Clearing the Smoke: The Changing Identities and Work in Firefighting

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ABSTRACT
The impact of computing devices on the nature of work has been a long-standing topic of inquiry. Removing the boundaries of traditional corporate organizations, mobile IoT has enabled a technology driven future, taking transformative technology off the desk and placing it in the field. The exponential increase in mobility and reduction in cost have expanded accessibility of computing technologies to whole new categories of work including emergency response. As new kinds of workplaces adopt and adapt to computing, we want to better understand how these technologies impact the organization and change the types of work people do. In order to answer those questions, we present a qualitative investigation examining the implementation of a wearable device into two fire departments in the Southeastern United States. Our analysis demonstrates how the particulars of these kinds of workplaces and organizations will shape how we design new digital technologies for the next generation workforce.

Author Keywords
Field Study; Firefighting; Qualitative Methods; Wearable Computing; Future of Work.

INTRODUCTION
The discipline of human-computer interaction emerged in response to computing's expansion into supporting everyday workplace practices. Among the early work that established the field, the foundational studies of groupware applications revealed that introducing new technology to the workplace leads to changes in both the nature of work and the structure of the organization [33, 36]. Early forms of technology integration, like email, impacted decision making practices and upset power dynamics [21]. Skill requirements changed for an entire generation of people entering the workforce. The ability to communicate instantly led to expectations for immediate response that have tethered us to electronic devices expanding far beyond the workplace setting. While these changes had the largest effect in office settings, we are beginning to see how new domains of professional life are being transformed as computing continues to get smaller, cheaper, and more connected.

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Emerging trends surrounding smart technologies encourage the implementation of new types of connected computing devices in the workplace. This recent category of computing includes the connected devices that make up the Internet of Things (IoT), as well as purpose-built sensor platforms, data capture, and analytic capabilities. Examples of how these smart technologies are transforming new working environments include: the emergence of smart agriculture creating networked sensors to monitor farm land and control irrigation systems [13]; IoT for healthcare where enabled mobile devices monitor and track cardiac rhythm from patients at home [37]; and wearables like smart watches and smart glasses that create connected employees on the manufacturing floor, and connected soldiers in the battlefield.

The dominant narrative of these smart technologies emphasizes their ability to create organizational efficiency through predictive analysis and real time data collection. In doing so, companies developing and deploying smart technologies aim to solve the problems of an increasing population, aging workforce, and growing skills gap [30]. It is critical that we comprehend how these new types of digital technologies stand to change the organizations and the kinds of work people do, to educate the next-generation workforce and put people to work *with* technology instead of displacing them *by* technology.

One workplace currently being transformed by the confluence of several of these factors is firefighting. The transitions occurring in firefighting are being driven by an aggressive expansion in service demands, an aging workforce, and an emergent skills gap compounded by technology changes in the workplace. Fire department responses in the U.S. have nearly tripled from 11,888,000 total incidents in 1985 to 35,320,000 in 2016. This increase is due in part to population rise but also as a result of the expanding responsibilities of the fire service [4, 16]. Fire departments increasingly respond to traffic accidents, calls for hazardous materials and conditions – gas leaks, oil spills etc. – and provide general emergency medical services (EMS) [16]. To meet the growing demands, there is a need for fire departments to attract and retain new talent and become more efficient [45]. Technology integration in the fire service is seen as a solution to both limited personnel and resources [20]. The affordability of new smart technologies makes it an attractive way to increase efficiency – to do more with less – and new recruit classes are accustomed to technology as a mechanism for learning. Fire departments present an opportunity to understand how smart technologies impact workplace practices in a dynamic setting, contributing to shifts in the duties of firefighters, as well as how we might design for dynamic workplaces far afield from the office settings historically at the center of HCI design.

In order to better understand issues of smart technology adoption and design in workplace environments, we undertook a qualitative investigation of two fire departments in the Southeastern United States who were implementing a wearable biometric device. Our interest in studying the implementation and use of the new device was to investigate how the two fire departments adjusted to the use of the device, and how it impacted front-line work as well as command communication. Additionally, since the device was still under development, the study acted as a site for understanding how design intersected with the changing nature of work in an unconventional field for computing research.

DESIGNING FOR EMERGENCY RESPONSE

To understand how new pervasive computing capabilities are changing the nature of emergency work, we need to look at how technology is delivering workplace efficiency, and those impacts on the mechanisms of organizational change. In the first instance, the rapid expansion and acceptance of smart technologies is often in response to an implicit or explicit need to drive efficiency across organizations. In the second instance, drawing upon earlier work in organizational studies, technology adoption and use shapes workplace practices but it remains unclear how those develop in organizations with very different structures and labor conditions than the white-collar settings traditionally at the center of HCI research. Together, this suggests the complexities of building responsive smart technologies that must support established, and safety-critical work practices.

Opportunities Through New Computing Devices

The development of mobile IoT has led to new affordable, highly functioning technologies being adapted for the fire service. Previously, consumer grade products were not able to withstand the workplace conditions found in emergency response fields, especially firefighting. Devices need to be able to endure extreme heat, water exposure, and rugged wear and tear; coupled with limited distance capabilities and the inability to receive signal within a structure meant that many devices could not withstand the daily job hazards of firefighters. Now, technology is being customized for these types of environments including the use of wearable devices [7, 23, 27], wireless sensor networks [38, 42], and mobile applications [9, 29].

Future forecasting for smart technologies continues to highlight the potential applications for emergency response and resource management systems. The benefits of smart technology for emergency response is the ability to "enable dynamic workflow adaptations" through instantaneous feedback, improving situational awareness [39]. These technologies are being used to track and collect information about response times, incident location, and cause to create gains in organizational efficiency [8].

Mobile applications like Active911 are enabling real time resource and logistics management for emergency services. The application enables location tracking of firefighters arriving to the scene and provides pre-plan information about the incident directly to mobile devices. Active911 makes "the alerting and response of emergency personnel "active" not passive" [3], changing what it means to be on duty. Other systems use wearable technology to provide bio-feedback to prevent overexertion and stress which accounts for over 50% of all firefighter deaths [15]. Globe's WASP – wearable advanced sensor platform – attaches a wearable device to a custom t-shirt worn under gear [40], but physiological sensors are improving and come in all shapes and sizes including skin patches [19]. Connecting across these different systems are mobile wireless sensor networks that provide more situational awareness of building structures and can identify exit paths for firefighters [43].

Taken together, these new technologies are changing firefighting and the eruption of low-cost and accessible tech has opened up completely new application spaces. The implication of how these technologies might help on-the-ground response and planning have led new fields like emergency response to embrace smart technologies to improve safety and operational efficiency. However, as new types of work are introduced it is not always clear what efficiency means and, as has long been the case, whether the people tasked with using the technology reap the benefits of its use [22, 28].

Evolving Organizations of Work

In order to begin to understand how smart technology might transform the work of emergency responders, we turn to organizational studies and its perspective on the structural shifts that can occur as new technology is appropriated and used [33]. There have been many studies conducted in this vein to understand the success and failures of technology implementation, adoption, and usage. The focus, however, has primarily been on software applications or tools in traditional corporate environments. Implementation typically documents new technology being pushed across large organizations by leadership in a top-down manner. New processes and procedures are distributed from a centralized IT group to members of the organization through some form of training. Technology provides opportunities but can also limit the social construction of work. Recognizing the duality of technology [34], we can expect to see changes in the design of smart technologies or the organization for adoption to occur in the fire service.

In the case of emergency response, smart technologies are being developed for firefighters without a comprehensive understanding of the organization. Fire departments are complex bodies with characteristics of both large and small organizations. Each department is a part of state and local government but acts as a semi-autonomous unit or series of units made up of multiple fire stations – each with their own distinct culture. In these environments, work is carried out with the pressure of someone's life or property depending on a job well done. Firefighting is unlike the office work typically under examination in HCI; simply put, the stakes are higher.

Smart technologies in the workplace reinforce the command and control structure as tools help management make decisions based on data. This appeal is contradictory according to Grudin because often managers or decision makers lack the time or ability to learn new technologies [21]. In industry this shift is referred to as transitioning from reactive to proactive decision making and can be seen in tools like Active911 with the concept of creating active, rather than passive, resource management for emergency response.

Smart technologies can deliver real-time results, but to reap all the benefits of these new technologies "requires extensive changes in organization processes, personal and interpersonal orientations and attention to information technology" [25]. The foundation of proactive decision making relies on a large base of consistent user data to establish patterns and forecast predictive trends, especially for wearable devices. Wearables need firefighters to wear the device around the clock while a different set of users interprets the data. This reliance on widespread use also runs against the recommendations of prior work: Grudin warns against applications that rely on a large number of users and encourages a balanced effort between all users to limit increasing one party's workload [21]. The balance of user needs is difficult to establish without a deep understanding of how decisions are made in an organization.

A key observation across groupware studies is the need for education and training both for the developers and end users, about the context of use and the capabilities of the technology [21, 25, 33]. Emphasis on training helps define technology use contributing to adoption across the organization referred to as a part of technological framing [35, 36]. Firefighters are a highly trained group of individuals, but mandated training only occurs at the beginning of a firefighter's career. It is up to the individual to stay current, seeking opportunities to attend professional conferences or participate in field trials. These are done at the individuals expense creating potential barrier, particularly for smaller departments that rely more on volunteer firefighters. Due to the front-loading of training in a firefighter's career, rookie firefighters act as a key mechanism for technology transfer, often bringing new methods to the field from training. Without training, users are left to interpret technology based on their own experiences "imposing assumptions, knowledge, and expectations about a familiar technology on the unfamiliar" [36]. Firefighters are a very niche social group that can be leveraged to create a shared understanding of technology.

Technology Design Ecosystem

Smart technology has traditionally focused on solving a problem that arises out of specific user group or scenario. The technology offers a solution to a problem that many people experience in the same way or under the same set of circumstances. When designing technology for new workplace environments, it means designing for a much broader diverse ecosystem of people and actions. It is hard then to expect practices of user centered design to deliver the same results. It becomes imperative to consider the entirety of the system within which the technology will be used. This kind of ecological perspective, where technology interactions are systemic and multiple, has an established history and HCI and related fields and can be instructive here [17, 31].

The notion of product and device ecologies is not new to researchers in HCI and can be seen as a way to address Grudin's concerns about unpredictable complexities when designing for groups instead of the individuals [10, 11, 22, 26]. By taking a systems-based approach, we can "describe and understand the dynamic relationships between people, products, social activities, and the context that surrounds a system" [18]. It is a mechanism for drawing out the linkages design and technology have with other fields like organizational studies. This type of work is especially relevant as new workplace settings emerge as grounds for technology design.

By bringing together reflections from product ecologies, with reflections on organization studies' understanding of change within professional settings, we can begin to analyze and understand how interaction design might begin to address new sites of work that is embodied, rooted in established practice, and which needs to integrate across a spectrum of technical and social practices. This becomes particularly apparent when confronting the complexities of designing for a field like firefighting where daily job functions are high risk, high stress, and reactionary environments. This poses a challenge especially when designing new technologies because the ability to recreate these conditions is limited and simulation does not always accurately represent the intensity of a real emergency situation.

CONTEXT AND RESEARCH METHODS

Our study of how new smart technologies are impacting emergency service was conducted at two fire departments located in the Southeastern United States who were implementing the use of a new wearable biometric device. This researched involved a volunteer and career department, which are two of three primary types of fire departments in the U.S. – the third type being a hybrid between volunteer and career.

Department classification provides an indication about the area of coverage, population density, and monetary support. Volunteer departments, like one of the departments in our study, are typically associated with more rural communities where fire incidents occur less frequently and the operational costs of a fulltime fire service cannot be justified [12]. Career departments, on the other hand, are found in urban settings where the population is denser, and more services are required. The primary difference between career and volunteer firefighters are compensation and schedule commitments. Volunteer firefighters receive little to no pay for their time in exchange for complete schedule flexibility. This contrasts with career firefighters who are payed an annual salary and follow a strict working schedule. Out of the approximately 1.2 million firefighters protecting the United States, 30% are career and 70% are volunteer [24]. However, this can be misleading because, as we experienced in our research, many career firefighters are also volunteer firefighters in their local communities.

The career department in our study was comprised of 16 individual fire stations and provided both fire and EMS services across the county employing approximately, 200 firefighters. The career department serviced double the population of the volunteer department. Both departments were located in urbanized areas based on population according to the US Census [1]. The career department was experiencing tremendous growth and was in the process of training their largest recruit class of 40 trainees. The smart technology was being tested primarily with the recruits.

The volunteer location was one of 12 independent fire departments in their county, serving a smaller county district as the only fire station, and not providing EMS. The roster for the volunteer department was approximately 30 firefighters. The volunteers were able to select their shift availability every two weeks. During each shift one firefighter would be the designated "lead" and would receive pay for remaining at the fire station during the entirety of the shift. According to the National Fire Protection Agency (NFPA) classifications, the department is technically a combination department because the lead firefighter receives a minimal amount of money [24]. The terminology "combination department" was not used by participants.

The way fire stations are distributed and staffed varies based on the political and economic conditions of each municipality, but the organizational structure remains steadfast across fire departments. The organizational structure of the two departments in our study was similar following a traditional pyramid hierarchical model based on years of service.

Our study examines larger trends in firefighting to move towards more technology-enabled futures that are now possible because of the evolution from fixed ICT to mobile IoT. Based on the dynamics of the two fire departments participating in the study, we expected to see different adaptations of the smart technology across the two fire departments.

Wearable Device Description

The wearable IoT device in this study is the product of a startup company. The wearable is marketed as a preventative tool to the problem of overexertion and stress for firefighters – the number one cause of firefighter fatalities [4, 15]. The device collects and relays individual biometric information to a web-based data dashboard viewed in real-time by supervision and accessible afterwards by firefighters, akin to a fitness tracker (see Figure 1). In a live fire scenario each firefighter would be outfitted with a wearable biometric device. The device would be monitored in real-time by the incident commander (IC) to verify the status of firefighters and make data-driven decisions. The role of the IC at any live fire scenario is to act as watchdog, assuming responsibility for the safety of each firefighter as well as others on the scene. The IC provides high-level directions to the firefighters and can provide supplemental information like where flames are visible and firefighter locations and progress inside the building. The IC remains sequestered in a designated vehicle at the scene of the fire to extensively document each incident via iPad or laptop. Therefore, the IC would have direct access to the data dashboard. Ultimately, the IC would instruct a firefighter via their communication system to leave the fire if their vitals caused concern.

The devices deployed in the field for this study attached to the firefighter's face mask via a universal attachment point. An earpiece, connected to the device housing, rested inside the firefighters' ear and gathered biometric information including internal body temperature, heart rate, blood saturation levels, and respiratory rate. A personal fitness profile was created by each user and linked to the device to improve the accuracy of the data, similar to programming a treadmill before a workout routine. The dashboard displayed individual biometrics including heart rate, body temperature, external temperature, percent of exertion and stamina, calories burned, distance traveled and speed in real-time. The exertion and stamina percentages were calculated based on an algorithm created by the US Department of Defense. The data was stored and continually monitored in real-time by supervision to identify patterns or trends.

Situations of Work

The fire departments involved in this study were the first two departments to agree to long-term use of the devices in partnership with the startup company. The devices were provided

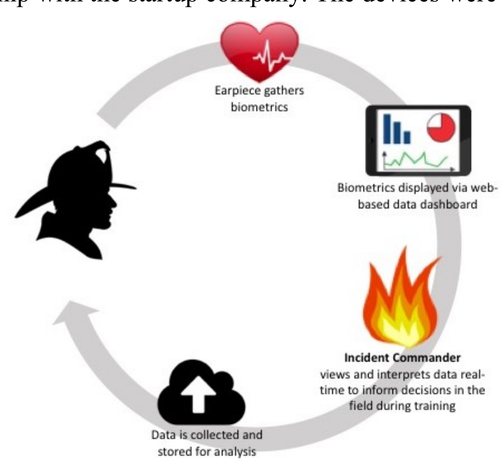

Figure 1. Data flow from biometric sensors that feed personnel dashboard and analytics engine

at no cost to each department with the understanding that the data collected would be used by the startup to refine the design of the device. There were 10 devices deployed in total, with each fire department having 5 at any given time. The device usage was rotated through different firefighters and trainees at both locations. Each location had a supervisor designated as the primary point of contact responsible for the devices and oversaw their use. Both points of contact held leadership roles and were involved in the training departments. Schedule availability resulted in the volunteer department being able to use the devices more frequently than the career department.

The two primary situations of work discussed for the device were during training and live fire. During the course of this study, the devices were only used during training exercises because of the ongoing evaluation and relative newness of the device.

Training Scenarios

Firefighters were given a brief overview of the device lasting no more than 5 minutes and asked to complete an online profile by their leadership directly prior to starting the exercise. Often, it was a firefighters first time hearing about the device on the day of use. A series of obstacles including ladder runs, hose drag, sledge hammers and crawling were set up as a part of a *job duty course*, a routine training exercise. Users were wearing full gear during training exercises including, helmet and face shield, gloves, mask, communications receiver, oxygen tank, coat, boots, and fire hood. The biometric device was used to monitor heart rate spikes during the course of the exercises. The firefighters did not have access to any data during the exercise they are simply instructed to wear the device. The data was accessible to firefighters afterwards by logging into the website. The supervisor was viewing the results in real time on the data dashboard using either a mobile phone or iPad. The results were used as a comparison or ranking tool for fitness levels across the user group. The supervisor would 'hassle' the firefighter exhibiting a low heart rate to make him go faster or push harder. The results were briefly discussed at the end of each exercise, in an informal classroom setting, providing each individual with a glimpse of their performance. The goal was to be able to create a baseline for individual firefighter performance overtime.

Data Analysis

Over a period of 3 months, detailed data collection was conducted through semi-structured interviews and observation. Field notes were collected during leadership meetings when the device was first being introduced to the department by the startup company, and when the device was in use during physical therapy and job duty courses. In total, 20 hours of field observation were completed along with 12 participant interviews each lasting approximately an hour in length with follow up questions directed to some participants. All interview participants had used the device at least once during training exercises.

The participants backgrounds and titles were varied along with their respective experience levels. All participants were male. The average fire experience of the interviewees was 15 years in the fire service. Participants from the volunteer department were either active or recently retired career firefighters. The volunteer designation is misleading because the participants had extensive training and experience working as full-time firefighters. The interviews included the founders, chief operating officer, and chief development officer for the startup company who developed the biometric device. The focus of the interviews with the technologists was to understand the initial design process and the motivations behind design changes and how they envisioned the technology being used. This was compared to how the technology was received and actually being used by firefighters.

A grounded approach was used to analyze interview transcripts and observations through open coding and focused follow-up questioning to establish overarching themes [14]. Borrowing from Charmaz's version of grounded theory allowed for more flexibility to embrace the diversity of participant experience. This work reflects only the beginning stages of implementation in what is a much longer and ongoing process.

FINDINGS

Our findings begin to characterize the relationship between smart technologies and new workplace environments. Through the interview process and subsequent analysis, prominent themes emerged surrounding *identity*, *power and authority* and *organizational structure.* These themes exemplify the importance of understanding how organizations operate when designing and implementing smart technologies. Opportunities exist for smart technologies to leverage organizational studies as a conscious decision to ensure designs are situated within context of use.

Identity Conflicts

The workplace culture of firefighting is deeply intertwined with identity and tradition. A common firefighter adage referred to by participants was "200 years of tradition unimpeded by progress." The fire service prides itself on not changing with the times but holding steadfast to tradition. At a national level it is recognized that the fire service must undergo a "paradigm shift" [20]. However, department diversity and the localized nature of fire stations pose challenges for smart technologies because the climate for innovation weighs heavily on the success of new technology deployment [32].

The identity of firefighters is grounded in the physical reality of fighting fires. P2 shared that "*If we see that fire blazing and we've got a couple of people in there to go save, we're not too interested in all those kinda things [technology], if that makes sense.*" P3 dubs this mentality as, "*The Johnny Waynes. They wanna go in there and just bust stuff down. "Here I am. I'm a fireman, I'm gonna put it out.""* Technology is not a part of the image of sheer tough and ruggedness. There is a perception that technology might weaken or otherwise disrupt the iconic image of fighting fire. P7 is adamant in his view," *You tell me we're going to send this machine in there or we're going to send this in there…you won't get me to do it. I'm going to go through the door and I'm going to go through there and I'm going to put it out how I've always been taught to put it out.*" Understanding identity is at the core of user acceptance.

The resistance to technology is not unfounded. As expressed by P1, "*When that iPad breaks, or goes down, or needs to be serviced, or just typical technology stuff, glitches, these guys freeze up*." P8 described several examples of firefighter deaths caused because of reliance on technology and forgetting the basics of firefighting. Setting the scene, P8 describes a Lieutenant and team of guys coming up from a basement fire, "*So they come up with a TIC [thermal imaging camera]. He scans the room, sees the floors there. Takes off walking through the middle of the living room floor. And never went back to the basics of sounding the floor. Him and his other two guys with him, fell through the floor and burned to death.*" Relying on technology too much can create dangerous conditions contributing to the skepticism of technology implementation especially by those who have a strong affiliation with the John Wayne archetype.

However, smart technologies can be designed and implemented in a way that creates positive change and leverages ongoing efforts to expand the workforce. Recruit classes are challenging traditional firefighter identities. Current firefighters view "*newer generations only having technology skills and not being able to adapt to the physical labor of our work*" P1. This is causing the fire service, like many other industries, to reevaluate their approach to technology use. The career department in our study incorporated several new types of technology into training for the recruit class out of necessity. Leadership was experiencing difficulty maintaining recruit attention for long periods of time in the classroom, so they created podcasts and started using YouTube videos to engage trainees. Using the wearable devices was also a part of this strategy. For example, P3 shared that "*If I take this [wearable] technology into the classroom into the recruits right now, I feel like I have an easier time of them understanding it because they don't know anything different*." While the physical demands of firefighting remain the same for recruits, the fire service was being forced to reevaluate technology's role its relationship to technology in order to attract and retain new talent.

Designing technology for identity also matters because technology has the power to disrupt or entrench these social norms. The use of technology with recruits works to emphasize divisions within the fire service because it engenders social groups based on age. P3 describes this shift as the breakdown "*into the blue collar versus the white-collar subset in the fire service… where it used to all be blue collar*." Traditionally, technology in the fire service meant physical tools and materials, which aligned with blue-collar work and came with certain preconceived notions of gender, labor, and organizational culture [5]. Now, technology is changing the nature of work through digital technologies – computers, iPads, cell phones – shifting the heroic, embodied image of firefighting to a more cerebral, white collar conception. As smart technologies migrate into work settings like fire response, they need to be designed with an understanding of identity so that they augment an organization's ability, rather than get rejected with the sentiment, "*we can do our job without technology*" P2.

Power and Authority

The wearable biometric device was initially developed with a user-centered design approach with firefighters as the target user group. The intention of the wearable device was to help firefighters in the field; however, through the iterative design process, leadership became the ultimate end user. The result was that the device became another tool that reinforcing existing power structures, rather than a tool to empower frontline firefighters through improved situational and physical awareness.

The first prototype developed by the startup company projected an infrared image onto the firefighter's facemask with a heads-up display (HUD) to increase situational awareness. Based on technological constraints, market evaluation, and firefighter feedback, the company re-evaluated their design and shifted to use the HUD to display biometric information. Reportedly, firefighters didn't have time to react to the information during fire suppression because their attention was solely focused on the task at hand. The technologists then further simplified the prototype interface to display red, yellow, green indicators for vitals instead of actual numeric values. They also added a messaging application between the IC and the firefighter. Additional field testing led the technologists to entirely remove the HUD unit from the prototype. Explaining that decision, P5 shared that "*the firefighters themselves don't need to see anything. It's just all the data gets sent out to someone else that cares.*" The technologists found that *"[Firefighters] are so focused on what they're trying to do, and they also just have a heroic attitude where they don't really care as much about themselves. They just want to perform*" P5. This user feedback exemplifies identity of "The Johnny Waynes," a professional identity the technologists did not recognize during the early design process.

Responding to both observations and feedback, the technologists created a more passive technology resulting in the design of the wearable device and separate data dashboard solution. As one of the technologists stated "*they're [firefighters] not really going to care about it besides just putting it on. But basically, it's going to be more of the Incident Commander looking at it. The Chief can look at it from his office. 9-1-1 dispatch can look at it and see when people are getting tired"* P6. While a passive technology may receive the praise of the firefighters, it removes personal accountability and deemphasizes the importance of a firefighter's responsibility for their own health and safety.

Shifting away from firefighters as end users signaled a change in the technology design that aligned with the organizational structure and reinforced power and authority dynamics. It is the expressed job of leadership to place importance on protecting their crew. Current practices, in the field and during training, rely on experienced leaders making health judgement calls based on physical appearance. For example, during recruit training, one leader referred to problems of the "weakest link." Recruits range in age from 18-40 and can come from any background and with diverse levels of fitness. Group mentality makes it difficult to know when a complaint is valid during physical exertion. Firefighter leadership welcomed the wearable device because it enabled an additional layer of accountability and justification for their decisions. Leadership discussed using the device as a decision-making tool in two primary ways: removing a firefighter from active duty or pushing recruits harder during training. These situations of use underpin command and control practices. P1 commented that "*From a leadership standpoint, from a command perspective, it allows me to protect my guys a little more.*" The technologists viewed leadership's response as positive which motivated them to continue to iterate on the device design moving away from direct firefighter interaction.

The design decision to place information access solely on the web-based data dashboard renewed the reliance on leadership. While firefighters would be wearing the device for their own well-being, the enforcement, tracking, and analysis falls on those in supervisory positions. As stated by a firefighter, leadership has the power to say, "*You will put this on and you will have it on, before you enter that structure. If you don't, then you're not going in. They can't do no fun*" P2. This aligns with a comment from P1, who said "*A lot of the fire services is just simply obedience*." The device adapted to fit the hierarchical structure of the organization consistent with early findings by Orlikowski that technology will either adapt to the organization or the organization will change to meet the requirements of the technology [33].

Organizational Structure

The ultimate goal of the device as expressed by the startup company was to become embedded as a part of firefighting culture, to be used on and off of the field. To achieve that level of semblance requires the technology to disrupt the organizational structure and contend with changes in identity and authority rather than fit into the existing workplace practices.

The current organizational structure relegates the wearable device to use only during training exercises. Participants were very open to using the device during training operations. P2 used it as a way to push recruits "*I thought it was pretty cool, just sitting there, looking at a monitor and again just calling them guys out.*" P8 saw it has an opportunity to help rid departments of obesity and encourage comradery sharing that it is great "*Great for recruits and then for crews when they PT and to track, is my fitness working? Is what I'm doing making me better over time to improve?*" Use of the device during training supports the identity of firefighters, it encourages physical fitness and feeds into the competitive nature of firefighters without changing roles or responsibilities.

When transitioning to other contexts of use like real emergency response calls, participants were reluctant making statements like, "*We don't want to be the ones that go, "Oh man this is hot, we need to back out"*" P8. In live fire scenarios, firefighters removed themselves from direct interaction with the device making statements like *"It would be a way for chief [to] see someone's heart rate, and be like, yeah I know this person he's gung ho, he's not gonna quit. It's time to pull him out*" P8. In live fire situations, the wearable device would actually prevent a firefighter from doing his job thus eroding the traditional identity of aggressive firefighting and changing the nature of work. Ultimately, this perspective influenced technology design decisions. Live fire use would require the fire service to place importance on health and safety before taking risks. Firefighters would need to be empowered to sit out and take responsibility for their health and safety rather than relying on leadership. Use during live fire requires a shift in organizational structure and workplace practices.

Participant conversations turned to adding a new position to the fire service designated to tracking health and safety metrics. As stated by P2, "*You just not gonna be able to have that and say, "Okay you gotta come out," and the house still burning. You still got to have that staffing on the back end*." The technologists support the dedicated position stating that some fire departments "*Already have health and safety officers, who this is their job, so they'll just use the information*" AP4. However, very few departments can afford health and safety officers, let alone, observe NFPA 1500, which specifies minimum health and safety requirements including recording baseline vitals [44]. Working in a department "*strapped for manpower,*" P2 struggled to justify hiring someone asking, "*how do you assign somebody like me or someone else to just sit there and look at this and look at that?*" His struggle exemplifies the difficulties facing smart technologies that are being designed and adopted to fit into existing structures. Instead of having a designated position, the device could be reimagined as a collaborative tool used to encourage better fitness across the organization and incorporate an educational component linking performance to safety in the field.

The fire service views their transformation as one that involves adopting new technology and increasing staffing. The most common perspective was to use the wearable device as a way to provide justification for more staffing and financial support. All participants shared that they would be more than willing to use the device for research and to help secure more funding for the department to increase staffing but do not want it to affect the job. The use of technology was viewed primarily as a symbol of progress and a way to gain additional resources towards that end. This perspective does not recognize that hiring personnel signals a phase of organizational restructuring as a result of technology implementation [6]. All participants recognized that the fire service has experienced significant change over the last five years bringing technology and health and safety to the forefront of firefighting. From a leadership perspective, P1 stated, "*As we move forward in the fire service, we begin to look for ways to take care of our employees."* Many participants discussed how firefighter magazines are now publishing research on the causes of firefighter deaths which is helping to popularize concerns. Yet, as a health and safety advocate, one participant stated, "*I can walk into a fire station today and people do not know anything about the health and safety problems or health and wellness problems that the fire service is facing*" P3. Smart technologies offer a way to make inroads into the complex issues of health and safety in the fire service, but we must recognize the advantages and potential consequences that these technologies introduce. By examining organizational shifts and changes in workplace practices, we can begin to see how the design of these types of technologies require more attention.

DISCUSSION

An organization has to be able to respond to the opportunities for structural change that technology creates [6]. Barley contends that these changes only increase further when participants are unfamiliar with the technology making prior structures "more difficult to maintain" [6]. This accounts for the dissention between new and old guard, or the blue- or white-collar interpretation of the work of firefighting offered earlier. As former technologies in the fire service could be measured based on time or cost savings, smart technologies open new horizons of impact such that "efficiency" includes performance, but also well-being, and safety in an inherently dangerous job.

The challenge presented here is how to bring new technologies into different kinds of workplaces in a way that supports and extends the ability for these organizations to respond to both the technology change and their professional responsibilities. The wearable device in this study is a new smart technology being implemented as a mechanism to modernize the fire service. Our findings highlight barriers to implementation and long-term use of the wearable device. The issues of identity, power, and structure are deeply rooted with the history of firefighting. Without a firm understanding of these characteristics and their specific form within a given organization, initial design decisions inadvertently reinforced practices of top-down decision-making and missed opportunities to restructure the organization, to empower firefighters, and to address issues of identity and gender bias.

A recent study suggested that the future of smart-firefighting revolves around four critical areas: data types, access, and privacy; information overload and sensory deprivation; tradeoffs: trusting and learning systems and organizational factors [5]. The case study documented the impact of two existing personal protective equipment technologies: flash hoods, worn under helmets as an additional layer of thermal protection; and low-air alarms that vibrate to notify firefighters that it is time to exit because oxygen levels have reach minimum levels. The study found that the wearables exposed firefighters to "unforeseen hazards" and displaced tacit knowledge used to "mitigate workplace risk" [5]. Without situating technology within everyday workplace practices, smart technology interventions in safety-critical settings can exacerbate risk and undermine the work practices developed over time to mitigate those risks. For this reason, organizational factors should be given more credence throughout the design lifecycle to situate technology within everyday workplace practices.

Direct Impact on Firefighters

The wearable device in our study was targeted as a way to decrease firefighter fatalities by emphasizing health and safety. However, safety wasn't seen as a benefit of the device in practice because of the reluctance to use it in live fire. Instead, it was through additional managerial control where impacts on safety could be indirectly gained. For example, as drawn out above, P8 discussed the device as a training tool to reduce department obesity or otherwise force firefighters to change their behaviors. In this instance, the device would prevent firefighters from having to rescue their own coworkers, thereby reducing the chance of putting more lives at risk because a firefighter was not in physical shape. In training scenarios, it carried through envisioned use where supervisors could tell 'slacking' firefighters to pick up the pace. The device, initially imagined as a tool for direct firefighter feedback, was appropriated to increase firefighter efficiency through physical fitness which has significant implications for firefighter performance – not all of them positive or empowering from a labor/management perspective.

Requiring firefighters to wear the device seems to be a menial task change to daily job duties but knowing that the device is being monitored by supervision could change how a firefighter acts and reacts in the heat of the moment. For example, firefighters could hesitate in the field meaning the difference in saving life or property. On the other hand, the device may very well encourage the reverse response, leading firefighters to take more extreme actions because their time actively fighting the fire may be artificially limited due to data reported through the dashboard. The element of not knowing when and where you could be removed from action potentially jeopardizes firefighter safety. Designing for firefighters means balancing the mix of identity pressures – heroic firefighters – and authority mandates that may lead firefighters to ignore health warning signs in the moment.

The complexity of performance is further combined with issues of trust and reliability. Firefighters have a reluctance to adopt new smart technologies because of concerns about technology failure and technological dependence leading to increased resistance. Skepticism is heightened because of past and current issues with new technology that affect performance. Like previously mentioned, when technology like GPS goes down "guys freeze up" P2. Comparatively, P8 shared examples about thermal imaging cameras where the technology jeopardized safety because firefighters forgot the basics. Technological dependency can reduce a firefighter's ability to be self-sufficient just as much as technology failure. This in large part due to firefighting being a viscerally embodied practice and the multi-sensory work of fire suppression, when mediated by technology, narrows the channels of sensemaking to what can be conveyed via sensors on a screen.

We can anticipate that firefighter feedback will continue to reinforce top-down decision-making because of the prominent influence of firefighter identity on information design. Removing firefighters from direct interaction with technology aligns with ideas of calm computing - moving technology to the background [41]. However, not all environments are suited towards practices of calm computing. As designers we have to be cognizant of the impact of "black boxing" information as a means to increase privacy and reduce cognitive load [5]. There is little about emergency response that is calm. Life-saving devices need to stand out amongst high stress hectic environments; they should not blend into the background. And emergency personnel need to be able to rely on performance of devices in the field. The relegation of the wearable device in our study to training environments is a key indicator that trust was missing. This is only compounded by an oversaturation of devices that claim to be for safety, weakening inherent trust in new products.

A suggested solution to technology adoption in group settings is to "ensure that everyone benefits directly from using the application" [22]. For that to happen, firefighters have to share a similar understanding of the technology as the designers who viewed the device as a life saving measure. The approach to design for emergency response requires a shift in how we as designers and technologists situate ourselves within the ecosystem.

Management and Local Organization Traits

Introducing smart technology affects identity management and changes the social and material arrangement in organizational structures. A part of designing for organizations is ensuring the technology is situated within the context of use. The technologists in our study employed principles of user-centered design. However, without a firm understanding of the organizational structure, the technology they were creating shifted from being for firefighters, to a tool for leadership. As noted above, there is a real concern that design can reify institutional hierarchies if a robust understanding of the organization is not present.

As we experienced, firefighters provided insights that embodied the traditional workplace culture stressing their desire to focus on the physical aspects of work. The technologists took initial user feedback by shifting where the information became visualized for action. To lessen firefighter information overload, the technologists eliminated firefighter access to real-time information in the field. The trade-off on information overload was handled by shifting who was getting the information and thereby who was empowered to act on that information. Therefore, the creation of a more passive technology was not necessarily the solution to the problem of information overload.

This difference points to a kind of design mismatch where the biometric device was seen by the technologists as a tool providing live fire support but was really being used as a training and enforcement tool by management. Prior work investigating the application of VR for firefighting did not experience the same push back. In that case, the VR device was geared towards increasing situational awareness, allowing firefighters to see through the smoke [2]. The technology was framed as a way to save time aligning with current workplace practices, reiterating the importance of situating technology design within the organization. However, the technologists for the wearable device did not provide a clear picture of how the device could be incorporated into everyday practices leaving leadership to come up with technology use cases that did not align with the original intent of the device.

Orlikowski revealed that creating a common understanding of a technology – technological framing – is key to user acceptance [33]. Furthermore, the same technology can result in different structural changes in organizations [6]. It can be expected then that each fire department and fire station could experience different organizational changes as a result of technology implementation. When looking toward the impact of wearables on fire organizations, an important factor is the saturation of individual fitness devices like FitBit and Apple Watch, and their relation to official forms of tracking and occupational surveillance. Experience with personal fitness devices and smart watches is helpful, but it also limits the use of wearable technology at an organization level because the users only expect a device to fulfill certain expectations. Wearables will have to overcome these perceptions of use including generational derisions surrounding technology by reshaping a user's technological frame.

To establish a shared understanding and appreciation of technology, organizations will need to turn to training in addition to new technology deployments. Training is a key component to establishing a shared understanding and appreciation of technology [33]. To realize the vision of smart-firefighting [20], training practices need to be revamped alongside the implementation of smart technologies. The fire service relies on front-loaded training that contributes to a culture steeped in tradition. New technology deployments, however, demand that organizations have structured and accessible on-going mechanisms to introduce new smart technologies to the field. Compounded by growing organizational requirements and limited resources, departments' abilities to implement new training programs are stifled [9]. The organization relies on individuals seeking out and paying for their own training throughout their career. Incorporating training with the introduction of new technology in the fire service is essential. Creating meaningful training requires an understanding of both the organizational structure and daily workplace practices.

The fire service relies on front-loaded training that contributes to a culture steeped in tradition. Fire departments do not have a formal way to introduce new smart technologies to the field because there is no mechanism for continuous training. Compounded by growing organizational requirements and limited resources, departments abilities to implement new training programs are stifled [9]. Incorporating training with the introduction of new technology in the fire service is essential. Creating meaningful training requires an understanding of both the organizational structure and daily workplace practices.

A Design Ecosystem Approach for Firefighting

The application of mobile IoT technologies in new workplace settings are challenging design approaches that have traditionally focused on narrowly defined problem-solution outcomes. Concentrating on technology function and use for a particular group and set of circumstances makes early user-centered design interventions tractable but creates challenges once those designs reach the complex contexts of organizational deployment. In order to fully realize the benefits of new mobile IoT technology, we have to understand and embrace complexity throughout the design process.

The diversity present across the fire service means that a one-size-fits-all approach to technology solutions is insufficient. The complexity of modernizing the fire service's use of technology is further compounded when you introduce the differences between career and volunteer fire departments, and state-based training requirements. To realize the vision of smart-firefighting [20], a design ecosystem approach needs to be applied to balance firefighter needs with internal business practices [17, 31]. Rather than a point solution, ecological design approaches suggest a more comprehensive method of merging service design with a systems-based approach [18]. In the case of the wearable device at the center of our study, an ecological design approach would have enabled the technologists to contend with a broader group of stakeholders, recognizing different sets of priorities that aligned with issues of firefighter identity and command and control structures. The ecological approach would also have enabled interface and service design to occur at the same time creating the opportunity to empower firefighters through interaction with the wearable device.

Furthermore, ecological design acknowledges that interactions move across individual and organizational levels in a variety of ways. By highlighting the range of stakeholders in the ecosystem, technologists and designers are able to contend with more possible outcomes rather than having a narrow focus on technology function and use. The reality is that we are never going to have perfect knowledge of these influences on one another, but an ecological perspective helps highlight the inter and intra-level links to ground design generation and assessment.

CONCLUSION

The study presented here highlights a number of challenges facing smart technologies and the new categories of organizations that wish to implement these tools. Emergency response organizations, like firefighting, are just one example of the ways in which smart technologies are becoming prominent outside of traditional corporate environments. The expanding domain of smart technologies necessitates the revitalization of organizational studies. For successful implementation to occur, we must embrace all the complexities of the organizational environment by applying product service ecology frameworks to technology design in new workplace settings. Generating a clear understanding of the impact of these new types of devices on workplace practices, will help orient training and education programs for the next generation workforce.

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