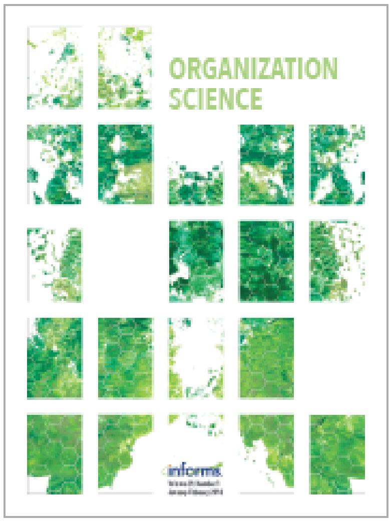

Organization Science

Publication details, including instructions for authors and subscription information:
http://pubsonline.informs.org

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To cite this article:
Joelle Evans, Susan S. Silbey (2021) Co-Opting Regulation: Professional Control Through Discretionary Mobilization of Legal Prescriptions and Expert Knowledge. Organization Science

Published online in Articles in Advance 10 Dec 2021

. https://doi.org/10.1287/orsc.2021.1525

informs
http://pubsonline.informs.org/journal/orsc

ORGANIZATION SCIENCE
Articles in Advance, pp. 1–24
ISSN 1047-7039 (print), ISSN 1526-5455 (online)

Co-Opting Regulation: Professional Control Through Discretionary Mobilization of Legal Prescriptions and Expert Knowledge

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Received: July 15, 2017
Revised: September 27, 2018; March 17, 2020; June 15, 2021; July 6, 2021
Accepted: July 26, 2021
Published Online in Articles in Advance: December 10, 2021

https://doi.org/10.1287/orsc.2021.1525

Abstract. The governance of front-line professionals is a persistent organizational problem. Regulations designed to make professional work more legible and responsive to both organizational and public expectations depend on these professionals' willing implementation. This paper examines the important question of how professional control shapes regulatory compliance. Drawing on a seventeen-month ethnographic study of a bioscience laboratory, we show how professionals deploy their discretionary judgment to assemble environmental, health, and safety regulations with their own expert practices, explaining frequently observed differential rates of regulatory compliance. We find that professional scientists selectively implement and blend formal regulations with expert practice to respond to risks the law acknowledges (to workers' bodies and the environment) and to risks the law does not acknowledge but professionals recognize as critical (to work tasks and collegiality). Some regulations are followed absolutely, others are adapted on a case-by-case basis; in other instances, new practices are produced to control threats not addressed by regulations. Such selective compliance, adaptation and invention enact professional expertise: interpretations of hazard and risk. The discretionary enactment of regulations, at a distance from formal agents, becomes part of the technical, practical, and tacit assemblage of situated practices. Thus, paradoxically, professional expert control is maintained and sometimes enhanced as professionals blend externally imposed regulations with expert practices. In essence, regulation is co-opted in the service of professional control. This research contributes to studies of professional expertise, the legal governance of professionals in organizations, regulatory compliance, and safety cultures.

Supplemental Material: The online appendix is available at https://doi.org/10.1287/orsc.2021.1525.

Keywords: occupations and professions • legal governance • culture • safety culture • expert work

Introduction

As professionals become an increasing portion of the employed workforce, the governance of professional work poses persistent organizational problems (Greenwood and Empson 2003, Gorman and Sandefur 2011, Bechky and Chung 2018, Chown 2020). Initially constituted as autonomous communities, professions have long claimed to exercise self-governance through internal norms and peer oversight (Freidson 1988, 2001; Abbott 1988). In organizational settings, professionals have maintained strong and sometimes quasi-exclusive control over their work, grounded in the mastery of distinct and often opaque expertise on which their clients and employers rely (von Nordenflycht 2010, Briscoe and Murphy 2012, Gray and Silbey 2014, Huising 2014).

At the same time, legal mandates designed to make professional work more legible and responsive to public and organizational expectations have been proliferating (Edelman 1992, Heimer 1999, Power 2005, Kellogg 2009, Pernell et al. 2017, Huising and Silbey 2018). At the organizational level, these mandates are administered through accountability infrastructures consisting of dedicated roles, rules, standard operating procedures, and incentives, as well as information, reporting, and audit systems (Huising and Silbey 2021). These regulations and associated governance mechanisms are put in place to mitigate the risks stemming from critical social goods such as, for example, healthcare (Heimer 1999, Kellogg 2009), science (Huising 2014), or finance (Pernell et al. 2017) and as such intrude on terrain otherwise governed by professions.

Although research has examined how legal prescriptions interact with professional control (Heimer 1999, Pernell et al. 2017), understanding how multiple and often conflicting professional and regulatory prescriptions are negotiated on the ground still remains elusive. We know that competing regulatory and professional imperatives generally overlap as they are simultaneously and selectively mobilized by organizational and professional actors (Heimer 1999, Binder 2007, Heimer and Gazley 2012). Deference to the expertise of collaborating professionals also creates patterns of heterogeneous and variable decision making and differential rates of compliance (Hughes 1958, Howard-Grenville 2005, Wakeham 2012, McPherson and Sauder 2013, Lee and Lounsbury 2015). Yet it remains unclear how legal and organizational mandates are translated into concrete action when professionals maintain significant discretion performing their expert work.

We need a clearer understanding of how legal regulations are translated into professional habits. Professionals routinely work where technically challenging performance can pose serious public risks (Heimer and Staffen 1998; Pires 2008; Silbey 2009; Coslovsky 2011, 2014; Pernell et al. 2017). Historically, professional norms and peer oversight have provided standards of care and degrees of altruism in the performance of these prosocial responsibilities. However, as professionals move from serving individual clients to being employees within hierarchical organizations, offering technical expertise in lieu of altruism (Abbott 1988, Brint 1994, Nelsen and Barley 1997, Evans 2021), they become more silent about their motives (Briscoe and Murphy 2012, Anteby 2013) and the enforcement of standards of practice transfers to organizational actors (Pernell et al. 2017). Managers recognize that professional control and expertise is central to the conduct of professional tasks (Greenwood and Empson 2003, Bechky and Chung 2018) but also require some form of compliance and accountability to organizational interests on the part of their professional employees. As organizations are long chains of loosely coupled action, "inhabited" by multiple occupations with competing interests vying for authority (Hallett and Ventresca 2006), studies of organizational governance need to move beyond formal compliance structures and occupations to consider front-line professionals as agents of regulatory implementation. Therefore, how does professional control and discretion shape the implementation and institutionalization of legally mandated regulations designed to manage complex technical work in and by organizations?

Drawing on a 17-month ethnography of a bioscience laboratory subject to multiple regulations designed to promote safe work, this paper builds from in-depth observations of laboratory practices to advance our understanding of how autonomous professionals respond to legally imposed regulations. Because professional control is at its core grounded in the exclusive or quasi-exclusive mastery of specific tasks (Abbott 1988, Bechky 2003), the locus of the contest between professional and regulatory workplace governance lies within routine work practices. We show how professionals use discretion and expertise to selectively implement and blend regulations with local norms of practice. We identify a pattern of responses, which reveals that responses to the law are more complicated than simple deference, avoidance, decoupling, or resistance. Specifically, although some regulations are followed absolutely, others are adapted on a case-by-case basis as professionals invoke their expertise to determine the appropriateness and effectiveness of prescribed procedures. In other instances, new rules are produced or tailored locally to control threats not addressed by legal regulations. These instances of selective compliance, adaptation, and invention enact professional expertise: the interpretations of risk, what hazards exist, what is threatened, and what are the probabilities for controlling hazards by following one or another rule or combination of rules. In sum, we find that legal regulation is co-opted as a resource for maintaining and extending professional expertise and discretion. At the same time, these professional decisions display and explain the oft observed variations in regulatory compliance.

Bioscience laboratories are replete with hazards posing threats to workers and the environment. The possible leak of a virus from a laboratory is just such an example of the environmental and human risks admittedly associated with scientific research. The regulations promulgated by federal and state agencies specify procedures for protecting the environment, such as maintaining air quality, handling radioactive materials, and chemical and biological waste, as well as for protecting individual worker's bodies, such as what to do in case of accidental contamination or bodily injury.

Yet, professionals, including scientists, recognize a wider range of hazards than those identified by regulations. Professional scientists also recognized and attempted to control threats to their work tasks and to the collegial sociality they deemed essential to their activity. For example, the introduction of unwanted substances into experiments, which may pose no threat to bodies or the environment, contaminates and therefore corrupts the core of this professional work: the experiment. Furthermore, the erosion of trust among professionals, because of potentially mishandled hazardous materials, impedes the collaboration on which science thrives.

We find that this gap between regulatory and professionally recognized hazards drives the adoption of regulations. When regulations applied to all four threats, to bodies, to material conditions, to work tasks, to sociality, professionals demanded and performed consistent compliance with regulations.[1] When regulations applied primarily to bodies and the environment but did not threaten work or sociality, compliance was treated as discretionary. Where work and collegial exchange were threatened and no existing legal regulations applied, scientists crafted their own safety rules, which achieved, within the organizational setting, a comparable authority.

These selective regulatory mobilizations move beyond ritualized compliance to assemble and maintain autonomous expertise in everyday routines. Although prior work emphasized that compliance to regulation might be merely ceremonial (Edelman 1992, Dobbin et al. 1993) or the result of bureaucratic enforcement (Huising 2014), we show that the practice of legal compliance by professionals enacts and expands their jurisdictional expertise and thus participates in the continued development of networks of professionally controlled expertise (Eyal 2013, Huising 2014).

From these findings, we make contributions to three related fields of inquiry. First, we contribute to studies of professional expertise and control (Freidson 2001, Huising 2014, Chown 2020, Evans 2021) by showing how, in the face of institutionalized challenges, experts co-opt externally imposed regulations to sustain and possibly enhance their own authority and control. Professional knowledge and experience are mobilized for continuous critical engagement with the regulatory regime and with professional conventions to craft organizationally appropriate safety practices. Second, we add to the literature on regulatory implementation by identifying one mechanism by which organizational processes may be recoupled with institutional demands at a distance from formal legal actors (Espeland 1998, Hallett 2010). This regulatory compliance is achieved not by deference, avoidance, or complacent embrace (Gray and Silbey 2014) but by co-opting legal constraints in discretionary alliance with professional expertise to expand the repertoire of organizationally sanctioned work processes, rules, and regulations. This discretionary co-optation helps to explain the frequently observed variation in regulatory compliance by professionals in formal organizations (Ewick 1985, Short and Toffel 2010, Haines 2011). Finally, we respond to what have become almost ritual calls for developing safety culture as the means of managing complex risks (National Research Council 2014). By deploying interpretive authority based on local and technical expertise, professionals move beyond compliance (Gunningham et al. 2004) to craft a locally resilient safety culture.

Following a brief review of the literature on professional control, the regulation of professional work, and safety culture, we introduce laboratory health and safety regulations as the context and field site. In a third section, we detail four forms of expert compliance. We show and argue in a penultimate section that these practical enactments constitute coherent practices that express and reproduce professional judgment and expertise about safety and thus expert control over work.

Organizational Control, Professional Expertise, and the Regulation of Risky Work

Professionals are adept at maintaining control over their work through their technical expertise on which external constituents such as individuals, organizations, or governments rely (Brint 1994, Freidson 2001, von Nordenflycht 2010, Huising 2014). Expert knowledge is essential to organizations' work of interpreting and translating technical requirements and regulations into operational procedures, although such expertise can also become a source of independence and resistance impeding both organizational control and regulatory compliance. Because "the work routines of experts … are largely unscripted, unobserved, and unsupervised," others in the organization, including those with supervisory authority, cannot "directly control or even manage knowledge-work processes" (Huising 2014, p. 1). Thus, whether implementing, moderating, or ignoring legally initiated managerial commands and whether in a supporting (Huising 2014) or a production role (Kellogg 2009, Hallett 2010), occupational groups with expertise (e.g., professionals such as scientists, doctors, engineers) exert independent influence on work processes (Bechky 2003, Bechky and Chung 2018), including organizational compliance (Binder 2007).

Professional control relies on acceptance by external communities and on internal occupational cultures that provide shared norms regarding how work is to be performed (Barley 1983; Freidson 1988, 2001) and direct peer oversight (Freidson and Rhea 1963). Because occupational culture is often tacit and not easily codified, it necessitates long on-the-job apprenticeship and socialization as older members enact and new members learn the tacit and explicit rules of their trade (Van Maanen 1973, Van Maanen and Barley 1984). Newcomers can find themselves devoid of requisite knowledge to handle complex and sometimes hazardous tasks, dependent upon senior members for the performance of their work. Importantly, practices that may not resonate with professional insider concerns, such as those generated by the physical environment and external stakeholders, may go insufficiently attended (Ho 2009, Howard-Grenville et al. 2017). As a corollary, the normalization over time of small yet consequential deviations may make it more difficult for workers to distinguish between inconsequential and more significant errors (Vaughan 1996). Locally shared interpretations and practices, such as understandings of what is safe and how safety is to be performed, circulate through ongoing practical engagement, primarily learned through mimicry, extensive collective storytelling, and mindful reflexive interactions (Weick and Roberts 1993; Gherardi and Nicolini 2000a, b; Wicks 2001). Through humor and informal conversation, members of local cultures indicate what is acceptable, even honorable and praiseworthy, and what calls forth not only rebuke but denigration and accusations of deviance (Shearing and Ericson 1991; Gherardi and Nicolini 2000a, b; Desmond 2007).

In effect, professionals ensure the collective enforcement of their norms through collective judgement or peer oversight (Lamont 2009), what is variously termed collegiality (Weber 1978), a “self-regulating company of equals” (Freidson and Rhea 1963, p. 119), or concertive control (Barker 1993). It is generally informal, although the principles are sometimes formalized through professional partnerships (Greenwood et al. 1990, Greenwood and Empson 2003), periodic reviews or reaccreditations, and disciplinary proceedings (Abel 2012). Yet, peer control rarely works efficiently in cases of on-the-job errors as professionals are reluctant to handle offenses from colleagues and may be lacking hierarchical or coercive tools to enforce compliance (Freidson and Rhea 1963). Because professional expertise is generally illegible to outside stakeholders, including those who rely on such expertise (von Nordenflycht 2010, McPherson and Sauder 2013, Huising 2014), professionals often remain unaccountable for central aspects of their work.

Thus, despite continual efforts to sustain control over tasks and collegial sociality, professionals are also aware of the limited governance achieved through occupational cultures. For example, professional cultures eliciting extreme forms of commitment and presence reach their limits when employees begin articulating alternative values and identities (Kellogg 2009) or become aware of their physical limitations (Michel 2011). In some contexts, professionals articulate alternative modes of practice and attempt to influence their peers to adopt these counter-norms (Howard-Grenville et al. 2017, Evans 2021). In other examples, some members have been shown to exit professional ranks to influence practices from the outside (Moore 1996). Thus, although professions as disciplinary associations generally sustain common criteria of responsible practice, insider attempts to address limitations in these professional cultures display variations in modes of self-governance.

In sum, research documents how managers seek to align the work of front-line professionals with social and organizational goals through programs and techniques ranging from financial, value-based or identity-based incentives (Greenwood and Empson 2003, Anteby 2010, Chown 2020) to centralized systems, procedures and dedicated roles (Huising and Silbey 2011, Pernell et al. 2017). The varied degrees of control over tasks within a given jurisdiction can influence the uptake of these programs (Gray and Silbey 2014, Chown 2020) and the extent to which program techniques are routinely instantiated within local professional practices (Huising 2014). However, this literature has not explained the observed variations across degrees of professional expertise and organizational control. How are the varied sources of authority, professional expertise, organizational hierarchy, and legal regulations, negotiated to sustain local control of work?

The Regulation of Professional Work

Many forms of regulation, covering the widest range of phenomena, from routine traffic management through consumer product safety and security of hazardous materials to complex financial transactions, are routinely followed with infrequent government intervention. The compliant practices, whether enacted in the quality of goods, the reliability of technologies, or more transparent business transactions, eventually become taken for granted habits and expectations, such as smoking outside rather than inside office buildings, wearing seat belts, installing scrubbers on building roofs to eliminate airborne pollutants, or constructing blowout preventers and hydraulic valves on drilling platforms to reduce damage from mechanical failures. Whether addressing the actions of individuals or organizations, regulations are effective “by working through internal organizational processes” (Heimer 1999, p. 17). Private organizations become the means of administering what might be considered a normatively powerful, but administratively weak state (Dobbin and Sutton 1998). Thus, in effect, the potency of legal regulations over time depends on their seamless integration within everyday organizational routines (Feldman and Pentland 2003).

Of course, such integration varies, given the wide-ranging and multifarious legal and self-imposed policies governing the work of expert professionals. Regulations can be uncertain and incomprehensible, engendering political and interpretive struggles (Kaplan 2008), becoming the focus of continuing resistance or turmoil (Hallett 2010). Professionals may actively protect their autonomy from external demands though ceremonial compliance, decoupling routine practices from their public representations (Meyer and Rowan 1977, Edelman 1992). Conversely, legal regulations may ultimately shape professional interpretations of work (Heimer 1999), with regulatory frameworks successfully penetrating professional jurisdiction and influencing on the ground arrangements (Silbey and Ewick 2003, Kellogg 2009, Hallett 2010, Huising 2014, Silbey 2022). Although we know that there is variation in how regulation is institutionalized in professional environments, we still lack an explanation of how this variation occurs and in particular how the discretion of expert professionals may play a role shaping the institutionalization of regulatory prescriptions within organizations (Huising and Silbey 2018).

Explanations for individual variation in compliance range from accounts of inconsistent and lax enforcement to misaligned incentives (Wilson 1980, Hawkins and Thomas 1984, Lester and Deutch 2004), with much recent scholarship and policy advocates recommendingnudges to push individual behavior to reduce anticipated risks (Thaler and Sunstein 2008). Yet, the empirical literature testing nudges for shaping regulatory compliance and prosocial behavior challenges meaningful synthesis or clear predictions (Huising and Silbey 2018). When the focus shifts to the organization, researchers again observe varied compliance, with explanation including competitive forces, strategic plans, operational factors, and relations with enforcement agencies (Hawkins and Thomas 1984, Edelman et al. 1999, Gunningham et al. 2004, Howard-Grenville et al. 2008). Studies also describe symbolic compliance and decoupling of practices from organizational and legal mandates (Edelman 1992, Pernell et al. 2017) responding to multiple institutional logics (Pache and Santos 2013).

However, this work overlooks the internal mechanisms through which decision making and practices may coordinate or interfere with regulatory requirements. Thus, although we have sophisticated hypotheses for why some organizations are committed to achieving compliance, we continue to have an impoverished sense of how this commitment is successfully enacted. With insufficient attention to the ways in which internal actions lead to compliance or noncompliance with regulations (Baldwin et al. 2010), organizational level analyses neglect the ways in which interpretations of regulations vary within organizations. Within organizations, the gap between regulatory expectations and performance is less a function of the inadequate specification of responsibilities than "the exigencies of practical action [that] repeatedly challenge efforts to comply consistently with regulatory standards" (Huising and Silbey 2011, p. 3). Because the habits of experts are frequently unscripted, others in the organization, including those with compliance responsibilities or supervisory authority, cannot directly control or even manage knowledge-work processes (Knorr Cetina and Brueger 2002; Newell et al. 2009, p. 43; Lepinay 2011). If professional labor is the discretionary enactment of expertise for problem specific solutions (Abbott 1988), we now have a dilemma: the professional expertise needed to interpret regulations is itself becoming the object of regulation. Thus, to anticipate, contain, and control ubiquitous risks, the work of professionals is a critical factor shaping the forms of risk mitigation and legal compliance (Bumiller 2009, Dobbin 2009).

Safety Culture in Science

The practice of safe science falls broadly under the term safety culture. Although there is a great deal of formal training, much bench science relies on tacit knowledge learned through informal exchanges within labs (Owen-Smith 2001). Consequently, safe science is also learned primarily within locally bounded research groups. The difficulties of specifying in advance, and providing locally specific training for would-be professionals, for how to handle all known and unspecified hazards challenges demands for regulatory compliance and ultimately for safety itself. The term safety culture has been invoked to address this persistent indeterminacy. "The subset of assumptions about safety in an organization [has been] loosely labeled safety culture" (Schein 2010; National Academy of Sciences 2016, p. 27; 2018). The word culture acknowledges the need for local signaling, adaptation, and discretion, enacted not only to follow prescribed techniques but also to identify emergent risks. As an explanation for accidents and noncompliance, safety culture has been identified as a means for improving reliability and security in high hazard organizations, including academic research laboratories housing a profusion of unspecifiable practices that elude the kinds of minute detail characteristic of legal rules (APLU 2016, National Academy of Sciences 2018). In essence, promoting safety culture acknowledges "that compliance with government regulations alone is insufficient to create and maintain a safe working environment" (National Academy of Sciences 2016, p. 22). Often considered a holistic and relatively effective approach to risk management, scholars have nonetheless struggled to define what makes for a reliable safety culture (Weick 1987, Roberts and Rousseau 1989, Eisenhardt 1993, Roberts et al. 1994, Weick et al. 1999, Silbey 2009). Most generally, however, it "reflects the extent to which an organization's culture understands and accepts that safety comes first, with a majority of organizational members directing their attention and efforts toward its improvement" (Vogus et al. 2010; National Academy of Sciences 2016, p. 28).

Although much literature has examined the complexity and resilience of safety cultures, much less heed has been given to how regulations interact with these complex and emergent sets of assumptions, practices and interactions related to safety. Given the proliferation of employed professionals and the risks within and by the work of complex organizations, how do professionals deploy their expertise to manage risk while routinizing legal and organizational control?

Fieldsite and Methods

Data were collected through 17 months of fieldwork in Med Laboratory (a pseudonym), a large academic laboratory performing basic research related to blood diseases and cancer located at a major university in the United States. To explore how professionals manage threats to their autonomy posed by legal regulations, we looked at the well-documented rivalry between law and science (Faigman 2000; Silbey 2022; Jasanoff 2009, 2016). We reduce the noise of multiple authorities competing for influence by looking at a protected space (Howard-Grenville et al. 2017) with clear ownership and responsibility: the research laboratory where academic freedom has traditionally bested efforts at routinized regulation (Silbey and Ewick 2003). As such, this constitutes an ideal case to extend theories at the intersection of regulation and professional expertise within organizations.

Regulation of Scientific Laboratories

Over the last several decades, academic laboratories have been subject to a growing array of regulations administered by multiple federal, state, and organizational agencies and departments. Radiation, toxins, chemical, and biohazard protection standards emerged as their effects on humans and the environment became better known and as new potential hazards were created and identified (Kelty 2009).

Since its formation in 1971, the Occupational Safety and Health Agency (OSHA) has issued regulations regarding limits on chemical exposure, use of personal protective equipment, and handling of dangerous equipment. In addition, the National Academies produce guidelines for prudent practices in research laboratories (National Research Council 2014). Regulation intensified in the late 1990s following a broad new initiative of the Environmental Protection Agency (EPA). The initiative aimed to limit the pollution of surrounding communities by universities and laboratories by recommending adoption and implementation of risk-management systems. Risk management systems try to centralize the management of compliance with myriad regulations though clearly defined offices, roles, and rules, with specified procedures for training, implementation, and self-surveillance. Risk-management systems also aim to provide centralized accountability for compliance efforts. Following the generic recommendations, Med Laboratory's university implemented such a system, known as the Environmental and Health Safety (EHS) system.

The EPA initiative itself led to multiple new regulations regarding waste containment and disposal that impacted laboratory practices. For instance, sharp objects such as syringes or glass pipettes were now to be disposed of in separate containers from other types of waste, thus multiplying the bodily gestures of scientists and the array of containers occupying limited laboratory spaces. Other examples include regulations regarding the disposal of bio-waste and chemicals to avoid dispersion in the broader environment. Scientists also face requirements for reporting environmental and health hazards. For instance, they fill out forms disclosing and registering all new viral constructs developed for experiments. Similarly, regulations require monitoring of chemical and biological supplies.

Yet safety regulations do not account for every technique, manipulation, or tool. For example, although the EHS office requires that chemical fumes be minimized, the methods for minimizing chemical fumes when vials are opened or a liquid is poured into a container are left to the discretion of scientists. Similarly, although the Material Safety Data Sheets (MSDSs) mandated by law to accompany purchased chemicals recapitulate the composition and major hazards for all chemicals, the MSDSs do not cover all steps that can be taken to minimize exposure. Moreover, during their research, laboratories regularly create new chemicals and viruses with distinct and not yet known hazards.

To a large extent, safety is left to the scientists' initiative. Scientists moving from one laboratory to the next during their career encounter different safety procedures for the same materials; consequently, the best way to handle a particular material can be ambiguous. Thus, safety performance is in a state of flux because of evolving rules, experimental requirements, local practices, and the interpretative work of the various actors (safety officers, senior scientists, postdoctoral fellows, graduate students, and technicians), all with responsibilities to achieve compliance. Overall, safety can easily be viewed as a process of continuous change and improvisation (Orlikowski 1996).

Med Laboratory

Med Laboratory is a large laboratory that uses many complex and hazardous materials and thus deals with most safety regulations. Although Med Laboratory is relatively large and productive, in most regards, it is a typical research laboratory at a major university medical school. When this fieldwork began in 2009, the implementation of the EHS system in the university's several hundred laboratories was still ongoing, dispersed over several administrative units and spatial locations (i.e., schools of medicine, science, and engineering) Med Laboratory has 41 members under the supervision of one principal investigator (PI), Gary, 17 postdoctoral fellows, 4 PhD students, and 20 technicians. The everyday supervision of the laboratory, including the supervision of safety, is the responsibility of one senior scientist (Walter). The scientists are organized into five research groups: blood, embryology, reprogramming, cancer, and core services. Each team is organized around specific experimental models, techniques, protocols, and theoretical assumptions that drive the inquiry.

Turnover is consistent with the usual variation in tenure of technicians and researchers in an academic laboratory, ranging from one to eight years. During the 17 months of fieldwork, 15 of the 41 members left the laboratory and were replaced by new members of similar rank and expertise. Technicians were generally hired after college with no prior laboratory experience beyond their undergraduate training. Postdoctoral fellows often joined the laboratory to train with different material platforms than those with which they were already expert. Members also switched teams regularly to learn new techniques and the handling of new hazards. Scientists in general are constantly integrating new materials or changing the properties of materials during their experiments (Owen-Smith 2001). In this changing context, the knowledge basis and routines, including safety knowledge and practices, are continuously updated with laboratory members teaching themselves (and each other).

Safety regulations are communicated through initial training and annual retraining sessions. Posts on walls and loose-leaf binders provide standard operating procedures for routine procedures and pieces of machinery and equipment, such as centrifuges, autoclaves, biosafety cabinets, and Bunsen burners that present various hazards.

Med Laboratory is classified biosafety level 2+ (BL2+). Biosafety levels categorize the degree and controllability of hazards from biomass such as recombinant DNA, as well as infectious agents in animals and humans. Laboratories are classified according to four biosafety levels, each with increasingly restricted architectural conditions and behavioral processes designed to contain risk. A BL2 laboratory is designed for work involving moderate hazards that are unlikely to transmit through the air. In the mid-2000s, Med Laboratory developed a human-inducible lentivirus to reprogram human cells into a state akin to embryonic stem cells. Human inducibility means that the virus can infect humans if it penetrates the skin. Because the effects of the virus on humans are unknown, but potentially problematic, special precautions are involved. The BL2+ level is used for laboratories using such viruses. Med Laboratory members were responsible for developing their BL2+ procedures for handling virus with respect to their architectural layout and the material, behavioral, and practical requirements of their research program with the EHS office.

Data Collection and Analysis

Table 1 summarizes the data collected by the first author as part of a broader ethnography of the laboratory. She was granted full access by the PI and by each laboratory member. During a general laboratory meeting, she presented her project to study how the laboratory organized work and developed experimental objects, requesting the possibility to observe, shadow, and interview laboratory members. During 17 months, the first author conducted participant observation approximately 2.5 days/wk. The number of days each week varied between one to five, depending on the availability of the scientists and the duration of particular experiments. She attended the university mandated newcomer safety training on chemicals, biohazards, radiation, and fire safety. Observation focused primarily on bench work. In addition, the observer attended collective events such as weekly meetings, safety inspections, training sessions, and informal events such as team lunches, breaks, and various celebrations. To understand how experimental practices were conducted, the first author shadowed individual scientists for one to three days at a time, as they performed experiments and interacted with coworkers. Newcomers, whether technicians or new PhD students, undertake a period of observing others, as they learn the experimental protocols. In this period, novices shadow senior scientists, who explain the science and techniques of specific procedures as they conduct experiments. During this learning by observing period, safety practices are routinely discussed. While observing, the first author asked the informant to explain their work and how the informant protected himself while performing the work. This posture of rookie observer thus allowed for nonobtrusive and detailed observation.

Scientists communicated both the biological knowledge related to their experiments and safety practices just as they did for other newcomers. The apprentice role allowed the observer to collect the varied on-the-job safety practices adopted by each scientist. For instance, scientists differed in their interpretation of the necessity for wearing a laboratory coat, using different types of gloves, touching surfaces, safe procedures for entering and exiting rooms such as the tissue culture room or the animal rooms, and managing the chemical and biological agents. Prescriptions ranged from precisely scripted procedures such as the exact order of layers of personal protective equipment to put on when gearing up for work in the animal rooms to more generic advice, for example, about never picking up anything that appeared unattended, "Don't touch anything! That's probably the best way to handle it." Scientists usually mentioned whether the prescription was warranted by legal regulation (e.g., such as regulations related to work in animal rooms) or whether it was a version of professional practice. The observer

Table 1. Data Collected per Role

Role	Members	Number of interviews	Number of members shadowed	Duration of shadowing (days)	Duration of observations	Types of observations
PI	1	2	—	—	30 hours	Laboratory meetings and events
Postdoctoral Fellow	20	18	16	60	Ongoing	Laboratory meetings and events Benchwork Breaks, meetings, and social events
PhD student[5]	4	4	5	30	Ongoing	Laboratory meetings and events Benchwork Breaks, meetings, and social events
Technician	20	7	8	35	Ongoing	Laboratory meetings and events Benchwork Cleaning and maintenance of shared laboratory areas and materials Safety inspection preparation Breaks, meetings, and social events
Safety coordinator (laboratory-based)	1	2	1	12	Ongoing	Daily safety duties Cleaning and maintenance of shared laboratory areas and materials Safety inspection preparation Safety inspection
Safety officers (not laboratory-based)	7	—	—	—	5 days	Safety training Radiation inspection General safety meeting Safety inspection

Notes. More PhD students were shadowed than present in the laboratory at a given time as some PhD students left the laboratory and others started their tenure in the laboratory during the observation time. As they were a relatively small population, they were oversampled for shadowing.

shadowed scientists across all three roles (postdoctoral fellows, PhD students, and technicians) and all five teams. Observations included instances of postdoctoral fellows mentoring technicians. Observations also included initial safety trainings, periodic inspections, radiation checks, and incident investigations. In addition, the first author collected all group emails that circulated during the observation period.

Finally, the first author conducted 33 open-ended, conversational interviews with 30 laboratory members (Mishler 1991). Interviews ranged from 30 minutes to two hours. The interviews were conducted after several months of observation once familiarity was gained with the laboratory's research and practices, after or during a period of shadowing of a scientist allowing both the interviewer and interviewee to refer to observed instances. All formal interviews were recorded and transcribed. Finally, whenever a safety incident occurred (e.g., spill, contamination, recognized violation of standard legal or professional practice), the author followed up on the incidents by again shadowing the scientist involved or discussing the event with laboratory members. Incidents were traced from their beginning through to their resolution, including the interpretation of laboratory members involved or informed about the incidents.

Adopting a grounded theory approach (Glaser and Strauss 1967, Charmaz 2006), both authors iteratively collected and analyzed data, comparing new data with emerging categories of interest derived from previously collected data. Data were coded using Atlas TI, first with inductively generated codes and later with theoretically and analytically generated codes. We isolated 230 safety events, defined as observed or narrated episodes involving action related to hazardous materials. These events[2] include safety trainings, inspections, meetings, and incidents of failure to follow standard practice, as well as routine compliant experimental practices in the laboratory. Events also included talk about safety, information exchanges, debates, and disputes over how to work with hazardous materials, observed or narrated in conversation or interviews.

From these events, we isolated 33 recurring safety practices. We then analyzed each practice to identify the patterns of safety enactment: whether scientists mobilized regulations or other forms knowledge when practicing safety. We identified four categories of hazards that scientists tried to address: whether the hazard threatened the experimenter's body, the material conditions of the laboratory and the environment, the experiment itself, or the social organization of the laboratory. To verify the source of the practice and not rely exclusively on the scientists' interpretations and discussion, we compared each reconstructed practice with the legal prescription as defined on the University's EHS website and the relevant regulatory texts.[3] Some practices were prescribed by federal and state regulations, some were university implementations of law, others were professional practices common to bioscience laboratories and others were locally invented norms, for which we use the word "rule." Last, these practices were analyzed to identify how laboratory members enacted them: whether safety regulations were constantly followed and who followed them. Four variations with respect to law, local rule, and professional practice emerged from our coding of the data. These data offer a catalog of circulating practices and interpretations that describe how safety is crafted through the dynamic combination of professional expertise and legal prescriptions.

Table 2 displays the variation in safety practices organized by the variations in compliance and the number of hazards managed, as well as whether legal regulations or local rules shape the practice. The detailed description of these practices is provided in the online appendix.

Legally and Professionally Recognized Hazards

Federal and state safety regulations managed primarily two classes of hazards: hazards to individual bodies and to the environment. Med Laboratory scientists recognized these hazards but also addressed two additional threats: to their experimental work and to collegial sociality.

Threats to Individual Bodies

Much safety regulation aims to prevent bodily harm. The approach is generally individualistic: regulations direct workers to adopt precautions required to protect themselves. The focus on individual bodies is apparent in some of the vocabulary used such as the denomination personal protection equipment (PPE) for protective items such as gloves, safety glasses, and laboratory coats. EHS regulations define guidelines for wearing different PPE items. Other individual protections mandate the use of air exhaust hoods for handling chemical, biological, or radioactive materials and screens for protecting the experimenter from materials that can become airborne. Other regulations direct the use of syringes or glass pipettes to prevent cuts and pathogen contamination; regulations for sharps disposal are designed to protect others who might come in contact with them. Most scientists acknowledged bodily threats and diligently followed many regulations aimed at individual protections such as wearing laboratory coats and changing gloves when needed. However, they also noted that the focus on individual protection was insufficient to ensure adequate protection and required interpretation and adaptation on their part. For instance, Walter, the senior scientist, noted that the rule for wearing gloves to protect the experimenter contradicted the imperatives for avoiding the contamination to common areas.

> "There are many conflicts about the uses of safety equipment. For instance, you should wear gloves when you carry cells. But it is against institutional policy to wear gloves in the common spaces such as the elevator. How do you do to take your cells from the lab to the FACS machine room [that requires to take the elevator]? Should you wear one glove with the hand that carries the cells and take one off to push the elevator button? The rules are not clear."

Thus, even when scientists agreed with the intent of these regulations, they needed to interpret these rules to work safely.

Threats to the Material Environment

Many regulations aimed to protect the material environment, such as the physical infrastructure or the surrounding community. The EHS system was implemented following a regional EPA effort to clean up the local environment, especially the waterways, heavily polluted by decades of scientific and industrial activities. Regulations specified procedures for disposing bio-waste, chemicals, and radioactive isotopes to limit their environmental dispersion. Waste containers sat on most laboratory benches but had to be removed within several days to larger storage containers. Regulations prescribed for solutions containing bacteria to be bleached before being poured down the drain, that bio-waste must be destroyed in high temperature autoclaves so that all cells are rendered inert. Regulations also prescribed how to construct formal records tracing the use of controlled substances. All radioisotopes, their quantities used, and their disposal must be recorded. All new viral constructs created by laboratories needed be recorded and reported.

Yet, these regulations also required interpretation. For instance, researchers had to investigate which chemicals could be mixed in waste bottles because the waste storage areas contain only a limited number of bottles. Although regulations specify forbidden assemblages, scientists still determined how any chemical

Table 2. Patterns of Professional Practice: Examples of Safety Practices According to the Hazards

Practice Number	Practice	(a) Hazard managed				(b) No. of hazards managed	(c) Legal regulation	(d) Laboratory rule
		Body	Environment	Experiment	Sociality			
	Consistent compliance							
1	Radioactive use and disposal log sign-up	X	X	X	X	4	Y	
2	EHS Radiation work training	X	X	X	X	4	Y	
3	Centrifuge use	X	X	X	X	4	Y	
4	Lentivirus work signalling	X	X	X	X	4	Y	
5	Biosafety Cabinet clean-up	X	X	X	X	4	Y	
6	Sharps disposal in dedicated containers	X	X	X	X	4	Y	
7	Chemical inventory management in common areas	X	X	X	X	4	Y	
8	Laboratory-based lentivirus work training	X	X	X	X	4	Y	
9	Laboratory-based radiation work training	X	X	X	X	4	Y	
10	Refrigerator clean-up	X	X	X	X	4		Y
11	Tissue culture room clean-up	X	X	X	X	4		Y
12	Lentivirus work supervision	X	X	X	X	4		Y
13	Radiation work supervision	X	X	X	X	4		Y
14	General laboratory safety organization	X	X	X	X	4		Y
15	General laboratory safety supervision	X	X	X	X	4		Y
	Discretionary compliance							
16	Gloves wearing when manipulating human cells	X	X	X		3	Y	
17	Laboratory coat wearing during laboratory work	X				1	Y	
18	Chemical spill management by hazardous materials team	X	X			2	Y	
19	Laboratory coat wearing during lentivirus work (coworkers)	X				1	Y	
20	Laboratory coat wearing during tissue culture	X				1	Y	
21	Drawing animal blood through mechanical pipetting	X				1	Y	
	Expert practice							
22	Using the radiation room when pregnant	X		X	X	3		
23	Contact avoidance - surfaces / coworkers	X		X	X	3		
24	Tissue culture signalling	X		X	X	3		
25	Signaling of hazardous materials handling	X			X	2		
26	Ethidium Bromide dispersion and contact limiting	X			X	3		
27	Phenol vapor minimizing	X			X	2		
28	Liquid waste minimizing		X	X	X	2		
29	Tissue Culture supplies planning	X			X	2		
30	Isopropanol vapor minimizing	X	X		X	2		
	Symbolic compliance							
31	Storing and labelling misplaced chemicals		X			1	Y	
32	Clearing storage 18 inches or more below the ceiling		X			1	Y	
33	Clearing obstructed corridors		X			1	Y	

Note. X indicates the presence of a particular hazard as acknowledged by the laboratory members; Y indicates the existence of a legal regulation or laboratory created rule governing some of the hazards present in a procedure and relevant for the particular safety practice.

solution used in one experiment would fare with another mix already present in a waste bottle and whether a new bottle further crowding the space is warranted. Threats to the environment were not always a central concern for scientists, although ability to limit the use and dispersion of hazardous materials was considered good practice.

Threats to Work

However, scientists were deeply concerned about protecting their experiments from contamination and thus corruption. They enacted safety practices, regulatory or not, to protect their experiments. For instance, although exhaust hoods protect workers from chemical fumes, the laboratory had rules to clean and ventilate hoods before and after use to limit contamination from chemicals or bacteria. Scientists rigorously followed this rule. Several scientists explained that although they were not concerned about bacteria making them sick, they were very concerned about bacteria contaminating their cells and ruining days or weeks of experimental work. For example, Pam, a postdoctoral fellow, explained how she sterilized her workspace primarily to protect her experiments: "I'm a little bit insane about squirting things with ethanol. But is it for contamination purposes? Or is it cell culture? I think it's a little bit more about keeping things sterile for the cells." Regulations did not recognize the threats to the experiment and scientists' focus on experiments could be viewed as a diversion by safety officers who emphasized in training that personal safety comes first.

Threats to Collegial Sociality

Keeping things safe for colleagues was often prioritized over individual protection. For example, Pam noted that "squirting things with ethanol" was more about protecting others than herself: "Even if I wiped the hands of the microscope and sprayed down the stage with ethanol, I think it's more to kind of prevent contamination. In terms of keeping things safe for other people, I think I'm probably more conscientious of that, than perhaps myself." The ability to trust one another is central to laboratory workers. The laboratory organization is communal, based on collegial exchange of what are expected to be shared skills and knowledge. Novice scientists develop skills by integrating themselves within the reciprocal trading of social and technical information in the laboratory. For instance, Alice, a new PhD student, described the PI's advice on her arrival in the laboratory. She should make the most of her apprenticeship, he said, to learn as many techniques as possible so that she could later exchange them for other techniques with fellow laboratory members. While establishing their professional expertise, scientists rely on each other in this active trading zone developing not only shared skills and knowledge but trust with each other.

The capacity to handle hazardous materials and to display this capacity is central to establishing trust. Scientists constantly assess whether colleagues are trustworthy as part of assessing whether their environment, their experiments, and their bodies are secure. For instance, they visually scan a neighbor's activities to see whether a hazard is properly handled or regularly sniff the air to identify whether a chemical vaporized through someone's mishandling. Pam similarly explained how her assessment of safety directly related to her assessment of her social environment:

> I feel pretty safe. I think I just have the perception that people in our lab are very responsible. In my previous workplace, there was one room for radiation that was essentially shared by four labs. And there could even be people from different buildings coming over and working with it. So there were a lot of cases where you'd scan [for radioactivity] and it'd be like, "Oh, crap. Somebody spilled something over here!" Vs. here, I think that people like for example Sally and Sam are very watchful. And so I trust that other people are watching too. And kind of keeping things safe.

Trust and sociality are performative and laboratory members demonstrated to each other that they could be trusted to be safe. Several practices highlighted this performance of legitimate membership. For instance, experienced scientists wore laboratory coats only when they handled what they considered to be particularly hazardous material. In doing so, they demonstrated to each other their expert judgment in discerning hazards in lieu of mindlessly applying regulation which conveyed inability to autonomously assess hazards. Similarly, scientists carried vials of hazardous materials demonstratively high and far from their bodies to signal to coworkers to be mindful of their passage.

Legal regulations did not generally address these complex social relations and sometimes threatened this carefully crafted social equilibrium. Several scientists noted how intervening safety officers could impede work and expose laboratory members as unsafe to others. For example, laboratory members often clean up spills without calling on the EHS staff. If safety staff arrive to clean up a spill, there is usually a temporary suspension of work or closing of the laboratory. In that situation, the scientist who spilled the material is exposed as lacking expertise, not only in causing the spill but also by failing to deal with it independently and by calling for assistance thereby threatening colleagues' work. When scientists expressed anxieties about vials of biomaterials and chemicals spinning in centrifuges or about handling large quantities of hazardous materials, they discussed the threat of exposing their incompetence by creating a visible spill to all.

Although regulations do not address sociality, scientists consider this dimension essential and are persistently concerned that it might fail. Indeed, the social environment, the local expertise, patterns of interaction and coordinated action are crucial to collective safety; yet these basic elements of sociality were under constant threat from mistakes. For instance, Walter, the senior scientist, discussed the importance of shared knowledge and coordination when high and even potentially lethal hazards were introduced in the laboratory. He was concerned that even with everyone's best attempt at developing interpersonal knowledge and coordination, sociality might fail: "When K. began doing parthenogenesis, he used to do his own needles for micro-injection and flushed them with hydrofluoric acid.[4] He bought a hydrofluoric acid first aid kit and showed it at the lab meeting. This was probably to say "if I faint on the floor, here is what to do," but it was also essentially to say, "hey I am bringing a new hazard in the lab." He concluded that laboratory members should no longer bring hydrochloric acid as there are now too many scientists, and interpersonal knowledge was no longer enough to manage such a hazard: "I know what is going on at my bench but I do not know what people do three benches away from me."

Overall, professional concerns covered a broader set of hazards than regulation and professional scientists sometimes considered that regulations impeded practices enacted to protect work and sociality. This mismatch directed the judgements of which regulations to apply and enforce and which regulations could be mobilized more flexibly.

Discretionary Mobilization of Regulation and Expert Practices

Relying on their expertise to recognize hazards, laboratory members selectively implemented and blended regulations with locally developed rules of practice. When all four hazards were present, laboratory members enacted constant compliance, with no discretionary variation. If regulation covered these hazards, scientists complied with regulation. If no regulation covered these hazards, professionals implemented and expected compliance with professional rules. When one to three threats were present, local practice displayed case-by-case discretion as scientists invoked their expertise to determine the appropriateness and effectiveness of safety procedures. These selective rule compliance, adaptation, and invention enacted expert interpretations of risk: what hazards exist, what is threatened, and what are the probabilities for controlling hazards by following one or another rule or combination of rules. Here, we detail safety practices illustrating these patterns of enactment.

Table 2 provides an overview of the practices and pattern of enactment. This table identifies for each practice: (a) the hazard that the practice seeks to control, threats to bodies; material and environmental conditions; the work tasks; and sociality; (b) the number of hazards addressed by the practice; (c) whether legal regulations pertain; and (d) whether a specific local rule has been adopted.

Constant Compliance with Regulation When All Four Hazards Are Recognized

When all four threats were present (practices 1–15 in Table 2), scientists expected and tried to produce constant compliance, whether it was implementation of a legal regulation or a rule that emerged through professional expertise and practice. The following practices highlight that constant compliance allowed scientists to draw on the legibility provided by standardized regulation to craft internal accountability, visibility, and standard laboratory-based rules.

Mobilizing Regulation to Enforce Accountability: Radioactivity Use and Disposal Log Sign-Up (Practice 1, Table 2). Consider the following incident related to the radioactivity logbook, in which every use of radioactive isotopes is to be recorded, a legal requirement. Users of radioisotopes must sign their name in the log, detail the quantity used, the quantity disposed, the container in which the waste is disposed, and state: "I have used radioactivity, I have checked myself and my equipment." The logbook is expected to account for and discipline all users and uses of radioactive agents, to identify variations between reported uses and laboratory stores of radioisotopes, and to keep track of users for scheduled retraining and periodic body scans.

While doing an experiment, Praveet, a postdoctoral fellow, noticed a radioactive spill in the hybridization oven, which had been purchased with funds from one of his grants rather than with general laboratory funds. He routinely allowed other laboratory members to use the oven when it was available and had posted a sign-up sheet on the hybridization oven to keep track of its use. When he noticed spilled liquid, he surveyed the area with a Geiger counter, identifying the spill as radioactive. Two tubes with materials also registering radioactive but without labels were also in the oven. No one had signed the sheet on the oven after Praveet's own recorded last use several months earlier. He initially thought the spill was intentional because he "could not fathom that someone would know so little about radioactive use and still feel comfortable using it".

To identify the perpetrator, he checked the logbook. No one had signed the log since Praveet last recorded his own last use. Unable to identify who made the spill, nor for how long the spill had been in the oven, he sent a collective email to the laboratory:

> I'd like the person who last used my hybridization oven without signing up and left a radioactive spill in it to come and talk to me and Ally about how to use radioactivity. I don't see any logged record of radioactive use, which is a more significant violation beyond this lack of regard for your colleagues. If I don't hear from anyone, we'll talk about this in laboratory meeting tomorrow.

The incident escalated to a laboratory-wide concern with everyone aware that radioactive materials had been left unattended and that someone was misusing hazardous material so that all were exposed to harm. Some members wondered in conversations whether the laboratory was no longer safe. Several members also began to wear their radiation-monitoring badge when not doing work involving exposure to particle radiation, even though they normally did not. The incident was partially resolved when the perpetrator of the spill came forward to Praveet and Walter, the laboratory's most senior scientist. The issue was described as a lack of training. The perpetrator was given a lecture by Walter and subsequently given a new round of radiation safety training.

Beyond concern for the potential radiation exposure, laboratory members were concerned that without being identified some people could create serious hazards for everyone. Trust that laboratory practices created a safe environment was shaken, awakening laboratory-wide skepticism: without routine compliance the laboratory could become an uncertain, fearful place, as Walter noted:

> It made me upset .... The radioisotope P32 has a half-life of 14.7 days. The amounts used are low, the radioactivity is low. Direct skin contact can cause at most a burn. But the situation in which it was used ... while I was concerned about the radioactivity, I was more concerned by the lack of attention to hygiene. If that person ends up being sloppy ... I am very intolerant of people making messes for others to clean.

Signing the logbook is considered imperative by all members. Violation of the regulation created a direct hazard to individuals by exposing both the novice user and the person in charge of the oven, Praveet, to radiation; it threatened the experiment by interrupting Praveet's work and the possibility of contamination; more generally, it posed a risk for the entire laboratory, creating fear and distrust because radioactive isotopes if not habitually managed safely constitute one of the most serious risks in and from biology research. Although the logbook's ostensible use is for accountability outside the laboratory (accountability to the university and to legal authorities regarding use of radioactivity), it was here mobilized to provide accountability within the laboratory.

Mobilizing Regulation for Interpersonal Visibility: Lentivirus Work Signaling (Practice 4, Table 2). Work with the lentivirus, generally conducted in BL3 laboratories, is used within this BL2 laboratory by its isolation in a unique biosafety cabinet clearly identified and isolated at the back of the tissue culture room. BL2+ safety regulations require lentivirus users to inform coworkers that virus work is underway by putting up a sign on the door and to make a vocal announcement to coworkers present in the room. The announcement aims to draw the attention of coworkers who might not otherwise notice the virus work. Once the work is announced, coworkers in the room are required to wear their laboratory coat. The first part of the procedure, sign posting, and voice announcement was expected to be invariant and actively enforced.

Compliance was often checked by the virus user and the coworkers. Coworkers acknowledged the announcement with a nod and if they did not, the lentivirus user would reiterate the announcement. In rare cases of deviance, for instance, when the door sign was posted but no one was actually working at the BL2+ biosafety cabinet or when there was no sign but the cabinet seemed occupied, scientists initiated enforcement by assessing whether virus work was under way before beginning their own work. Scientists used the tools provided by regulation to assess the safety of their environment: whether the BL2+ cabinet is occupied, whether the user is wearing the additional disposable protection layers required by the BL2+ regulation, whether the other users in the room are wearing their laboratory coat. In doubt, laboratory members asked if someone was using the virus.

The lentivirus was considered a high threat to bodies. Because the effect of an infection was yet unknown, the lentivirus was the hazard of most concern. Many members openly feared working with the virus, as one PhD student stated: "This is human infecting retrovirus, which is terrifying. This is the scariest reagent that we deal with in this lab. And so I feel like any time I'm gonna be making human infecting virus, I'm gonna be nervous."

The lentivirus was also a threat to sociality. The lentivirus workstation was in a small and heavily used tissue culture room where scientists worked with an extensive array of chemicals and biomaterials. Signaling and avoidance tactics were heightened and developed into a self-conscious choreography one scientist referred to as the "tissue culture dance," signaling to one another the types of materials they were using and whether they should be avoided. For example, scientists getting up from a workstation, first turned around slowly in their chair, lifted their culture plates with their hands, and scanned the room to observe if people had noticed them with their samples and if their path was clear before standing up and moving forward. They observed other colleagues and made themselves visible to them. As lentivirus was invisible to scientists, it was not identifiable by smell or through the naked eye, scientists had to rely on their colleagues to properly contain the virus.

In this context, the regulatory prescription of signaling with a door sign and a vocal announcement provided the visibility scientists needed. They thus mobilized it consistently and ensured that their coworkers also complied. A regulatory prescription aimed at protecting scientists' bodies was there mobilized to protect sociality by enabling interpersonal visibility and oversight.

Mobilizing Regulation to Craft Laboratory Rules: Lentivirus Work Supervision, Radiation Work Supervision, and Laboratory Safety Organization and Supervision (Practices 12, 13, 14, and 15, Table 2). With official training and inspections occurring episodically, not more than once or twice a year, there was infrequent regulatory oversight of scientists' use of radioisotopes and viruses. To organize oversight and sustain working competence, laboratory members created local rules and distributed relevant responsibilities. For example, lentivirus and radioisotopes work were overseen by named laboratory representatives with practical expertise. Each scientist new to lentivirus or radioisotopes had to identify herself to the dedicated representative and undergo a dedicated training. Alex, a technician, described how John and Samer, two postdoctoral fellows with expertise with virus work, supervised and trained users and the areas where the virus was handled:

> John does a lot of virus downstairs. He is one of the main guys. They do tell you, "If you intend to work with virus, talk to these people first." It's like an in-laboratory rule that if you want to work with their virus hood, you need to speak to either him or Samer. You have to speak to either one of them before you start meddling with virus, certainly in their hood.

As this quote illustrates, these local practices concerning supervision of laboratory-specific techniques, achieved a rule-like status within the laboratory, although they lacked the coercive nature of legal regulations that could entail fines or temporary laboratory closures. Similarly, Walter, the senior scientist and other postdoctoral fellows organized laboratory-compulsory sessions for cleaning the tissue culture rooms and other heavily used common spaces such as fridges and incubators in which potentially hazardous residues accumulated over time.

In sum, for laboratory workers, hazards were more or less visible, dependent on one's own and one's colleagues' behavior and thus only more or less under one's own control. Scientists judged danger to be low when working with materials identified as harmless such as a physiological fluid. They considered danger to be higher when going to the cell culture room where more "potent" materials were handled or to the chemical waste storage area. Laboratory members regularly observed their colleagues, what they did, where they sat, what they wore to assess the hazards colleagues might pose to them. When working at their bench, they remained attentive to their environment: where their colleagues stand, what they do and what they wear. In this way, safety was construed as an ongoing effort to minimize contact and contamination. In the tissue culture room, scientists considered the level of danger to be higher and even still higher when lentivirus work was ongoing.

In these three cases, with hazards the most serious, threats to sociality were significant. Scientists viewed safety as dependent not on their ability to protect themselves alone but on their ability to expect and enforce safe practices from and for all coworkers. Thus, safety was a collective endeavor. Laboratory members' central concern was whether they could trust their coworkers: will everyone adopt the same precautions and will coworkers avoid one another when carrying hazardous materials down busy corridors? When describing whether they were safe, laboratory members generally commented on others' behaviors: they noted whether "people know what they are doing here" or whether they are "lax," "sloppy" or "lack attention to hygiene," which were interpreted as indicators not only of personality traits but as markers of scientific quality.

When hazards threatened all professionally recognized dimensions, regulations provided legibility, for example, by requiring the sign-up of logbooks for radiation work. Similarly enforced legal regulations included the appropriate handling of centrifuges, the signing of log forms for lentivirus work, the disposal of sharp materials, the inventory of chemicals and biomatter, and their disposal in appropriate containers (e.g., Practices 3, 4, 6, 7, Table 2). These regulations allowed scientists to signal that they were working with hazardous materials and to verify the safe practices of their coworkers. In a place where many hazards are invisible, legal regulations provided visibility. In these instances, legal regulation was co-opted to ensure internal, interpersonal oversight, and accountability.

Discretionary Compliance with Regulation When Not All Four Hazards Are Present

In contrast, when some but not all four hazards were present, constant compliance was not expected. Rather, scientists enacted their professional expertise through discretionary compliance with legal regulations.

Discretionary Compliance for Signaling and Enacting Expertise: Wearing PPE (Practices 16, 17, 18, and 19, Table 2). Wearing PPE, such as gloves and laboratory coats, was a clear example of discretionary compliance. Legal regulations require that laboratory coats be worn when working with most chemicals and biomaterials. This requirement thus covered most laboratory tasks. Newcomers generally elected to always wear laboratory coats, whereas more advanced scientists did not. Indeed, experienced scientists adapted a variety of regulations to maintain interpersonal signaling, often using PPE to communicate danger. Sporadically but not always wearing PPE, such as the laboratory coat, functioned as one such communicative signal. When experienced scientists put on a laboratory coat, they signaled that they were working with a particular hazard that required added protection. Sherry, a postdoctoral fellow explained: "I never see Sam wearing his lab coat, except when he is working with radioactivity … So then I know." In response, coworkers enacted avoidance tactics: laboratory coat wearers were scrutinized and avoided.

Always wearing a laboratory coat undermined the coat's communicative potential of hazard, while also communicating a different signal: status as novice and incomplete knowledge of one's working material. Indeed, constant wearing of PPE often resulted from, and denoted, the worker's lack of technical understanding and practical experience of experimental work, as these quotes from Alice, a new PhD student, illustrate:

> In a lot of cases, every chemical you order, it says wear goggles, wear gloves and in 90% of them, the vast majority of scientists would consider that way overkill. And it's hard for me to come into the lab and know which one is overkill and which one, they really are lazy about it and I should wear protective measures. So I generally wear my lab coat.

Thus, newcomers often strove to develop sufficient expertise to enact more flexible safety practices and to graduate from their newcomer status. As Alice noted:

> When you are a rotation student, you're walking a delicate line between being into someone's way and trying to learn something and it's part of their job. You have a certain amount of political capital and you decide how to spend it and if you're always asking for a lab coat and glasses, then that's who you are going to be, the rotation student with lab coat and glasses.

The senior scientist, Walter, also specifically watched over newcomer wearing of laboratory coats as he considered that they did not have sufficient expertise to protect themselves otherwise. When he found newcomers without a laboratory coat, particularly in the tissue culture room where hazards abounded, he asked them to stop their work and put on a laboratory coat.

Thus, regulatory prescription such as those directing the use of gloves and laboratory coats were found useful by and for new PhD and technicians, who lacked the professional knowledge to adopt the more embodied, skilled, and tacit practices of experienced scientists. As such, several technicians and doctoral students preferred to always wear laboratory coats and goggles when handling chemicals. Alice referred to herself, another PhD student, and a technician as the laboratory coat gang. One PhD student explained to the first author where to find laboratory coats for herself, noting that this is not something senior laboratory members necessarily communicated. Thus, discretionary adoption left room for newcomers to adopt more standardized practices while also providing an impetus for these newcomers to develop their professional expertise and move toward skilled, embodied practice.

In explaining these variations, several scientists noted a hierarchy not only among the personnel, novices versus senior scientists, but of the safety practices themselves. They considered practices that protected from all threats, such as cleanliness procedures, as superior to those that protected only from some threats, in particular, threats to individual bodies or the environment only. For instance, commenting on a regulation that requires scientists to wear an additional, disposable laboratory coat when working with viruses in the BL2+ category, Sam, a postdoctoral fellow, noted: "The BL2+ is a joke! These are just things to make you feel better. How many layers do you need? It is more about how you bleach things." He was aggravated that some laboratory members diligently followed legal procedures such as wearing gloves and coats and then carelessly took virus vials across the laboratory beyond the BL2+ area and place them in shared centrifuges where they could spill.: "Some people carry tubes full of virus to the other end of the lab, they centrifuge them at thousands spins per minute, take them out, look quickly if there's a spill or notice someone else's spill, 'oops … '"

Thus, the adoption of primarily individual protective practices was heavily discouraged and sometimes openly derided, after early socialization to the laboratory's hazards and procedures. A senior scientist described wearing a laboratory coat as "putting on air." Shaming comments pointed to inexperience, with the repeated ironic prescription "Laboratory coats are for when you are cold." One technician noted that her mentor explained to her that laboratory coats impeded swift and skilled movements needed to perform fast and reliable experiments and made it more likely that she will spill stuff. Alice, the PhD student, reported about how a colleague's and her attempts to wear their laboratory coats at all times were promptly dismissed: "People walk in our bay and say 'oh, people are wearing their PPE'" in a sarcastic and demeaning tone.

These discretionary adoptions of some safety regulations are an integral part of the laboratory's expert practices. They are grounded in expertise of the materials handled and the understanding of the laboratory's signaling practices. More centrally, discretion furthers collective safety by signaling to others that one has gained appropriate expertise to know when and when not to follow regulations.

Expert Practices When Some Hazards Are Present

When hazards were present but not legally regulated, and when sociality was threatened, safety practices were crafted and adapted as part of the repertoire of local expert practices. They became normalized as local variations on a general norm. Some of the practices were developed as a result of the laboratory's particular material assemblage; other practices were brought by members trained in other laboratories. The mismatch across laboratories was a constant theme within conversations about which technique provided more safety or should or should not be used in a specific experimental condition. These practices relied on skills developed through apprenticeship, mentoring, and ad hoc interpersonal enforcement. In Med Laboratory, expert practices included techniques for containing toxic or flammable vapors, limiting harmful agents from traveling throughout the laboratory, as well as minimizing laboratory waste and pollution (Practices 22–30, Table 2).

Crafting Expert Practices in the Absence of Specific Legal Regulation: Minimizing Toxic Vapors (Practice 27, Table 2). Regulations concerning chemicals that emit toxic vapors (such as phenol chloroform) require a dedicated exhaust hood with negative air pressure and glass front to limit airflow to the rest of the laboratory. Med Laboratory had only one chemical hood that also doubled as the laboratory's hazardous waste accumulation area (such a space is mandated by law). Consequently, handling chemicals in the dedicated hood had become impractical and even hazardous since diverse chemical mixes were stored there until ready for removal from the building. Yet there was no detailed regulation about how to avoid vapors other than using a hood with negative air pressure exhaust. The EHS Standard Operating Procedure for Phenol Chloroform instructs users to "keep liquid phenol tightly closed" but does not detail how this might be achieved while performing the repeated task of transferring small chloroform quantities to many test tubes. In the absence of formally prescribed steps, toxic vapors were minimized through dexterous practices.

In one experiment, a technician, Emily, had to place both phenol chloroform and an organic layer in several dozen test tubes that contained DNA samples. Two steps were necessary to add phenol to each sample and then two steps to remove the waste composed of phenol, the organic layer, and the non-DNA cell waste. "It's an all-day routine," she commented. The first step involved lining up 10 test tubes on a rack in a hood and injecting phenol in each one. She did the first step involving pure phenol in the chemical hood as phenol emits strong toxic vapors. The second step was done at the bench as she and the postdoctoral fellow overseeing the experiment agreed that the now diluted phenol within the tubes was less toxic. Nonetheless, to minimize toxic vapors escaping from the tubes, she had to uncap and recap the tubes swiftly during each step.

Emily lined up two rows of 10 tubes in a test tube holder. She aspirated part of the solution from one tube in the first row and injected it in its mirror tube in the second row. To reduce exposure time, she capped and uncapped the tubes with two fingers of her right hand while holding the pipette with the left. For each manipulation, she opened the tube, aspirated the solution, and recapped the tube. Then she uncapped the parallel tube with the right hand, injected the solution with her left hand, recapped the tube with the right hand, and ejected the pipette tip into a dedicated bin on her bench. This dexterous manipulation minimized vapors without slowing a very long experimental step. Vapor minimization provided protection for the experimenter and her neighbors. Scientists learn such embodied craft through mentoring, habituated through repeated practice. In this case, Emily learned to perform these steps in collaboration with Praveet, the postdoctoral fellow with whom she worked.

Variations in Training: Minimizing Liquid Waste (Practice 28, Table 2). Although central to safety, skilled manipulation is only a probabilistic achievement conditioned on situated learning. In the following instance Sherry, a postdoctoral fellow, mentored a technician, Max, to develop thrift when using chemical and biological compounds, although the reproduction of the practice was not assured. The ways in which chemical consumption and waste can be minimized are not described in the legal regulations or the MSDS sheets that accompany chemical purchases. In one observed instance, Sherry and Max were retrieving mice embryos aortas, which is a particularly minute procedure. Sherry took a culture plate (a small plastic dish used primarily for culturing live cells but also used to perform various minute experiments) and carefully laid eight distinct droplets of a saline solution on the plate with a pipette. She placed one mouse embryo in each droplet and began to dissect it with a syringe needle. Each droplet filled with blood. Once she removed the embryo sac, she prepared a new dish with eight new droplets and transferred the embryos without the sac in the clear droplet. She then threw the first dish with a small amount of liquid waste in the sharps bin.

Max filled his plate with saline solution and placed three embryos in the plate. When he removed the sacs, the plate full of solution became tainted with blood. He then filled a new plate with saline solution and transferred the embryos. He then threw the old plate, filled with solution and animal blood, in the sharps bin. When the observer inquired about the difference in methods, Max acknowledged that Sherry taught him to do it her way, which he had forgotten and thus developed his own way. He acknowledged that he was less efficient and created liquid waste in a bin designed for sharps but not liquid biohazardous waste (as sharps cut through materials and skin and can lead to bodily and environmental contamination when associated with contaminated liquids).

Sherry explained anew to Max that by using a droplet of solution rather than filling the plate, she could repeatedly wash the embryos by vacuuming the liquid with a pipette and reinserting a clean solution while using the same plate. The debris stayed contained and did not crowd the other embryos, thus protecting the experiment. She disposed of very little solution in the sharps bin, avoiding first the step of collecting the liquid, second bleaching the liquid, third disposing of it in the sink, and fourth avoiding spills when discarding the plates. In this procedure, she protected herself, the experiment, and the broader environment. In contrast, Max's plates were overflowing with liquid. Over the course of the various steps, he deposited abundant amounts of plastic and glass dishware, as well as large amounts of bio-waste in the sharps bin.

In sum, to manage the absences, limitations, paradoxes, and contradictions of regulations, laboratory members used and promoted expert practices. Other such expert practices included minimizing surface contact contamination by keeping hands to oneself, by crossing arms or keeping hands alongside bodies, or avoiding the touch of a door if someone had already opened it. Experienced scientists communicated the following tips to newcomers: "I change my gloves each time I exit this room," "I avoid touching the bench surface with my hands," "You don't need to wear gloves, just don't touch anything." Sherry summarized how her sense of safety was grounded in her expert knowledge of materials and practices, creating a foundation for her safety practices:

> I feel pretty safe. We do have some chemicals that are toxic obviously. It's just you're trained and we have chemical fume hoods. For example, you work with [Phenol] in a fume hood so you're not inhaling it and you wear gloves and you're really careful not to splash it around. I know enough about it to know that I wouldn't set it up on my bench and not [work with it all day]. So, I don't worry about chemicals because I pretty much know if something's toxic and when I should wear gloves.

Expert practices are mostly tacit, embodied, and unnoticed, until their failure or absence becomes a problem. They are developed at the bench while doing repeated tasks such as DNA purification, cell culture, pipetting or circulating back-and-forth among various pieces of laboratory equipment. Much bench skill consists of choreographed movements that become unthinking habits. They are transmitted by repeated observation and emulation of skilled members, although, as these instances illustrate, practical accomplishment is variable and in need of repeated mentoring. Where expert practices did not seem sufficient to protect laboratory members, they then relied on regulation.

Symbolic Compliance When Few Hazards Are Recognized (Practices–33, Table 2)

Symbolic or ceremonial compliance is normally understood to be a performance, often at odds with routine practice, undertaken in anticipation or presence of a relevant audience of inspectors or the public (Meyer and Rowan 1977, Edelman 1992). As observation of laboratory activities was confined primarily to laboratory members, instances of ceremonial compliance were quite rare. In the daily practice of science and safety, ceremonial compliance with safety expectations was not a notable concern. However, the regular inspections by EHS radiation staff and the yearly safety inspection provided a noted exception to the disregard for compliance with regulations addressing less serious hazards.

As an example of a less serious matter governed by formal regulations, fire protection laws required an 18-inch clear space between the top of shelves and the ceiling. Much of the time, shelves were piled high with equipment and supplies. Walter kept a ruler with a mark at 18 inches. In anticipation of an inspection, he toured the laboratory, checking the storage above each bench with the help of the marked stick to remove materials stored above the mark. Another instance of symbolic compliance involved the clearing of corridor areas. Boxes of analysis kits would accumulate at one end of the laboratory's main corridor. Although the area did not block the passageway, the laboratory manager nonetheless cleared the boxes in preparation for the safety inspection to comply with the fire safety legal requirement that all corridors have a cleared 44-inch pathway. In another instance of performance for an inspection, scientists cleared their benches from extraneous supplies and chemicals, reorganized and improved the labeling of the bottles of chemicals, and disposed of various expired or damaged chemical and biological materials. The materials would gradually return after the inspection, thus the characterization as symbolic compliance.

The instances of symbolic compliance also involved discretionary judgment. Although some scientists treated the inspection as an opportunity to clean up the laboratory, they also allowed the buildup of materials in areas legally required to be clear because they ranked these hazards as lower risks. Scientists also made judgements predicting which laboratory conditions the safety inspectors would likely challenge. For instance, scientists considered that, although pipetting is prohibited, they did not need to hide mouth pipettes because restrictions on mouth pipetting are not routinely observed and thus enforced, although the materials are present. At the same time, regulatory prescriptions were also mobilized to locally enforce better safety practices. For example, Sam used the inspection as an opportunity to clean his bench and train his technician on how to organize and label chemicals and thus what distinguished an orderly from a crowded bench. Walter suggested that an inspection every six or three months, rather than yearly, would motivate more regular laboratory cleaning and organizing.

Overall practices of ceremonial compliance with regulations were also an occasion to improve on safety substantively.

Discussion

In this paper, we seek to explain the persistent variations in regulatory compliance by looking at a difficult case: the regulation of professional expert work. If professional practice is both a source of risk and the possibility of its responsible management, how do professionals recognize and manage the risks inherent in their work? More specifically, how do experts pursue their professional projects within externally, i.e. legally, imposed regulations? To what extent do they retain professional discretion over their work? How does professional expertise and authority become normalized within complex organizations where professionals are employees rather than autonomous actors? To what extent can legal regulations provide resources for the expert construction of responsibility?

We show that professionals selectively mobilized legal regulation to enrich local expert practices. Using their discretion and expert judgment, they selectively implemented and routinized regulations through a combination of constant surveillance, invariant compliance with some regulations, discretionary case-by-case enactments of others, as well as expert professional and symbolic compliance practices. Rather than resist legally imposed demands, scientists selectively implemented regulations based on their interpretations of the regulations' appropriateness to the conditions, work protocols, and population of the laboratory, thus co-opting regulations to enact expert judgments about the relative effectiveness of regulations, local rules, and expert practices. Although scientists did not perfectly follow the letter of the law, they generally embraced the substance of regulations. Thus, the externally imposed constraints of regulation became reconfigured as resources for sustaining the authority of professionals to govern their work.

Balancing the different types of practices depended on the managerial and organizational skill of the senior scientists. The oversight of this complex assemblage required detailed knowledge of these components. Thus, local training, supervision, mentoring, and socialization was central to laboratory members' understanding of when regulations should be followed, when they could be or had to be adapted, what local rules should be invented, and what distinct practices were performed in the absence of regulation and by whom.

When scientists recognized all four hazards, compliance was expected, and failures were interpreted as serious and as indicators of professional incompetence. Professionals mobilized the legibility provided by regulations to overcome the limitations of peer-control. When tasks did not involve all hazards, the more expert members adapted regulations on a case-by-case basis. Scientists with low expertise were expected to follow regulations more consistently. For less experienced members, regulations were reassuring. In these instances, the standardization of regulation was mobilized to guide junior professionals and overcome the limitations of tacit professional knowledge. With increasing experience and knowledge, the limitations and contradictions of regulatory prescriptions become more apparent (Gray and Silbey 2014). Increasing expertise with different materials, techniques, and embodied self-protection practices enabled discretionary judgment concerning the effectiveness of specific regulations and discretionary reliance on these regulations.

Of course, regulations did not cover all practices or all hazards. The Laboratory Standard, from which EHS regulations evolved, was originally designed by OSHA primarily for industrial sites where work can be routinized and programmed with little variation (National Research Council Committee on Prudent Practices in the Laboratory 2011). Most scientific laboratories, like Med Laboratory, typically perform a more varied array of procedures on a smaller scale, using smaller quantities of hazardous material and sometimes with unknown hazards. Med Laboratory, after all, is developing new techniques to address cancer and blood diseases. The dangers that attach to laboratories, protocols and experimental models are to some extent unspecifiable in advance. Professional scientists thus relied on expert practices to address these hazards. These practices required both cognitive and embodied expertise, such as capping and uncapping tubes to minimize vapors, using thrift when working with health hazards, or how paying attention to one's hands and body to minimize contact and contamination. There, professional training, supervision, rules, and norms developed a mindful, expertise-based approach to safety.

Overall, professional safety is a local endeavor grounded in detailed, pragmatic, tacit, embodied, constantly questioned, and renewed expertise, developed through collective work. The construction and enactment of professional expertise questioned and adapted regulatory prescriptions to local conditions, ultimately blending regulations with local conditions in a habituated choreography of safe science. To the extent that the security of the persons, environment, work tasks and collegial sociality is a local assemblage of fine-tuned practices, and not entirely a product of formal rules and prescriptions, legibility and accountability may be sacrificed to professional discretion. On the other hand, the combination of expertise and formal regulation crafted resilient, locally specific safety practices.

Contributions

In this paper, we observed how the externally imposed constraints of legal regulation are reconfigured as resources for sustaining the authority of professionals to govern their work. We identify the situational conditions and professional values that explain variable responses to legal regulations. Through these observations, we make contributions to scholarship on professional control, on the governance of professionals in organizations, explanations of variable regulatory compliance and the development of local safety cultures.

Legal Regulation as Resource for the Maintenance of Professional Expert Control

First, we contribute to studies of professional expertise and control (Freidson 2001, McPherson and Sauder 2013, Huising 2014, Chown 2020) by showing that legal regulations, rather than merely a threat to professional authority, create resources and opportunities for sustaining professional control over work. Professionals use their expertise to assess the relevance and appropriateness of regulatory prescriptions for locally specific events and circumstances. In this case, legal regulations were implemented not just by compliance experts (e.g., EHS officers) but also embedded in procedures including the means of storing, using, experimenting with, and disposing of hazardous materials, as well as regulatory devices and artifacts such as logbooks, laboratory coats, segregated bins, or radiation rooms that shape how experimental steps are to be performed.

Although peer oversight is notoriously difficult to achieve (Freidson and Rhea 1963), legal regulation can extend oversight and accountability. For example, when scientists enforced the use of a logbook for tracking radioactive isotopes, they used regulatory expectations and devices in service of local safety. By adapting and integrating regulations within their practices, scientists mobilized the expert knowledge embedded in regulations to sustain, if not expand their knowledge and control. Thus, this work suggests that the imposition of legal regulation does not necessarily threaten professional expertise or control; rather, it can offer additional resources in an extended repertoire that professionals can mobilize and control.

In this way, we also show how the law reorganizes social relations at a distance from formal agents. Recent studies illustrate how new occupations such as in-house compliance officers, inspectors, EHS managers, and regulatory intermediaries (Huising 2014, Abbott et al. 2017, Huising and Silbey 2018) have become carriers of legal authority within and across organizations, reorganizing social relations but at a distance from state legal actors. Although a common view of organizations still describes organizational governance in terms of clear lines of authority, organizations may be better conceptualized as long chains of loosely coupled action, "inhabited" by multiple occupational groups with competing interests vying for authority (Hallett and Ventresca 2006), notably with some who derive their authority, such as EHS managers, indirectly from the legal demands for compliance with safety regulations. In this complex network of competing occupations and professional interests, diverse groups such as investors and executives (Pernell et al. 2017) and front-line employees (Kellogg 2009, Hallett 2010) become central to compliance. Although front-line employees such as professional experts have conventionally enjoyed larger than average degrees of autonomy, they nonetheless need to mobilize resources to maintain and expand such autonomy in contests with the legally buttressed interests of regulators.

Legal Governance of Organizations

Second, we contribute to current research quandaries concerning regulatory compliance and organizational governance. Since the emergence of the regulatory state in the early 20th century, some observers, policy advocates, and researchers have been ready to declare regulation a failed adventure, often invoking inconsistent compliance to justify relatively unfettered reliance on markets to achieve the same public goods regulation seeks (e.g., safer workplaces, pollution control, financial resilience). The production, revision and reform of regulatory programs have been features from their inception (Dabney 1892), with a consistently unsolved and puzzle: how to explain the variation in regulatory compliance. In this paper, we identify a salient variable: the professionals' expert definitions and assessments of their work and associated hazards. We show that when regulations address not only the risks identified by the law, but also address risks central to the professional actors' project, the law is followed without exception. If regulations do not address the serious risks to the actors' central values, they will be followed less reliably. By assessing the hazards and differentially valuing threats to bodies, the environment, contamination of the experiment, or trust among laboratory members, scientists invoked their expertise to determine which regulations should be followed and when. At the same time, they mobilized their expertise to create additional local rules that they followed as consistently. By associating local rules with legal regulations, and consistently complying with both when all four hazards were present, they washed each with the legitimacy of the other. Legal regulations were endowed with scientific authority, and local rules were treated as if they were legal mandates.

Professionals may respond to legal control through resistance or symbolic compliance (Meyer and Rowan 1977, Edelman 1992, Dobbin et al. 1993, Espeland 1998, Pernell et al. 2017). Compliance may also be inconsistent (McPherson and Sauder 2013) or take precedence as it erodes professional authority (Heimer 1999, Huising 2014), or in rare circumstances become habitual if implementation responds positively to local organizational cultures (Silbey 2022). In this paper, we also show that professionals do not necessarily resist regulation, but neither do they complacently embrace its guidance. Rather, they assemble the knowledge and authority embedded within regulations with their own expertise and values, the work tasks and trust, to expand the available repertoire of expert practices while creating compliance.

In these loosely coupled environments, professionals exercise great discretion when deciding which rule to adopt, although constraints embedded in these rules do dictate professionals' decisions to mobilize them (Heimer 1999, McPherson and Sauder 2013). Similarly, we find that Med Laboratory professionals exercised ample discretion when deciding which rule to adopt. Moreover, we find a distinct pattern of adaptation where professionals seek to adopt the substance and not the letter of the law. Over time, the implementation of each regulation was subject to judgment about its relevance to safe work, reliable experiments, and mutual trust. For instance, laboratory coats wearing without judgment about whether a task threatened the body was demeaned and shunned whilst wearing laboratory coats was acceptable when experimental steps were deemed hazardous. In other words, professionals considered the substance of legal requirements, wearing a laboratory coat as protection, but did not follow the EHS recommendation to always wear laboratory coats. Even instances of apparent ceremonial compliance such as the preparation of the laboratory for safety inspections were treated as an opportunity to improve on existing practices. This observation documenting the importance of the perceptions and definitions of the substance of the law for patterns of compliance is supported by research on contract compliance. For example, an extensive online experiment shows that contracts are followed more consistently when the substance of the contract is considered morally right than when compliance is simply what law demands or when sanctions are threatened (Eigen 2012)

Safety Cultures as Assemblage of Regulatory Prescriptions and Expert Knowledge

Third, this work contributes to studies of safety culture (Weick 1987, Roberts, and Rousseau 1989, Eisenhardt 1993, Roberts et al. 1994, Weick et al. 1999, Silbey 2009) and to what has become almost ritual calls for developing a safety culture as the means of managing complex risks (National Research Council 2014). By showing how safety cultures can be constituted as an assemblage of regulatory prescriptions and expert knowledge, we extend prior understandings of safety culture as solely tacit understandings about safety that emerge from routinized work practices or positive opinions and attitudes toward the performance of safety. When deploying interpretive authority based on local knowledge and technical expertise, professionals move 'beyond compliance" (Gunningham et al. 2004) to craft what regulators seek: locally supported safety. At the same time, safety cultures in regulated spaces are not composed of only tacit knowledge that may be difficult to communicate and learn but may be supplemented by more formalized specification and subject to enforcement though legal regulations. Through this reclaiming and insertion of regulatory knowledge and artifacts into professional practices, legal knowledge is decoupled from its carriers (regulators, inspectors) to become local, eventually tacit, and consistently controlled by professionals. Although expertise was transferred away from regulators, the substance of the law was partially adopted by scientists leading to partial recoupling of front-line practices with legal demands (Espeland and Sauder 2007).

Our findings highlight the centrality of the overlap between the categories of interest to regulators and to professionals in the uptake and routinization of regulatory prescriptions within expert work. Regulations often focus on primary goals to be achieved, here environmental, health, and safety management, and do so by partially separating these norms from the specific work context to achieve generalizable prescriptions. In contrast, expert professionals consider the embeddedness of these norms in their work and social and collegial environment. We show that regulations do not always conflict with professionals' work and sociality and that these overlapping concerns may fuel the most successfully routinized prescriptions.

Further research could explore how legal regulation penetrates previously impermeable professional spaces. Scientists are adept at appropriating knowledge from other intersecting institutions such as commercial enterprises to maintain autonomous control over their work (Murray 2010). Classic studies predict that professionals expand or maintain their jurisdictional authority by appropriating other knowledge bodies (Abbott 1988). Our findings suggest that other in-depth inquiry into the patterns of uptake of regulation by various expert professionals are warranted, especially, study of the alignment of the categories of regulatory concern and the categories of professional concern. Our observations show quite conclusively that when legal regulations address categories of concern for front-line professionals, these regulations are more likely to be systematically implemented and durably assembled within autonomous professional cultures. How might social expectations within similarly complex and autonomous professions such as medicine or finance be translated into regulation that might appeal to professionals on the ground, perhaps eliciting thoughtful implementation within expert practices? Similar studies could also uncover patterns of regulatory compliance in complex and hazardous industries, such as road or rail transportation, where direct oversight and enforcement is not easily achievable.

Acknowledgments

The authors thank Daisy Chung, Kristina Dahlin, and Ruthanne Huising for helpful comments and suggestions on earlier drafts and Ayn Cavicchi for research assistance. This paper greatly benefited from the thoughtful guidance of Sarah Kaplan and three anonymous reviewers. This paper also benefited from the constructive feedback of the participants of the HEC Paris Society and Organizations research days and the Ninth International Symposium on Process Organization Studies. The authors are profoundly grateful to all the members of Med Laboratory for their openness and generosity throughout the field work.

Endnotes

[1] In this paper, regulation refers to legislatively enacted laws with their formally required implementation. To avoid confusion, we reserve the term "rules" for procedures developed by the laboratory.

[2] We use the words events, episode, and instance interchangeably for narrative flow to identify an individual acting alone or a transaction among two or more persons. We reserve the word practice to signify a repeated and generally familiar set of actions. A practice is defined as a recurrent category of talk or action that has analytic significance although the participants will often regard it as mundane and may not explicitly describe it as such (Lofland and Lofland 1984, p. 75).

[3] The main regulations applying to laboratories include the standards for Bisoafety in Microbiological Laboratories (BMBL), 5th Edition, National Institute of Health (NIH); the NIH Guidelines for Research Involving Recombinant DNA Molecules, the OSHA laboratory standards, the standards for Prudent Practices in laboratories (National Research Council), the standards from the International Commission on Radiological Protection, the "Eastern" State Department of Public Health Radiation Control Program, the U.S. Environmental Protection Agency Radiation Protection Program, as well as a number of federal and state fire regulations. Specific statutes include among many others: RCRA, Resource Conservation and Recovery Act 1976, 40 C.F.R. part 260-280; CAA, The Clean Air Act, 1990, Title 42, Chapter 85; CWA, The Clean Water Act, P.O. 92-500, 86 Stat.816 (1972) 33 U.S.C. 1251 et. seq.

[4] Hydrofluoric acid is a chemical that can be fatal on contact with skin. It is the only laboratory chemical that is rated "very high hazard" on a scale of 1 to 4 (very high hazard). Special safety precautions are in place for handling this chemical including the use of specific gloves and laboratory coats.

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