurance, felt responsibility and problem-solving efficacy ($p>.10$). Finally, as there were over 900 nurses at the conference, 5% of nurses attending the conference participated in our experiment, which is a very small percentage, making it very unlikely that participants had heard about the experiment from prior participants. Furthermore, none of the participants indicated that they had heard about the experiment from prior participants.

5.4. Manipulation Check for Difficulty of Engaging in a Policy-Compliant Workaround

We checked the manipulation of work blockage by asking participants the following question, "It was easy to get the supplies that I needed to administer the medications." The response scale was 1 for strongly disagree and 5 for strongly agree. Participants answered this question after they had administered the medications and contributed improvement ideas, but before they answered questions about felt responsibility or problem-solving efficacy. A t-test of means in response to this question between the easy and difficult workstation participants was significant ($t=2.35$, $p<.05$, two-sided test), with participants from the easy stations reporting higher scores (mean 4.1, std error 0.30) than participants from the difficult stations (mean 3.05, std error 0.33).

5.5. Results from Study 1

Table 1 shows the means, standard deviations, and correlations for our variables of interest. Being in the difficult workaround station was positively associated with contributing improvement ideas ($\rho=.61$, $p<.001$) as well as engaging in risky workarounds ($\rho=.36$, $p<.05$), which in turn was positively correlated with making a 10x overdose with the insulin dose ($\rho=.33$, $p<.05$). Overall, 48% of participants used a risky workaround, and of those, about 75% were in the difficult workaround condition. About 39% of participants (n=17) used the mL syringe to administer insulin, and just over a third took the digoxin pill from another patient's drawer. With regard to insulin errors, 13.6% (n=6) administered an incorrect amount of insulin, with four (9%) administering ten times the required amount.

Table 1. Means, standard deviations, and correlations for the main variables for Study 1. (n=44 participants)

	Mean (SD)	1	2	3	4	5	6	7	8	9	10
1. Wrote improvement slip	0.39 (.49)										
2. Spoke up about problem	0.34 (.48)	-0.08									
3. Insulin dose error	0.14 (.35)	-0.04	0.13								
4. 10X overdose of insulin	0.09 (.29)	-0.09	-0.06	0.80***							
5. % medications omitted	0.06 (.17)	-0.30*	0.18	0.32*	0.07						
6. Risky workaround	0.48 (.51)	0.36*	-0.11	0.15	0.33*	-0.20					
7. Difficult station	0.50 (.51)	0.61***	0.24	0.00	0.00	-0.21	0.50***				
8. Self-assurance	3.68 (.65)	0.27^	-0.39**	-0.20	-0.33*	-0.13	0.04	0.07			
9. Attentiveness	4.05 (.81)	0.24	-0.15	0.14	0.10	-0.20	0.29^	0.25	0.56***		
10. Problem-solving efficacy	3.90 (.56)	0.13	-0.08	-0.09	-0.19	-0.21	0.07	0.03	0.19	0.30*	
11. Felt responsibility	4.03 (1.04)	0.05	-0.16	-0.35*	-0.01	-0.18	-0.01	0.01	-0.05	-0.10	-0.08

*** p<0.001, ** p<0.01, * p<0.05, ^ p<0.10

To test our hypotheses, we employed a logistic regression due to the binary nature of our outcome variables. We controlled for self-assurance, attentiveness, problem-solving efficacy, felt responsibility, whether the nurse had a bachelor's degree or higher (1=yes, 0 = no), and if they had been a nurse for more than 15 years (1=yes, 0=no). **Table 2** reports the results from the logistic regression as well as the average marginal effects (AME). As Model 1 shows, we find no evidence of an effect of the difficulty of the workaround on the likelihood of speaking up about the operational failures, lending no support for H1a. Although self-assurance was negatively associated with speaking up (β= -1.761, p<.05), felt responsibility and problem-solving efficacy were *not* significant at predicting speaking up.

Table 2. Study 1 Logistic Regression Results, Coefficients are Log Odds, Std Errors in Parentheses (n=44 participants, 22 in difficult and 22 in easy workaround)

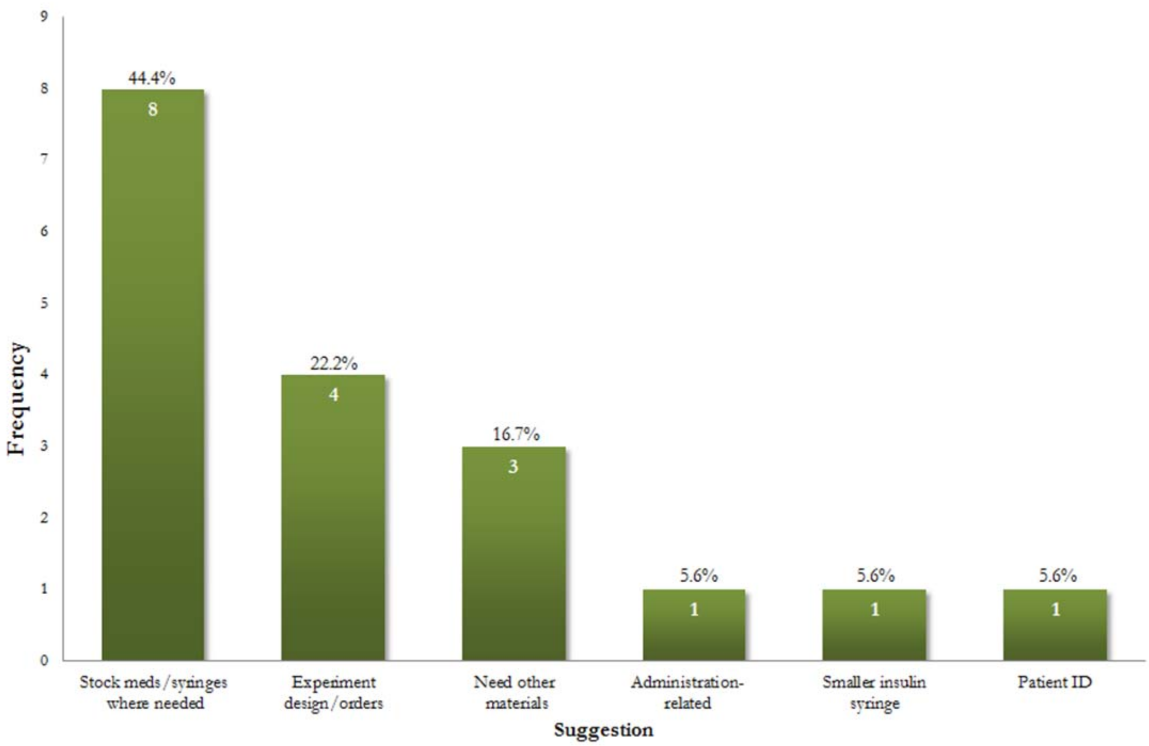
	Model 1		**Model 2**		**Model 3**	
Outcome variable	*Spoke Up (a)*		*Improvement Idea (b)*		*Risky Workarounds (c)*	
	Logistic Coefficient	AME	Logistic Coefficient	AME	Logistic Coefficient	AME
(H1) Blockage	1.225	0.195	3.629***	0.592	3.066**	0.514
(difficult to work around)	(0.858)		(1.074)		(1.029)	
Self-assurance (pre)	-1.761*	-0.265	1.648	0.211	-0.941	-0.133
	(0.771)		(1.023)		(0.842)	
Attentiveness (pre)	0.051	0.008	-0.157	-0.02	0.841	0.119
	(0.631)		(0.809)		(0.695)	
Problem-solving efficacy	0.252	0.038	0.206	0.026	0.490	0.069
	(0.775)		(0.896)		(0.910)	
Felt Responsibility	-0.501	-0.075	0.009	0.001	0.339	0.048
	(0.384)		(0.427)		(0.448)	
Tenure >=15 yrs	0.127	0.019	0.297	0.038	-1.956*	-0.276
	(0.846)		(0.887)		(0.974)	
At least Bachelor's degree	-1.363	-0.227	0.307	0.039	1.729^	0.236
	(0.834)		(0.936)		(0.986)	
Constant	6.512^		-9.344*		-5.028	
	(3.835)		(4.393)		(4.179)	
LR Chi^2 (7)	15.55*		23.10**		22.16**	
Pseudo R^2	.28		.39		.36	

*** p<0.001, ** p<0.01, * p<0.05, ^ p<0.10

Model 2 provides support for H1b because the coefficient for blockage is significant and positive, indicating that participants in the difficult workaround condition were more likely to contribute improvement ideas (β=3.629, p<.001). The average marginal effect indicates that being in the difficult work around condition increases the probability of a participant contributing an improvement idea by 59.2 percentage points, increasing the average predicted probability from 8.8% to 68%. Out of the 18 improvement ideas that participants offered, 44% addressed missing medication or syringes. However, as **Figure 2** shows, participants also contributed valid improvement ideas about five other types of issues, such as stocking smaller insulin syringes to make it easier to accurately administer the 8-unit dose.

In Model 3, we find that being in the difficult workaround station increased the probability of engaging in a risky workaround by 51.4 percentage points, from 21% to 72.5% (β=3.066, p<.01), providing support for H1c. Participants who used risky workarounds were more likely to make medication errors. Of those participants who performed a risky workaround, 19% (n=4) administered a 10X insulin overdose while no participants who used a safe workaround did (t=-2.27, p<.05, two-tailed).

Figure 2. Histogram of Improvement Suggestions from Study 1 (n=18 ideas)



Study 1 thus suggests that employees who encounter work blockages will be more likely to contribute improvement ideas, but also more likely to use a risky workaround that can lead to error. Therefore, it appears that managers should not use work blockages alone as a mechanism to increase frontline employees' SOPS. One limitation of Study 1 was that the experimenters were not easily accessible to participants to provide problem solving support. Toyota's implementation of the Andon cord system uses an easily accessible problem solving support person in combination with blockages, which might decrease risky workarounds. Therefore, we ran a second experiment to investigate the impact of a support person in conjunction with blockages.

6. Study 2: Problem-Solving Support Person

6.1. Methods

To test our hypotheses about a problem solving support person's impact on SOPS and risky workarounds (H2), we ran an experiment at a third national nursing conference. This conference was held in Boston in 2013 by the American Association of Critical Care Nurses. Over 7,000 nurses attended this conference. The experiment set-up was similar to that of Study 1, with a few exceptions. Due to the specific booths that were available to us at the conference, the difficult workaround cell was about 60 feet from the pharmacy. This distance was 25% closer to the pharmacy than in Study 1. In addition to the shorter distance, the pharmacy was somewhat visible to the participants in the difficult work around cell. Thus, the workaround difficulty level in Study 2 was less than the difficulty level in Study 1. We had two booths with four experiment stations per booth. Most critically, we added a second component – the physical presence of a problem-solving support person – in addition to workaround difficulty, which enabled us to run a 2x2 experiment design. The four conditions in Study 2 were: 1) no blockage, no support person; 2) no blockage, support person; 3) blockage, no support person; and 4) blockage, support person. We operationalized the problem-solving support person by having an experimenter in the cell with the participants. Those nurses who were randomly assigned to the cell with no problem-solving person did not have an experimenter physically present in their booth, but instead in the other booth 60 feet away. Participants were recruited from the staffed booth, received their instructions there, and then were walked to their station in the other, unmanned booth. They were told to return to the staffed booth to claim their $10 after completing the experiment. To gather data from the participants in the unmanned "no-person" stations, an undercover, second experimenter observed from a slight distance from this cell and cleaned up the workstations and recorded the data once all participants had finished.

6.2. Sample

A total of 137 nurses participated in the experiment, which was less than 2% of the conference attendees, making it unlikely that participants had heard about our experiment from prior participants. Nearly 75% of the participants worked in an intensive care unit, and 94% were non-manager nursing staff. There was no difference in self-assurance, felt responsibility, and problem-solving efficacy between participants randomly assigned to the easy and difficult stations.

6.3. Manipulation Check for Difficulty of Engaging in a Policy-Compliant Workaround

We checked the manipulation of the difficulty of engaging in a policy-compliant workaround by asking participants the same question as in Study 1 about the ease of getting supplies. A t-test between the easy and difficult workstations was significant ($t=3.41$, $p<.001$, two-sided test), with participants in the easy condition reporting higher scores (mean 3.85, std error .13) than participants in the difficult condition (mean 3.05, std error 0.15).

6.4. Results from Study 2

Table 3 shows the means, standard deviations, and correlations for the SOPS variables and errors. Forty-four percent of participants spoke up about an operational failure. Thirty-nine percent wrote an improvement slip, with some participants contributing multiple ideas. Out of a total of 81 improvement suggestions, 51.9% concerned the missing digoxin and insulin syringe. However, participants also had many other valid improvement ideas. For example, 8.6% made suggestions related to the medication administration process, such as changing our forms so that they could document the double check of the insulin dose. Being in the difficult workaround cell (blockage condition) was positively correlated with writing an improvement slip ($\rho=.24$, $p<.01$) and speaking up about a problem ($\rho=.22$, $p<.01$). Having a problem-solving support person readily available was positively correlated with speaking up ($\rho=.58$, $p<.001$), and negatively associated with a risky workaround ($\rho = -0.21$, $p<.05$).

In terms of risky workarounds, 26% of participants (n=36) used the mL syringe to administer insulin, and 8% took the digoxin pill from another patient's drawer, with a total of 44 participants engaging in a risky workaround. Out of the participants who performed a risky workaround, 38.6% (n=17) drew up an incorrect dose of insulin, and 18.2% (n=8) administered a 10X overdose. Of the nurses who used a safe workaround, 17.2% made a dosing error in the insulin, and none made a 10x overdose. Using a risky workaround was positively associated with an insulin error ($\rho=.24$, $p<.01$) and a 10x overdose of insulin ($\rho=.36$, $p<.001$). Nurses were more likely to make both minor ($t=-2.80$, $p<.01$, two-tailed) and major ($t=-4.51$, $p<.001$, two-tailed) insulin errors when using risky workarounds.

Table 4 reports the results from the logistic regression, as well as the associated AMEs. As shown in Model 1, the difficult workaround condition was associated with a 20 percentage point increase in the probability of speaking up ($\beta= 1.339$, $p<.01$), lending support to H1a. In the easy workaround condition, the average predicted probability of speaking up was 35%, whereas it was 55% in the difficult condition. The presence of a problem-solving support person increased the probability of speaking up by 56 percentage points from 15% to 71%, providing support for H2a ($\beta= 3.093$, $p<.001$). The interaction between difficult workaround and support person was not significant and the results do not change if the interaction term is included. Therefore, we omit the interaction term from our model. We also found no evidence that felt responsibility, problem-solving efficacy, and self-assurance influence speaking up.

Table 3. Means, standard deviations, and correlations for the main variables for Study 2 (n=139 participants)

	Mean (SD)	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
1. Wrote improvement slip	.39 (.49)											
2. Spoke up about problem	.44 (.50)	.22*										
3. Insulin dose error	.25 (.44)	.01	-.08									
4. 10X overdose of insulin	.06 (.23)	.12	-.09	.43***								
5. % medications omitted	.08 (.16)	.003	.02	.32***	.07							
6. Risky workaround	.32 (.47)	-.14^	-.27**	.24**	.36***	.20*						
7. Difficult condition	.48 (.50)	.24**	.22**	.17*	.07	.08	-.02					
8. PS Support Person	.51 (.50)	.01	.58***	-.13	-.07	-.13	-.21*	.02				
9. Self-assurance	3.68 (.81)	.03	.10	.0008	.02	-.04	-.04	.02	.09			
10. Attentiveness	3.93 (.78)	.08	.10	-.11	-.06	-.14	-.15^	-.001	-.03	.75**		
11. Problem-solving efficacy	3.83 (.84)	.06	.09	-.04	-.14^	-.01	-.19*	-.01	.11	.22*	.25**	
12. Felt responsibility	4.13 (.91)	.09	-.08	-.05	-.13	.01	-.13	-.10	-.003	.21*	.20*	.67***

*** p<0.001, ** p<0.01, * p<0.05, ^ p<0.10

Model 2 shows the results from our tests of H1b and H2b. The average predicted probability of contributing an improvement idea was 26% for participants in the easy condition versus 53% for participants in the difficult workaround condition, for an average marginal effect of 27 percentage points, lending further support for H1b (β= 1.27, $p<.01$). We find no support for H2b, which predicted that a readily available problem-solving support person would increase contribution of improvement ideas. The interaction between workaround difficulty and support person was insignificant, and its inclusion does not change our results. Therefore, it is not included in the model. Self-assurance was marginally and negatively associated with contributing improvement ideas (β= -0.75, $p<.10$). Finally, neither felt responsibility nor problem-solving efficacy was associated with contributing an improvement suggestion.

Table 4. Study 2 Logistic Regression Results, Coefficients are Log Odds, Std Errors in Parentheses (n=139 participants)

	Model 1		**Model 2**		**Model 3**	
Outcome variable	*Spoke Up (a)*		*Improvement Idea (b)*		*Risky Workarounds (c)*	
	Logistic Coefficient	AME	Logistic Coefficient	AME	Logistic Coefficient	AME
(H1) Blockage	1.339**	0.199	1.271**	0.256	-0.166	-0.030
(difficult to work around)	(0.479)		(0.398)		(0.409)	
(H2) Support person	3.093***	0.559	-0.005	-0.001	-1.298**	-0.239
available	(0.529)		(0.396)		(0.441)	
Self-assurance (pre)	-0.579	-0.084	-0.747^	-0.151	1.168*	0.212
	(0.467)		(0.395)		(0.460)	
Attentiveness (pre)	0.967*	0.140	0.708^	0.143	-1.204**	-0.218
	(0.478)		(0.386)		(0.451)	
Problem-solving efficacy	0.463	0.067	-0.125	-0.025	-0.604^	-0.110
	(0.382)		(0.327)		(0.343)	
Felt Responsibility	-0.595^	-0.086	0.427	0.086	-0.115	-0.021
	(0.345)		(0.301)		(0.298)	
Tenure >=15 yrs	0.237	0.034	1.093**	0.220	0.644	0.115
	(0.476)		(0.409)		(0.438)	
At least Bachelor's degree	-0.090	-0.013	-0.132	-0.027	0.165	0.030
	(0.562)		(0.453)		(0.480)	
Constant	-3.676*	-	-2.913*	-	2.611^	-
	(1.490)		(1.404)		(1.342)	
LR Chi^2 (9)	64.97***		21.59**		24.19**	
Pseudo R^2	0.35		0.12		0.14	

*** p<0.001, ** p<0.01, * p<0.05, ^ p<0.10

In Model 3 of Table 4, we used logistic regression to test the effect of difficult workarounds (H1c) and a problem-solving support person (H2c) on risky workarounds. Contrary to the positive relationship found between blockages and risky workarounds in Study 1, we did not find evidence of an effect in this study. The average predicted probabilities were 34% for the easy workaround station and 30% for the difficult workaround station. Thus, Study 2 lends no support for H1C. The presence of a problem-solving support person was associated with a 23.9 percentage point decrease in the probability of engaging in a risky workaround, thus providing support for H2C ($\beta = -1.30$, $p<.01$). The average predicted probability of engaging in a risky workaround was 45% if no support person was present in the cell and decreased to 21% if a support person was present. The interaction between difficult workaround and support person was not significant and is therefore not included in the model. Self-assurance was positively associated with risky workarounds ($\beta=1.168$, $p<.05$). Average marginal effects indicate that a one standard deviation (0.78) increase in self-assurance increases the probability of engaging in a risky workaround by 21 percentage points. Problem solving efficacy was marginally negatively associated with risky workarounds ($\beta= -0.604$, $p<.10$), and felt responsibility was not significant.

In summary, Study 2 found that having easy access to a problem-solving support person—as operationalized by the experimenter being present in the cell—was associated with a higher probability of speaking up about operational failures, and a lower probability of engaging in risky workarounds. However, the experimenter's presence did not impact the probability of contributing improvement ideas.

When it was more difficult to engage in a policy-compliant workaround, which was operationalized by participants being 60 feet away from a supply of the missing materials, participants had a higher probability of contributing improvement ideas. Contrary to the findings in Study 1, in Study 2 we find that the difficulty of engaging in a policy-compliant workaround was associated with a higher probability of speaking up about operational failures, but had no impact on risky workarounds. We speculate that the difference between the two studies may stem from the existence of a tipping point in the level of difficulty of the workaround that pushed workers to become more inclined to engage in risky workarounds in Study 1, but not in Study 2 as the pharmacy in Study 2 was 25% closer to the difficult station than it was in Study 1. Although both sets of participants were shown the pharmacy location and were told that they could use any of the supplies there as they needed, Study 2 participants may have been more willing to walk to obtain the policy-conforming supplies and to speak up to the experimenter.

7. Study 3: Education Portraying Operational failures as Waste

7.1. Methods

At the Boston conference, after running Study 2 we made a slight modification to our experiment set-up to test H3a-c. As in Study 2, we tested work blockages by manipulating whether participants had the pharmacy in their experiment cell or not. However, for Study 3, the second condition was education describing operational failures as "waste" and delineating removal of this waste as part of employees' routine work ("Education"). We operationalized education by having a random half of the participants watch a video clip of a hospital that had implemented work principles from Toyota's production system (Toussaint, et al., 2010) before administering medications.[2] In the three-minute clip, the hospital's CEO described what waste was, giving a specific example of nurses having to search for materials. He emphasized that it was part of everyone's job to find and eliminate waste in hospital processes. The video then showed nurses and their manager discussing improvement ideas. This video aimed to heighten participants' awareness that operational failures were waste and that addressing them could be part of nurses' routine work. Finally, we did not vary the presence of a support person in Study 3, but kept an experimenter in both cells for all conditions.

7.2. Manipulation Check for Education Video

After they had viewed the clip, participants were asked what the video was about and were given a list of five different topics, the second of which was the correct answer ("removing waste"). Two participants answered the question incorrectly and were subsequently dropped from our analyses.

7.3. Sample and Summary Statistics in Study 3

A total of 119 subjects participated in the experiment, but two were dropped due to missing control variable data and two were dropped for not answering the video question correctly, leaving us with a final sample size of 115. Because this was our last experiment and because we had a limited amount of exhibitor hours, we had fewer participants for the education condition. There were 36 participants in the no education, easy workaround condition; 35 in the no education, difficult workaround condition; 23 in the education, easy workaround condition; and 21 in the education, difficult workaround condition. Means, standard deviations, and correlation coefficients are shown in **Table 5**. Forty-eight percent of the participants wrote an improvement suggestion and 71% spoke up about an operational failure. Watching the education video was positively associated with contributing an improvement idea ($\rho=.21$, $p<.05$). Being in the difficult station was positively associated with speaking up ($\rho=.22$, $p<.05$) and contributing improvement ideas ($\rho=.23$, $p<.05$).

7.4. Results from the Logistic Regression in Study 3

Table 6 reports the results from the logistic regression. As Model 1 indicates, we find no evidence that watching the education video influenced speaking up, lending no support for H3a. Being in the difficult

[2] Thinking Lean at Thedacare: Strategy Deployment. Lean Enterprise Institute.

Table 5. Means, standard deviations, and correlations for the main variables for Study 3. (n=115 participants)

	Mean (SD)	1	2	3	4	5	6	7	8	9	10	11
1. Wrote improvement slip	0.48 (.50)											
2. Spoke up about problem	0.71 (.45)	.30**										
3. Insulin dose error	0.21 (.41)	.07	.04									
4. 10X overdose of insulin	0.03 (.18)	.10	.02	.37***								
5. % medications omitted	0.08 (.15)	-.09	.09	.39***	.08							
6. Risky workaround	0.23 (.43)	-.04	-.01	.12	.34***	.21*						
7. Difficult condition	0.49 (.50)	.22*	.23*	-.03	-.09	-.05	.04					
8. Education video	0.38 (.49)	.21*	-.01	.04	-.05	.18^	.03	-.02				
9. Self-assurance	3.81 (.78)	.07	.13	.13	.03	.14	-.02	.06	.10			
10. Attentiveness	3.96 (77)	.08	.18^	.05	-.07	.08	-.05	.09	.09	.81***		
11. Problem-solving efficacy	3.93 (.88)	.02	-.01	.21*	-.13	.09	-.13	.03	.02	.46***	.38***	
12. Felt responsibility	4.15 (.97)	.06	-.09	.08	-.14	.10	-.18^	.01	.03	.42***	.29*	.76***

*** p<0.001, ** p<0.01, * p<0.05, ^ p<0.10

Table 6. Study 3 Logistic Regression Results, Coefficients are Log Odds, Std Errors in Parentheses (n=115 participants)

	Model 1 (Voice)		Model 2 (Idea)		Model 3 (Risky)	
Outcome variable	*Spoke Up (a)*		*Improvement Idea (b)*		*Risky Workarounds (c)*	
	Logistic Coefficient	AME	Logistic Coefficient	AME	Logistic Coefficient	AME
(H1) Blockage (difficult to work around)	1.055* (0.456)	0.194	1.063* (0.414)	0.234	0.162 (0.459)	0.027
(H3) Education Video	-0.212 (0.462)	-0.038	0.936* (0.427)	0.208	0.034 (0.474)	0.006
Self-assurance (pre)	-0.091 (0.517)	-0.016	-0.249 (0.490)	-0.053	0.430 (0.558)	0.072
Attentiveness (pre)	0.682 (0.505)	0.122	0.257 (0.460)	0.055	-0.319 (0.524)	-0.053
Problem-solving efficacy	0.163 (0.400)	0.029	-0.123 (0.381)	-0.026	-0.098 (0.426)	-0.016
Felt Responsibility	-0.537 (0.392)	-0.096	0.230 (0.337)	0.049	-0.426 (0.357)	-0.071
Tenure >=15 yrs	0.632 (0.479)	0.118	0.594 (0.451)	0.128	0.446 (0.530)	0.072
At least Bachelor's degree	-0.056 (0.569)	-0.010	0.953^ (0.528)	0.200	-0.757 (0.532)	-0.141
Constant	-0.524 (1.432)	-	-2.667^ (1.376)	-	0.732 (1.391)	-
LR Chi^2	14.25^		16.95*		7.41	
Pseudo R^2	0.10		0.11		0.06	

*** p<0.001, ** p<0.01, * p<0.05, ^ p<0.10

workstation was associated with speaking up about the operational failures (β=1.055, p<.05), providing further support for H1a. The average marginal effect shows that being in the difficult workaround station increases the probability of speaking up by 19 percentage points, increasing the average predicted probability from 62% to 81%. There was no evidence that the interaction between difficult workaround and education video had an effect on speaking up, and its inclusion did not change our results. Therefore, it was excluded from the model. There also was no evidence that self-assurance, felt responsibility, and problem-solving efficacy impacted speaking up.

Model 2 shows the results of the tests of H1b and H3b. Being in the difficult workaround station was significantly associated with contributing improvement ideas (β=1.06, p<.05), lending support for H1b. The average marginal effect shows that participants in the difficult workstation had a 23 percentage point higher probability of contributing improvement ideas compared to participants in the easy workstation. The average predicted probability of contributing an improvement idea was 36% for participants in the easy station compared with 60% for those in the difficult station. On average, participants who watched the education video had a 21 percentage-point higher probability of contributing an improvement idea (β=

0.936, p<.05), providing support for H3b. The average predicted probability of contributing an idea was 40% for those who did not watch the education video and was 61% for those who did. The interaction term between difficult workaround and the education video was also not significant and its inclusion did not change our results. Therefore, it was omitted from the model. There also was no evidence that self-assurance, felt responsibility, and problem-solving efficacy were associated with improvement ideas.

Finally, as shown in Model 3, watching the education video was not associated with a higher probability of engaging in a risky workaround, providing no support for H3c. There was also no support for H1c, as the difficult workaround condition was not associated with risky workarounds. The interaction between difficult workaround and education video was not significant and its inclusion did not change our results. Therefore, it was excluded from the model. There also was no evidence that self-assurance, felt responsibility, and problem-solving efficacy impacted risky workarounds.

8. General Discussion and Conclusions

We ran a series of experiments to unpack three aspects of Toyota's Andon cord system. Our goal was to gain a better understanding of actionable mechanisms that managers can use to increase frontline workers' likelihood of engaging in SOPS. To summarize our findings, **Table 7** shows the average predicted probabilities for the independent variables in each of the three studies across the three dependent variables.

Table 7. Summary of Results: Average Predicted Probabilities from the Logistic Regressions in the Three Studies

	Spoke Up (a)		Contributed Improvement Idea (b)		Used Risky Workaround (c)	
H1. *Blockages (difficult workaround)*	*Easy*	*Difficult*	*Easy*	*Difficult*	*Easy*	*Difficult*
Study 1. Very Difficult (pharmacy 80 ft away)	NS	NS	8.8***	68.0***	21.1**	72.5**
Study 2. Difficult (pharmacy 60 ft away)	35.0*	54.9*	26.4*	52.9*	NS	NS
Study 3. Difficult (pharmacy 60 ft away)	61.9*	81.3*	36.5*	60.0*	NS	NS
H2. *Problem-solving Support Person*	*No Person*	*Person*	*No Person*	*Person*	*No Person*	*Person*
Study 2. Support Person	15.3***	71.2***	NS	NS	44.7^	20.8^
H3. *Education*	*No Educ.*	*Educ.*	*No Educ.*	*Educ.*	*No Educ.*	*Educ.*
Study 3. Education	NS	NS	40.0*	60.8*	NS	NS

Note: Significance levels refer to differences in the outcome variable between the two components of each independent variable (i.e. easy vs. difficult, no person vs. person, no education vs. education).
*** p<0.001, ** p<0.01, * p<0.05, ^ p<0.10

We found that the three components of the Andon cord system each fostered different patterns of behaviors important for SOPS, suggesting that utilizing all three in conjunction with each other will yield the best results. Across the three studies, work blockages increased the average predicted probability of contributing improvement ideas from a range of 8.8% to 36.5% when participants were in a work environment where it was easy to work around operational failures to a range of 52.9% to 68% when it was difficult to engage in a policy-compliant workaround. Similarly, the probability of speaking up about operational failures ranged from 35% to 61.9% in the easy workaround condition to 54.9% to 81.3% in the difficult workaround condition. Furthermore, our regression results provided no evidence of an interaction effect between work blockages and the availability of a support person on either the probability of contributing improvement ideas or speaking up. Thus, blockages appear effective at increasing SOPS. However, blockages also resulted in unintended negative consequences. In Study 1, where it was very difficult to work around operational failures due to the relatively far distance of the pharmacy, participants who encountered the work blockage were much more likely to use a risky workaround (21% in the easy workaround condition, 73% in the most difficult workaround condition). This is important because, across the three studies, an average of 23% of the participants who used the mL syringe administered a 10X overdose of insulin.

Participants who received education about removing waste from hospital work systems had a higher probability of contributing improvement ideas (61%) than participants who did not receive this education (40%). This positive effect of education on the probability that nurses contributed an improvement idea was similar in magnitude to that of a work blockage. However, education did not spur risky workarounds, as did blockages. Thus, education plays an important role in proactive behaviors because it can spur employees to contribute improvement ideas independent of whether or not there are work blockages. This is beneficial for organization's improvement efforts because it is likely infeasible to create work blockages for every possible operational failure. Therefore, organizations need an alternative mechanism to foster improvement efforts for failures that employees are able to easily work around, but which nonetheless disrupt work.

Finally, the physical presence of a support person increased from 16% to 72% the probability that participants would speak up to the experimenter about operational failures. However, the support person's presence did not increase the likelihood that the employee would contribute improvement ideas. Thus, relying on the physical presence of a support person to garner improvement ideas through verbal communication will likely yield fewer suggestions than the other methods of blockages and education. A benefit of the physical presence of the support person was that it decreased participants' tendency to engage in risky workarounds.

Our study suggests that it may be beneficial to combine work blockages with readily available problem-solving support. Installing blockages to prevent workarounds without also providing readily available support personnel to assist employees who encounter a blockage is likely to backfire. This is because employees who face blockages are likely to use creative, but potentially error-prone ways to accomplish their tasks. We believe that the tendency to resort to risky workarounds when faced with a difficult work blockage exists in real work settings as well as in our experiment setting. Studies of barcode medication administration medication systems in hospitals have similarly found that nurses engage in risky workarounds when the system blocks their ability to administer medications to their patients (Halbesleben, et al., 2010, Koppel, et al., 2008).

8.1. Implications for Research

Our study has important implications for research on operational failures and problem solving. Our results show that three situational, job-design variables—work blockages that increase the difficulty of engaging in policy-compliant workarounds, education about waste in operating systems; and the presence of a support person—foster a positive, learning response to operational failures. To our knowledge, our study is one of the first to use random assignment of subjects to different work conditions, which enabled us to causally test managerial levers to manipulate employees' proactive behaviors. Furthermore, our results suggest that the three variables play complimentary roles in fostering a learning response to operational failures. Blockages spark the contribution of improvement ideas, but may also contribute to risky workarounds that lead to medication errors—a negative side effect which can be tempered by readily available problem-solving support personnel. Education can spark the contribution of improvement ideas in situations where employees could otherwise easily workaround operational failures. Our study thus proposes a "bundled intervention" that could be used in practice to drive SOPS in hospitals, a concept that has been used successfully for clinical interventions, but to our knowledge has not been used as frequently for process improvement interventions. A third contribution is that the three work design variables in our study are a useful addition to the list of situational antecedents of proactive behavior identified by previous research—accountability, ambiguity, autonomy (Grant and Ashford, 2008), and flexible role orientation (Parker, et al., 2006). This is because the variables that we investigated may be more practical in healthcare settings where compliance to policy and standard procedures are necessary to prevent errors while ambiguity and autonomy may have the unanticipated, negative consequence of contributing to undesirable variability, risky workarounds and higher error rates. Our research therefore highlights the importance of controlling for potential negative side effects, such as variability, workarounds and errors, in future examinations of proactive behaviors.

Our study also makes a contribution to theory by answering the call for research on proactive behaviors that controls for individual differences while testing antecedents that can be influenced by managers (Parker, et al., 2006). We did not find any evidence that the individual personality traits of felt responsibility, problem-solving efficacy, and self-assurance were associated with SOPS. Thus, our three situational variables appear to be a more promising route to fostering employees' proactive behaviors than selecting employees based on individual-level personality traits associated with proactive behaviors in previous research (Bateman and Crant, 1993, Crant, 2000, Morrison and Phelps, 1999). Our inability to replicate prior research findings may be because those studies asked respondents to recall coworkers' general tendencies to engage in proactive behaviors (Morrison and Phelps, 1999), whereas we gathered data about people's real-time, specific responses to the same set of operational failures across a variety of work design conditions. Our results are consistent with prior research in social psychology that found that personality effects disappear when situational variables are manipulated. As our sample consisted of nurses who elected to attend a national nursing conference, it is possible that we failed to replicate prior studies because our participants had higher and less variable levels of proactive personality traits than the prior studies. However, the data does not seem support this explanation as the mean and standard deviation for felt responsibility in our studies (M= 4.1, SD= .99) was very similar to the mean and standard deviation for felt responsibility (M=3.7, SD=.78) in Morrison and Phelps' study (1999).

Our sample extends the literature on proactive behaviors beyond managers (Morrison and Phelps, 1999) and manufacturing employees (Parker, et al., 2006) because we examine frontline employees in service organizations. Our methodology also makes a contribution. We developed a laboratory experiment that created conditions that warranted, yet did not mandate speaking up. This enabled us to gather objective measures of SOPS close in time to when they occurred rather than having to rely on recollections about one's own or other's past actions (Morrison and Phelps, 1999, Parker, et al., 2006). By using an experiment with random assignment to conditions, our study answers the call for research that isolates the impact of antecedent variables on proactive behaviors (Parker, et al., 2006). Specifically, we were able to gauge the impact of work design that prevents workarounds independent of organizational-level variables (e.g. job autonomy, co-worker trust, and supportive supervision) that often confound research on employee voice in organizations.

8.2. Implications for Practice

Our research also has implications for practice. First, our study suggests that managers should create strategies for safely increasing the probability that their staff will contribute improvement ideas in both the presence and absence of blockages. In the face of blockages, the physical presence of a support person decreases the probability that employees will resort to risky workarounds when they encounter a problem. In the absence of blockages, workers may not be able to identify waste in the system because the ease of working around the problem decreases their sensitivity to the problem's occurrence. Under these conditions, operational failures are likely to remain latent in the system. Our research suggests that education about process improvement can be useful to help workers be more sensitive about opportunities for improvement independent of whether or not blockages make it difficult to work around the failures.

Second, our results highlight a tension in using "fail-safe" poka-yoke methods to prevent workarounds. On the one hand, many healthcare managers try to prevent workarounds by creating deliberate blockages, such as stocking only certain types of supplies on units or having IT checks and safeguards that do not allow work to continue if some condition is not met. On the other hand, if operational failures occur and workers are unable to get their supplies in a policy-conforming manner, employees may decide to use risky, error-prone workarounds to deliver patient care, defeating the purpose of the blockage. The only time that we observed this behavior was when there was a difficult blockage and workers had no reasonable, alternative way of completing their work other than to use a risky workaround. Toyota seems to avoid this negative consequence by simultaneously providing both work blockages and high levels of problem-solving support. Thus, when workers encounter a problem, they can easily signal for and receive help (Liker, 2004). This suggests that a tightening of inventory on nursing units, either due to space or cost pressure, or IT workflow blockages should be accompanied by an increased support system for resolving operational failures. However, financial pressure to keep labor costs low means this may not always be possible in hospitals. An alternative approach would be to foster safe workarounds by stocking extra equipment and supplies, so that workers can obtain what they need even when there are operational failures. In addition, deepening of expertise through education—such as learning how to correctly calculate medication conversions—may provide nurses with the capability to safely circumvent operational failures, thus further ensuring safe workarounds. Furthermore, our results suggest that managers may wish to create medium difficulty blockages that foster speaking up without going so far as to drive employees into risky workarounds.

8.3. Future Research and Conclusions

Our paper has several limitations that should be addressed in future research. Our study may be an upper bound in predicting SOPS because nurses were not embedded in an established organization and did not have to provide care to actual patients. It is possible that providing care to patients and having an employment relationship with an organization would decrease their likelihood of contributing improvement ideas. Future research could test blockage, problem-solving support, and education interventions to increase speaking up and improvement suggestions in actual hospitals. It is difficult to consider how one might create controlled problem conditions to carefully test these interventions, but it may be possible to partner with a hospital that has a realistic simulation center with mannequin patients to approximate an actual hospital setting. Another limitation is the short time between watching the education video and asking nurses to engage in the experiment. It is likely that the value of the education video fades quickly over time. It would be useful to conduct additional studies to determine how long education interventions remain effect at increasing the contribution of improvement ideas. It also would be useful to gain a deeper understanding of the mechanism that makes an education intervention successful, which would help in the design of education programs in practice.

In competitive environments, it is essential that organizations develop techniques to increase employees' willingness to speak up about operational failures and contribute their improvement ideas, while also complying with organizational policies. This is especially important in complex, risky service organizations, such as hospitals, where employees have a wide range of discretionary activities that they can perform and lower levels of supervision. We believe that designing work that considers the natural responses of employees when they encounter operational failures will be helpful in creating improvement programs that are successful over multiple dimensions, such as safety and efficiency.

References

Angle, H.L., J.L. Perry. 1981. An empirical assessment of organizational commitment and organizational effectiveness. *Administrative Sci. Quart.* **26**(1) 1-14.

Ash, J.S., M. Berg, E. Coiera. 2004. Some unintended consequences of information technology in health care: The nature of patient care information system-related errors. *Journal of American Medical Informatics Association* **11**(2) 104-112.

Ashford, S.J., K.M. Sutcliffe, M.K. Christianson. 2009. Speaking up and speaking out: The leadership dynamics of voice in organizations. J. Greenberg, M.S. Edwards, ed. *Voice and Silence in Organizations*. Emerald Group Publishing Limited, Bingley, UK.

Bateman, T.S., J.M. Crant. 1993. The proactive component of organizational behavior: A measure and correlates. *J. Organ. Behavior* **14**(2) 103-118.

Bernstein, E.S. 2012. The transparency paradox: A role for privacy in organizational learning and operational control. *Administrative Sci. Quart.* **57**(2) 181-216.

Borgatti, S.P., R. Cross. 2003. A relational view of information seeking and learning in social networks. *Management Sci.* **49**(4) 432-445.

Brief, A.P., S.J. Motowidlo. 1986. Prosocial organizational behaviors. *Acad. Management Rev.* **11** 710-725.

Buerhaus, P.I., D.O. Staiger, D.I. Auerbach. 2000. Implications of an Aging Registered Nurse Workforce. *JAMA* **283**(22) 2948.

Burris, E.R. 2012. The risks and rewards of speaking up: Managerial responses to employee voice. *Acad. Management J.* **55**(4) 851-875.

Burris, E.R., J.R. Detert, A.C. Romney. 2012. Speaking up vs. being heard: The disagreement around and outcomes of employee voice. *Organ. Sci.* **Articles in Advance** 1-17.

Bush, R. 2007. Reducing waste in the US Health Care Systems. *Journal of American Medical Assocation* **297**(8) 871-874.

Cohen, M.R. 2003. ISMP medication error report analysis. Tuberculin syringe confused with insulin syringe. *Hospital Pharmacy* **38**(1) 15.

Connolly, C. 2005. *Toyota assembly line inspires improvements at hospital*. City.

Coyle-Shapiro, J., I. Kessler, J. Purcell. 2004. Exploring Organizationally Directed Citizenship Behaviour: Reciprocity or 'It's my Job'?. *J. Management Studies* **41**(1) 85-106.
Crant, J.M. 2000. Proactive behavior in organizations. *Journal of Management* **26**(3) 435-462.
Detert, J., E. Burris. 2007. Leadership Behavior and Employee Voice: Is the Door Really Open? *Acad. Management J.* **50**(4) 869-884.
Detert, J.R., A.C. Edmondson. 2011. Implicit voice theories: Taken-for-granted rules of self-censorship at work. *Acad. Management J.* **54**(3) 461-488.
Detert, J.R., L.K. Treviño. 2010. Speaking up to higher-ups: How supervisors and skip-level leaders influence employee voice. *Organ. Sci.* **21**(1) 249-270.
Edmondson, A.C. 2003. Speaking up in the operating room: How team leaders promote learning in interdisciplinary action teams. *J. Management Studies* **40**(6) 1419-1452.
Frese, M., W. Kring, A. Soose, J. Zempel. 1996. Personal initiative at work: Differences between East and West Germany. *Acad. Management J.* **39**(1) 37-63.
Furman, C., R. Caplan. 2007. Applying the Toyota Production System: Using a patient safety alert system to reduce error. *The Joint Commission Journal on Quality and Patient Safety* **33**(7) 376-386.
Galanter, M. 1980. Psychological induction into the large group: Findings
from a modern religious sect. *American Journal of Psychiatry* **137**(12) 1574-1579.
Gneezy, A., A. Imas, A. Brown, L.D. Nelson, M.I. Norton. 2012. Paying to be nice: Consistency and costly prosocial behavior. *Management Sci.* **58**(1) 179-187.
Grant, A.M., S.J. Ashford. 2008. The dynamics of proactivity at work. *Research in Organizational Behavior* **28** 3-34.
Grant, A.M., S.K. Parker. 2009. Redesigning Work Design Theories: The Rise of Relational and Proactive Perspectives. *The Academy of Management Annals* **3**(1) 317-375.
Gurses, A.P., P. Carayon. 2007. Performance obstacles of intensive care nurses. *Nursing Research* **56**(3) 185-194.
Halbesleben, J.R.B., G.T. Savage, D.S. Wakefield, B.J. Wakefield. 2010. Rework and workarounds in nurse medication administration process: Implications for work processes and patient safety. *Health Care Management Review* **35**(2) 124-133.
Halbesleben, J.R.B., D.S. Wakefield, B.J. Wakefield. 2008. Work-arounds in health care settings: Literature review and research agenda. *Health Care Management Review* **33**(1) 2-12.
Hall, L.M., C. Pedersen, L. Fairley. 2010. Losing the moment: Understanding interruptions to nurses' work. *Journal of Nursing Administration* **40**(4) 169-176.
Hofmann, D.A., Z. Lei, A.M. Grant. 2009. Seeking help in the shadow of doubt: The sensemaking processes underlying how nurses decide whom to ask for advice. *Journal of Applied Psychology* **94**(5) 1261-1274.
Holden, R., A. Rivera-Rodriguez, H. Faye, M. Scanlon, B.-T. Karsh. 2012. Automation and adaptation: nurses' problem-solving behavior following the implementation of bar-coded medication administration technology. *Cognition, Technology & Work* 1-14.
Imai, M. 1986. *Kaizen: The key to Japan's competitive success*. Random House Business Division, New York.
Jimmerson, C., D. Weber, D.K. Sobek. 2005. Reducing waste and errors: piloting lean principles at Intermountain Healthcare. *Joint Commission J. Quality and Patient Safety* **31**(5) 249-257.
Kasouf, C., K.G. Celuch, J.H. Bantham. 2006. An Examination of Communication Behaviors as Mediators in Individual-Level Interorganizational Exchanges. *Psychology & Marketing* **23**(1) 35.
Kish-Gephart, J.J., J.R. Detert, L.K. Treviño, A.C. Edmondson. 2009. Silenced by fear:The nature, sources, and consequences of fear at work. *Research in organizational behavior* **29** 163-193.
Kobayashi, M., S.R. Fussell, Y. Xiao, F.J. Seagull. 2005. Work coordination, workflow and workarounds in a medical context, ed. *CHI Late Breaking Results*. ACM Press, New York, 1561-1564.

Koppel, R., T. Wetterneck, J.L. Telles, B.-T. Karsh. 2008. Workarounds to barcode medication administration systems: Their occurrences, causes, and threats to patient safety. *Journal of the American Medical Informatics Association* **15**(4) 408-423.
Kotter, J.P. 1995. Leading change: Why transformation efforts fail. *Harvard Bus. Rev.* **73**(2) 59-67.
LePine, J.A., L. Van Dyne. 1998. Predicting voice behavior in work groups. *Journal of Applied Psychology* **83**(6) 853-868.
Liker, J. 2004. *The Toyota Way*. McGraw-Hill, New York, NY.
Lukas, C.V., S.K. Holmes, A.B. Cohen, J. Restuccia, I.E. Cramer, M. Shwartz, M.P. Charns. 2007. Transformational change in health care systems: an organizational model. *Health Care Management Review* **32**(4) 309-320.
McGuire, E., S.M. Kennerly. 2006. Nurse managers as transformational and transactional leaders. *Nursing Economic$* **24**(4) 179-186.
McNeely, B.L., B.M. Meglino. 1994. The role of dispositional and situational antecedents in prosocial organizational behavior: An examination of the intended beneficiaries of prosocial behavior. *Journal of Applied Psychology* **79**(6) 836-844.
Mishina, K. 1992. *Toyota Motor Manufacturing, U.S.A., Inc.* Harvard Business Publishing, Boston, MA.
Morrison, E.W. 1994. Role definitions and organizational citizenship behavior: the importance of the employees' perspective. *Acad. Management J.* **37** 1543.
Morrison, E.W., F.J. Milliken. 2003. Speaking up, remaining silent: The dynamics of voice and silence in organizations. *J. Management Studies* **40**(6) 1353-1358.
Morrison, E.W., C.C. Phelps. 1999. Taking charge at work: Extrarole efforts to initiate workplace change. *Acad. Management J.* **42**(4) 403-419.
Nakajo, T., H. Kume. 1985. The principles of foolproofing and their application in manufacturing. *Reports of Statistical Applications Research, Japanese Union of Scientists and Engineers* **32**(2) 10-29.
O'Reilly, C.A., J. Chatman. 1986. Organizational commitment and psychological attachment: The effects of compliance, identification, and internalization on prosocial behavior. *Journal of Applied Psychology* **71**(3) 492-499.
Parker, S.K. 1998. Enhancing role breadth self-efficacy: The roles of job enrichment and other organizational interventions. *Journal of Applied Psychology* **83**(6) 835-852.
Parker, S.K. 2000. From Passive to Proactive Motivation: The Importance of Flexible Role Orientations and Role Breadth Self-efficacy. *Applied Psychology* **49**(3) 447-469.
Parker, S.K., T.D. Wall, P.R. Jackson. 1997. "That's not my job": Developing flexible employee work orientations. *The Academy of Management Journal* **40**(4) 899-929.
Parker, S.K., H.M. Williams, N. Turner. 2006. Modeling the antecedents of proactive behavior at work. *Journal of Applied Psychology* **91**(3) 636-652.
Pearce, J.L., H.B. Gregersen. 1991. Task interdependence and extrarole behavior: A test of mediating effects of felt responsibility. *Journal of Applied Psychology* **76**(6) 838-844.
Pennsylvania Patient Safety Authority. 2004. *Overdoses caused by confusion between insulin and tuberculin syringes*. Patient Safety Authority, City.
Plsek, P.E. 1999. Quality improvement methods in clinical medicine. *Pediatrics* **103**(1 Suppl E) 203-214.
Repenning, N.P. 2000. Drive out fear (unless you can drive it in): The role of agency and job security in process improvement. *Management Sci.* **46**(11) 1385.
Robinson, A.G., D.M. Schroeder. 2009. The role of front-line ideas in lean performance improvement. *Quality management Journal* **16**(4) 27-40.
Schultz, K.L., D.C. Juran, J.W. Boudreau, J.O. McClain, L.J. Thomas. 1998. Modeling and worker motivation in JIT production systems. *Management Sci.* **44**(12, part 1 of 2) 1595-1607.
Shannon, R.P., D. Frndak, N. Grunden, J.C. Lloyd, C. Herbert, B. Patel, D. Cummins, A.H. Shannon, P.H. O'Neill, S.J. Spear. 2007. Using real-time problem solving to eliminate central line infections. *Joint Commission J. Quality and Patient Safety* **32**(9) 479-487.

Spear, S.J. 2004. Learning to lead at Toyota. *Harvard Bus. Rev.*(5) 1-12.
Spear, S.J. 2005. Fixing health care from the inside, today. *Harvard Bus. Rev.* **83**(9) 78-91.
Spear, S.J., M. Schmidhofer. 2005. Ambiguity and Workarounds as Contributors to Medical Error. *Annals of Internal Medicine* **142**(8) 627-630.
Steel, R.P., K.R. Jennings, J.T. Lindsey. 1990. Quality circle problem solving and common cents: Evaluation study findings from a United States federal mint. *The Journal of Applied Behavioral Science* **26**(3) 365-381.
Steel, R.P., R.F. Lloyd. 1988. Cognitive, affective, and behavioral outcomes of participation in quality circles: Conceptual and empirical findings. *The Journal of Applied Behavioral Science* **24**(1) 1-17.
Stewart, D.M., J.R. Grout. 2001. The human side of mistake-proofing. *Production and Operations Management* **10**(4) 440-459.
Toussaint, J., R.A. Gerard, E. Adams. 2010. *On the Mend: Revolutionizing Healthcare to Save Lives and Transform the Industry*. Lean Enterprise Institute, Cambridge, MA.
Tucker, A.L. 2007. An empirical study of system improvement by frontline employees in hospital units. *Manufacturing Service Oper. Management* **9**(4) 492-505.
Tucker, A.L., A.C. Edmondson. 2002. Managing routine exceptions: A model of nurse problem solving behavior. *Advances in Health Care Management* **3** 87-113.
Tucker, A.L., A.C. Edmondson. 2003. Why hospitals don't learn from failures: Organizational and psychological dynamics that inhibit system change. *Calif. Management Rev.* **45**(2) 1-18.
Tyler, T.R., S.L. Blader. 2005. Can businesses effectively regulate employee conduct? The antecedents of rule following in work settings. *Acad. Management J.* **48**(6) 1143-1158.
Victor, B., A. Boynton, T. Stephens-Jahng. 2000. The effective design of work under total quality management. *Organ. Sci.* **11**(1) 102-117.
Vogelsmeier, A.A., J.R.B. Halbesleben, J.R. Scott-Cawiezell. 2008. Technology implementation and workarounds in the nursing home. *Journal of the American Medical Informatics Assocation* **15**(1) 114-119.
von Hippel, E. 1994. "Sticky information" and the locus of problem solving: Implications for innovation. *Management Sci.* **40**(4) 429-440.
Watson, D., L.A. Clark, A. Tellegen. 1988. Development and validation of brief measures of positive and negative affect: The PANAS scales. *Journal of Personality and Social Psychology* **54**(6) 1063-1070.
Wech, B.A., K.W. Mossholder, R.P. Steel, N. Bennett. 1998. Does work group cohesiveness affect individuals' performance and organizational commitment?: A cross-level examination. *Small Group Research* **29**(4) 472-494.
Womack, J., D. Jones, D. Roos. 1990. *The Machine that Changed the World*. Macmillan, New York.
Wysocki, B.J. 2004. *To fix health care, hospitals take tips from factory floor*. City.
Zohar, D., G. Luria. 2007. Group Leaders as Gatekeepers: Testing Safety Climate Variations Across Levels of Analysis. *Working paper*.