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Alert fatigue as a consequence of external accountability approaches to patient safety

DISSERTATION

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for the degree of

DOCTOR OF PHILOSOPHY

in Informatics

by

Mustafa Ibraheem Hussain

Dissertation Committee:
Professor Kai Zheng, Chair
Associate Professor Yunan Chen
Associate Clinical Professor Ariana M. Nelson
Professor Geoffrey C. Bowker

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DEDICATION

This dissertation is dedicated
To Jacob and Hunter
Who were not fond of rules.

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VITA

Mustafa Ibraheem Hussain

EDUCATION

Doctor of Philosophy in Informatics **2021**
University of California Irvine *Irvine, California*

Master of Science in Innovation and Technology **2016**
Florida Polytechnic University *Lakeland, Florida*

Bachelor of Science in Computer Science **2014**
University of Utah *Salt Lake City, Utah*

FIELD OF STUDY

Human and Social Factors in Health Information Systems

PUBLICATIONS

Molldrem S, **Hussain MI,** Smith AKJ. Open science, COVID-19, and the news: Exploring controversies in the circulation of early SARS-CoV-2 genomic epidemiology research. Glob Public Health. 2021 Mar 4:1-14. PMID: 33661076.

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ABSTRACT OF THE DISSERTATION

Alert fatigue as a consequence of external accountability approaches to patient safety

By

Mustafa Ibraheem Hussain

Doctor of Philosophy in Informatics

University of California, Irvine, 2021

Professor Kai Zheng, Chair

Medical error is the third leading cause of death in the United States, causing nearly a quarter million deaths each year. Clinicians such as physicians, nurses, and pharmacists are shown clinical decision support (CDS) alerts, which are intended to reduce medical errors. However, since these alerts are often irrelevant, clinicians frequently ignore them. This problem is known as alert fatigue.

In this dissertation, I approach the problem in the styles of three disciplines, using three methods. First, I use a human factors style. I conduct a usability test comparing a conventional CDS alert design with an alternative design of my own. Resident physicians participated in a randomized, blinded and controlled study, which simulated patient scenarios, and solicited prescriptions using a mock electronic health record. Two attending physicians evaluated the prescriptions independently. I used ANOVA analysis and found that the residents in the alternative condition wrote more appropriate prescriptions. When shown both designs, residents vastly preferred the alternative design.

Second, I use a medical approach. I conduct a systematic review of the literature, comparing acceptance rates as an outcome on the basis of interactive design and role tailoring—the "fit" of the alert's contents to the clinician's role. I find that both interactive design and role tailoring can affect the likelihood that an alert will be accepted.

Third and finally, I use a science and technology studies (STS) style. I combine interviews of hospital clinicians and administrators with a document analysis. I use abductive analysis, and arrive at a novel view of alert fatigue: as a consequence of approaches to patient safety that involve holding healthcare organizations accountable to a growing number of external bodies, including accreditors, payers, government incentive programs, and patient advocacy groups. My findings raise questions regarding what alternative form of accountability might more effectively improve patient safety.

Chapter 1

Introduction

It is a fact of contemporary life in industrialized nations such as the United States that one will almost certainly at some point in time be incapacitated and at the mercy of clinicians such as physicians, nurses, and pharmacists. It is a fact of critical public importance, then, that a recent estimate suggests that medical error[127] is the third leading cause of death in the US, ahead of automobile and firearm-related incidents.[163] Unlike these causes of death that are comparable in magnitude, medical errors are not consistently reported.[163]

Challenges in public accountability abound. To start with, it is not easy to prove that any given incident was preventable, and was therefore an error; this epistemological problem is typically side-stepped by referring to adverse events 'considered' to have been preventable.[267] Indeed, a variety of factors external to the individual clinician, such as inadequate staffing,[109] may contribute to unsafe conditions.

Another challenge is that the medical professions have historically been quite powerful,[2] due in part to the trappings of professional authority. In Abbott's analysis of professional authority and conflict, these trappings—the professional association with its membership rules, the licensure backed by the authority of the State, the examination and the sovereign

education, and the code of ethics—serve to distinguish the 'professionals' from the 'lay public,' and restrict the scope of who may legitimately account for and evaluate professional practice.[2] Adding human and system factors to the 10th revision of the International Classification of Diseases (ICD-10) as has been suggested in the British Medical Journal [163] could create grounds for the concession of considerable authority to a wide range of non-physicians.

1.1 Aviation as a model for healthcare

In the year 2000, a landmark report, *To Err is Human*[146] was published by the National Academy Press. That report urged a cultural shift in medicine away from a 'blame' culture to a 'safety' culture that would recognize medical error as normal; this culture would then allow medical error to become visible without fear of retribution; authors pointed to aviation's impressive record as a goal, and to their postwar safety processes as a model. This particular, optimistic fiber of the reformative effort might have been undermined somewhat in 2008, when the US's public payer, Centers for Medicare and Medicaid Services (CMS), stopped reimbursing hospitals for certain adverse events that occurred within the hospital, such as bed sores and hospital acquired infections.[22] Some hospitals responded by underreporting such incidents.[22]

Attempts to regulate healthcare since then have been a tad more subtle. First, the US federal government focused on information infrastructure. In an ongoing attempt to reduce medical error while also increasing the quality of care and reducing costs, the HITECH Act of 2009, aiming to create an interoperable health information infrastructure, heavily incentivized the widespread adoption and use of Electronic Health Records (EHRs), which at present come bundled with clinical decision support (CDS) alerts and best practice alerts (BPAs).[122] For short, I refer to both forms of alert as CDS alerts in this

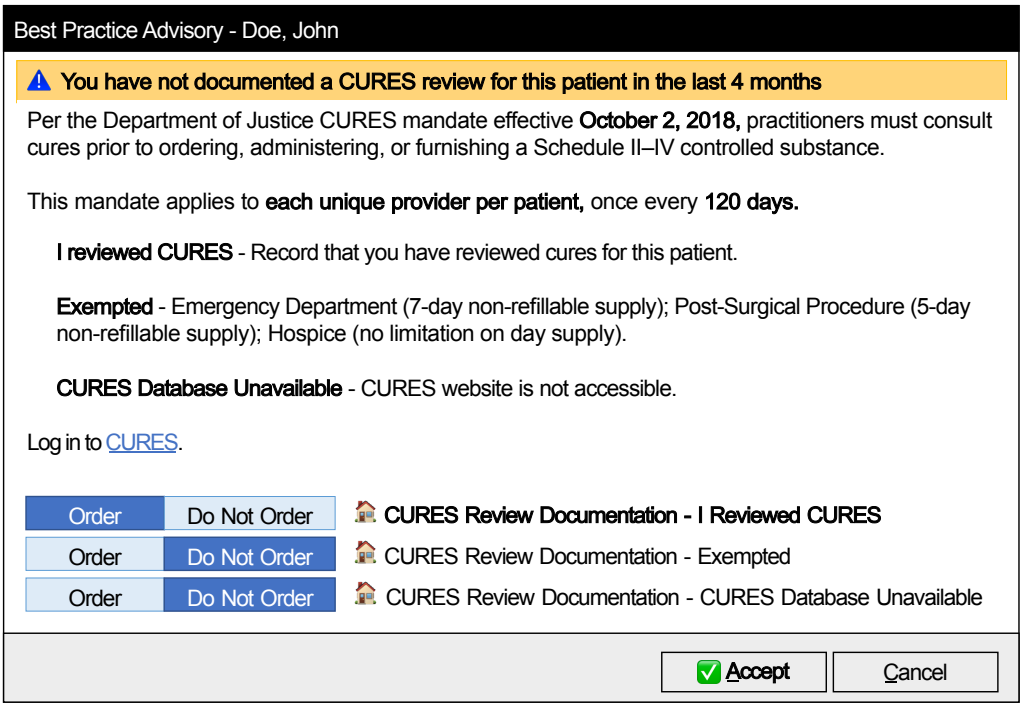


Figure 1.1: Wireframe illustration of a real alert for opioid prescribing. Note that 'John Doe' is conventionally used as an anonymous placeholder.

dissertation. Quality benchmarks relevant to more recent incentive programs such as the CMS Quality Payment Program may also be met using CDS.[48]

1.2 Physician, interrupted

CDS alerts canonically take the form of pop-up windows that interrupt the prescriber, appearing front and center on the computer screen, after a prescription has been written, and preventing further action until the window has been dismissed. See Figure 1.1 for an example. In the absence of consistent error and incident reporting, these alerts—and evaluations of their efficacy—tend to focus on adherence to processes assumed to yield safe conditions for patients, rather than examining adverse events to prevent their recurrence.[136, 204]

Figure 1.1 is a wireframe of a CDS alert implemented at the field site of my dissertation, a large public teaching health system[1] in Southern California. I have transcribed the text verbatim, and it is fairly complex. The link titled "Log in to CURES" links the physician-user to a law enforcement-administered database from which they may retrieve a patient's prescription opioid history. Although some physicians let me know they find this alert useful because it helps them comply with a recent California law requiring them to check opioid histories to prevent potentially dangerous overprescribing,[23] there is always room for improvement. At first glance, this alert is not tailored to the roles receiving it. Here we see advice for the emergency department, surgery, and hospice appearing in the outpatient pain clinic, and it is left to the physician-users to figure out its relevance to their role and present situation, and how to best respond.

Now imagine seeing irrelevant alerts hundreds of times over the course of, say, a month. Car alarms are meant to indicate that a car is being stolen, but city residents generally regard them as a nuisance. A similar problem happens with CDS alerts. Clinicians frequently come to ignore them, in a process psychologists might characterize as *habituation,*[8] and which medical informaticists have come to call *alert fatigue.*[261]

1.3 Alerts as nudges

There are a potentially infinite number of ways to frame any scientific problem. Over the course of my dissertation work, I have framed the problem of alert fatigue through the lenses of three different disciplines: human factors, allopathic medicine,[2] and science and technology studies (STS) in order to trace its prevalent contemporary framing.

[1] In the US, a *health system* typically comprises at least one hospital and a collection of primary care practices in the surrounding area,[6] often formed through organizational mergers.[255]

[2] Allopathic medicine is characterized by the isolated analysis of the disease and use of treatments that directly oppose the specific disease. In the US, allopathic medicine is commonly understood as synonymous with 'medicine.'

The origins of CDS appear connected to the logic of cybernetics. A key article, authored by McDonald, a physician at the Regenstrief Institute, centered *"limits to man's capabilities as an information processor that assure the occurrence of random errors in his activities,"* and offered computerized reminders as a means of supplementing this limited information processing capability to reduce the occurrence of medical error.[171] In the decades since, the scope of CDS has expanded immensely, to encompass the cost and quality of care, and the locus of control has shifted beyond the walls of the individual hospital, toward institutions that today govern medicine.[122]

I have come to view the dominant contemporary framing of CDS as falling under the banner of *libertarian paternalism,* as it is openly described by its proponents in behavioral economics.[243] Libertarian paternalism is a stream of thought within neoliberalism[45] popularized by *Nudge,* a New York Times bestseller coauthored by Chicago school economist Thaler, and Sunstein of Harvard Law.[248] Together, they have articulated a basis for political economy built on actuarialism,[75] a practice and ethos of accounting for and controlling risk in order to reduce costs.[3]

Neoliberalism is a post-WWII policy framework in which many of the state's bureaus, such as its welfare services, are withdrawn, leaving only the means of to protect private interests, such as the police and militaries, and certain parts of the legal apparatus.[115] The entrepreneurial spirit, which is believed to make the market the most efficient information processor,[175] is then 'liberated' to take over functions previously performed by the government.[115] Governments experiment with minimalist market regulations and interventions intended to reduce social expenditure,[272] such as using taxes to dissuade the consumption of sugary soda in an effort to reduce costs associated with obesity-related

[3]In my usage, a *political economy* is a view of how states and markets are enjoined to one another, or how they ought to be enjoined. For example, when a figure on Fox News says "governments should not regulate markets," that is a statement about one's view about an ideal political economy—that corporations should be regarded as sacred sanctuaries that, like religious institutions, operate largely outside the view and reach of the legal system.

healthcare on public payers such as Medicare and Medicaid.[130]

The United States and United Kingdom—a contemporary superpower allied with a historic empire—have modelled neoliberal policies in order to tout their economic benefits and encourage their adoption by postcolonized nations, reformed and overthrown socialist and communist nations, and social democracies.[115] So, it is worthwhile to examine neoliberal policies in role model nations.

In 2015, President Obama signed an order to expand research funding in behavioral economics and to inject its fruits into US policy.[19] During Obama's presidency, New York City former mayor and billionaire Michael Bloomberg advanced a soda tax policy built on libertarian paternalist principles.[130]

I will illustrate libertarian paternalism using the soda tax as an example. For a brief explanation of the policy's form and rationale, please refer to Figure 1.2. Whether the soda tax 'works' or is efficacious is beside the point. Whether it is just is beside the point as well—though it is arguably unjust, and I will return to this in a moment. Whether the tax is opposed by Big Soda[280] (Coca-Cola, PepsiCo and the like) is also beside the point.

My point is that the neoliberal framework in which the soda tax is embedded is distinct from its predecessor, a postindustrial form of US governance in which a bureau reliant on scientific expertise, such as the Food and Drug Administration, would aim to protect consumers by regulating the beverage corporations, for example by investigating and setting limits on grams of sugar per fluid ounce, and then by conducting regular inspections and imposing fines for non-compliance. Alternatively, a bureau that regulates advertising such as the Federal Communications Commission could restrict or ban the advertising of sugary sodas, as has been done for cigarettes.[247] The soda tax is by contrast a *provisional*[29] intervention which attaches to the private infrastructure through which beverages are sold, and captures revenue for the government while potentially

Problem. Sugary sodas cause obesity, a public health problem, among Consumers.

Intervention. To improve public health, the City shall dissuade sugary soda consumption by imposing a Tax on their purchase.

Execution. In order to bridge the Tax with the site of the Consumer's body, a range of institutional and organizational coordination and control mechanisms shall be mobilized. E.g., Health and Human Services shall convey guidance on the Policy to food and drink retailers; the Department of Finance shall account for and collect the Tax; the Strategic Planning branch shall coordinate with advertising firms to run a public campaign to inform Consumers of the alteration that has been made in their beverage consumption choice landscape.

Desired outcome. The Policy shall manifest in the mind of the Consumer through a behavioral conditioning process. If one chooses a sugary soda, then he or she encounters the minor mental stress associated with the Tax. With time, this stress conditions the Consumer to avoid choosing sugary beverages. In turn, this benefits the Consumer's body; reduced calorie intake leads to reduced weight gain.

Figure 1.2: Brief explanation of a soda tax policy for any given city. Not an endorsement.

minimizing expenditure for the compensation of experienced administrators.

1.3.1 The role of CDS in connecting the point of care to the state

In the case of the HITECH Act and ongoing CMS oversight, policies charged with the motivating energy of finance are mediated through institutions of healthcare and organizations such as health systems, affecting the individual clinicians' provision of patient care. A range of guidance on, e.g., how frequently to calculate and record body-mass index, the administration of routine screenings, and guidance on safe opioid prescribing, are passed from institutions to organizations that implement automated pop-up alerts, which in turn intervene in the work of clinicians. Clinicians see these alerts at a broad level of detail and either consciously analyze or ignore them, and interact with the alerts accordingly through the clicking and tapping of computer mice and

keyboards.[263] When clinicians accept a particular bit of advice as relevant, they may examine and collect information on the patient's body, or act on it through prescribed regimentation in accordance with standards of care.

My intent in theoretically likening the technological intervention in physician labor to the taxing of the soda-consuming public is to reveal the pervasiveness and flexibility of a particular ethos that guides the construction of a wide range of control structures: *'Make it hard to do the wrong thing and easy to do the right thing,'* where the subject is often implicitly expected to accept the distinction between 'right' and 'wrong' received from authorities as given.

To be clear, authority is not inherently good or bad, but it is dangerous.[143] In Foucault's disciplinary societies, the power of pure reason promised by Enlightenment philosophers such as Kant is meant to make the assertion of authority through violence virtually obsolete,[97] but as he wrote late in life, contemporary Euroamerican societies are far from achieving this ideal.[98] As Starr noted in his social history of US medicine, while assuming the legitimacy of authorities such as medical experts may promote comfort and convenience, authorities should always be open to inquisition; the use of violence or threats by authority figures represents a failure on their part to maintain legitimacy.[237] It is rare for self-described libertarian paternalists to meaningfully reckon with questions regarding authority and legitimacy. Instead, they tend to emphasize the range of choices they aim to offer their subjects as evidence that essential liberties have in fact been preserved, while leaning on the apparent objectivity of actuarial techniques to justify the restriction of choice—the paternalism—they openly acknowledge.[243]

A note on my epistemological position. I say *apparent* objectivity because there is no guarantee that any given 'nudge'-based policy such as the soda tax will be rooted in objective fact. Indeed, as an STS researcher, I would also contend there is no guarantee that any medico-scientific consensus will be rooted in objective fact either, or even that

such a thing as objective fact—as opposed to cautiously reasoned interpretations of carefully collected empirical data—can be obtained through scientific process. As is common in STS, I generally aim to suspend my own beliefs for the purposes of providing an *agnostic* analysis.[154] Callan and Latour's principle of *symmetry*[42] transcends the divide between the 'natural' and the 'social,' focusing instead on people, materials, and relations and practices which structure everyday life.[42]

Libertarian paternalists tend to lay claim to political and scientific neutrality, which is distinct from agnosticism. A key distinction is that neutrality assumes there is one correct view, whereas an agnostic believes that most views deserve fair treatment, and that some views are more legitimate than others. In my personal experience, claims to neutrality are often motivated by a rather flat characterization of position-taking as 'bad.' On the contrary, I believe that the political is merely what is of interest to the body politic—to people—and it should absolutely be the *delicate* business of authorities in government, scholarship, and medicine alike. Indeed, politics are always present in scholarly work. For example, when one starts an article with 'Problem X results in Y casualties per year,' one is making a statement about political relevance. So, I do not believe neutrality is possible or even desirable.

To return to the soda tax example, in *Fearing the Black Body,*[238] Strings traced the medicalization of obesity in the United States to anti-Black racism. As she recounted, just prior to the turn of the 20th century, it was widely believed that skinniness in White women was unfavorable; that such women were unprepared for the labors of life. Soon after the turn of the century, racial scientific rhetoric about "greedy" Africans combined with Protestant beliefs about the sin of indulgence to reverse the dominant consensus, recasting skinniness as healthy and moral.[238] These beliefs have persistent consequences for heavy patients, with whom physicians tend to spend less time and more frequently misdiagnose.[211]

It is clear that the patient labor meant to produce a society that recognizes and acts on pure reason remains elusive,[98] and it is a desperately tricky business to build overarching policy frameworks on broad scientific consensus, not least because the totality of the knowledges of the disciplines—such as the contemporary interdisciplinary milieu of views on the characteristic of embodiment known as 'obesity'—contain conflicts that might be settled and unsettled until the dusk of civilization.

Let us refocus on the dominant perspective and those who articulate it. According to Deleuze,[74] those who dare to alter a global politic jump between registers such as body, mind, organization, institution, and government, imposing visions in each register. The sum total effect of this jumping is a bold re-envisioning of how power structures become real at the site of the body. For example, the soda tax, mediated through financial institutions and retail stores, induces psychological stress on the consumer, who responds by choosing to drink lower-calorie beverages; over time, the consumer's mental conditioning leads to a reduction in weight.

Frameworks for the exercise of power can be infinitely interpretable, aiming to affect the furthest reaches of daily life all at once.[74] Researchers have offered nudges to address a range of threats to societal wellbeing and public health, such as climate change[164, 160] I am included among these researchers—together with my advisor, I had the pleasure and privilege of applying for government funding that was made available following Obama's directive.[19] We applied for funding[4,5] to address the opioid crisis, which at the time had been driven in no small part by prescription opioids,[187, 131, 128] and we conducted one such study—more on that in a bit.

As a result of this infinite interpretability, frameworks for power may appear analytically

[4]PA-14-001 Exploratory and Developmental Grant to Improve Health Care Quality through Health Information Technology (IT) (R21) funded by Agency for Healthcare Research and Quality (AHRQ) Feb 2017.

[5]RFA-AG-17-013 Encouraging Appropriate Care Using Behavioral Economics through Electronic Health Records (R21/R33), National Institutes of Health (NIH) Jan 2017.

incoherent.[74] Indeed, the founders of neoliberalism, in the Mont Pèlerin Society, sought for decades to hide their movement from public view in order to avoid ridicule for their more boldly optimistic ideas.[175] Neoliberal ideas have been applied in the policies of countries such as Chile, Russia, the United States and the United Kingdom,[114] shifting responsibilities from welfare institutions-turned-markets to individual citizens-turned-consumers as wealth concentrated in the coffers of an emerging oligarchic class of billionaires.[198, 274, 117] Neoliberal policies have even begun to pick away at the Scandinavian social democratic consensus,[72] which has held for over a century.[26]

In order to understand a shifting political landscape, then, scholars must follow how dominant logics jump between registers, which they understand as units of analysis. Many social scientists consider such analysis risky; the principle of *emergence* holds that activities that take place at one unit of analysis lead to unpredictable changes at neighboring layers and beyond,[219] so analysis that cut across units of analysis—for example, the individual and the social—can appear incoherent. The maintenance of the boundaries between units of analysis can give the system of professions a semblance of order—it can serve to keep peace between the dominant views of physicians and sociologists, for example—but as Abbott wrote, the appearance of order between professions obscures long-standing tensions and conflicts at such boundaries.[2] The bold theory of libertarian paternalism within behavioral economics, an incursion by certain professors of law and economics on both medicine and public health, and which has been adopted within those fields, comes to mind as one example. While I recognize the principle of emergence, I posit that a certain degree of incoherence is the price to be paid for examining the effects of popular interdisciplinary expeditions.

In composing this dissertation I aimed to achieve a reasonable degree of internal coherence by centering the perspectives of physicians-users and physician-administrators as I jumped between units of analysis. Works of scholarship on the perspectives of those not empirically

represented in this text—patients and government administrators, for example—are highly valuable, and outside the scope of this work.

For an illustration of registers of analysis referred to in this text, see Figure 1.3. The left side of the figure shows concentric circles: governments are subsumed by institutions, which are in turn subsumed by organizations, then worksites, and finally the public. The order is often presented as the opposite, with government outside all other realms. I have intentionally inverted the form of this figure to highlight that members of governments such as Presidents are themselves members of the public; they work at worksites such as the White House, in organizations such as the Presidential Administration, in institutions such as the Executive Branch of the United States; at the end of their term or life, whichever comes first, they formally return to civilian status. In other words, for better or for worse, authority figures are people, and while influence tends to run downstream, from authority figures to laypersons and civilians, the basins of power are filled with water that is drawn from and returns to the lowest basin, and is fundamentally no different in terms of its quality. The right side of the figure shows what I attend to in this dissertation—the public comprises patients and caregivers, examples of implicated worksites include the floors, clinics and offices where physicians work, and so on.

It is rare, but sometimes pertinent, for social analysts to venture into the mind and body.[74] While these are traditionally the jurisdiction of the medical professions [74], the technologists have made inroads in those jurisdictions through the use of persuasive technology—a branch of usability design devoted to achieving preordained outcomes without outright forcing the user's hand, akin to a designerly mode of nudge-work.[92] The physicians have been quick to defend their territory, at least within the EHR—only those with medical licenses are allowed to become board-certified Clinical Informatics professionals,[9] and the medical informatics field has been quick to co-opt both the technologists' design methods and the political-economic language of libertarian

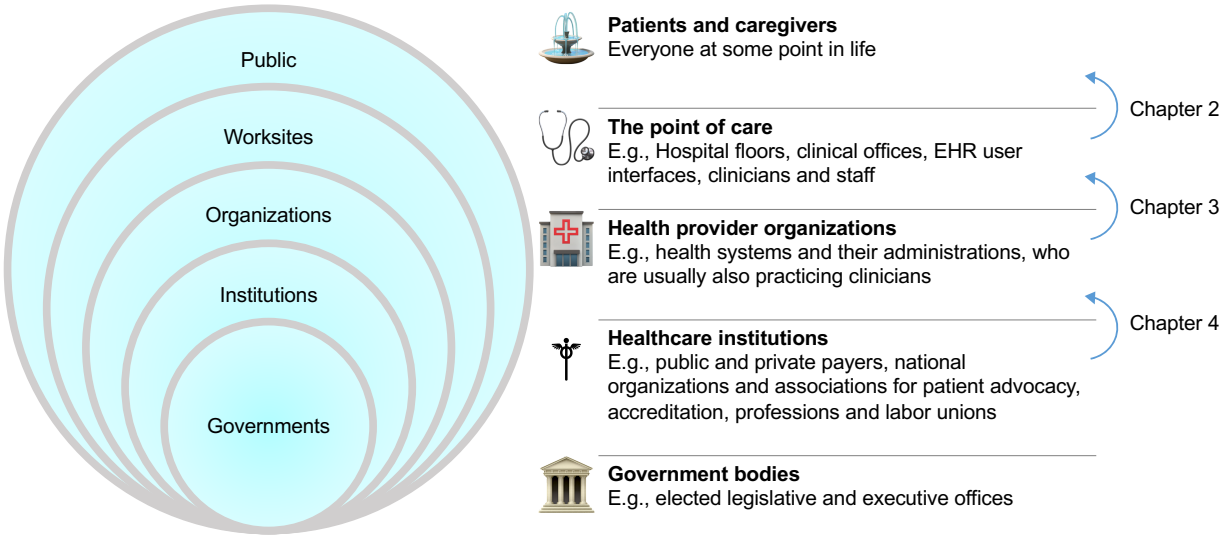


Figure 1.3: Layers of analysis referenced in the text.

paternalism.[54]

The physicians have made for interesting social studies in the postindustrial United States (early 20th century onward) because of their status as the most powerful profession. As Abbott documented in his social history of the system of professions,[2] the proliferation of psychiatry in the US industrial period displaced the authority of the religious clergy over the spirit with the psychiatrists' claim to the biomedical milieu of the mind at the site of the brain.[2] In Foucault's analysis, psychiatric diagnosis came to serve as a basis for a 'science' of criminality; the discipline of the patient's body was thus enjoined to the authority of the state.[96] Medical incarceration proliferated; at their peak in the mid-20th century, the psychiatric asylums collectively held half a million people.[213] They were emptied in the postwar period on human rights grounds in favor of community mental health models,[2] which ultimately failed to guarantee healthcare as a human right. At the onset of the COVID-19 pandemic in 2020, an estimated 13% of US residents under the age of 65 had no medical coverage,[67] and the average mortality rate for unhoused people, many of whom lived with diagnosable psychiatric conditions, was roughly 10 times higher than that of the overall population.[188]

There is reason to doubt that neoliberal frameworks such as libertarian paternalism will be sufficient to address ongoing human rights crises in the United States,[253] and I will return to this in the concluding chapter. First, an overview of my dissertation.

1.4 Jumping registers: an overview of the chapters

Here I aim to prepare the reader for the next two chapters, which I wrote in a sharply different style from this one. I wrote Chapters 2 and 3 in the style of human factors-within-medical informatics and medical informatics, respectively, because I had adopted the framings of those fields in those studies. Within Latour's groupings of STS scholars,[154] I fall most cleanly into the sixth group: those who participate in the study of technoscientific issues and influence the fields they study, and through participation maintain a view of technoscientific endeavors as concrete rather than abstract. I feel participation is key to my appreciation for the field's complexity. During my doctoral program I have participated extensively in medical informatics, attending AMIA, the annual conference of the American Medical Informatics Association, every year. Through proximity I have gained sympathy for the physicians I have studied, and I have made every attempt to treat my results with both fairness and honesty.

In Chapter 2, I set out to understand alerts from an *individual* perspective, at the level of the prescriber who contends with alerts. As mentioned, CDS alerts were intended to benefit patients by improving practices at the point of care, such as prescribing practices, but I felt their conventional design was less than ideal. At the outset of my dissertation, I asked myself: if I thought the conventional pop-up alerts had usability issues, then what other technological design might improve usability without compromising safety? This question might be phrased in the form of a common human factors question:

How might the workplace be reconfigured so that it is easier to comply with official guidance?

This ethos is neatly compatible with that of libertarian paternalism, and I selected the opioid crisis, a topic of significant interest in public press as a target for intervention. In the typical style of human factors, I proceeded to design an alternative prescribing interface and conduct a usability test. As is typical in the human factors tradition, the unit of analysis was the individual prescriber. I then compared a prototypical prescribing interface featuring conventional alerts with the novel prescribing interface of my own design, which provided information in-context, without interrupting user action, *while* the prescription was being written. Resident physicians participated in my study, and were randomly assigned to use either a conventional design or my design. They were faced with several realistic patient cases, and were asked to write prescriptions for each case. Attending physicians then evaluated the prescriptions. I used analysis of variance (ANOVA), and found that physicians wrote more appropriate prescriptions when using my design—the design which they preferred. Chapter 2 is a republication of the resulting manuscript on the study; it was accepted at the Journal of the American Medical Informatics Association (JAMIA). I quite enjoyed building the apparatus, as well as the conduct and writing of the study, and through that study I came to appreciate the draw of technical, individuated approaches to larger problems—in terms of presenting the work at meetings, I usually felt comfortable and assured that the work would be received favorably.

Many medical informatics researchers in addition to myself had tried a variety of alternative designs, some of them quite creative, for CDS to mitigate alert fatigue, with mixed success. In Chapter 3, I sought to collate these creative alternatives together, while at the same time providing evidence for their relative efficacy and appropriateness that could be useful for health system administrators. In that chapter I present a systematic

PRISMA[6] review of alert design in the tradition of allopathic medicine, aggregating the results of these papers. In so doing, I studied a variety of organizational interventions into the point of care in the same way biomedical researchers study the effects of a variety of antidepressants in patient's bodies (e.g., [88]). I asked a behavioral-scientific question, as one might do in psychiatry:

How do workplace interventions alter prescribers' behavior in responding to CDS guidance?

This review showed, using evidence legible to those trained in biomedicine, that conventional human factors considerations such as alert design—which, again, fit neatly into a 'nudge' framework—can affect prescribers' overall compliance with automated guidance. This fact was of importance to physician-administrators, since CDS compliance can translate into organizational compliance with expectations set by external accountability bodies such as payers.[49]

I appreciate the value of evidence-based medicine (EBM)—if myself or a loved one have a serious health crisis, I will insist on allopathic remedies. After conducting that systematic review, I found an added utility in EBM research: there always seems to be the leftover data that did not fit so neatly into the review framework, and in my experience it sort of 'nags' the researcher, motivating the development of more capacious frameworks. In the case of in Chapter 3, I found that my individual and administrative framework needed to be stretched to accommodate a *social* factor which was present in the literature. The role of the consultant pharmacist appeared critical to the prescriber's level of alert fatigue.

Additionally, a pragmatic discussion was unfolding in the health informatics world on the role of requirements from external bodies in contributing to alert fatigue.[10] Since CDS systems were being used for regulatory compliance purposes,[181] it would stand to reason that regulatory burden would also contribute to alert fatigue.

[6]Preferred Reporting Items for Systematic Reviews and Meta-Analysis[176]

So, next I sought to interpret the regulatory burden problem and its effect on alert fatigue from a social lens. In Chapter 4 I studied a healthcare organization's relations with accounting institutions such as payers and accreditors, indirectly backed by state authority. I did this by conducting an interview study in the style of STS-informed computer supported cooperative work (CSCW). I asked a question relevant to those two fields:

How do clinical administrators respond to regulatory burden, how does that contribute to or mitigte alert fatigue, and how do they assert intellectual authority over healthcare information technology?

To that end, I interviewed physician-users and physician-administrators, as well as a couple nurses and a pharmacist, to get their perspectives on what makes alerts useful, the relation between practices, alerts and compliance, and to get their thoughts on organizational approaches to EHR reconfiguration. My findings supported a novel view of alert fatigue: as a consequence of approaches to patient safety that involved holding healthcare organizations accountable to a milieu of external public and private healthcare institutions such as payers, accreditors, and patient advocacy groups. Together, these external bodies serve to reinforce a culture within the administration of a healthcare organization in which a single measure—revenue—is meant to serve as a proxy for an immensely multidimensional and elusive construct: *quality of care.* The participants I interviewed were generally skeptical of the assumption embedded in their practice that revenue was a satisfactory reflection of the professional spirit of medicine, but due to their organizational roles were required to act as though such an assumption held nonetheless.

My findings are significant for physician-administrators and physician-users, the administrators of healthcare institutions that maintain external accountability mechanisms, and culturally-oriented STS scholars looking for a 'way in' to the field of medical informatics. Administrators of health systems and institutions are generally aware of the problems of alert fatigue[184] and regulatory burden,[10] and tend to treat them as

separate issues. In this dissertation I offer a social view of the role of clinical decision support in compliance that reveals its role in facilitating regulatory burden. In Chapter 5, I explore the possibility that more meaningful approaches to accountability might benefit from a shared spirit of the public commons.

Chapter 2

How the presentation of patient information and decision-support advisories influences opioid prescribing behavior: a simulation study

Objective. The United States faces an opioid crisis. Integrating prescription drug monitoring programs (PDMPs) into electronic health records (EHRs) offers promise to improve opioid prescribing practices. This study aimed to evaluate two different user interface designs for PDMP-EHR integration.

Methods. Twenty-four resident physicians participated in a randomized controlled experiment using four simulated patient cases. In the 'conventional' condition, prescription opioid histories were presented in tabular format, and computerized decision support (CDS) was provided via interruptive modal dialogs (i.e., pop-ups). The 'alternative' condition featured a graphical opioid history, a cue to visit that history, and

non-interruptive CDS. Two attending pain specialists judged prescription appropriateness.

Results. Participants in the alternative condition wrote more appropriate prescriptions. When asked after the experiment, most participants stated that they preferred the alternative design to the conventional design.

Discussion and conclusion. How patient information and CDS are presented appears to have a significant influence on opioid prescribing behavior.

2.1 Introduction

Opioid overdose deaths quadrupled between 1999 and 2016 in the United States, accounting for more than half of drug overdose deaths [212]. Prescribed opioids are believed to have contributed to the crisis: 1 in 10 patients prescribed opioids became dependent [264]; 4 in 5 heroin users started with an opioid prescription [58]; and many opioid prescriptions have been diverted [62].

This is not the first opioid crisis in the U.S.—lawmakers responded to the crisis of the 1960s by writing the Controlled Substances Act of 1970, which set the contemporary framework for controlling drugs with "abuse potential" via criminological and medical institutions [233]. In response to the current crisis, all 50 U.S. states and Guam have developed prescription drug monitoring program (PDMP) databases to track prescriptions of most controlled substances, and to make patients' prescription histories available to licensed prescribers. [256, 124] Further, the U.S. Centers for Disease Control and Prevention (CDC) and other governing bodies have recommended or even required that prescribers verify each patient's PDMP history before prescribing opioids [76, 77, 258].

In most states, PDMPs are provided via standalone websites; they are not integrated with

the electronic health records (EHRs) that most prescribers now use to place medication orders. Therefore, accessing PDMP information is often a tedious task: A prescriber must first locate the website, and then contend with strict password logistics, rigid search engines, and cluttered information displays [124, 128, 157, 111].

There have been some efforts to integrate PDMPs into EHRs [1, 17, 189, 244], which may address the difficulties locating and logging into PDMPs. Whether this integration should be mandated has also been discussed [244, 66]. However, little attention has been paid to where and how PDMP information should be presented in the EHR, as well as how clinical decision support (CDS) should be designed to augment cognition while introducing minimal disruption to workflow [124, 89, 226].

A conventional method of implementation would be to provide the PDMP in a dedicated tab in the user interface, and to present CDS via interruptive modal dialogs (i.e., pop-up alerts). Such a design is, however, susceptible to a number of issues known in the human factors and health informatics literature. First, prescribers have difficulty reading and interpreting PDMP reports (e.g., due to cluttered, disorganized displays) [124, 157]. Second, without contextual cues to draw prescribers' attention to the PDMP information, the tab may likely be neglected [202]. As for CDS, the problem of *alert fatigue* [262] may arise: When a CDS system issues too many alerts, and when many of them are irrelevant, users tend to cease to pay attention to them [271]. Further, the literature suggests against restrictive designs such as modal dialogs,[11, 132] because of their interruptive nature; and excessive use of modal dialogs may have contributed to clinician dissatisfaction and burnout [107, 103, 245, 159].

In this work, I applied human factors principles to improve the design of PDMP-EHR integration. Human factors research aims to develop technologies that fit users' expectations, rather than requiring users to conform to any given design. It has been widely applied in health informatics to study a variety of applications such as medical

devices [218, 165], EHRs [194], and computerized prescriber order entry systems (CPOE) [214, 106, 25, 120, 199].

In this study, I conducted a simulation experiment to compare two designs for PDMP-EHR integration. In the *conventional* design, the patient's controlled substance prescription history is presented in tabular format, in a separate PDMP tab; and CDS advisories are presented in interruptive modal dialogs when an order is about to be placed. In the *alternative* design, multiple contextual cues are provided to draw prescribers' attention to PDMP information, along with non-interruptive CDS presented as part of the ordering process. I provide details and illustrations of these two designs in the Methods section.

I hypothesized the alternative design would increase the appropriateness of physician prescriptions, because it was intended to facilitate "information foraging," [202] convey information through cognitively efficient graphic representation [124, 63], and deliver CDS early on in the prescribing process [116]. I also hypothesized that physicians would prefer the alternative design, that the alternative condition would require less time to use, and that physicians would visit the PDMP tab more often under the alternative condition when information was available. Next, I describe the two designs, and the protocol for the simulated experiment.

2.2 Methods

2.2.1 Two competing designs for PDMP-EHR integration

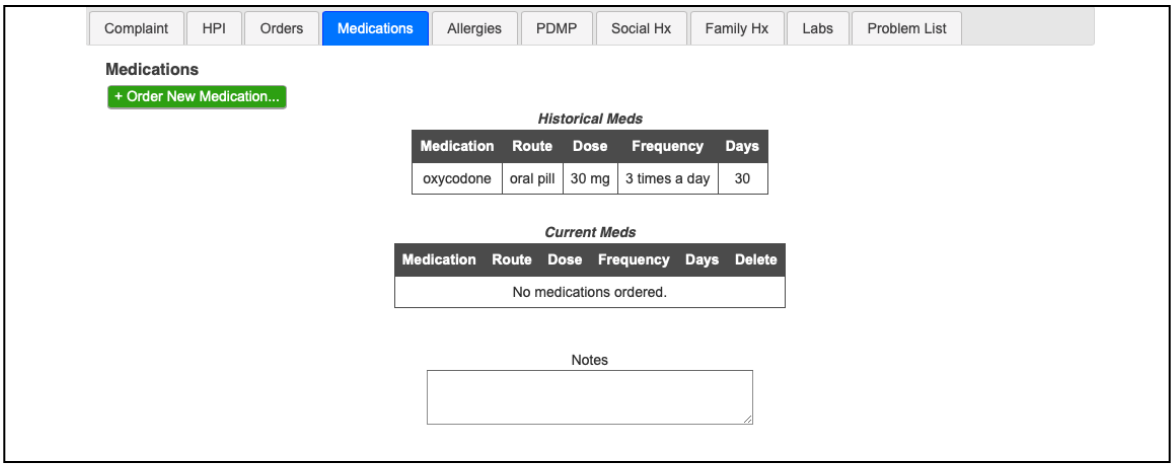
Demonstrations of the two designs are available online (https://www.ics.uci.edu/~mihussai/demos/2019-simulation-study/). In Table 2.1, I summarize the features present in each of the designs. Briefly, the conventional design

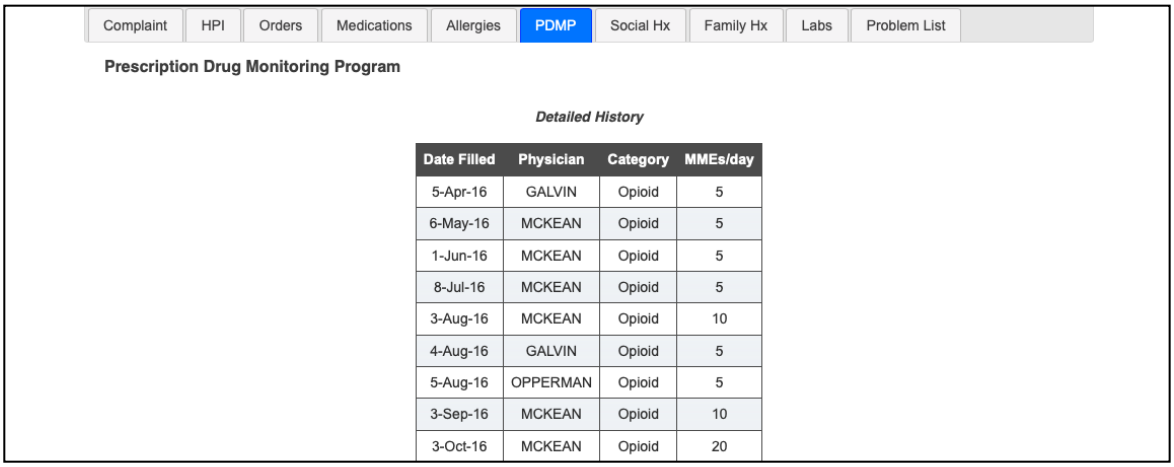
(Figure 2.1) has a dedicated PDMP tab, which presents controlled substance prescription history in a tabular format, as is typical of PDMPs [124]. It also features a typical CDS design, which presents text-only modal dialogs immediately before the order is placed [214, 116]. The alternative design also presents a non-interruptive cue to draw the prescriber's attention to PDMP information, a graphical opioid prescription history along with tabular PDMP data, and non-interruptive CDS advisories presented as part of the ordering process (Figure 2.2).

In the experiment, participants completed four scenarios, developed by an attending pain specialist (AMN). These scenarios, and accompanying graphical prescription opioid histories, are provided in Appendix A. I created mock patient interview videos to present the scenarios, each of which featured a white male actor between the ages of 28 and 56, to minimize potential discriminatory prescribing effects—prior research [118, 173] has found that opioids are prescribed less frequently for black and female patients.

2.2.2 Study setting and experiment protocol

All study participants were either anesthesiology or physical medicine and rehabilitation (PM&R) residents; practitioners in these disciplines commonly prescribe opioids. All participants had completed at least one year of residency training at a large academic medical center in Southern California. Researchers presented the study during monthly resident meetings and recruited in person. All eligible residents but one agreed to participate. Half of the participants were randomly assigned to use one of the designs. At the beginning of the experiment, participants viewed a tutorial video about how to use the simulated EHR. Then, participants proceeded to the first patient interview video, reviewed the patient's medical records, and placed medication orders. The experiment concluded after the participant completed all four patient scenarios, which were presented in a





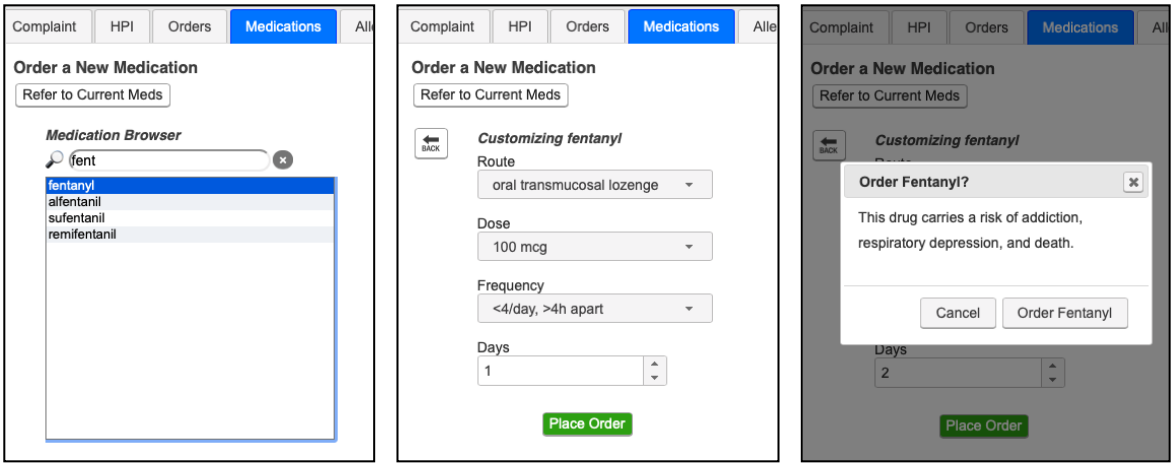


Figure 2.1: Conventional design, which presents the patient's medication history as a simple list (top), the PDMP information in a tabular format on a separate tab (middle), and interruptive modal dialogs for delivering decision support (bottom).

Figure 2.2: Alternative design, featuring a contextual cue when PDMP information is available ①, a graphical presentation of opioid prescription history ②, and non-interruptive decision support delivered as contextual cues as part of the ordering process ③ ④ ⑤

Table 2.1: Feature description and comparison

Feature	Conventional	Alternative
Medication list	Displays medication history and current medications.	*Cue for availability of PDMP information.* When PDMP data are available for the patient, a non-interruptive cue appears, with a shortcut to the PDMP tab ①.
Prescribed controlled substances tab	Displays a table, showing date filled, prescribing physician, drug category, and milligram morphine equivalents (MMEs).	*Graphical presentation of opioid history.* The tabular PDMP data are supplemented with a stacked bar chart showing MMEs and distinct prescribers in the past year ②.
Medication ordering entry	The user orders medications by searching for a drug, and then selecting a route, dose, frequency, and duration. After the prescription is fully defined and before the order is placed, the system pops up CDS. *Modal dialogs.* CDS is delivered via modal dialogs. The user clicks "Cancel" to return to the ordering screen, or "Order" to override the alert.	The user is guided by three types of contextual cues: *Query expansion suggestions.* When ordering a medication, if one types "fent" into the search bar, medication classes similar to the fentanyls, such as "analgesic combinations" and "NSAIDs," appear below the search results. The query expansion algorithm is based on the RxNorm[40] classification system ③. *Contextual prescription opioid history.* When one adds an opioid to the Your Options panel, the graphical prescription opioid history appears on the right side of the screen ④. *Medication suggestions.* The CDC Guideline recommends first seeking alternatives to opioids, then starting with low MMEs.[6] Accordingly, if one adds a high-MME opioid such as fentanyl to the Your Options panel, the system would display a generic reminder to use lower-risk pain medications, such as acetaminophen, ibuprofen, and codeine. One can then add one or more of these medications to the Your Options panel as potential substitutes ⑤.

random order. In this paper, I refer to each instance of a participant completing a scenario as a *trial,* in accordance with how it is described in experimental psychology studies. This portion of the study took approximately half an hour, with no apparent differences in time between the two conditions.

After the experiment, participants who used the conventional design were shown a video tour of the alternative design, and vice-versa. They were then asked to preferentially compare the two designs, and to provide a reason for their preference. Participants did not receive compensation or an honorarium for their participation. The institutional review board (IRB) of the University of California, Irvine reviewed the research protocol of the study and determined that it met the exemption criteria.

2.2.3 Data collection and appropriateness review

I implemented a tracking mechanism in both designs to record mouse clicks as well as timestamps of interaction events in order to measure the time spent between actions (e.g., starting an order and placing an order).

In order to assess whether the pain medication orders placed for each scenarios were appropriate, I developed an appropriateness panel review, based on the process described by McCoy et al [170]. First, two pain specialists (AMN, BY) created a scoring rubric (included in Appendix A) through consensus development. Then, they independently reviewed the prescriptions placed for each trial. During the entire process, reviewers were blinded to the experimental condition (alternative vs. conventional) in which each prescription was written. Inter-rater reliability was assessed using Cohen's kappa [153]. If there were scoring differences, they were reconciled through discussion and consensus development.

2.2.4 Data analyses

I used JASP (Amsterdam, The Netherlands) to conduct a two-way mixed-effects ANOVA analysis of appropriateness. I tested the sphericity and equality of variance assumptions using Mauchly's and Levene's tests, respectively.

I used a chi-squared test to evaluate participants' design preferences. I also conducted a mixed-effects ANOVA to assess time reduction from each trial to the next, between conditions, to examine the learning effect and time efficiency of each of the designs.

Further, I conducted a one-way mixed-effects ANOVA to test to assess whether those in the conventional condition visited the PDMP tab less often than their peers in the alternative condition when the patient's PDMP information was available. I also analyzed the usage of different features presented in the interfaces of the two conditions (e.g., recommended alternative medications or pop-up alerts).

2.3 Results

2.3.1 Participant demographics

Seventeen of the participants were anesthesiology residents (71%) and the other seven were PM&R residents (30%). I randomly assigned nine of the anesthesiology residents (53%) and three of the PM&R residents (43%) to the conventional condition, and the rest to the alternative condition. Among the participants who reported demographic data, the mean age was 31 (range 26–38); there were eight women (40%) and 12 men (60%). Fifty-five percent of them were White (10 participants), 35% were Asian (seven participants), and 8% were Black or African American (2 participants). Appendix A provides additional

demographic details.

2.3.2 Appropriateness analysis

Participants completed 94 trials in total; two were incomplete due to loss of network connectivity. Inter-rater reliability was high between the two attending physicians' appropriateness ratings ($\kappa = 0.93$) [153].

The results of our two-way mixed-effects ANOVA analysis are shown in Table 2.2. According to these results, there was a borderline significant effect of the experimental condition, which explained 14% of the variance ($F(1, 18) = 4.40$, $p = 0.05$, $\eta^2 > 0.14$); prescribers who used the conventional design achieved lower scores (mean = 3.94, SD = 1.96) than those who used the alternative design (mean = 4.85, SD = 1.84). Further, there was a significant main effect of specialty, which explained 28% of the variance ($F(1, 18) = 8.73$, $p < 0.05$, $\eta^2 > 0.28$). Overall, anesthesiology residents received higher appropriateness scores (mean = 4.80, SD = 1.83) than PM&R residents (mean = 3.43, SD = 1.86).

There were no significant interaction effects. This analysis withstood Mauchly's test ($p > 0.05$) and Levene's test ($p > 0.05$). As shown in Figure 2.3, those in the alternative condition tended to receive higher scores.

2.3.3 Participants' preferences

As described earlier, researchers showed a video of the alternative design to participants randomly assigned to the conventional condition, and vice versa. Among those who provided a preference, seven (70%) in the conventional condition stated that they preferred the alternative design, and nine (81%) in the alternative condition preferred it to the conventional design. Using a chi-squared test, I found this result to be statistically

Table 2.2: Two-way mixed-effects ANOVA analysis of prescription appropriateness

Between participants effects						
	Sum of Squares	df	Mean Square	F	p	η^2
Condition	18.546	1	18.546	4.398	0.050	0.140
Specialty	36.819	1	36.819	8.732	0.008	0.278
Condition * Specialty	1.113	1	1.113	0.264	0.614	0.008
Residual	75.897	18	4.217			
Within participants effects						
	Sum of Squares	df	Mean Square	F	p	η^2
Scenario	76.292	3	25.431	13.955	$< .001$	0.242
Scenario * Condition	5.732	3	1.911	1.049	0.379	0.018
Scenario * Specialty	0.411	3	0.137	0.075	0.973	0.001
Scenario * Condition * Specialty	2.061	3	0.687	0.377	0.770	0.007
Residual	98.406	54	1.822			

Note. Type III Sum of Squares

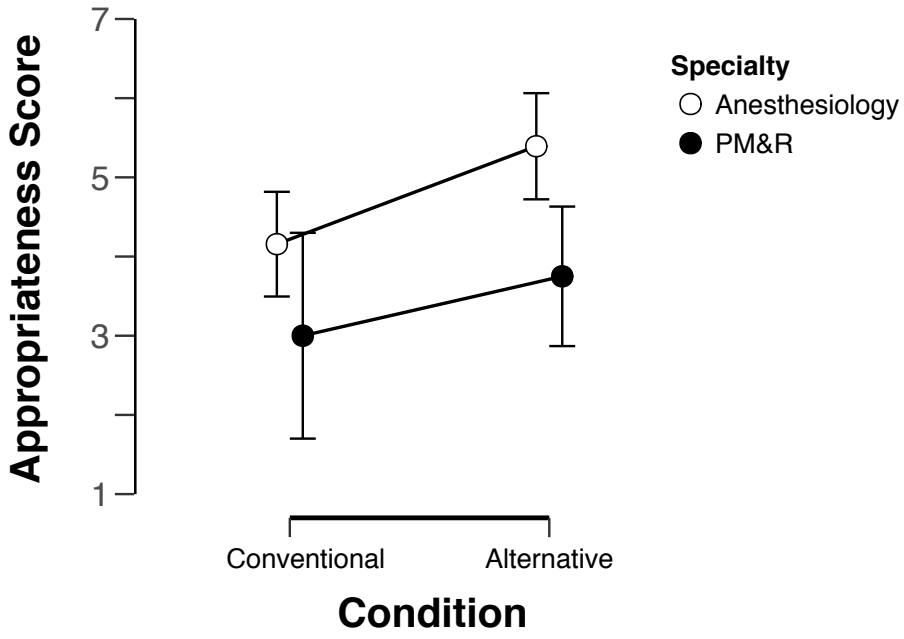


Figure 2.3: Appropriateness scores by specialty and experimental condition.

significant ($N = 21$, $\chi^2 = 5.74$, df = 1, $p < 0.05$). The top reason provided by the participants for preferring the alternative design was the visual representation of PDMP information, followed by its flexibility in interaction, and participants' aversion to modal dialogs.

2.3.4 Trial duration and feature usage

In our mixed-effects ANOVA analysis of time, while I detected a statistically significant overall reduction in trial completion time as participants progressed through the four trials (144s vs. 135s vs. 89s vs. 91s, $F(3, 60) = 6.24$, $p < 0.001$), I did not detect a statistically significant difference in trial completion time between the two conditions. I also did not detect an interaction between trial progression and experimental condition.

As mentioned in the Methods section, I conducted a one-way mixed-effects ANOVA analysis to measure the influence of the experimental condition on whether participants checked the PDMP tab when information was available. I found a significant interaction effect of scenario and experimental condition on whether the participant visited the PDMP tab—meaning that the design and the presence of a PDMP history produced the effect together—which explained 10% of the variance ($F(3, 60) = 3.44$, $p < 0.05$, $\eta^2 = 0.10$). Scenarios 3 and 4 were the only scenarios in which PDMP information was available; both patients had been prescribed opioids in the past year. In these scenarios, participants in the conventional condition neglected to visit the PDMP tab 58% of the time; whereas their peers in the alternative condition neglected to visit the tab only 8% and 27% of the time, respectively. There were no main effects, as expected. Levene's test did not pass under Scenario 3 ($p < 0.05$).

In the conventional condition, participants overrode 45 of 47 modal dialogs (96%). In the alternative condition, the patient's PDMP information was available in 23 trials. In 14

(61%) of these cases, participants clicked the PDMP shortcut button (Figure 2.2, ①). In another 6 trials (26%), they clicked the PDMP tab directly, rather than using the shortcut. Among the other features provided in the alternative condition, alternative medication suggestions were barely clicked, and search suggestions were never used. However, I do not know whether the information presented on screen had an influence on participants' prescribing decisions.

2.4 Discussion

To combat the opioid crisis, there is a broad consensus that it is imperative to integrate PDMP into EHRs to make it easier for prescribers to access patients' prescription history of controlled substances at the point of care [124, 128, 157, 111]. However, how PDMP information should be presented in the EHR, and how this information should be optimally incorporated into clinicians' workflow and decision-making processes, have remained understudied.

As mentioned earlier, the primary approach to presenting medication safety alerts is through modal dialogs. Modal dialogs are relatively easy to implement, and there seems to be a perception that modal dialogs—because of their interruptive nature—are an effective means of obtaining clinicians' attention, leading to a higher likelihood of actions. However, as I will elaborate in Chapter 3, there has been an extensive body of literature suggesting that alerts delivered through modal dialogs are frequently overridden, much like in our study, in which participants overrode 96% of modal dialogs. Further, modal dialogs are a significant contributing factor to clinician frustration [200], burnout [119], and potentially unsafe prescribing practices [103].

2.4.1 The alternative design improved prescription appropriateness

In our study, participants who used the alternative design for integrating PDMP information into the EHR, which features non-interruptive, contextual cues, wrote more appropriate pain medication prescriptions than those who used an interruptive, modal dialog-based design, as I had expected. This result suggests that attention to interactive design can improve the effectiveness of PDMP-EHR integration while minimizing disruption to workflow and clinicians' decision-making processes.

2.4.2 Participants preferred the alternative design

Most participants preferred the contextual cue-based version, again as expected. The results of participant feedback suggest that participants found the graphical PDMP display to be valuable, and they also liked the fact that interaction with the system in the alternative design was more flexible. In related research, prescribers have stated that they are unlikely to check the database unless they see a legitimate reason to do so [124, 128, 157]. I believe that the PDMP history indicator provided one such reason: The fact that the database actually *had* some information to offer.

2.4.3 Contextual information preferable to direct persuasion

While the alternative condition did not appear to save time, it also did not appear to increase the time burden. It appears, then, that the alternative condition allowed physicians to make better use of their time, as measured by appropriateness. For example, according to our usage statistics, those in the alternative design condition were far more likely to visit the PDMP tab when information was available, as I had expected; I attribute

this to the PDMP history indicator, which participants frequently clicked.

Further, direct persuasion features (e.g., modal dialogs and alternative medication recommendations) were almost always ignored. I believe that alternative medication recommendations could be more acceptable if they were more tuned to the patient's chief complaint, problem list, or diagnoses—developing such a recommender system would require careful research in its own right.

The relative apparent efficacy of those "guiding" features, such as the PDMP history cue and the visual representation of PDMP data, seems to lend credence to design principles such as "anticipate clinician needs and bring information to clinicians at the time they need it" [21]. I also note that participants said they liked the alternative design's flexibility. By this, I believe they were referring to its support for flexible *task wayfinding* [174], the process by which a user explores the structure of a task, such as composing a medication order. The alternative design allowed users to move quite freely between the "high-level" (e.g., compiling medication options and regimens) and the "low level" (specifying order details, such as route, dose, and frequency). By contrast, the conventional condition was more regimented; it required the user to fully specify route, dose, and frequency as soon as a medication was selected. We believe the alternative design's support for flexible task wayfinding contributed to the overall improvement in appropriateness.

I conclude that alert fatigue continues to be a barrier to realizing the efficacy of CDS systems. Future research should seek alternative means of delivering decision-supporting information, such as through contextual cues.

2.4.4 Limitations

This study has several limitations. First, our simulation apparatus only displayed generic names of the medications, whereas most commercial EHRs display both generic and brand names. However, since generic names were presented in both conditions (alternative and conventional), I do not believe it influenced the outcomes of the study. Second, both attending physicians who scored the results are anesthesiologists. This might explain why the anesthesiology residents received slightly higher overall scores than the PM&R residents. Third, participants were all resident physicians. Therefore, the results may not be generalizable to more experienced participants, or physicians in specialties other than anesthesiology and PM&R. Fourth, our study was designed to evaluate multiple user interface design features; further research is needed to isolate which features contributed more to the overall effect. Further, this was an experimental study conducted in a simulated setting; further evaluation in realistic clinical environments is needed. Lastly, it should be acknowledged that certain U.S. states prohibit PDMP–EHR integration by law. Alternative methods for facilitating provider access to PDMP information may need to be developed for these states, or lawmakers may consider allowing some form of integration given the improved information utility.

2.5 Conclusion

With PDMP-EHR integration efforts projected to be underway across the U.S., it would be prudent to consider using human factors principles to ensure such integration is not only useful but also usable, in order to achieve its maximum benefits. In this study, I found that an alternative design using graphical presentation of PDMP data and contextual cues resulted in improved pain prescribing compared to a conventional design that features tabular data display and modal dialogs for presenting CDS. Based on these results, I

conclude that the effectiveness of PDMP-EHR integration is critically dependent upon interactive design.

Chapter 3

Medication safety alert fatigue may be reduced via interaction design and clinical role-tailoring: A systematic review

Objective: Alert fatigue limits the effectiveness of medication safety alerts, a type of computerized clinical decision support (CDS). Researchers have suggested alternative interactive designs, as well as tailoring alerts to clinical roles. As examples, alerts may be tiered to convey risk, and certain alerts may be sent to pharmacists. I aimed to evaluate which variants elicit less alert fatigue.

Methods: I searched for articles published between 2007 and 2017 using the PubMed, Embase, CINAHL, and Cochrane databases. We included articles documenting peer-reviewed empirical research that described the interactive design of a CDS system, to which clinical role it was presented, and how often prescribers accepted the resultant

advice. Next, I compared the acceptance rates of conventional CDS—presenting prescribers with interruptive modal dialogs (i.e., "pop-ups")—with alternative designs, such as role-tailored alerts.

Results: Of 1,011 articles returned by the search, I included 39. I found different methods for measuring acceptance rates; these produced incomparable results. The most common type of CDS—in which modals interrupted prescribers—was accepted the least often. Tiering by risk, providing shortcuts for common corrections, requiring a reason to override, and tailoring CDS to match the roles of pharmacists and prescribers were the most common alternatives. Only one alternative appeared to increase prescriber acceptance: role-tailoring. Possible reasons include the importance of etiquette in delivering advice, the cognitive benefits of delegation, and the difficulties of computing 'relevance.'

Discussion and Conclusions: Alert fatigue may be mitigated by redesigning the interactive behavior of CDS, and by tailoring CDS to clinical roles. Further research is needed to develop alternative designs, and to standardize measurement methods to enable meta-analyses.

3.1 Background

According to the most recent U.S. government reports, one in every 20 deaths in the United States have been attributable to an adverse drug event (ADE) [41, 145]. Many ADEs result from erroneous prescriptions [16]. By the most conservative estimates, one in every 50 prescriptions is inappropriate [16].

Clinical decision support (CDS) is intended to reduce prescription error by providing prescribers with automated guidance during computerized order entry [28]. Some have held high hopes for CDS, believing that it would significantly reduce prescription errors [148]

The reality has proved more complex—CDS can create new patient safety risks. For example, in some instances, "hard stops" have prevented patients from receiving potentially life-saving treatment in time [204]. The IT infrastructures that organizations must install to integrate CDS into the medication-ordering process—often accompanied by changes in workflow and communication patterns—can disrupt work during "roll-out," as well as in long-term use [112]. These disruptions can increase instances of ADEs, which can, in turn, increase patient mortality [112].

CDS can also fail to improve patient safety due to *alert fatigue* [262]. Alert fatigue occurs when a high number of irrelevant alerts leads users to habitually override them. It is a term derived from "alarm fatigue," a term that psychologists and human factors researchers have used when studying high false alarm rates in fields like aviation and nuclear power plant operation [271].

Alarm fatigue was once referred to as the "cry-wolf effect," because, much like Aesop's fable [5], it describes a situation where people stop responding to false alarms [271]. Severe consequences can result from alarm and alert fatigue conditions. For example, a 1997 plane crash was attributed to alarm fatigue—the control tower operators had disabled a minimum safe altitude alarm due to its frequent false alarms [149]. Similarly, the patient safety goals of CDS can be compromised by alert fatigue.

Some researchers have focused on increasing alert sensitivity and specificity by modifying CDS rulesets [39, 169]. The results have been mixed. It is often difficult to justify disabling alerts, due to safety concerns or pressure from patient safety groups (e.g., Leapfrog) [249, 261].

Psychologists and human factors researchers have developed strategies to reduce alarm fatigue via *interaction design*—the design of the way the "dialogue" unfolds between the human user and the computer. Some have applied these strategies in CDS, with promising

results. For example, *tiered alarms* [271] indicate the likelihood or severity of an adverse event, and they seem to have been well-received in CDS [195]. As another example, "patient" alarms—those that avoid distracting airplane pilots when they are busy—may be accepted more often than "impatient" alarms [193]. Similarly, in CDS, researchers have implemented alerts that avoided requiring attention at a particular time—again, with some success [106].

To address whether the interactive design of CDS affects clinical alert fatigue, in the aggregate, I conducted a systematic PRISMA review [176]. Existing systematic reviews have tended to focus on prescriber performance and patient outcomes rather than alert acceptance [38, 104, 134, 140, 141, 180]. I only found three published reviews that addressed interactive design [120, 172, 262]. In 2006, van der Sijs *et al.* [262] conducted a conceptual analysis, noting that they had identified only nine studies that reported override rates. Subsequent reviews by Horsky *et al.* [120] and Miller *et al.* [172] deferred to prior authors' assessments of effectiveness. These assessments were based on a variety of factors, ranging from provider usability and satisfaction to patient morbidity and mortality. In this review, I continue this line of inquiry by centralizing alert fatigue and specifically examining the relationship between interactive designs and prescriber acceptance rates.

3.1.1 Defining acceptance

I defined *acceptance*—our main outcome—as *a change to a prescription based on computerized advice.* This definition excluded "intention to monitor" and "acknowledgment"—explanations of these concepts follow.

Intention to monitor. Some CDS alerts have allowed prescribers to select "intention to monitor" as an override justification, and some researchers have counted this justification-selection as evidence of "acceptance." However, Slight *et al.* [229] found

evidence of monitoring in only 36% of instances in which the prescriber indicated an intention to monitor.

Acknowledgment. Many CDS alerts have been presented as modal dialogs (also known as pop-ups), and some of these have provided a button that indicates "acknowledgment," but which takes no action. Some researchers have considered a click of this button to count as "acceptance"—but this, too, may rely on an incorrect assumption. Under alert fatigue, modal dialogs become obstacles, and "acknowledgment" buttons become the work-around [283].

Additionally, in this review, I paid attention to the clinical role of the recipient of the automated guidance, e.g., a prescriber or a pharmacist. Other authors [44, 262] have identified that delivering the right guidance to the right recipient is crucial to the acceptance of the alert.

3.2 Methods

I conducted a systematic review according to the PRISMA model [176]. I started by searching the PubMed, Embase, CINAHL, and Cochrane literature databases. The search terms I used are shown in Table 3.1. We identified papers published between 2007 and 2017. Myself and a colleague, Tera Reynolds, screened the search results, extracting relevant details (interactive features, clinical roles, acceptance rates, and methods) from included studies for analysis. We met often to ensure consistency.

Table 3.1: Search query structure

Decision Support...	Advisories...	Acceptance Rates...	Timeframe
("allergy" OR "computer-assisted" OR "computerised" OR "computerized" OR "cpoe" OR "decision support" OR "drug interaction" OR "drug-drug interaction" OR "electronic prescribing" OR "expert system" OR "order check" OR "order checks" OR "order entry" OR "prescribing" OR "prescription" OR "rules based")	AND ("alert" OR "alerts" OR "alerting" OR "alarm" OR "message" OR "messages" OR "prompt" OR "prompts" OR "reminder" OR "warning" OR "warnings")	AND ("alert fatigue" OR "alarm fatigue" OR "distraction" OR "error" OR "errors" OR "override" OR "overridden" OR "overrode" OR "guideline adherence" OR "non-adherence" OR "practice patterns" OR "practise patterns" OR "problem" OR "problems" OR "usability")	AND (published between 4 Oct 2007 and 4 Oct 2017)

3.2.1 Eligibility criteria

I included peer-reviewed, English-language articles reporting empirical studies about CDS for medication safety. I included articles that documented acceptance rates, as defined in the Background section, or enough information to calculate an acceptance rate. When I found more than one article documenting the same CDS and setting, I retained the more thorough version.

While screening, I used the following additional criteria. First, since our goal was to understand how prescribers acting of their own free will responded to different interventions, I excluded "hard stops," which impose heavy time penalties to override, and which therefore materially restrict the prescriber's range of action. Readers interested in an analysis of hard stops should refer to a 2018 systematic review by Powers *et al.* [204]. Second, I excluded articles that did not describe the interactive design in enough detail to

produce a description. Third, I excluded articles in which researchers made global changes to an alerting system, but only reported acceptance rates for those alerts intended to convey the most urgency, for certain drug categories, or for a selected subset of users exposed to the alert; some of these authors may have chosen to report only the most palatable results. If, on the other hand, the researchers set out to improve acceptance of a certain type of alert, like antibiotic stewardship or renal dosing, then reporting the acceptance rate for only those alerts was considered appropriate for our analysis.

3.2.2 Data extraction process

For included papers, I extracted interactive features, the clinical role that received CDS, measurement methods, acceptance rates, and rates of override appropriateness. For articles documenting time series trials of incremental changes to the CDS ruleset, I extracted the last recorded result. If an article reported more than one intervention—for example, if the authors compared plain modal dialogs with dialogs that provided additional context [82]—I extracted results from each intervention separately. When an acceptance rate was not directly given, I used the equations provided by McCoy *et al.* [170] to derive an acceptance rate.

The same two authors (TLR, MIH) split this data extraction workload evenly, and checked one another's work. Doubts on inclusion were handled by interpreting the inclusion criteria in-person to achieve consensus.

3.2.3 Data analysis and synthesis of results

I coded features and measurement methods as short descriptions (e.g., "tiered modal dialog presented to the prescriber," "counted dialog button-clicks"). I sorted these descriptions

into categories as commonalities emerged.

I also paid attention to the methods used to construct acceptance rates. In this paper, I refer to the two main methods as *in-dialog action analysis* and *event analysis.*

In-dialog action analysis is only applicable when the CDS intervention takes the form of a dialog that features a button that the prescriber can click to modify or discard their order (e.g., "Discard Warfarin Order"). Researchers count the number of times the "acceptance" button was clicked, and divide that count by the total number of dialogs that appeared.

Event analysis may be applied to any form of CDS, including dialogs. When conducting an event analysis, researchers search the patient chart for evidence that the prescriber accepted advice, in addition to any changes that prescribers may have made by clicking buttons inside CDS dialogs. For example, a prescriber might dismiss a modal dialog warning against a warfarin order, and then reduce the dose later. Or, a pharmacist might receive an alert from a CDS system, and counsel the prescriber by phone—in which case the researchers must check to see if the prescriber made a change to the chart.

I plotted the frequencies of measurement methods by publication year, to examine their popularity over time. For those studies that used more than one measurement method, I compared the results of those measurement methods. I also plotted the frequencies of interactive and role-tailoring features reported over time, to identify trends.

Next, I used a t test to compare acceptance rates between CDS systems by interactive design and clinical role-tailoring. In addition, we constructed a plot to holistically examine prescribers' acceptance rates by feature.

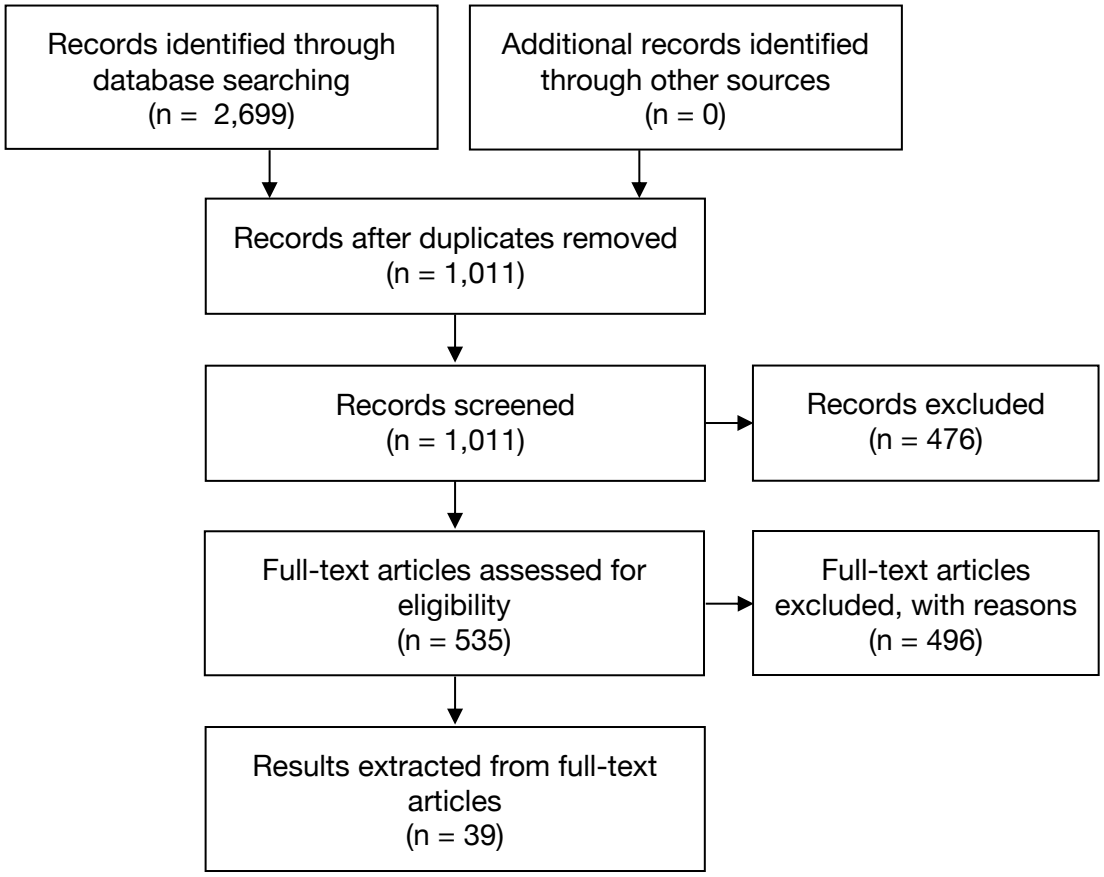


Figure 3.1: PRISMA [176] flow diagram.

3.3 Results

3.3.1 Study selection

As shown in Figure 3.1, I initially identified 2,699 records by querying the literature databases. After removing duplicates, screening titles and abstracts, and examining full-texts to determine eligibility, myself and Tera Reynolds determined that 39 articles met our inclusion criteria. Extracting results from these articles yielded 42 different interventions, since there were three articles that reported two interventions each.

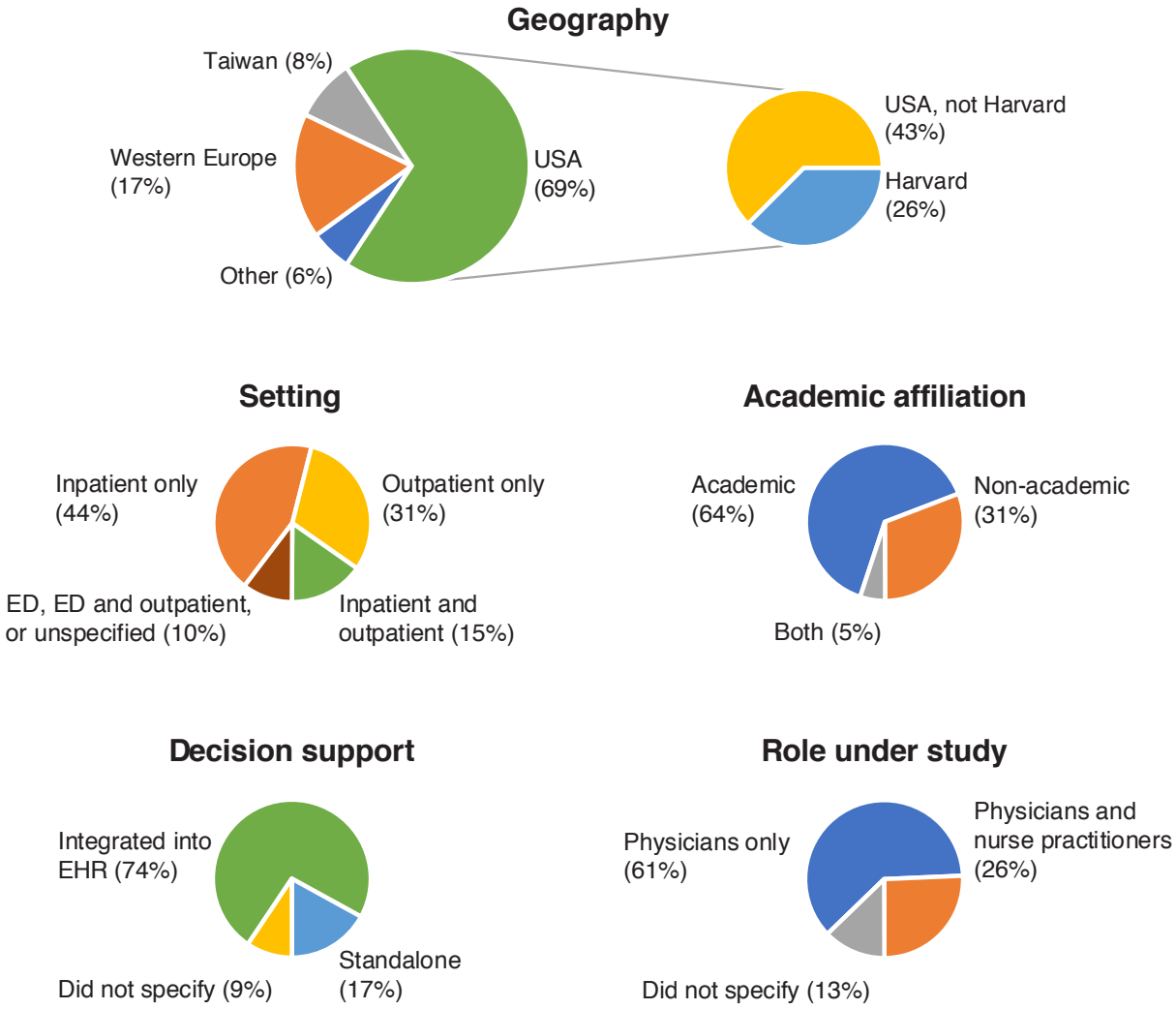


Figure 3.2: Study characteristics.

3.3.2 Study characteristics

The study characteristics are shown in Figure 3.2. Twenty-four (61%) of the 39 included papers reported studies conducted in the USA, and 3 (8%) reported studies from Taiwan. There were two studies from Switzerland, two from the Netherlands, and one from each of the following: the UK, China, Canada, and Belgium. Nine of the 24 (38%) studies conducted in the USA were conducted in Harvard-affiliated institutions.

Seventeen (44%) were conducted in inpatient settings only, 12 (31%) were conducted in outpatient settings only, 6 (15%) studied both inpatient and outpatient settings, and the remaining 4 (10%) of studies were conducted in the ED, in the ED and outpatient settings, or in an unspecified setting. Twenty-five of the 39 (64%) included papers studied academic healthcare settings, 12 (31%) studied non-academic settings, and the remaining 2 (5%) studied both settings.

Twenty-five of the 39 (64%) included papers documented an EHR-integrated CDS, 9 (23%) documented a standalone CDS, and 5 (13%) did not specify whether the CDS was integrated into an EHR. Three of the 39 included papers (8%) reported more than one intervention;[68, 82, 246] each intervention was treated as a separate study.

Twenty-four (60%) of the papers solely studied physician behavior. Ten (26%) studied both physician and nurse practitioner behavior, and 5 (13%) did not specify the clinical roles that were studied.

3.3.3 Trends in measuring acceptance

As mentioned in the Methods section, I analyzed the methods that researchers used to construct acceptance rates. The number of studies that conducted in-dialog action analyses (23) was approximately equal to the number of that conducted event analyses (22). Eight of the studies in our analysis—all between 2012 [170] and 2017—conducted a review of appropriateness, either of the CDS alerts or of overriding behavior, using the method described by Weingart *et al.* in 2003 [268]

Three papers contained measurements of prescriber acceptance using both in-dialog action analysis and event analysis. Woods *et al.* [277] arrived at an acceptance rate of 26% using in-dialog action analysis, and an acceptance rate of 41% using event analysis. Slight *et al.*

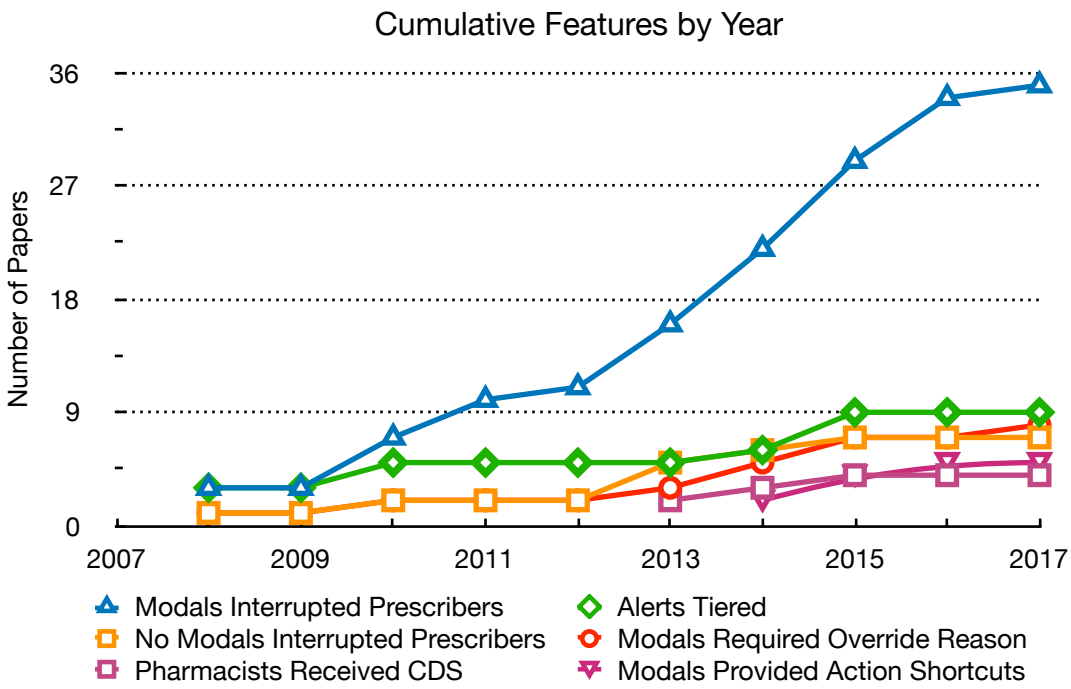


Figure 3.3: Feature prevalence over time. "Pharmacists Received CDS" is a subcategory of "No Modals Interrupted Prescribers." All others are subcategories of "Modals Interrupted Prescribers."

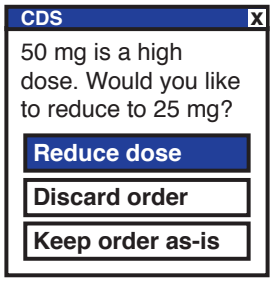
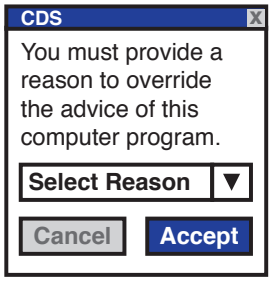
[228] arrived at acceptance rates of 40% and 66%, using in-dialog action analysis and using event analysis, respectively; McCoy *et al.*[170] arrived at acceptance rates of 18% and 47%, respectively. Event analyses generally yielded acceptance rates twice as high (194%) as in-dialog analyses.

3.3.4 Trends in CDS interventions

Features present in four or more included studies are plotted cumulatively, over time, in Figure 3.3. Three of the most common interactive features—tiering alerts, providing shortcuts for common corrective actions, and requiring a reason to override—are described and illustrated in Table 3.2.

The most commonly reported type of CDS—which comprised 83% of results—interrupted

Table 3.2: Common interactive features

Name and Description	Sample Design
Tiered Alerts present an indication of the risks associated with an override. In some cases, higher-priority alerts are modal dialogs, while lower-priority alerts are modeless.	
Action Shortcuts Modal dialogs provide the ability to perform common corrections. For example, one might wish to reduce the dose, or substitute another medication, rather than discard an order altogether.	
Override Reason Required Modal dialogs mandated that the prescriber provide a justification prior to dismissal. Justifications may be solicited with a pick-list, a free-text field, or both.	

prescribers with modal dialogs. The most common variants were tiered to convey levels of risk, provided shortcuts for common corrections, or required a reason to override.

I also found advisories that were not automatically issued using computerized systems. These included fax or mail alerts, and interactive designs in which a user manually retrieved a list of alerts [281] or manually triggered a battery of modal dialogs [246]. Only one article documented a design that allowed the user to dismiss a modal, and then retrieve it later for reference, rather than memorizing the contents of the alert [281]. A list of all designs for presenting CDS is available in Appendix

3.3.5 CDS acceptance by feature

For the analysis of feature acceptance, I included the 22 studies that used event analysis. Of those studies, 15 (68%) were based on CDS systems that interrupted prescribers with modal dialogs. Among the seven alternatives, four (18%) presented alerts pertaining to areas such as antimicrobial stewardship or renal dosing to pharmacists [99, 138, 185, 230]; two (9%) delivered fax or mail alerts to prescribers [12, 87]; and one (4.5%) depended on the prescriber to manually trigger a review process [281].

I compared those interventions that interrupted prescribers with modal dialogs with all other interventions. The group of alternative interventions included any alerts that were sent to the pharmacist instead of the prescriber, as well as any alerts that were sent to the prescriber but were not modal dialogs. Using a t test, I found that prescriber-interrupting modals were accepted significantly less often, as predicted (38.67% v. 61.57%, $p = 0.026$). The acceptance rate distributions are shown in Figure 3.4.

Our plot of acceptance rates by CDS feature is shown in Figure 3.5. In that figure, CDSs with multiple features appear on multiple lines. For example, a CDS that interrupted

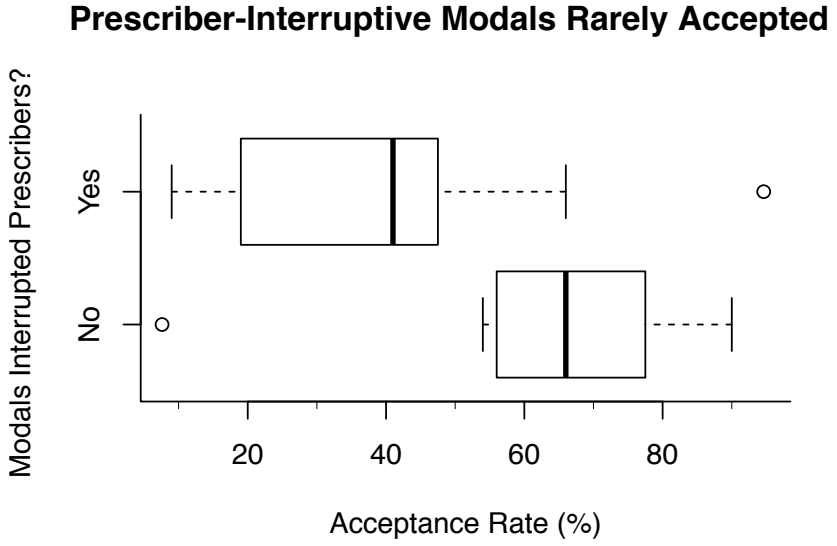


Figure 3.4: Box plot comparing how often prescribers accepted advice directly from interruptive modal dialogs versus alternatives.

prescribers with tiered modal dialogs will appear twice in the figure, once on the "Modals Interrupted Prescribers" line, and once on the "Alerts Tiered to Convey Risk" line.

Visual inspection suggested that prescribers accepted advice from CDS-guided pharmacists more frequently and with less variability than they accepted advice when interrupted by modal dialogs.

3.4 Discussion

In this systematic review, I found that interrupting prescribers with modal dialogs have become the least accepted—yet the most prevalent—design. In this section, I analyze possible reasons to account for this observation. Afterward, I discuss some methodological dilemmas faced in CDS research. Some of these have been a matter of methodological inconsistency—and they presented a practical barrier to meta-analysis. Finally, I conclude

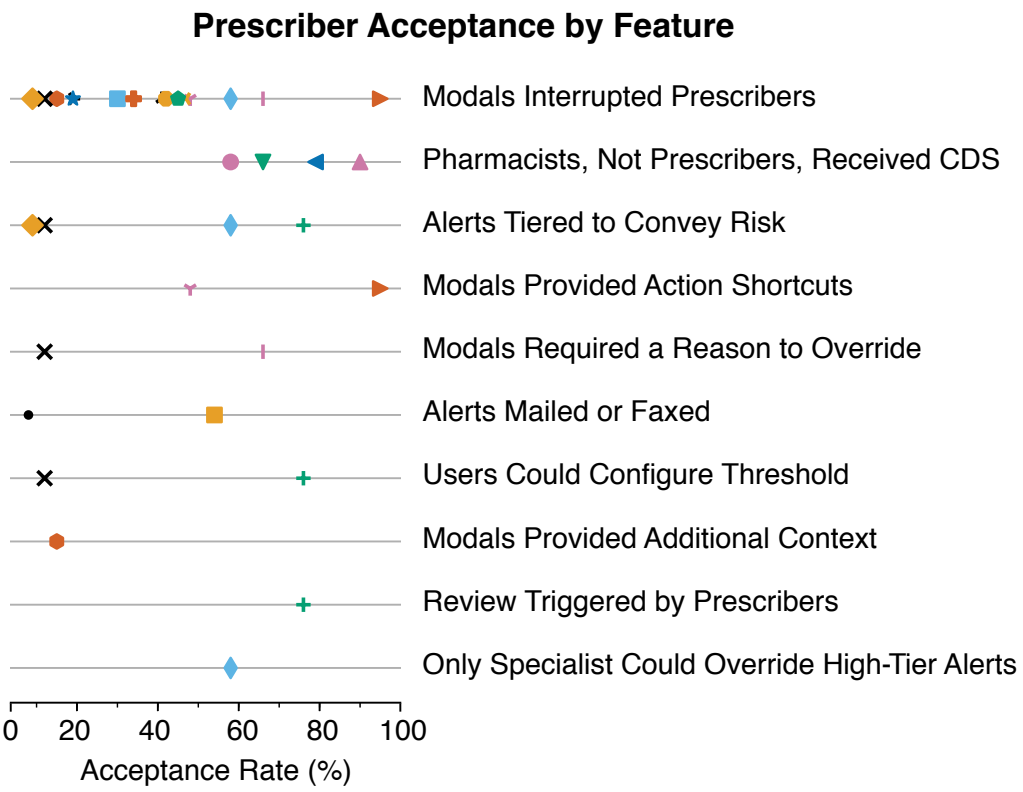


Figure 3.5: Prescribers' acceptance rates for CDS advice, by feature, measured using event analysis. CDSs with multiple features appear on multiple lines.

this section with our recommendations to improve the quality of CDS design and research.

3.4.1 Reasons why prescriber-interruptive modals seem to elicit alert fatigue

When I compared prescriber-interruptive modal dialogs with alternatives, I found evidence favoring the alternatives—in particular, those that tailored CDS to the roles of pharmacists and physicians. I believe there are three explanations for this finding. The first concerns *etiquette*—'proper' etiquette often makes advice easier to receive. The second concerns the *division of expert labor* between prescribers and pharmacists. The third concerns *relevance,* which comes naturally to humans, but which remains difficult to compute.

Etiquette. In the Background section, I mentioned that psychologists and human factors researchers tend to endorse presenting guidance "politely"—even in emergencies [193]. Prescribers might have accepted pharmacists' advice so readily because those pharmacists produced behavioral patterns culturally recognized as "polite." In some cases, it is appropriate to carefully design and program computers to produce similar "behavior" to solicit the user's reciprocity [265]. Some of the modal dialogs that I saw, which featured large, capitalized red text, and which required several clicks and keystrokes to dismiss, might have been seen as patronizing, rather than polite. In our review, attempts to imitate "politeness" in CDS were rare to find.

Division of expert labor. It has been common practice for prescribers to consult pharmacists about the appropriateness of particular medications for patient cases [273]. Presenting certain medication-related CDS to the pharmacist—such as those concerning antibiotic targeting and renal dosing—therefore may support (rather than disrupt) an established clinical practice. This division of expert labor might have a hidden advantage: Sheltering prescribers from most of the details of pharmacy review might allow prescribers to focus

more of their attention on the key details of clinical cases, so that they may think more clearly [59]. This may not be feasible in certain cases until regulatory barriers are changed.

Relevance. Prescribers may have found pharmacist-mediated CDS alerts highly acceptable because pharmacists filtered out irrelevant advice. Whether computers might, someday, handle *relevance* and *context* as capably as humans has been a matter of debate [80, 108, 222]. Indeed, CDS does not seem to perform at the same level of precision and relevance as the humans they advise [239].

The prevalence of prescriber-interruptive modal dialogs in the literature might be due to overly narrow definitions of "decision support" by certain patient advocacy groups [249] or it may be due to actual prevalence in clinics. Additionally, EHR homogenization [147] may have determined which types of decision support have been convenient for clinical institutions to implement, and which have been expensive, at scale.

CDS homogeneity presented one of several barriers to meta-analysis. The other barriers were primarily due to methodological inconsistencies in the literature. Next, I discuss methodological issues.

3.4.2 Mediation analysis may address methodological dilemmas

As mentioned in the Results section, I found that researchers had been using two main ways to measure how often a prescriber accepted computer-generated advice: in-dialog action analysis and event analysis. Some studies explicitly conducted comparative analyses of the validity of the two methods [170, 228, 277].

As previously mentioned, when using in-dialog action analysis, the researchers dichotomize the actions taken inside a modal dialog: The prescriber either accepts the alert (e.g., by clicking "Discard Order") or overrides it (e.g., by clicking "Proceed Anyway"). I note three

problems with this method's validity. First, those clicks provide a rather partial story of the order—for example, they do not account for possible corrections that the prescriber may take after responding to the alert. This is related to the second problem: Applying in-dialog action analysis to modals that feature action shortcuts may artificially inflate acceptance rates with respect to other modal dialogs, because more actions that would otherwise take place outside the dialog would instead take place inside the dialog. Third, in-dialog action analysis cannot be used with CDS interventions that do not offer decision-buttons to prescribers—these interventions must be studied with event analysis.

When using event analysis, the researcher additionally searches for corrective actions that the prescriber made after dismissing any alert, including a modal dialog. For example, the prescriber may change a dose, or switch to a narrow-spectrum antibiotic, after dismissing a modal dialog. These adjustments are taken as evidence of acceptance. This main problem with this method's validity is that there is no way to know whether the prescriber would have taken the same action if the intervention had not been delivered.

One might expect that in-dialog action analysis errs on the side of specificity (it systematically fails to recognize corrective actions), while event analysis errs on the side of sensitivity (it may misattribute some corrections to interventions). The evidence we gathered from three studies that compared these two methods [170, 228, 277] suggest that this intuition is correct. These methods are *biased,* in a traditional sense: They produce results that predictably depart from the results that one would expect from the most accurate instrument imaginable.

Despite their limitations, I believe these methods to be valuable, since they seem to be the most cost-effective ways to capture data for CDS acceptance. However, I must caution that these methods produce results that are non-comparable. I suggest using event analysis, to enable rigorous comparisons between modal and modeless forms of CDS.

Appropriateness panel reviews [170, 268] were rare to see. I imagine these reviews to be particularly costly. Indeed, half of the included papers that reported an appropriateness review were from well-resourced academic institutions.

In fact, the scarcity of information that was useful in our review was surprising given the quantity of available CDS literature. Nearly 9 in 10 of the papers I excluded did not report prescriber acceptance, an important mediating variable between the technological intervention and patient outcomes that seems to have been assumed. Earlier, I described a homogeneity of CDS interventions in the reported literature—specifically, prescriber-interruptive modal dialogs comprised five in six included results. This also constrained the analyses that could be conducted with adequate statistical power. Finally, a roughly 50-50 split between two incomparable measurement methods precluded meta-analysis.

This review revealed several issues in the literature. Future work is needed to develop standardized, low-cost, informative measures for determining acceptance for CDS, and for relating CDS acceptance to patient outcomes. Next, I present some feasible recommendations for improving the quality of the CDS literature.

3.4.3 Recommendations for future work

Given the preceding discussion, I propose the following three recommendations for future CDS research:

First, I recommend that researchers consider alternatives to prescriber-interruptive modal dialogs, since there is evidence that the latter suffers from relatively lower acceptance. Role-based tailoring appeared to improve acceptance rates, and further work is needed in this area. Ideally, those who will receive the alerts should be involved in role-tailoring

decisions. Alternatives to modal dialogs should also be explored.

Our second recommendation is to measure acceptance rates using event analysis, rather than in-dialog action analysis. Since event analysis is more widely applicable, using it will enable meta-analyses that accommodate varied CDS interventions.

Our third recommendation is to report both acceptance rates and patient outcomes. Much of the literature that I saw in our review reported one or the other; few reported both. This has made it difficult to analyze patient outcomes as a function of CDS design and role-tailoring, *mediated* [162] by acceptance.

3.5 Conclusion

Alert fatigue remains a persistent challenge in CDS. Among prescriber-interruptive modal dialogs, acceptance rates have been highly variable. In our analysis, prescribers accepted alternative interventions more often—especially those which tailored CDS to the areas of expertise associated with clinical roles. Although there are plausible reasons why some alternative CDS interventions would improve acceptance, contemporary literature has not supported detailed analyses. I recommend that future studies pay more attention to alternative designs, measure acceptance using event analysis, and report patient outcomes as well as acceptance rates.

Chapter 4

The automated supervision of medical professionals: alert fatigue as a consequence of external accountability approaches to patient safety

Electronic health record (EHR) infrastructure has been established by mandate in the United States, with the stated goals of improving patient safety and quality of care while reducing costs. The EHR has afforded external bodies such as payers and accreditors new ways to intervene in healthcare through the use of financial mechanisms; health systems respond to these incentives by implementing clinical decision support (CDS) alerts, and this can overwhelm frontline clinicians through a phenomenon known as 'alert fatigue.' In this study, I investigated how one health system maintains control over their EHR to manage alert fatigue. I conducted 14 interviews among a range of practitioners, mainly physicians, with varying degrees of administrative responsibility. Among other findings, clinical administrators resisted external intervention by preemptively implementing

safeguards in the EHR, and from the organization's financial division by arguing that practitioners had authority over 'care,' which the EHR was nominally intended to support.

4.1 Introduction

United States hospitals and physicians have been under political pressure to address some fairly serious shortcomings in the healthcare system. According to a 2016 estimate, medical error has been the third leading cause of death, ahead of automobile and firearm-related incidents [163] and on par with the COVID-19 pandemic [47]. At the same time, it has been widely reported that the US spends far more than peer countries such as Australia, Canada, and the UK on healthcare, while underperforming in terms of population health, access to care, and quality of care [90]. Healthcare disparities in the US follow class, gender, and racial lines [101].

The Health Information Technology for Economic and Clinical Health (HITECH) Act of 2009 established technology use standards intended to reduce medical error and cut costs while improving the quality of care [40]. It mandated the widespread adoption and use of Electronic Health Records (EHRs) by hospitals and physicians by rewarding early adopters (c. 2011–2012) and penalizing late adopters (after 2015), using the government's public payer, the Centers for Medicare and Medicaid Services (CMS) as a financial enforcement mechanism [40].

Stark, then-Chair of the Health Subcommittee of the House Ways and Means Committee, published a commentary in which he called healthcare a 'glaring exception' to 'the digital revolution' [234].[1] He stated also that health information technology (IT) would help providers manage the information overload, bringing health innovations to the point of care

[1]For an analysis of techno-revolutionary rhetoric in the period following the release of the Apple iPhone, see Campbell and La Pastina *et al.* [43]

while also saving payers money by increasing efficiency [234].

The HITECH Act delegated to the Office of the National Coordinator for Health Information Technology (ONC) the authority to set health IT standards [234]. ONC's certification test assumed that some sort of clinical decision support (CDS) existed [190]. EHR offerings at the time usually included functionality to support the use of CDS and best practice alerts (BPAs), which could be used to serve a range of goals including safety, quality, and finance [122]. These alerts usually took the form of a pop-up window (e.g., Figure 1.1). For brevity, I refer to both CDS and BPA alerts as 'CDS alerts.'

CDS alerts were known at the time to contribute to a problem known as *alert fatigue* [262, 263]. Briefly, alert fatigue arises when an alerting system offers the clinician too many irrelevant or unimportant alerts too often, and the clinician ceases to view it as a reliable source of pertinent information. Alert fatigue therefore partially undermines the potential safety and quality benefits of CDS. Health systems[2] administrators may manage alert fatigue by iteratively refining CDS [139].

Leapfrog, a patient advocacy group focused on constructing market ratings to support informed health consumer choices [249] had developed a safety test of their own for the EHR's order entry system, through which practitioners wrote prescriptions [142]. The test was time-limited [156] and according to a source familiar with the test, it only counted pop-up alerts as decision support; alternatives did not count [249]. EHRs offered at the time were marketed as assuring compliance with a range of external bodies [51], and it is generally most straightforward to make such an assurance by conforming to the most restrictive definitions available. CMS attempted in 2014 to make clear that they took a capacious view of CDS, and that they were *not* requiring hospitals to implement lots of annoying pop-up alerts [64]. By that time, the conventional form of CDS had already been

[2]In the US, a *health system* typically comprises at least one hospital and a collection of primary care practices in the surrounding area [6], often formed through organizational mergers [255].

settled.

CDS alerts were used to achieve compliance with expectations set by external accounting bodies. These included expectations related to patient safety and public health set by public payers such as Medicare and Medicaid, such as implementing drug-drug and drug-allergy alerts, recording and charting changes in body-mass index, and providing counseling on tobacco cessation [49]. Other external accounting bodies included hospital accreditors such as the Joint Commission [206] and patient advocacy groups such as Leapfrog.

The results of government-mandated EHR adoption and the emergence of widespread computerized safety accounting have been mixed. There have been reports of positive patient outcomes [150] alongside consequences, such as novel patient safety risks due to human factors issues, onerous busywork for clinicians,[3] increased software maintenance costs, reduced patient volume, patients withholding information due to new privacy and confidentiality concerns, and attrition of experienced clinicians [282].

Sholler [224] has provided an extensive overview of the HITECH transformation in US healthcare from a CSCW perspective. Through resistance to policy, physicians established a considerable degree of control over EHR infrastructure, and remained in charge of healthcare. Additionally, a pragmatic discussion was unfolding in the health informatics world on the role of requirements from external bodies in contributing to alert fatigue;[10] CDS systems were being used for regulatory compliance purposes.[181] In this work, I contribute to a body of CSCW research on computerization in healthcare (e.g., [205, 167, 200, 32]), by addressing the following main research question:

Research question. *How do clinical administrators respond to regulatory burden, how does that contribute to or mitigate alert fatigue, and how do they assert intellectual*

[3]The term *clinicians* refers to those who engage in direct contact with the patient, such as frontline physicians, nurses, and pharmacists.

authority over healthcare information technology?

I took a science and technology studies (STS) approach to this question. In order to address it, I conducted semi-structured interviews with clinicial practitioners, mainly physicians, at a teaching health system in Southern California. In the style of abductive analysis [252], I prepared for interviews in part by brushing up on organizational theory cited above, such as Suchman's critique of organizational intention-accounting [240], Power's analysis of auditing [203], and March and Simon's theory on uncertainty absorption [166]. Additionally, I brushed up on STS literature and adjacent social science literature pertaining to contemporary social histories on US medicine, such as Abbott's analysis of interprofessional conflict [2], Bowker and Star's analysis of information infrastructure [35], and Timmermans and Berg's analyses of medical standards and protocols [251, 27]. Further, I brushed up on a range of social theories that may be brought to bear on the connections between society and the individual at the site of the organization or institution, such as Foucault's theory of panopticism [97], Deleuze and Guattari's control societies [74], and Chun's critical analysis of technological control [56, 57].

A bit of theory and background is in order.

4.1.1 Organizational theory

The relationship between clinical decision support and 'value-based' [46] reimbursement models represents a fairly mature form of a classical concept in science and technology studies (STS)-centered approaches to computer supported cooperative work (CSCW). CDS comprises a formal, computerized set of rules paired with software which is useful for intervening in and restructuring worker behavior [285, 240]. This restructured behavior is then tracked, enabling the organization to present accounts of its service in terms of important but ultimately uncertain factors such as quality and safety to external

accounting bodies [203]. Those bodies then financially treat the organization with specific monetary rewards or penalties. In this way, the uncertain (quality, safety) is absorbed by the certain (rewards, penalties), producing motivating affect (relief, anxiety) [166].

In the case of CDS, there are formal alerting rules which trigger pop-up alerts, which intervene in and restructure clinical labor; the rules may be modified by health system administrators following guidance from accounting bodies such as CMS or the Joint Commission; accounts of activity include billing statements to be evaluated by public payers such as CMS and CDS language to be evaluated by accreditors such as the Joint Commission in terms of compliance with safety, quality of care or cost savings criteria.

Internal organizational parties which advise on the rule-set—in this case a clinical decision support advisory committee—are charged with balancing interests that cannot be assumed to perfectly align, such as clinician satisfaction and organizational finance, and make choices about when and how to solicit broader clinician engagement in what is effectively a technocratic form of workplace governance.[4]

4.1.2 Social theory

The tearing asunder of the physician, and its recasting in the forms of physician-manager and physician-employee, has been in the making for decades—for more on that, see Starr's [236] social history of American medicine. Here I examine how this divide has been rendered ever so slightly more real through information infrastructure embedded in organizational structure and process. A new divide akin to an administrator-user partition in healthcare—between those who advise the labor of CDS reconfiguration and those who almost solely practice medicine—has emerged.

[4]Whereas 'technocracy' is often used as a pejorative, for this text I define *technocracy* as governance by, of, and through technological means—leaving open the possibility of democratic technocracy.

So, software studies comes to mind. I will set the stage with Foucault's theory of panopticism, on a control system enabled by earlier, paper-based technologies. Then, I will extend it to the reinforcement of the manager-employee division between medical practitioners via the administrator-user software metaphor, drawing inspiration from Chun's work on computers and control [56, 57].

In Foucault's original description of panoptic control [97], he studied the regimentation of officials' practices of inspecting private residences to account for behavior, which minimized the 'need' for traditional discipline to enforce quarantine in the 18th century bubonic plague in a town in France. He then showed how the structure of quarantine regimentation during the plague served as a model of the structuration of the disciplinary institutions—prisons, accredited schools, and grand hospitals—that proliferated in the region.

In a panoptic structure [97], the means of administrative inspection and discipline are always present, but there is no way for the subjects of inspection to tell whether their actions are (or will be) under inspection at any given time, or by whom. So, they behave as though they are under inspection at any given time by disciplining themselves. Because anyone can report on anyone, panoptic subjects tend to urge the adoption of self-discipline of those in their vicinity—*don't do that; someone might be watching.* Those in administrative positions do not simply abdicate their responsibilities because they themselves are always potentially under inspection by those in their charge, including members of the public—anyone might at any time question if they are 'doing their job.' The overall effect is a fairly robust system of social conformity that is effective at increasing production [97].

Nominally, panoptic structures were oriented toward a concept of 'Enlightenment.' Enlightenment was an ideal to work toward, a form of societal maturity in which control could be allowed to crumble and fall away, as discipline had already been internalized [98].

Punishment would no longer be necessary to assert authority, because citizens would comport themselves in a manner of pure reason. While some of Foucault's critics may believe him to have been opposed to the project of the Enlightenment, he was in fact sympathetic to it—prior to his passing, he wrote:

"I do not know whether it must be said today that the critical task still entails faith in Enlightenment; I continue to think that this task requires work on our limits, that is, a patient labor giving form to our impatience for liberty."

– Foucault, 'What is Enlightenment?' [98].

That is to say, as an academic critic of the status quo, Foucault was himself embedded in the status quo, and offered rigorous criticism—the patient labor of the critical task—as part of the overall process of incremental improvement embedded in Enlightenment ideals, such that liberty from control systems might someday be possible.

Panoptic structures have remained in place in medicine. The medical record is the means of administrative inspection; practitioners are always potentially under inspection by their peers, whose administrative responsibilities vary; their work may be inspected at any time without their knowledge; they are aware of the possibility of discipline for discovered misconduct, comport themselves accordingly, and consult their colleagues for guidance on expected conduct. Medical misconduct (or 'alleged' misconduct) may be reported by patients or practitioners to the free press, and the surest way to avoid the stress of public scrutiny is to behave as though one is always under audit. Regular inspection is administered by public payers, accreditors, and patient advocacy groups.

In the US, the medical record has been made electronic. Computers, as accounting devices, are useful for representing and supporting panoptic structures [56]. As computers are increasingly used to mediate work, they provide mechanisms to support automated recording of behavior and interference in that behavior [285].

In this study, I find an ongoing tension between formal representations of work and the competencies expressed through situated practice. The threat of a loss of authority at the point of care to external bodies and the organization's financial division looms. At the same time, medical professionals have adopted strategies for maintaining their authority over the EHR, and by extension the point of care.

4.2 Background

When researching CSCW in healthcare, It is important to distinguish between the realms of policy, the organizational context, and the context of the immediate workplace [18]. It is also important to keep an eye on how larger-scale, policy level issues play out in organizational life [91]. In this section I provide a brief overview of the policy-driven computerization of healthcare from a social perspective, paying particular attention to the United States, followed by key context regarding the site I studied. This will set the stage for the study at hand, in which I asked a range of clinicians, mostly physicians, with and without responsibilities in technology administration questions about CDS alerts that were automatically presented at the point of care, as well as about the organizational structures and practices that maintained the CDS system.

4.2.1 The computerization of US healthcare

The computerization of medicine demarcates a shift in the gaze of financial and regulatory interests, from biomedical interventions such as pharmaceuticals to intervention at the site of the patient's data, whether genetic data [207] or medical record data [200]. Because, as Abbott [2] wrote in his analysis of the system of professions, the medical professions claim jurisdiction over body and mind, they are the most powerful professions. The social study

of medicine may therefore serve as a bellwether for a wide range of institutional and organizational contexts studied within CSCW, and even for the technological discipline of patients [197]. It is therefore pertinent to briefly attend to the recent social history of US healthcare.

Following the second World War and the rise of austerity in the United States [114], welfare services such as Medicare and Medicaid came under political scrutiny and hospitals and physicians were increasingly pressured to cut costs [27]. In this adversarial political environment, physicians picked up tools of rationalization, such as statistics, protocols, and consensus reports, to shield themselves from allegations that public funds were being wasted on irrational, idiosyncratic medical practices [27].

Computers, as useful accounting[5] mechanisms, have become *the* tool to glue the logic of rationality to the practice of clinical work [27]. It is nearly universal to find, for any given real-world problem for which rationalization is sought, an unresolved distance between the goals of computer-aided formalization and the innumerable contingencies that emerge in practice [95, 241, 7, 79]. In other words, the expert labor of physicians has not been automated despite the advancement of information storage and processing speed in part because novel illnesses and patient cases arise all the time, resulting in an ever-changing body of medical knowledge and ever-shifting clinical priorities. So, medical standards for both practice and records of practice cannot be impartial [251, 33]. In order to manage the distance between formal structure and emergent contingencies, CSCW authors tend to recommend the preservation of discretionary space so that workers may responsibly improvise when needed [201, 167], serving the spirit of the practice when idealized stipulations about work conflict with its immediate, material reality.

EHR systems and their alerts may embody idealizations of work, and in studies from the

[5] 'Accounting' is a term that arises frequently in CSCW literature. In this context it refers to the technologically-aided construction of accounts of social activity—in a word, surveillance.

US, Netherlands, and Australia they have been found capable of *facilitating* medical errors, often due to shortcomings in usability and information design [148, 13]. These shortcomings tended to stem from mismatches between the expectations of policymakers, administrators, and vendors about the EHR's role in achieving service integration and the lived reality of medical practice [113]. In Denmark, Winthereik and Vikkelso [275] studied discharge letters as an example of the dual roles of clinical artifacts—as informational tools and as organizational accounting devices—and argued that the formalization that tends to accompany computerization tends to weaken clinical value while strengthening organizational accounting value.

Policymakers across North American, European and Australian contexts marched on, and following the Great Recession of 2009 the US government advanced the HITECH Act, mandating the adoption of EHRs through the use of financial incentives and penalties in order to facilitate detailed organizational reporting as well as information exchange between healthcare providers [40]. In an extensive article detailing the policy and its ramifications for medical professionals, Sholler [224] conducted interviews with government officials, healthcare administrators, and IT personnel, in addition to a range of clinicians and technicians, to provide a detailed accounting of resistance to the HITECH Act through the American Medical Association.

Ultimately, professional resistance served to slow down, reshape, and soften the impact of the HITECH Act. Still, the shift to EHRs was not a smooth journey—EHR rollouts were infamously 'chaotic,' 'bewildering,' and 'frustrating' [69]. The process of computerization has tended to reify administrative priorities in healthcare systems. For an example from the United States, Pine and Mazmanian [200] documented one particularly litigious decision support system encountered by nurses in an obstetrical unit which, if obeyed to the letter, would significantly delay the approval and therefore the timely administration of an intravenous sugar and saline drip, a fairly safe and common supplement, potentially

lengthening the infant delivery procedure and increasing the risk of complications.

Concerns regarding the time-consuming nature of data entry at the cost of delivering timely care have cut across international contexts. To illustrate, I turn back to Denmark, where the government recently fired over 80 percent of their medical secretary labor force *en masse* following the acquisition of technological capital in the form of a nationwide EHR system [78]. The Danish physicians, now tasked with the billing duties that had previously been managed by secretaries in addition to their usual medical duties, completed their work more slowly, leading to the death of one patient who died waiting for care [31]. Additionally, physicians entered billing-related data inaccurately, leading to a 7% loss for the capital region in the year following EHR acquisition [31].

As Bowker and Star [34] mentioned, once infrastructure is embedded in practice, the indefinite labor of fixing it in modular, local increments begins. So, hospitals and physicians in the US have been engaging in an immense amount of skilled customization at the organizational level [14]. In the organization under study, an initial customization phase was underway.

4.3 Methods

I conducted semi-structured interviews among clinicians, and aimed to solicit the perspectives of those in positions of elevated authority within the healthcare organization. So, I mainly interviewed physicians with primary responsibilities in clinical care or in technological advisory positions, as well as a pharmacist, a nurse, a nurse practitioner, and an executive for good measure. Clinicians tended to have busy or unpredictable schedules, and those with higher rank in the administration tended to describe their working schedules as more severe. So, in recruitment I started with physicians who more readily

expressed interest in participation in research centered on alert fatigue as a consequence of healthcare policy reform, and I requested referrals to colleagues who might be interested in the research, gradually working my way through a semi-formal network crossing disciplinary and professional boundaries toward those with greater administrative responsibilities. I concluded sampling when I had sufficient data to construct a coherent theoretical orientation.

In addition to complying with all IRB requirements and using participant numbers instead of names, I followed some privacy-protecting safeguards commonly used in ethnographic practice [30]. For example, I have altered names of enterprise software systems to obscure the organization's identity. To protect participants' identities, I have obscured genders by using the gender-neutral 'they/them' constructions in place of the 'he/him' or 'she/her.' Additionally, to avoid revealing some members of certain small groups to one another, I have intentionally coarsened some participants' identities to a greater degree. For example, I have described some lower-ranking members of the CDS committee as simply informatics physicians, dropping their areas of clinical practice from mention.

4.3.1 Procedure

Together with a key participant, I scheduled interviews via email, and conducted interviews using a video teleconferencing service that allowed me to request verbal consent from each participant to record prior to recording. In addition to recording, I took notes to keep track of the conversation when it wandered. I began interviews by asking questions about the participant's institutional position and background, including their motivations for getting into their line of work. Then I asked some questions about their technology and work, including asking for their perspectives on the nature of institutional and organizational governance, and how things should work in an ideal world. I wrapped up each interview

with some demographic questions. The main questions included but were not limited to:

- What first drew you into medicine?
- How did you get into (specialty or clinical area)?

For most practitioners:

- Please tell me about a/another time you found an alert helpful.
- Please tell me about a/another time you found an alert *un*helpful.
- Do you know if (alert) is related to a compliance effort?
- How do compliance efforts support or detract from your care?

For those with administrative responsibilities:

- Some have found (alert) less than helpful in (circumstances). If (disabling for all/disabling for some/modification) were proposed, would you anticipate any compliance-related concerns to be raised?
- Would you anticipate other concerns, such as patient safety?
- How does (specific compliance process/structure) work?
- How does (specific organizational process/structure) work?
- How should compliance work, in your opinion?
- How should organizational governance work, in your opinion?

I modified the question set from one participant to the next according to my informational needs and interview time allotment. Interviews were initially scheduled for 30 minutes, some early interviews were as short as 15 minutes and in later interviews some participants allowed the time to run over to approximately 45 minutes. At the end of each interview, I stopped recording, requested a referral to an additional practitioner who might have been interested in the study, and arranged to send $50 USD as participant compensation. I extracted audio from recordings prior to transcription.

4.3.2 Data analysis

I analyzed the transcripts using *abductive analysis,* which is useful in theoretical generation [252]. Whereas grounded theory centers inductive reasoning—setting aside preconceptions, taking the smallest units of data, and organizing them into ever-larger structures—abductive analysis starts with brushing up on theory, locating surprising or novel results, and attempting to explain them by forming initial hypotheses about the data [252]. Hypotheses that appear contradictory, such as *medicine is a profession* and *medicine is a business* may proliferate in early stages of analysis. These serve as starting points for further investigation; some hypotheses are stricken, whereas others may be reconciled by constraining them or by making them more specific. Other times contradictory forces, such as the practice and business of medicine, simply exist in tension, and rather than being resolved they are instead managed on an ongoing basis.

A general description of the data analysis follows. First, I took an inventory of topics related to the research question (e.g., the role of the EHR in compliance), as one does in *hypothesis coding* [215]. Next, I imposed conceptual frameworks on the data, in an iterative process of *elaborative coding* [216]. I modified both the conceptual framework and the codebook until there was a firm fit between the framework and the data. For example, I

explored values (e.g., care and business viability), epistemologies (knowing the patient personally and via the record), and identities (patient as a professional and as a user) in tension at the levels of the individual practitioner and the organization. Finally, I cut a narrative pathway through the resultant proliferation of firm-standing hypotheses that revealed key and interesting information learned from participants.

Throughout analysis I conducted online searches of material relating to the practice and business of medicine to guide explanation. This included medical literature as well as gray literature, such as material for medical education and continuing education and reports from industry press and consultancies specializing in compliance. This both eased burden on participants' time and provided translational information for qualitative researchers as well as medical informatics practitioners.

4.4 Findings

In this section, I describe participants' professional identities and demographics in aggregate terms. I also provide organizational context and historical recollections gleaned from participant interviews, industry press, and semi-formal conversations with key members of the organization over the course of my doctoral program.

Next I introduce the theme that guided the main findings—that advances in concentrating medical authority, such as through medical specialization, are generally supposed to be justified through their promissory benefits for patient care. So, the EHR, with its concentrative potential realized through care-accounting practices, was or should have been envisioned as an information infrastructure for the sake of improving care.

The EHR had indeed been useful for care, especially when used *endogenously*—within the organization as a tool within a broader process of continual improvement by dedicated and

experienced professionals. It was also used for *exogenous* care accounting and intervention, with mixed results.

While the EHR could be conceptualized as a tool for compliance, participants broadly viewed 'compliance' as a detractor from the spirit of their profession—that they should be guided by reason and evidence with the sake of care as motivation enough, that reward and punishment should not be necessary. So, at times practitioners felt guidance delivered via EHR was guidance they would follow in any case, and at other times they felt alienated from their labor, plodding through make-work for the sake of demonstrating care to an abstract and external entity.

Further, the EHR provided selective transparency within the organization. While it was useful for creating some amount of lateral transparency, e.g. so that an outpatient practitioner may keep tabs on their patient once checked into the hospital, it also functioned as a barrier that obscured the goings-on in the bureaucracy that had been built around the organization's EHR.

Finally and perhaps most importantly, participants expressed a sense that the conveniences offered by the EHR threatened their expert judgment—that one day the push-and-pull of compliance mediated by the CDS system could in fact supplant and subsume the inner life of expertise.

4.4.1 Participants

All participants were drawn from H1. Eight participants worked in more than one area of care (such as primary outpatient care) or department (such as Informatics). Five participants worked solely in one area of care, 6 had a secondary area of care, one physician had tertiary responsibilities, and one participant had quaternary responsibilities. Four

participants worked in primary outpatient care, 4 worked in informatics, 3 worked in pain management, two each worked in the Neuro-ICU, emergency department, as hospitalists, or in anesthesiology; one each worked in the Surg-ICU, Cardio-ICU, Burn-ICU, stroke center, palliative care, or as a pathologist.

Six participants had the sole title of MD (Medical Doctor). Three had an MD MBA (Masters in Business Administration), two had an MD and MPH (Masters in Public Health), and one each had an MSN CNRN (Masters of Science in Nursing, Certified Neuroscience Registered Nurse), NP (Nurse Practitioner), or Pharm.D (Doctorate in Pharmacy).

Eight participants had some level of administrative responsibility, ranging from sitting on a committee to a Manager, Director, or Chief position. Six participants had less than 10 years of experience, 5 had 10–15 years of experience, and 3 had more than 15 years of experience. Experience ranged from 4 to 28 years.

There were 8 women and 6 men. Eight participants were White, 4 were Asian, and one each were Indian and Hispanic or Latino.

4.4.2 Organizational context

I conducted the present study at a health system in Southern California (H1). H1 comprises a teaching hospital with over 400 beds, as well as outpatient clinics. The health system serves patients with private insurance as well as Medicare, the public insurance program for US residents aged 65+ and Medi-Cal, California's state bureau for administering Medicaid, a federal program for low-income residents. Additionally, the health system has a Federally-Qualified Health Center (FQHC), serving as a safety net for the uninsured and underinsured.

In the period from 2016 to 2021, during which I maintained relations with key physicians and medical students, the health system had undergone at least two exogenous shocks. An *exogenous shock* is an event such as a merger or introduction of a new technology that prompts a deep shift in the social order of an organization.[20]. Shocks tend to open up wide spaces for novel practices to develop, so phenomena observed prior to a shock may not persist afterward, and phenomena observed following a shock may not have existed prior.

First, H1 had, in 2017, transitioned from a custom build of a vendor EHR, which I will refer to as TotalScribe, to a peer health system's (H2's) build of another EHR, which I refer to as Incredible. The two health systems are separated by approximately 130 kilometers. According to Participant 14, an executive who practices medicine, the transition was mandated by the parent organization of both health systems. It is common for a transition in health information infrastructure to be imposed for the purposes of service integration [83], and this case followed the usual pattern—it was expected that the transition would enable smoother service integration between several peer health systems within the state of California.

Second, prior to my data collection, the health system responded to the COVID-19 pandemic in late March 2020. During this time I collected publicly available documents and stayed in touch with key informants to provide the following contextual information. Operationally, the organization enacted measures such as a pause on elective surgeries and expanded intensive care capacity by pitching special tents. In an address to the medical students, a psychiatrist invoked logics of heroism and sacrifice, comparing the pandemic to a wartime scenario, and notifying medical students they might be called upon in the event a physician shortage was encountered. Physician-administrators, who tend to emphasize their identities as practicing physicians, expressed outpourings of appreciation for clinicians with primarily clinical duties on email listservs.

Historical recollections

Participant 3, an experienced stroke and informatics nurse and district manager, recalled an early electronic medical record system at the health system, a DOS system specifically suited to documenting stroke cases to better manage care, as well as to collect patient data for later analysis. Later on, the institution installed TotalScribe, which was marketed as a highly tailored EHR. According to an industry press article on the transition, highly tailored solutions tend to produce cost overruns and high risk of project failure.

As previously mentioned, H1 adopted H2's EHR, a relatively lightly customized build of Incredible in 2017. At time of writing, the main build of Incredible was maintained by one of two contenders in a *de facto* market duopoly of EHR vendors. According to Participant 14, an executive and practicing physician, the vendor preferred not to guide clinical practice. It was common industry practice to import CDS rules from a commercial knowledge base,[151] and the CDS rules imported in 2017 were most likely imported from one such knowledge base and then customized by H2 before being imported to H1.

Also according to the same executive, H2 was more focused on primary care practitioners, whereas H1 was more focused on specialist care. So, the switch from TotalScribe to Incredible meant that H1 was adopting an EHR that was built for H2's needs rather than for H1's own needs, and it entailed a loss of highly customized safety guards for specialist.

To be sure, TotalScribe had not been perfect—according to Participant 1, a pain physician, upon initiating a prescription for codeine, one of the least potent opioids, TotalScribe would provide an alphabetized list of alternative medications with Actiq, a powerful opioid recommended only for cancer-related pain [250] near the top.

Concerns about the loss of safety guards had been raised prior to the move, but were dismissed as they were unsubstantiated by empirical evidence—there was no telling what

could happen as a result of the Incredible rollout until it was actually completed. Three years later, the executive felt the passage of time proved early concerns were credible, and that the new version of Incredible had not yet been brought up to par with the safety guards they had in TotalScribe.

Intellectual authority in the name of care[6]

Primary care physicians tended to have chosen their profession for the gratification of working with individual patients as whole people, and for families on a longitudinal basis. Some had left public health in order to work with patients on an individual rather than population-level basis:

"I was first actually a public health professional...I did that for several years and really loved it, but was really interested in...having a career where I could do a little bit more individual kind of work as opposed to more community-based so decided then, in my mid-twenties to return to medical school and did that. And by then I was very passionate about public health and also wanted a career in medicine that would allow me to do a lot of public health work. And I felt like primary care was a good place to do that."

– Participant 4, Primary Outpatient Physician

On the other hand, specialists and informaticists tended to have chosen their department or specialty due to preference for working in acute situations, intellectual interest, elevated compensation, or position of authoritative stature. Inclinations toward topics of intellectual interest were usually articulated in terms that related those interests back to care. For example, informatics was pursued as a means of leveraging medical record information in order to inform care, to improve care for further patients. Even care for one's fellow physicians was articulated as rooted in care for patients, as illustrated in the following

[6]A play on the title of a book, 'Markets in the name of socialism' [37]

passage:

"I considered a fellowship in informatics when I was in residency and I was really interested in this way of utilizing it to improve physician quality of life and burnout. And I was somewhat sad that nobody seemed interested in that as the major outcome. People were interested in it as a tool to improve streamlined processes, to improve quality metrics, which is very important, I don't mean to undermine it. But my ideas of using it to make physicians' lives easier so that they could spend, I mean, and by easier, what I really mean is that we want to spend time with our patients."

– Participant 2, Neuro-ICU Physician

Frustrations with technological interventions often stemmed from a mismatch between the imperative to care and what appeared to the clinical user as cleverness for the sake of cleverness:

"A lot of 'smart' features in Incredible are very clever, but it needs to be done so that we improve patient care as the goal."

– Participant 13, Primary Outpatient Physician

In the above passage, the participant expressed a position that cleverness in computing—much like intellectual authority in physicians—should serve the goals of patient care.

In addition to cleverness, the EHR may serve as a means of injecting financial interests into the point of care. Participant 14, an executive and informaticist, mentioned how they defended the minutia of clinical practice against the interests of finance:

"The big problem we've got is, people from quality and people from a finance lens. They want a bunch of alerts, but you've got incentive structures that don't match up because this

is hospital-based; the docs get no funds here. So [people coming from a quality assurance or finance lens] may want us to get an alert, but we're saying, hold on, unless the alert helps us or augments care, we don't want the alert.'

– Participant 14, Physician Informaticist and Executive

Some organizations reportedly passed along quality reimbursements to physicians; H1 did not. In the above passage we see how this material reality reified a social division within the organization: *you have authority over the business side of things; we have authority over care.*

4.4.3 Infrastructure for care accountancy

The infrastructure of the EHR facilitated bureaucratic processes of opening the organization up to examination processes such as those of accreditation. It also served as the substrate for continually evaluating and re-engineering the practice of medicine. Further, it served as the means of yoking the logics of preventative medicine to clinical practice.

The imperative of continual improvement

H1 had developed a bureaucratic apparatus for mediating the continual examination and reconfiguration of care by making technical tweaks to the EHR and its CDS system. Health systems such as H1 are deep and complex, with many committees and offices; a handful of relevant bodies are described here. The main body under study was the CDS Advisory Committee, a physician-dominated body which fielded complaints and requests from throughout the health system regarding EHR safety, including the CDS system. It advised two governance bodies, one devoted to governance of the inpatient version of the

EHR and the other devoted to governing the outpatient version. According to Participant 12, a physician and informaticist who sat on the CDS Advisory Committee, these governance bodies officially had the final say over Information Technology's (IT) priorities, and they were staffed by physician leaders.

The information infrastructure of the EHR was conceptualized as a tool for yoking the latest in evidence-based medicine to the point of care. Facts regarding what constitutes quality clinical practice made their way through a complex information ecosystem; a description of a typical path for clinical guidance follows. Evidence to inform clinical guidance usually started in medical literature, and then was collated and summarized by professional associations such as the American Stroke Association. This guidance was then collated and summarized in turn by accreditation bodies such as the Joint Commission, and then it was later encoded in the standards of payers such as Medicare. While complying with payer requirements may ensure some baseline level of quality, Participant 3, an experienced stroke and informatics nurse and district manager, took pride in carrying H1 to a higher standard:

"You kind of have to look at both your process, your clinical practice, and what you can do to help guide the healthcare providers in making sure that they are providing the best care for patients....we have Joint Commission requirements. We follow the American Stroke Association, scientific statements are their guidelines, how we treat strokes. We also incorporate current evidence and research that maybe is not completely a guideline yet, but there's enough research to indicate that it is the right thing to do."

– Participant 3, Stroke and Informatics Nurse

Participant 3 stressed the importance of engaging domain experts and clinical end-users at every stage in the process of EHR and CDS revision, as well as using a mock-up in simulation, soliciting feedback, and educating clinical end-users about the change and its

rationale prior to implementation in the clinical setting.

H1 used the EHR for yoking the latest in evidence-based clinical guidance to the daily practice of care on their own terms. As reported in the next section, they also used the EHR to implement similar interventions for similar purposes, but on terms that were more exogenous in nature.

Opening the organization to accounting and intervention

The EHR facilitated the opening of H1 to external inspection to the goings-on at the point of care. For example, the Joint Commission would search through the Neuro-ICU's records and search for duplicate orders. Additionally, the EHR facilitated intervention in daily clinical practice; the Joint Commission (JCAHO) would recommend or require revisions to the CDS system, such as improving the phrasing or specificity of an alert's text.

In addition to accounting in the sense of *inspection,* H1 was held accountable for clinical activities in a *financial* sense. Participant 10, a primary outpatient physician and medical director, mentioned the Risk Adjustment Factor (RAF) score, a Medicare-defined system for calculating a patient's complexity [71]. Physicians were to recalculate these scores on an annual basis in order to maintain a robust stream of revenue for the organization.

Participant 12, a physician informaticist, offered the example of CMS's reimbursement for diabetic nephropathy screening [65]. In the following passage, the imperative to minimize opportunity cost—missing out on chances to capture potential revenue by taking actions intended to ensure high-quality care—translated in a fairly direct way into mouse-clicks at the point of care:

"CMS or Medi-Cal will pick things that they feel like they're spending too much money on, more than they should be, and in this sense money is a reflection of health; the healthier

people are the less money you end up spending on them. So things like, there's one for diabetic nephropathy, and so clearly they probably think we aren't screening for diabetic nephropathy enough, or at least we're not documenting that we're doing it enough for them to be happy, and so they put 'Oh, here's [$X] if you can document that [Y%] of every diabetic patient gets a urinalysis within the first [Z] months of their diagnosis.' They'll set that criteria, so then we'll build some sort of CDS that says either at that first appointment 'Hey remember to schedule six-month follow up with a urinalysis one week before."'

– Participant 12, Physician Informaticist

The above passage provides an example of how the logic of preventative care was translated into a specific CDS rule, which then intervened in clinical labor in an automated fashion. As the logic dictated, a healthier population should be in need of less costly care; proactive measures such screening can catch chronic diseases earlier, and early identification leads to healthcare cost savings. Participant 12 believed that payers had fairly sparse information about patient records, and based their judgments of care mostly on cost.

Key finding: Participant 12 also mentioned that in certain instances, alerts related to incentive programs were at times implemented with the informal thumbs-up of perhaps three or so members of the CDS committee. The participant was careful to add that implementation without much end-user consultation was only done in 'rare' circumstances, and only when the members reviewing the alert genuinely believed that the alert would be 'valuable.'

Participant 10, a primary outpatient physician and medical director, described some trade-offs implicated in different modes of motivating compliance among reluctant clinicians, who may have viewed externally-motivated compliance as piling on additional work. Reportedly, some organizations passed along incentive payments to clinicians in exchange for acts of compliance; according to Participants 10 and 14, a physician and

executive, clinician compliance incentives had not been implemented at H1, and Participant 10 was aware that some healthcare organizations have found ways to 'game' the metrics. Alternatively, a clinic could hire more staff or acquire new equipment, which could be regarded as a rather abstract reward. When asked to imagine an ideal mode of motivation, Participant 10 offered the notion of *care:*

"In my vision, it would be more putting a face to it. So, have stories of people. So, I've seen other things where they, for example, the colon cancer screening, when you train the staff or things like that, you can give them a number like, 'one in 10 people or one in five people would get colon cancer if they don't screen forward in this amount of time. How many people are in your family? That means imagine your brother or sister having it, when we could've cut it earlier.' And so that kind of changes it, it makes it a little more personal for them.

– Participant 10, Primary Outpatient Physician

At the same time, Participant 10 noted that it was not easy to invoke the spirit of care for all target measures. An incentive program could offer nearly twenty targets, leaving it to the individual healthcare organization to select their priorities [192]. At times, the goals of incentive programs were reportedly at odds with the clinician's main goal, to use the time available to address the individual patient's most pressing needs.

4.4.4 Wires in the musculature of practice

In the previous section we saw how the infrastructure of the EHR provided the substrate for both endogenous and exogenous efforts to improve the quality of patient care within the healthcare organization. Here we focus on the effects felt at the point of care, and we find that compliance, widely recognized as important, can also produce a sense of alienation in

expert labor; we see also that what is made transparent and opaque to the practitioner is critical, and that there is a looming sense that an undercurrent of careless compliance threatens to submerge the treasures of clinical expertise from practitioners' collective consciousness.

Compliance and alienation

Participants generally expressed a rugged attitude toward the concept of 'compliance,' as follows: *If a rule reflects what I would do anyway then I do not need it, and if it does not then it is problematic.* They tended to view 'compliance' as what one did for the primary purpose of seeking reward and avoiding punishment, such as putting away the coffee mugs when the compliance representative arrives, inputting billing codes for financial purposes, or writing documentation purely to attest that an inpatient had in fact been turned over every two hours. In this way, compliance implied fundamentally *alienating* labor; compliance as a concept existed within a regulatory constellation that ought to have no bearing on professional conduct. At the same time, participants generally believed compliance and governance existed for the good reason that *others, elsewhere* may need to be brought into line with generally-accepted expectations for clinical practice. In the words of Participant 6, a critical care and anesthesiology physician:

"Sometimes [representatives] make really unreasonable requests that just sound like they're doing it just to make sure that they continue to have a job, because they can find something that they can say that you need to do. But other times I think that regulatory bodies overall probably need to exist because not every institution cares about everything."

– Participant 6, Critical Care and Anesthesiology Physician

At times, participants felt they were performing make-work purely for the purposes of demonstrating that appropriate care was taking place, to somebody, somewhere.

Participant 2 mentioned they did not feel certain the EHR was predominantly for patient care, and Participant 13 felt they mostly documented for billing purposes. Participants 7 and 9 distinguished between immediate acts of care, such as removing a urinary catheter or turning the patient every two hours, from acts of record-keeping—documenting that the catheter was in fact removed or that the patient had in fact been turned in a timely manner. If complete documentation of appropriate care was not present, then external accounting bodies did not believe appropriate care had been performed.

Acts of care and documentation thereof were frequently prompted by the CDS, which would remind clinicians to remove the urinary catheter even if it had already been removed, because the change had not yet been documented. Outpatient practitioners (Participants 4 and 13) described certain tasks prompted by CDS, such as cleaning up outdated diagnoses and coding, as repetitive, annoying, and tiresome; as a drain on time that could have been better spent with patients. In the words of Participant 14, an executive, *"pop-up alerts do not do anything except for let someone check the box."* Accordingly, Participant 14 pushed back on requests for 'hard-stop' alerts that were difficult to override: *"Can you guarantee with 1,000% certainty that you're not going to have one variant case?"*

At the same time, Participant 4, a primary outpatient physician mentioned that they did in fact value population and public health guidance, and that they regarded screenings such as mammogram and colonoscopies as well vaccinations such as those for influenza and coronavirus as important. Additionally, Participant 7, a primary outpatient physician on inpatient service four weeks out of the year, offered a subtle perspective on compliance:

"In medicine, it's such a critical field...we're dealing with the lives of people....I'm very likely to follow [guidance] as long as I'm being reminded and it's clear and helpful....I don't think in medicine we can cut any corners."

– Participant 7, Primary Outpatient Physician and Hospitalist

Participant 7 found reason enough for motivation in the stakes implicated by clinical practice, and regarded external guidance as generally welcome—with the caveat that it be both clear and useful for the practitioner's purposes. This perspective appeared to be embedded in practice; Participants 13 and 14 noted that the EHR infrastructure allowed for instances in which new knowledge regarding patient safety risks, such as the release of a black-box warning from the Food and Drug Administration (FDA) to be addressed straight away. So, while it may have been the norm to assert rugged professional authority, practitioners did recognize legitimacy and utility in external bureaucratic authority.

Transparency and opacity

The information infrastructure of the EHR could, with some effort on the part of the individual practitioner, provide lateral clarity in support of peer oversight within the health system. At the same time, there was a noted lack of transparency for practitioners attempting to raise issues regarding infrastructural reconfiguration, similar in nature to the perspective of organizational leadership regarding external governance.

First, a case to illustrate lateral clarity. Primary care providers may practice in the outpatient setting, where they see patients who come in and out of the clinical office, and they may also practice in the inpatient setting, where they monitor patients closely as those patients are transferred from one unit to the next within the hospital. Whereas some primary care physicians are on inpatient duty four weeks of the year, others are *hospitalists,* whose sole duty is to ensure cohesive and resource-efficient inpatient care. When a patient is checked into a hospital, their primary outpatient physician may feel inclined to keep tabs on their patient; this may also serve as a means of inspecting peer practitioners within the health system.

In the following passage, a primary outpatient physician described how they could follow a

patient electronically as that patient moved through the inpatient hospital setting:

"I get a notification that my patient's admitted and then I will sort of keep that record in my [Incredible] in-basket and so I just keep the message, a little bit like an email. Every so often I will log in to sort of look at the events of the day...it still requires keeping [the email], taking the time out to find it, sorting through filters to figure out where it is. In terms of usability, it probably could be better. I have to remember the patient's admitted; if I delete it, it's gone. I have to search through stuff....I think that would be a recommendation to coordinate, improve inpatient and outpatient communication, to create some better communication method."

– Participant 13, Primary Outpatient Physician

In the above passage, the physician noted that the process of tracking one's patient through the hospital took more effort than desired, and could have been better supported.

Second, on opacity in infrastructural reconfiguration. Participant 9, a pain nurse practitioner, described an alert which the pain committee agreed was not suited to their practice:

"Every time we try to change the medication on the epidural order, this alert pops up saying 'The patient has an epidural order already, are you sure you want it to change or modify this order?' That makes no sense."

– Participant 9, Pain Nurse Practitioner

Reportedly, an anesthesiology leader had raised the issue to the appropriate bodies within the organization, the leader reported back that it was to be removed, and the alert remained for two years and counting. Participant 4, a primary care physician, mentioned that requests for the sake of provider convenience were treated with lower priority than clear and present dangers to patient safety.

According to two members of the CDS committee, requests to modify CDS were tracked using a ticketing system similar to the sort of system conventionally used by information technology departments for tracking and resolving software bugs, and were prioritized according to a rank-scoring system. In order to be officially handled, personal requests including those sent by email were required to first be entered into the ticketing system. One member of the CDS committee noted a lack of "clarity in who does what" in infrastructural maintenance at H1, and that requests 'eventually' made their way to the CDS committee. Another mentioned that they were looking into strengthening the process of reviewing old alerts. Participant 14, the executive, mentioned that CDS window volume and clicks were recorded, and that if many users were clicking the 'X' button rather than another button that might indicate acknowledgment, then the alert was a good target for disabling.

This noted lack of clarity was similar in nature to the perspective of members of the CDS committee regarding external regulatory bodies:

"There are regulatory bodies that don't say you have to have these things but if somebody dies and you didn't have it, suddenly that regulatory body cares, because they said 'Have things to protect patients' and then retroactively they can decide that was a thing you didn't have, that's not good."

– Participant 12, Physician Informaticist

The informaticist noted also that one was typically not aware of any specific cases, and that this was the nature of external regulation—similarly, while one would be aware that violations of regulations such as HIPAA (Health Portability And Accountability Act) could incur a fine, one was usually certain that fines had in fact been written without being aware of specific cases. However, in one instance, Participant 3, a stroke and informatics nurse and district manager, had been made aware of a compliance-related fine at H2,

because leaders at H2 immediately paid the fine, moved forward to make the required change to their information system, and made contact with Participant 3 to recommend reflecting the change at H1. Participant 3 described the citation as "out of left field," pushed back on the recommendation, and believed that H2 should have contested the citation because, in Participant 3's opinion, H2 was in fact compliant due to safeguards already in place. In Participant 3's opinion—which was largely reflected in the opinion of Participant 14, an executive and informaticist—for compliance processes to be sensible, they should be carried out with respect for organizational knowledge and experience, and this often involved questioning the initial word of peer organizations and authorities.

There were limits to which authorities within the organization could 'push back' on external accounting bodies. As the COVID-19 pandemic was taking hold in the United States, CMS mandated that health organizations including H1 enable patients to authorize the release of their medical records from the electronic system to designated third parties [50]. According to Participant 14, H1 readily complied.

The atrophy of expertise

Dependency on the computer system for situation awareness may desensitize the practitioner to the situation at hand, supplanting critical judgment with routine facilitated by automation. Unthinkingly following automated guidance was not considered an adequate means of complying with expectations for appropriate care. Participants emphatically stressed the importance of clinical judgment. As one physician stated:

"We're implementing all this CDS technology, but then you still have to put in your clinical view and your knowledge into it. You can't solely rely on the technology and computers to tell you what to do."

– Participant 11, Physician Informaticist

Indeed, relying on the computer to tell one what to do was not advisable in all cases. As an example, emergency physicians routinely encounter patients who report allergies to opioids with relatively weaker euphoric effects, such as morphine and fentanyl, perhaps because they would prefer to receive opioids with relatively more powerful euphoric effects, such as Dilaudid:

"People can have a side effect to a medication, like nausea or vomiting, and they write it down as an allergy, when really that's not an allergic reaction. So it does flag in the chart and does slow the clinician down. Then there are patients that know that this happens.... The patient will say that they're allergic to morphine and fentanyl, but they're not allergic to Dilaudid. In general, the goal is to avoid Dilaudid."

– Participant 8, Emergency Physician

In the passage above, the allergy alerting feature, intended to protect patient safety, could be put in tension with the allopathic imperative to use medicine only to ameliorate problems, and not for pleasure.[110] The automated system was not equipped to handle cultural distinctions in judgment.

An experienced nurse and district manager compounded the importance of clinical judgment with an anxiety that expertise was being lost:

"We can't dismiss clinical judgment. To have an order set do it all, and have the health provider not have to think about anything is really not the answer. The answer is, here's an order set. Here's what the things that probably most patients will need, not all but most .... You don't want to make it so easy that they're just going to click, click, click, and not even think about what they're doing."'

– Participant 3, Stroke and Informatics Nurse

Finally, a pharmacist made a rather bleak statement regarding the state of their profession:

"I'll listen in the workroom to, maybe, a physician or an NP (Nurse Practitioner) calling a pharmacy and I could hear on the other end, it's somebody that's, maybe a new pharmacist or, maybe just not that experienced and they're reciting something that the computer is spitting out at them. And it's just not appropriate. You should know better as a pharmacist, you should use your education to know that that's not something you call a physician about. And I know 100% that that's the computer telling you this is an interaction, but you should know better. And it makes me cringe, honestly, because I think sometimes it's like, oh my gosh, we lost our education."

– Participant 5, Inpatient Pharmacist

The above passage conveyed a sense of existential dread. A tragic loss of professional expertise loomed, exemplified by an exchange that should never have happened. A pharmacist had read the print-out of a drug-checking computer system aloud, right into the ear of an inpatient practitioner—and in that moment had effectively yielded their jurisdiction of expertise to whomever controlled the computing machinery they operated.

4.5 Discussion

At H1, as a consequence of a mandate to complete an EHR transition on time, the quality of fit between a computer system and the clinical practices it was intended to support was, according to an executive at H1, reduced—in order to fulfill a mandate to improve service integration in the long run. Few CSCW attendees will be surprised to learn about a story in which a promissory technological future turned out to be a mix of provisional compromises.

Why do so many organizational leaders tend to trust their instincts rather than CSCW research [55]? Perhaps because organizations are 'turned in' on themselves, and are dependent on the examination of past errors to prevent future recurrences. Just as

prescribers find it easy to dismiss theoretical or rare drug-drug interactions, so it was easy for H1's parent organization to dismiss concerns about theoretical cases that would not be covered by the new EHR's safeguards. In this study, an executive actor within a medical organization was powerless to prevent the potential harms of technological intervention; the parent organization had no precedent to which to point. At time of writing, the same executive actor projects to the future, promising incremental improvements to redress present shortfalls.

In this discussion I offer theoretical contributions relevant to computer-mediated work. I also offer interesting avenues for mutually beneficial collaboration between CSCW researchers and clinical informaticists. Finally, I offer some information that may be useful to policymakers and government administrators interested in improving the means of holding healthcare organizations accountable [191].

4.5.1 Inspect and intervene

In sociology, there are models, and the reality is never quite the model; the model's value is in what it reveals in application. Starr [236] speculated that the AMA would not be a highly effective mode of resistance for the physicians against the power drain associated with pressure to reduce costs because it would represent both physicians and the hospitals for which they work, noting that conditions were ripe for a wedge to be driven between those physicians who primarily practice and those who primarily serve in administrative roles.

A wedge has been built, and it has taken the shape of a grand information infrastructure, the EHR. This wedge has reified the division between 'user' and 'administrator' roles in the healthcare organization—a boundary which many clinicians now straddle to varying degrees. Some clinicians split their time between frontline work and inspection, and have a

certain degree of control over their EHR. Others experience the EHR from a more individuated perspective. For those without administrative responsibilities (and privileges), the organization's administrative functions are obscured by the EHR's user interface in addition to the distance between their sites of practice and decision-making meetings. The wedge of the EHR mediates a metrified regime of constant inspection, backed with the threat of lost opportunities to capture revenue, which motivates the use of automated interference in clinical practice on a moment-by-moment basis.

Adopting a paranoid, Deleuzian lens for a moment [73], one can imagine all manner of chaos enabled by the EHR. For example, once the government 'took over' healthcare [234]:

Hypothetical scenario. *The government fired all the health system administrators, using IT to lock them out. The administrators were replaced with contractors, who implemented newly managerial and compliance-centric approaches to care. When clinicians raised concerns about the new approaches, the contractors flouted responsibility with catchphrases such as "that sounds like a you-problem" and "you're the expert; figure it out." Medical errors committed in the chaos and confusion were pinned on the practitioners involved as a matter of routine; clinical experts were replaced with subcontractors, one by one. And then, once all the expertise in the hospital was evacuated, the health system was reincorporated.*

It does not appear the dystopian future described above has come to fruition in US healthcare—yet. In light of Sholler's findings [224] as well as mine, it appears instead that the AMA and health system administrators have proven a tad more resilient than one might expect. As Chun reminds us [56] actual practices are not purely determined by structural descriptions.

Now I will address the research question: *how do clinical administrators assert intellectual authority over healthcare information technology?*

A variety of strategies may be available, and they may shift over time. I will focus on two:

1. Care for the information infrastructure.

2. Argue that it is practitioners who put the 'care' in healthcare.

The first strategy was used to defend the organization from undue interference from external bodies. This strategy, caring for the technology oneself, allowed the administrator to claim that external intervention is unnecessary. In this study, Participant 3 in particular mentioned engaging in robust participatory processes for continual improvement in medical *technology,* an extension of the spirit of continual improvement in medical *practice.* For example, they stressed the importance of attention to process and practices in infrastructural reconfiguration, and a view of invasive technologies such as CDS as one tool in a toolbox which also included education. Participant 3's views broadly aligned with CSCW evidence. For example, Participant 3 made use of participation and staging in iterative infrastructural development [137, 257]. Also, Participant 3 noted that the documentation inspected by external accountability bodies is not the whole story; this reflects findings by Pine and Mazmanian [200]. Care for the infrastructure became useful to Participant 3 when the organization comes under scrutiny by an external accounting body; since safeguards were in fact in place, they were able to contest a citation's legitimacy. In other words, *"We've already taken care of that."*

The second strategy was used to defend clinicians from undue interference from the organization's financial division. This strategy entailed arguing that practitioners have authority over care. This may have been effective for Participant 14, a physician informaticist and executive, because the EHR was nominally an infrastructure for care; it therefore logically followed that practitioners had authority over the EHR. This strategy appears to be effective becuase 'incentive structures were not aligned;' in other words, because H1 did *not* pay physicians for aiding in compliance efforts, there was a strong case for financial concerns to be of interest to the clinical side of the health system only to the extent that finance could express what some intervention or another would do for care.

Further investigation in pay-for-performance health systems may be revealing.

The twofold strategy above fits neatly into a panoptic framework. 'Care for the information infrastructure' may be conceptualized as the internalization of discipline in the healthcare organization, which reduces the 'need' for external intervention. The second strategy, the assertion of authority over care, implied that the mechanisms of examination and accounting were only useful insofar as they supported the expertise that practitioners already possessed; this was a claim to enlightenment. Among other things, I offer finer detail relating the findings to panoptic theory in the following sections.

4.5.2 Practical panopticism

The traditional imperatives of allopathic medicine—to care for the individual patient, and to do no harm—can at times be in tension with a variety of values which have been imposed on medicine. For example, business imperatives include resource efficiency, risk mitigation and revenue maximization; public health imperatives focuses on screening and treatment of the population largely irrespective of the individual patient. Healthcare appears to have been tied in knots.

Exogenous accounting and intervention is not a simple business, and this study has raised more questions than answers regarding health economics. Any model of care quality that sets forth a list of metrics and connects them in a weighted sum to a financial reward ultimately flattens the deeply multidimensional *qualia* of care within a single quantitative dimension, and creates a game that may be figuratively 'played.' Additionally, the assumption that care cost is inversely correlated with care quality simply must have boundaries; it cannot possibly be true that spending zero dollars on care means that a population is perfectly healthy. Further, if health systems that achieve higher quality scores receive more in reimbursements, then it stands to reason that those which have more

resources to put toward presenting themselves as 'high performing' in the first place have a competitive advantage which is reinforced through quality reimbursement programs, potentially facilitating market consolidation. Collaborations between STS-oriented CSCW researchers and health economists may be revealing.

The Learning Health System initiative [22, 135, 217], which emphasizes penalty-free peer evaluation, might in part address this issue. In this emerging regime, organizational knowledge is to be cross-pollinated via "Hospital Improvement Innovation Networks"[22]. The webpages of these efforts tend not to emphasize public accountability, instead highlighting large numbers of participating hospitals, prevented incidents, and cost savings.[7] I personally look forward to finding out what policymakers do next to make data on patient outcomes publicly available.

4.5.3 Compliance as an alienating force

While members of the CDS committee stressed that they were judicious in implementing new alerts, they also mentioned that they did in fact implement new alerts for compliance purposes, and that processes for removing alerts was an area ripe for improvement. The hypothesis that external accounting bodies contributed to alert fatigue was supported.

H1's CDS advisory committee used an approach to the automated intervention in clinical practice that was simultaneously 'top-down' and loosely coupled. That is to say, while decisions about the CDS system largely took place without facilitating extensive deliberation between those who would be affected, the alerts were kept easy to override; in an effort to avoid undue interference at the point of care, the CDS advisory committee

[7]The following webpages have been saved at archive.org:
http://www.fha.org/health-care-issues/quality-and-safety/mtc-hiin.aspx
https://patientcarelink.org/ma-hospital-engagement-network-hen/
https://cha.com/quality-patient-safety/
https://www.arkhospitals.org/Online/Quality/HIIN/Online/Quality/HIIN.aspx

took care to avoid implementing 'hard stop' alerts that could have tightened the coupling between the formal idealizations of work encapsulated in CDS rules and the actual work being performed. Without the opportunity to undertake a bold upfront configuration effort, H1 instead spread out the work of configuration over an indefinite period of continual negotiation and iteration, with the hope that fit between CDS and practice would gradually improve over time—a hopeful labor seeking the gradual reduction of alienation.

The medical informaticists interviewed in this study had apparently adopted an attitude toward the relation between rules and work akin to Suchman's theory of plans and situated action [242]. In Suchman's theory, while *a priori* formalizations for work such as those set forth in medical protocols serve an important role in the conduct of work, emergent conditions always arise which require the expert user to improvise in the style and comportment of one who operates in one's role as, say, a physician. Whether the medical informaticists interviewed in this study have received that attitude through the CSCW literature or a combination of medical informatics literature and practical experience (e.g., general guidance to avoid micromanaging residents [86]) is an open question. However, detailed, naturalistic, observational, qualitative work is uncommon in *JAMIA,* the flagship journal in medical informatics [123]. Speaking from my experience in the editorship of *JAMIA,* CSCW researchers looking to influence health system administrators should be advised that, at time of writing, *JAMIA* editors expect qualitative research to be summative rather than formative, and to have established a degree of generalizability by conducting investigation at more than one site.

The gradual, iterative approach to specification that dominated in this study contrasts with the case of a software vendor studied by Johannessen and Ellingsen [137]. In that case, a vendor was working to generify a tailored software solution for a broader market using a time-consuming 'bottom-up' approach, characterized by facilitating engagement between user-stakeholders with conflicting priorities. It is possible that Incredible takes an

approach similar to that of the vendor studied by Johannessen and Ellingsen; however, the development practices of H1's vendor, code-named Incredible in this study, remains understudied. In my experience medical informaticists widely regard the company that maintains Incredible as litigious and hostile to academic investigation, for example by claiming copyright infringement when researchers publish screenshots of their software's user interfaces. Guidance on gaining access to secretive organizations is available [178].

I am not aware of any instances of policymakers getting involved in the now years-long stalemate between Incredible's lawyers and university researchers, which complicates the investigation of EHR and CDS usability. Policymakers should know that their requirements may be translated directly into CDS clicks at the point of care without a great deal of deliberation; responsible external governance may require going the extra mile to continually forge personal, fruitful, honest, trusting, and caring relations with clinical users who do not have administrative responsibilities within the organization where they practice.

4.5.4 Glass windows and silicon curtains

In the findings I described the selective transparency offered by the EHR—broadly, participant practitioners found it easier to observe the activities of peer practitioners than to observe and participate in activities of infrastructural reconfiguration. Opacity tends to be the default state of affairs when organizational relations are mediated by computing machinery that is designed to be secure; infrastructural transparency is created through will and action enabled and constrained by organizations and institutions.

The description of peer examination may reveal something for those trained in Foucauldian scholarship. Personally, it is my hope that, when a loved one is in the hospital, that a medical expert who personally knows and cares about my loved one is keeping vigilant watch over the situation. So, the EHR may reify clinical panopticism, and it is as

important as ever that relations of lateral oversight enabled by panoptic structure are also relations of care.

A word for the clinical informaticists. In my experience, clinicians often think of bureaucracy as onerous, opaque and imposing, and it can be. Strictly speaking, bureaucracy is a means of separating out and rationalizing organizational functions to create organizational competencies that, for better or for worse, are relatively robust to variation at the level of the individual. I believe that the key is to ensure the organization does not get "lost in its head;" that, e.g. the coordinative capacities of computer infrastructure are incorporated into broader practices in which the musculature of practice is exercised and stretched. For example, it may be advisable to establish a practice wherein any clinician may file a request, and for those responsible for managing cases to follow up to solicit detailed cases from clinicians, invite clinicians to advisory and governance meetings, represent and accompany clinicians through the process, and follow-up with clinicians to ensure that a ticket's closure in fact represents satisfactory resolution. Speaking from my experience in academia, clear bureaucracy may not always be easy or comfortable, but it is well worth the resources and care.

In a study of the information technology (IT) department of a regional health system, Spence and Reddy [232] argued that organizational knowledge management systems should facilitate informal exchanges between IT. These systems could also be used to facilitate informal exchanges between clinical users and those in charge of continual improvement of IT resources, in this case the members of the decision support advisory committee. As mentioned by a CDS commitee member they were considering the development of an orderly review process in which they may solicit broader participation. One might refer to Microsoft Word as an example of how feedback might be solicited at the artifactual level. See Figure 4.1 for an example. Imaginably, a similar, brief feedback flow could be implemented in CDS alerts. Questions regarding organizational process remain open, such

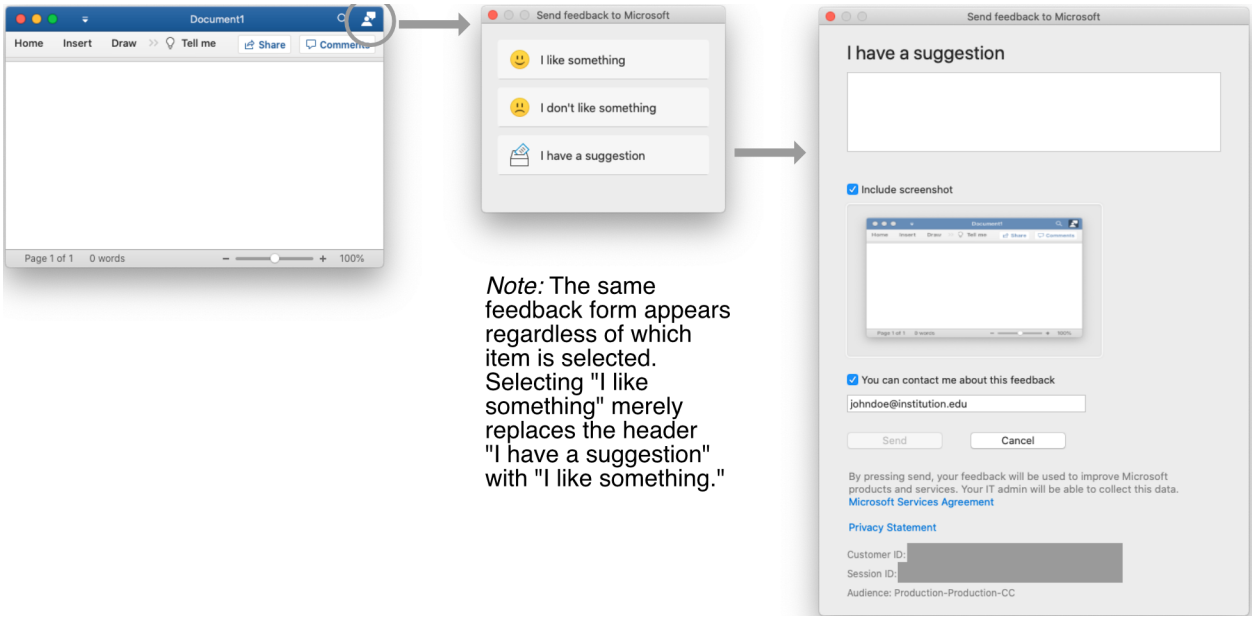


Figure 4.1: Example of feedback flow available in Microsoft Word.

as:

- How and when should the CDS committee reach out to which hospital units to:
  - Introduce the feedback mechanism,
  - Provide guidance on how to provide persuasive and useful feedback, and
  - Invite engagement in the process?
- How should the feedback process work, in terms of:
  - The period, duration, and regularity of solicitation,
  - Follow-up with relevant hospital units, and
  - Facilitating deliberation, prioritization, and a collective course of action?
- In what cases should issues be escalated to organizations that hold the hospital accountable?
  - How should hospitals coordinate escalation of shared issues?

– How should escalation proceed?

Deliberative processes for the purposes of standardization tend to be a difficult, contingent, time-consuming, and ongoing process [251], occasionally requiring stakeholders hailing from different professions to simply trust one another rather than arriving at a shared understanding [257]. Physician subdisciplines often take divergent approaches to the same problems [158]. I therefore expect the process of rule revision—effectively standard-setting at the organizational level—to be reliant on a spirit of trust that stems from serving a shared institutional mission.

At an inter-institutional level, ongoing resistance to external accountability might resemble professional organizing as documented by Sholler [224].

External governance is meant to function as public inspection, so I would like to offer food for thought to those interested or involved in such activity, such as policymakers. CMS recently mandated that health systems such as H1 enable patients to authorize the release of their electronic records through an application programming interface (API) [50], in the name of 'liberating patient data.' In addition to creating new opportunities for patient advocacy that is genuinely aligned with patients' interests, CMS has acknowledged that this has opened up new risks for health consumers and for civil rights [50]. Given the effects of racialized inequality in the United States on health vulnerability [3], the critical question will be *for whom* effective advocacy will be afforded.

4.5.5 Professions in regress?

In Deleuze's [73] societies of control, Foucauldian disciplinary structures and mechanisms such as the school and the examination give way to perpetual training and continuous intervention. A pharmacist expressed to me an anxiety that compliance was gradually

replacing professional expertise; this betrayed to me a sense of Deleuzian horror.

The pharmacist's anxiety was reflected in popular and academic literature. Community pharmacists working at chain pharmacies have reported systemic overwork and short-staffing [100, 4]. According to the US Bureau of Labor Statistics, the market for pharmacists grew rapidly over the past decade, by 17% or more (Table 4.1); an influx of fresh graduates is wont to create some oversight problems. Of concern, the Bureau has also projected that the pharmacist job market will shrink by 3% over the coming decade; I would expect the most experienced pharmacists to exit first.

Concerns that CDS will replace pharmacist labor and reduce the pharmacist job market due to overly optimistic beliefs in computational competence have been widespread [278]. The trade group representing chain pharmacies claimed that technology had supplanted certain routine pharmacist labor [4]. It is generally considered inappropriate to replace pharmacist labor with CDS [278]. Given participants' views on drug safety alerts in this study, there is little reason to believe that computerized alerts will be an adequate substitute for pharmacy expertise, especially for the management of complex medication regimens.

The situation in pharmacy appears to be a severe case in a general trend toward more lightly-trained healthcare labor. Growth in nurse practitioners, who may prescribe medications, has far outpaced that of physicians and surgeons (74% vs. 8%). Additionally, growth and prospects for pharmacy technicians and medical assistants have been robust, and have been projected to remain so. The safety benefits and consequences of professional development and fluctuations in junior and senior pharmacy labor deserves investigation. Also, the potential safety benefits of professional development and training, including in the safe use of technology, for high-growth healthcare jobs should be investigated.

Table 4.1: Healthcare labor market statistics.

	Job Growth, 2010-2019	Job Outlook, 2019-29	Median Pay 2020 (Hourly)
Physicians and Surgeons	+8%	+4%	$100
Pharmacists	*+17%	-3%	$62
Nurse Anesthetists, Midwives, and Practitioners	*+74%	+45%	$57
Physician Assistants	+50%	+31%	$55
Registered Nurses	+13%	+7%	$36
Pharmacy Technicians	+26%	+4%	$17
Medical Assistants	*+38%	+19%	$17
Nursing Assistants and Orderlies	+5%	+8%	$15

*2012 statistic used in place of 2010.
Note. Projected average growth is generally 3–4%
Source: US Bureau of Labor Statistics.

4.6 Conclusion

Physicians have maintained a fair degree of control over the EHR, its CDS system, and by extension the point of care in the United States, and the EHR has enabled panoptic practices which appear stable at time of writing. Of surprise and concern, pharmacy has been projected to *shrink* overall in the next decade, apparently due to a specious belief that pharmacists primarily check the safety of drugs, and that since CDS is meant to perform the same task, there is less need for pharmacists. Further investigation centralizing the role of complementary expert labor in creating safety in computer-imbued clinical practice may be revealing.

Chapter 5

Conclusion

It is not easy to produce rigorous research in time to influence contemporary events.[81, 235, 276] For example, at the time that my simulation study on opioid prescribing behavior (Chapter 2) had been published, the conventional design of CDS had been settled and cemented in US EHR infrastructure for years, and the opioid crisis was already shifting outside the walls and control of the clinics, driven largely by street fentanyl.[61]

The value of research is often what it reveals about questions to be asked moving forward—hence why expertise implicates education and training.[61] My design in Chapter 2 was inspired by something an art teacher from secondary school tole me—that artists compose paintings as builders build houses, in broad strokes first before honing in on detail. Perhaps my design will be picked up and implemented by ambitious students, or it will otherwise inspire far-off work on computer-aided guidance outside of healthcare.

Outcomes of Chapters 3 and 4—that role-tailoring in CDS matters, and that the expertise must be applied to CDS output—raised important questions about how CDS interfaces and integrates with various roles within healthcare—for example, what is the role of

physicians, pharmacists and medical assistants in picking up where the relevance of automated advice falls short? And how *should* such labor be divided?

I feel it is fair to say that the effort to pave EHR infrastructure during the HITECH era was dominated by a spirit of technological optimism. Policy guidance set the tone—that the EHR was to be a source of *safety,*[40] and implicitly not of risk; researchers treaded carefully around those policy dreams, using phrases such as *unintended* consequences[15] and safety *concerns*[227] to avoid pointing an accusatory finger at policymakers. My advisor put it succinctly in one meeting during my first year in the doctoral program: 'nobody [wanted] to look like they [were] getting in the way of the future.'

The relative safety and risk consequences of the EHR have not been easy to quantify. Systematic reviews of voluntarily-reported research findings have not indicated an overall effect in either direction,[177, 180] Public longitudinal medical error data remain unavailable at the national level.[163] Risk management records are carefully guarded and record-keeping practices probably vary from one site to the next. Additionally, there are critical methodological questions to be asked when attempting to isolate the effects of technology and labor on safety, especially given that, e.g. a prescription written at a health system may be dispensed at virtually any community pharmacy; inpatients may be transferred from one health system to another; staffing and technology vary from one place to the next over time, and both labor and technology comprise many dimensions.

In my opinion, it is little use speculating what could have been—what has been made would (probably) be unmade at great peril. But perhaps the case of EHR infrastructure in US healthcare may serve as a guide for what should be asked in ongoing efforts to improve patient safety moving forward, as well as prior to undertaking efforts to pave computer infrastructure in critical industries across the world.

5.1 Who governs?

For better or for worse, CDS has served as one tool among several for responding to external intervention—especially financial pressure—at the point of care. This is made clear in Chapter 4, in which organizational finance was used as leverage by CMS to encourage the adoption of measures such as routine screening at the point of care. The rugged style with which health system physician-administrators responded to quality payment programs may develop into more routine and proactive organizational processes. Time will tell. To its credit, CDS was also instrumental in the pandemic response of healthcare organizations which used it to quickly set up new processes to respond to COVID-19.[208] How the members of a crisis response team are selected for assembly at a moment's notice—when a fresh crisis has hit—matters.

Information infrastructures such as CDS render clinical processes flexible and open to intervention. There are no guarantees that authority exercised via CDS will be legitimate. During my doctoral program, a healthcare software vendor with control over some CDS systems used in practice compromised safety in favor of finance. PracticeFusion, the vendor in question, admitted to accepting money from a pharmaceutical corporation in exchange for implementing CDS alerts aimed at increasing opioid prescriptions.[260] They were investigated and fined by the US Department of Justice. It has become critical, then, to ask a question that is central in political science and studies: *who governs?*

5.2 Is aviation a satisfactory model for healthcare?

I do not believe that aviation, long heralded as a model for safety in healthcare,[146] has a robust answer to this question. To take an example, in 2019 Boeing's 737 MAX aircraft had a software problem that resulted in two crashes and hundreds of fatalities.[210]

According to Bloomberg, Boeing had been gradually replacing senior engineers with recent college graduates to cut costs.[210] inadequate oversight by company management and by Federal Aviation Authority (FAA) representatives, both of which were ridiculed within Boeing prior to the incidents,[70] was undoubtedly a contributing factor to the safety incidents. A root cause analysis cited a schedule rushed by "market rather than engineering estimates." The Department of Justice mandated that Boeing's engineers report to the chief engineer and *not* to the company's business functions, mentioned that airliners should avoid placing 'efficiency and profit' prior to 'integrity and transparency,' and fined the company $2.5 billion.[259]

So, what can healthcare learn from aviation? Perhaps that expertise is an important and often overlooked contributing factor for safety in dangerous industries, and that it is critical that those in charge of CDS systems—*those who govern*—have current, hands-on, and extensive expertise in the work in which they intervene.

Finance tends to have a corrosive effect on expertise,[29] replacing deep expertise with *provisional* expertise—understandings which work 'well enough for now,' while leaving fundamental questions underaddressed. In my experience, expertise may be dismissed using statements such as the following:

- 'That's too philosophical/theoretical/abstract.'
- 'What's the use in principles?'
- 'I don't care *how* it works; I only care *that* it works.'

Professional associations are responsible for safeguarding expertise at the industry (or *institutional*) level. It is worth investigating how expertise might be better sheltered from financial priorities at the *organizational* level in critical industries such as aviation and health care.

5.3 Are nudges enough?

It is worth asking whether nudges are a sufficient framework for addressing serious societal issues. I will use as an example a story which has been unfolding in Long Beach in particular, the city in which I sat to write this dissertation. In an instance of overlapping crises, the convention center has been set to dual purposes: as a vaccination site and as a child migrant detention facility; migrant children have reportedly tested positive for the virus; 67 of the children had been placed in isolation and received vaccinations according to an LA Times report in early May.[60]

According to the CDC, persons designated 'Latino or Hispanic' have been underserved during the vaccine rollout overall. National polling from the Kaiser Family Foundation[152] has indicated that distrust in the vaccine itself has not been the problem, and that missing work was a chief concern. Over half of Hispanic-designated people reached by pollsters had reported having been asked for government identification or a social security number, and self-reports strongly suggested that offering broad choice in clinical site and paid time off would increase population immunity.

According to an article published in US News and World Report written by Brocas, a University of Southern California professor of behavioral economics, *some* companies have offered paid time off and, e.g., donuts as incentive to drive vaccinations. Brocas suggested that policymakers additionally run social media campaigns in favor of vaccinations, and to install vaccine sites in subway stations.[36] At time of writing, there are no subway stations in Long Beach, and migrant amnesty and a right to paid time off for public health appointments have not been established.

Regardless of whether the US will successfully nudge its way to herd immunity specifically, it is worth contemplating whether nudges *should* be how things work. Concerns have been raised that nudge-based approaches are not appropriately matched to serious contemporary

challenges facing public health. I will provide three examples in the US.

First, climate change is a threat to public health.[266] Some have proposed the use of nudges to address climate change, and researchers have raised doubts that nudges would be an appropriate response.[164, 160]

Second, life expectancy, long considered a key metric for global population health in traditional academic and policy research,[209, 168] has stagnated and declined in the United States in the past decade.[179] In a curious twist, Ezekiel Emanuel, a chief architect of Obama's health policy reform who has published on the use of behavioral economics in 'value-based,' 'cost-conscious' care,[85] has argued that life expectancy should be capped at a specific age.[84]

Bringing it back to the topic of this thesis: *third,* the opioid crisis was 'nudged' out of the clinic between 2013 and 2019,[157, 258, 77] partly through the use of CDS alerts, which were embedded in the same information ecosystem as reports in press of the threat of arrest by police SWAT (Special Weapons And Tactics) teams.[155] Instead of vanishing, the problem spilled out into the streets; the CDC's own statistics report that deaths due to synthetic opioids rose steadily through the past decade, reaching nearly 12 out of every hundred thousand in the US population.[61]

Attempts to 'nudge' away these serious problems without addressing their underlying issues appear, at best, palliative.

US public health infrastructure, underfunded for nearly half a century,[183] was not prepared for the COVID-19 pandemic. With a death toll over 580 thousand at time of writing[93] the response was hardly successful. During the response to COVID-19, ongoing at time of writing, information infrastructure such as supply chain management systems and CDS were only effective for marshalling resources and coordinating work when resources—supplies, equipment, and labor—were made available to be

marshaled.[270, 208, 231] So, while nudges and information infrastructure may have their uses, it is important to ask larger and deeper questions about resources and authority as well.

5.4 Is hope enough?

Similar to Foucault, my criticism of the status quo is offered in service of the goals of Enlightenment.[98] I offer it in faith that there is some possibility, no matter how small, that the ailments of the present system's approach to remediation—too often too little, too late—can themselves be remediated. The EHR, a magnificent infrastructure and newly invasive control mechanism capable of reshaping care at the national level and a moment's notice, may prove instrumental in addressing crises, but it is by no means a panacea. It is instead a means of injecting external values into healthcare, and those values—such as those of business and public health—cannot be assumed to coexist in harmony.[94] Moreover, just as there are limits to the perfectibility of the individual clinician,[171] so too are there limits to the informated clinician. Indeed, the informated clinician is newly vulnerable to financial concerns that have wrought havoc in aviation. Let it not be so in healthcare.

In addition to a slim dash of hope, I call for a bold and consolidated investment of faith in public health and public healthcare. I believe this will be key to moving beyond an adversarial and litigious reimbursement framework and toward finding common ground between institutions of health, in order to build a healthcare infrastructure that is as coherent in its values as it is adaptive. The business of saving lives may be expensive, but life is all we have.

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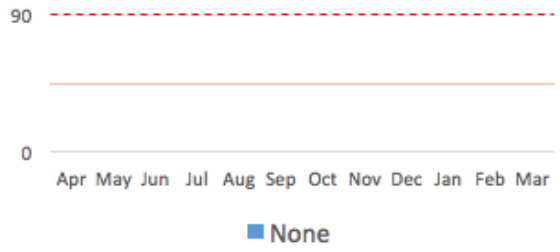
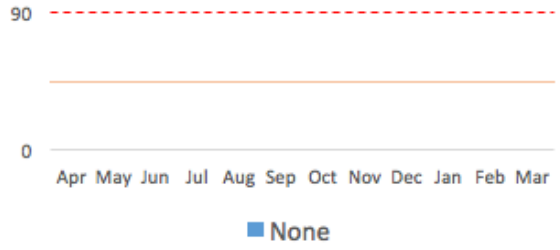
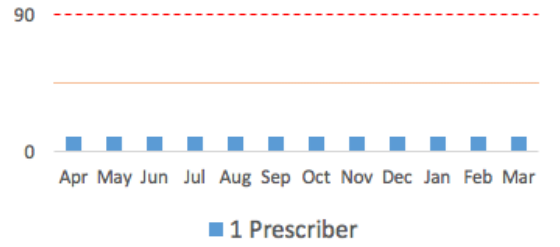
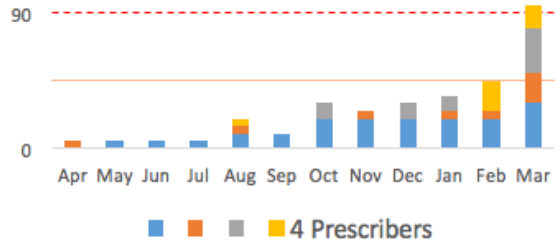
Appendix A

Supplementary materials for simulation study

Please see tables on following pages.

Table A.1: Patient scenarios and graphical prescription opioid histories

	Brief description	Graphical prescription opioid history
1	*History of present illness:* After lifting a box and feeling a "pop," the patient experienced sudden pain in the lower back and leg. Over-the-counter naproxen and acetaminophen have not been effective. *Prescription opioid history:* None.	
2	*History of present illness:* The patient experienced a gradual increase in right knee pain over several years and now has pain while walking. *Prescription opioid history:* None.	
3	*History of present illness:* After sustaining an injury two years ago, the patient has had consistent, moderate pain in the lower back and leg. The patient was previously prescribed oxycodone from one prescriber. *Prescription opioid history:* Low MMEs from the same prescriber for the past year.	
4	*History of present illness:* After lifting a box and feeling a "pop," the patient experienced sudden pain in the lower back and leg. The patient received oxycodone prescriptions from four different prescribers in the last month. *Prescription opioid history:* Escalating MMEs from multiple prescribers over the past year.	

Note. The graphical prescription opioid histories show orange and red lines at 50 and 90 MMEs/day, the thresholds of moderate and high caution set by the CDC.

Table A.2: Details of patient scenarios

	Patient 1	**Patient 2**	**Patient 3**	**Patient 4**
Weight, height, BMI, sex, age	112 kg, 190 cm, 31, male, 28	114 kg, 188 cm, 32.3, male, 56	114 kg, 190 cm, 31.6, male, 30	116 kg, 188 cm, 32.8, male, 30
Complaint	Low back and leg pain.	Right knee pain.	Low back and leg pain.	Low back and leg pain.
History of present illness	Two days ago, patient was lifting a box at work at which time patient felt a "pop." Pain started suddenly. Patient has been taking over the counter naproxen and acetaminophen at high doses without benefit.	Pain began gradually over several years; now it hurts to walk.	Pain has been present constantly following an injury two years ago.	Two days ago, patient was lifting a box at work, at which time patient felt a "pop." Pain started suddenly.
Exams	Decreased sensation in the lateral RLE. Motor strength intact. Pain worse with flexion. Cannot ambulate; mother transports patient in a wheelchair.	Decreased mobility of the right knee. Crepitus during passive and active ROM. Signs of ligamentous injury absent. No pain on palpation.	Decreased sensation in the distal medial RLE. Motor strength intact. Pain worse with ambulation.	Decreased sensation in the lateral RLE. Motor strength intact. Pain worse with flexion. Cannot ambulate; mother transports patient in a wheelchair.
Medications	Acetaminophen oral pill, 1500 mg daily, for 2 days; naproxen oral pill, 1000 mg daily, for two days.	None.	Oxycodone oral pill, 10 mg, 3 times a day, for 30 days.	Oxycodone oral pill, 30 mg, 3 times a day for 30 days.
Family history	Father with back problems.	Mother with osteoarthritis.	Noncontributory.	Mother with back problems.
Labs	None.	X-ray demonstrates mild osteoarthritis of right knee.	None.	None.

Note. In all scenarios, there were no known drug allergies; social history reported "alcohol socially; denies drug or tobacco use," and problem lists showed "None."

Table A.3: Scoring rubric. A score of 8 indicates the most appropriate course of action.

Score	Patient 1	Patient 2	Patient 3	Patient 4
8	Added Schedule II opioid in correct dose, and at least two adjuvants.	Added non-prescription strength NSAID and additional adjuvant.	Opioid rotation and more than one adjuvant.	Discontinued opioid and added three adjuvants, or two adjuvants and naloxone.
7	Added Schedule II opioid, and exactly one adjuvant.	Added prescription strength NSAID and additional adjuvant.	Opioid rotation and one adjuvant.	Discontinued opioid and added two adjuvants or naloxone.
6	Added opioid in inappropriate dose or duration, and one adjuvant. Or, added Schedule II opioid in correct dose, but no adjuvants.	Added NSAID but no other adjuvant analgesic.	Opioid rotation or wean but no adjuvant.	Discontinued opioid and added one adjuvant.
5	Added opioid with inappropriate dose, schedule, or duration, and no adjuvants.	Added prescription strength NSAID or oral steroid.	Continued opioid and added adjuvant.	Discontinued opioid and added nothing.
4	Added two or more analgesics, but no opioids.	Added one analgesic, but no NSAIDs.	Continued opioid without weaning and did not add any adjuvants.	Continued, reduced, or rotated to a safer opioid, and added an effective adjuvant.
3	Added one non-opioid analgesic.	No recommendation.	Discontinued opioid and added one effective adjuvant.	Continued opioid and added one ineffective adjuvant.
2	Ordered oral steroid.	Added a Schedule III opioid.	Discontinued opioid and added adjuvants ineffective for low back pain.	Continued opioid as requested and added no adjuvants.
1	Ordered nothing.	Added a Schedule II opioid.	Discontinued opioids and did not add adjuvants.	Increased opioids.

Table A.4: Participant demographics

Total	(%)	
24	(100.0)	
		Age
5	(20.8)	26–28 years
5	(20.8)	29–30 years
4	(16.7)	31 years
6	(25.0)	32–38 years
4	(16.7)	Did not specify
		Gender
8	(33.3)	Women
12	(50.0)	Men
4	(16.7)	Did not specify
		Race
11	(45.8)	White
7	(29.2)	Asian
2	(8.3)	Black or African American
4	(16.7)	Did not specify
		Residency
17	(70.8)	Anesthesiology
7	(29.2)	Physical medicine and rehabilitation

Appendix B

Supplementary materials for systematic literature review

Table B.1: Table of included results

Article	Type of CDS	Measures
Armstrong, 2013[12]	Fax Alerts	Event Analysis (8%)
Beeler, 2016[24]	Modal Dialogs	In-dialog (55%)
Bell, 2014[25]	Modal Dialogs with Action Shortcuts	Event Analysis (95%)
Bryant, 2015[39]	Modal Dialogs, Tiered, Override Reason Required	In-dialog (7%)
Cho, 2014[52]	Modal Dialogs with Action Shortcuts	In-dialog (22%), Override Appropriateness (29%)
Cho, 2015[53]	Modal Dialogs	In-dialog (42%)

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Table B.1: Table of included results

Article	Type of CDS	Measures
Cornu, 2015[68]	Modal Dialogs, Tiered, Additional Context Provided, Override Reason Required	In-dialog (52%)
Cornu, 2015 (Two interventions)	Modal Dialogs, Tiered	In-dialog (2%)
Duke, 2013[82]	Modal Dialogs, Additional Context Provided	Event Analysis (15%)
Duke, 2013 (Two interventions)	Modal Dialogs	Event Analysis (19%)
Feifer, 2010[87]	Fax or Mail Alerts	Event Analysis (54%)
Fritz, 2012[99]	Pharmacy Review: Pharmacist Panel Discusses Prerecorded Modal Dialogs, Counsels Prescriber via Face to Face, Phone Call, Chart Notes	Event Analysis (58%)
Galanter, 2010[102]	Modal Dialogs, Override Reason Required	In-dialog (19%)
Genco, 2016[105]	Modal Dialogs	In-dialog (4%), Override Appropriateness (100%)
Hsu, 2011[121]	Modal Dialogs	In-dialog (73%)
Isaac, 2009[129]	Modal Dialogs, Tiered	Event Analysis (9%)
Jani, 2011[133]	Modal Dialogs	In-dialog (89%)

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Table B.1: Table of included results

Article	Type of CDS	Measures
Joosten, 2013[138]	Pharmacy Review: Pharmacist Reviews Auto-generated Report, Counsels Prescriber via Phone Call, Email, Modal Dialog	Event Analysis (66%)
Knight, 2015[144]	Modal Dialogs with Action Shortcuts	Event Analysis (48%)
Long, 2008[161]	Modal Dialogs	Event Analysis (34%)
McCoy, 2012[170]	Modal Dialogs	In-dialog (18%), Event Analysis (47%), Override Appropriateness (18%)
Nanji, 2014[182]	Modal Dialogs, Override Reason Required	In-dialog (47%), Override Appropriateness (53%)
Niedrig, 2016[185]	Pharmacy Review: Modal Sent to Pharmacist, Counsels Prescriber via Phone Call, Email, Chart Notes	Event Analysis (79%)
Nishimura, 2016[186]	Modal Dialogs with Action Shortcuts	In-dialog (96%)
Paterno, 2009[195]	Modal Dialogs, Tiered	In-dialog (29%)
Perlman, 2011[196]	Modal Dialogs	Event Analysis (45%)

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Table B.1: Table of included results

Article	Type of CDS	Measures
Saxena, 2011[220]	Modal Dialogs	Event Analysis (42%)
Scharnweber, 2013[221]	Modal Dialogs	In-dialog (8%)
Sethuraman, 2015[223]	Modal Dialogs	Event Analysis (19%), Override Appropriateness (89%)
Simpao, 2015[225]	Modal Dialogs with Action Shortcuts	In-dialog (15%)
Slight, 2013[229]	Modal Dialogs, Override Reason Required	In-dialog (40%), Event Analysis (66%), Override Appropriateness (68%)
Slight, 2017[228]	Modal Dialogs, Override Reason Required	In-dialog (19%), Override Appropriateness (97%)
Smith, 2014[230]	Pharmacy Review: Pharmacist Views Modal Dialogs, Dashboard, Counsels Prescriber via Phone Call, Chart Notes	Event Analysis (90%)
Tamblyn, 2008[246]	User Clicks Button and Views Several Modal Dialogs, Tiered, User Configurable Threshold	Event Analysis (76%)

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Table B.1: Table of included results

Article	Type of CDS	Measures
Tamblyn, 2008 (Two interventions)	Modal Dialogs, Override Reason Required, Tiered, User Configurable Threshold	Event Analysis (12%)
Topaz, 2015[254]	Modal Dialogs	In-dialog (10%)
Van der Sijs, 2010[263]	Modal Dialogs	Event Analysis (30%)
Weingart, 2014[269]	Modal Dialogs, Tiered, Override Reason Required	In-dialog (1%)
Woods, 2014[277]	Modal Dialogs	In-dialog (26%), Event Analysis (41%), Override Appropriateness (14%)
Yeh, 2013[279]	Modal Dialogs, Override Password Required	In-dialog (35%)
Zhang, 2016[281]	Modal Dialogs, User Clicks Button and Views List of Alerts	In-dialog (85%)
Zimmer, 2008[284]	Modal Dialogs, Tiered, Specialist Override for High Alerts	Event Analysis (58%)

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