CLEARING THE SMOKE: THE CHANGING IDENTITIES AND WORK IN FIREFIGHTING

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CLEARING THE SMOKE: THE CHANGING IDENTITIES AND WORK IN FIREFIGHTING

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LIST OF SYMBOLS AND ABBREVIATIONS

ICT	Information and Communications Technology
IoT	the Internet of Things
CHI	Computer Human Interaction
CSCW	Computer Supported Cooperative Work

SUMMARY

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, the evolution from fixed ICT to 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 to whole new categories of work including emergency response, manufacturing, and construction. There is a need to revitalize organizational studies alongside emerging technologies as new structures and environments make the kinds of initial questions in organizational studies relevant again. This work presents a qualitative investigation examining the implementation of a wearable device into two fire departments in the Southeastern United States. The analysis demonstrates the importance of understanding how these types of new digital technologies impact organizations and shape how we educate and train the next generation workforce.

CHAPTER 1. INTRODUCTION

Disciplines like CHI and CSCW emerged in response to computing's expansion into supporting everyday workplace practices. 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 [31, 34]. Early forms of technology integration, like email, impacted decision making practices and upset power dynamics [20]. Jobs were lost, and skill requirements changed for an entire generation of people entering the workforce. The ability to communicate instantly has led to expectations for immediate response that have tethered us to electronic devices expanding far beyond the workplace setting. While these changes have 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.

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 healthcare has enabled mobile devices to monitor and track cardiac rhythm from a patients home [35]; and wearables like smart watches and smart glasses create connected employees on the manufacturing floor [4] and connected soldiers in the battlefield [43].

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. 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 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 compelled by technology and 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 due in part to population increase but also as a result of the expanding responsibilities of the fire service [6, 17]. 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) [17]. 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 [19]. 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.

In order to better understand issues of smart technology adoption 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 device was to investigate whether and how the two fire departments adjusted to the use of the device, how it impacted front-line work as well as command communication, and as a site for understanding the changing nature of work in an untraditional field.

CHAPTER 2. RELATED WORK

To understand the changing nature of work there are two primary areas of intersection. First, the rapid expansion and acceptance of smart technologies place emphasis on efficiency as a means to encourage adoption across organizations. Second, drawing upon earlier work in organizational studies, the role technology adoption and usage plays in shaping workplace practices reveals a set of concerns such as safety and loss of tacit knowledge, when looking at new kinds of workplaces. Putting these two fields in conversation provides a way to explore how the design and implementation of a digital technologies enables new forms of decision making and task analysis at an individual and organizational level.

2.1 Smart Technology Transformation

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 range 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 [9, 22, 26], wireless sensor networks [36, 41], and mobile applications [11, 28].

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 [37]. These technologies are being used to track and collect information about response times, incident location, and cause to create gains in organizational efficiency [10].

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" [5], 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 [18]. 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 [42].

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 [21, 27].

2.2 Organizational Studies

In order to begin to understand how smart technology might transform the work of emergency responders, it is imperative to turn to organizational studies and its perspective on the structural shifts that can occur as new technology is appropriated and used [31]. 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 [32], 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 [20]. In industry this shift is referred to as transitioning from reactive to proactive decision making and can be seen in Active911's concept of creating active not passive resource management for emergency response. Smart technologies 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" [24]. 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 [20]. 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 [20, 24, 31]. Emphasis on training helps define technology use contributing to adoption across the organization referred to as a part of technological framing [33, 34]. 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" [34]. Firefighters are a very niche social group that can be leveraged to create a shared understanding of technology.

CHAPTER 3. CONTEXT AND METHODS

This 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. There are four official departmental classifications: (1) Career: 100 percent of a department's firefighters are career; (2) Mostly Career: 51-99 percent of a department's firefighters are career; (3) Mostly Volunteer: 1-50 percent of a department's firefighters are career; (4) Volunteer: 100 percent of a department's firefighters are volunteer [NFPA]. Out of the approximately 1,160,450 firefighters protecting the United States, 30% are career firefighters and 70% are volunteer firefighters [23]. The primary difference between a career and volunteer firefighter is the pay and schedule commitments. However, from field observations, it was discovered that it is a common practice for career firefighters to also serve as volunteer firefighters in their local communities. A career firefighter is committed to a regular schedule, usually working 24 hours on and 48 hours off, and volunteers typically commit their time as available and receive little to no compensation for their work. Volunteer departments have been found to be the most cost-effective option in less populous areas while career departments make financial sense when quick response times and more fire services are needed [12]. Department classification provides an indication about the area of coverage, population density, and monetary support.

The field research conducted for this study involved a volunteer and career department. Both departments were located in urbanized areas based on population [1]. The career department was comprised of 16 fire stations and provided both fire and EMS services across the county. The volunteer location was 1 of 12 independent fire departments in the county, serving a county district as the only fire station but not providing EMS. The 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.

3.1 Fire Departments Transitions

Currently, fire departments are going through a transition, a shift in culture, driven by technology and changes in the workforce. Departmental procedures and processes are being modernized for the incoming firefighters who rely more on technology than previous generations. The standards that outline fire department operations are overseen by national standards developing organizations (SDOs). The National Fire Protection Association (NFPA), a non-profit organization established in 1896, has published more than 300 consensus codes and standards outlining rules and regulations for fire practices. Contributing to the diversity between departments, these standards are strong suggestions but are selectively implemented based on budgetary constraints and leadership vision. The experiences of 9/11 revealed the flaws of these widespread departmental differences, when responding to a national incident requiring multiple departments to work together. The outcome led to a new organizational perspective from a national level leading to the implementation of the Incident Command System (ICS) and adaptations from the National Incident Management system (NIMs).

ICS requires a single point of contact to supervise all field coordination. When responding to a scene for firefighting, the Incident Commander (IC) arrives in a separate vehicle and remains sequestered until the conclusion of the event. It is the IC’s role to monitor the scene, give direction, and ensure proper procedures are followed. NIMs led the transition from custom departmental codes to the use of “plain talk” as a means to create common codes corresponding to the type of incident (i.e. house fire vs car accident). Prior to the utilization of these systems, each department had a different set of processes and procedures for fire suppression without the ability to successfully coordinate with other departments. National leadership communicated a clear vision for fire departments to strive towards which led to the adoption of new procedures, reinforced at a local level by the inability to work together without modernizing workplace practices. This is significant especially for rural communities who have limited emergency response resources and may rely on neighboring departments to assist.

New technologies have also supplemented fire departments as a means to become more efficient to compensate for the lack of personnel and population growth. The focus of technology assessment has been driven by the need for efficiency. Thermal imaging cameras (TIC) are one example of successful integration and adoption of technology into the workplace for fire departments. Thermal imaging and infrared technologies allow firefighters to gain more information from the scene by quickly providing increased visibility. The technology was originally adopted for military use in the 1940s but it wasnt until the early 2000s, when NIST brought together industry and emergency response, to discuss barriers to use, that adoption began to occur in fire departments [8]. The outcome of the NIST workshop revealed that the highest priority for industry was not directly aligned with emergency response professionals. Industry was focused on image clarity while emergency response professionals ranked training and certification and human factors/dynamics/ergonomics as the two most important factors for use [8]. Cost and size were two specific features that were identified as further limiting adoption. The TIC workshop led to the creation of an NFPA standard and changes in training practices to encourage adoption but the technology had to be customized to meet the needs of fire departments [8]. TICs are now able to withstand extreme environments with decreased size and weight, which is especially relevant for firefighters who enter buildings with temperatures exceeding 100 degrees Fahrenheit, wearing over 40 lbs. of gear. Thermal imaging has become embedded into the fire service because the technology adapted to meet the specific needs of the fire service and it drives efficiency through decreased emergency response times [29]. Advances in technology, like TIC, have equipped firefighters with new tools changing the industry and nature of firefighting.

While technology has been developed to equip firefighters with better gear and tools to fight fire, technology also enables firefighters to be more aggressive increasing risk for firefighter health and safety. Stress and/or overexertion remain the leading cause of firefighter fatalities in the United States accounting for more than 50% of all firefighter deaths [39]. The most common result of stress or overexertion is a heart attack leading to sudden cardiac death (SCD), yet overexertion is not directly correlated to incident response. Although approximately "33% of SCD events occur during fire suppression and the relative risk is highest during fires, more than 60% of firefighter SCD occurs across a variety of other duties" [25]. The cause of overexertion is difficult to identify because it is unique to each individual. The solution relies on early identification to prevent escalation. A health and safety standard already exists requiring fire departments to regularly record and collect vitals for firefighters, NFPA 1500 HS Standard, but financial means prohibit departments from enforcing the standard. A needs assessment conducted by NFPA in 2015 concluded that 73% of fire departments in the United States do not have a program to maintain basic firefighter health and fitness [44]. The desire for firefighting departments to address this problem arises alongside the quantified self movement. The tech health revolution catapulted wearable technologies like Fitbit onto the consumer stage resulting in numerous companies working on wearable biometric technologies for emergency response. Unlike previous technology advances in the fire service, biometric devices present an additional layer of complexity for emergency response because the device services the firefighter and the organization but not the citizens directly.

3.2 Wearable Device Description

The wearable IoT device in this study was being developed as a preventative tool to the problem of overexertion and stress for firefighters. The device collects and relays individual biometric information to a web-based data dashboard (i.e. Figure 1). The devices deployed in the field for this study comprised an electronics housing unit and incident commander (IC) application. The housing unit attaches directly to the left side of the firefighter's face mask on the universal self-contained breathing apparatus (SCBA) attachment point. The housing protects the electronics from the thermal dangers present in a fire. An earpiece, connected to the housing, rests inside the firefighters' ear and gathers biometric information including internal body temperature, heart rate, blood saturation levels, and respiratory rate. A personal fitness profile is linked to each device to increase the accuracy of the results similar to programming a treadmill before a workout routine. The dashboard displays 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 are calculated based on an algorithm created by the US Department of Defense. The data is stored and can be continually monitored to identify patterns or trends.

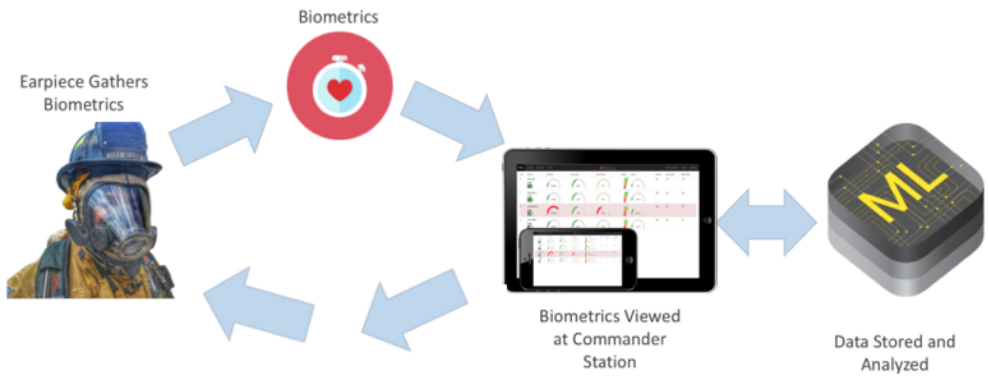

Figure 1 - Information Flow Process for Wearable Device

The original product development began 3 years ago and evolved into a start-up company after receiving funding in December 2016. Initially, the device was designed to increase visibility for firefighters through smoke screens to better identify their surroundings. The prototype incorporated a heads-up display (HUD) to project warnings and show vital signs on face masks during fire suppression. firefighters reportedly didn't have time to react to the information during fire suppression because their attention was solely focused on the task at hand. However, it this claim is also contradictory to the results expressed by other research groups investigating the application of VR/AR for firefighters [2, 3]. To lessen the level of required attention and interpretation, the prototype was adapted to display red, yellow, green indicators for vitals instead of actuals and a messaging application was enabled from the incident commander (IC) - the supervisor - to the firefighter using the HUD. Based on user feedback, the HUD was replaced entirely by a web-based data dashboard that was integrated for real time data tracking and reporting, accessible by the IC on the scene and captured for review later by the firefighter. Currently, the same functionality is being adapted into a wrist-based device to increase universality.

3.3 Device Usage in the Field

The departments selected for this study were the first two departments to agree to the long-term use of the devices. The organizational structure of each department was similar following a traditional pyramid hierarchical model based on years of service. One department is designated as a volunteer fire department, not responsible for providing emergency medical services (EMS), with 23 registered firefighters on the department roster. According to the National Fire Protection Agency (NFPA) classifications, it is a combination department because each shift the lead firefighter receives a minimal amount of money [23]. In contrast, the other department is a larger career department comprised of 16 different fire stations responsible for both EMS and fire services in the county.

There were 10 wearable IoT devices deployed in total with each of the fire departments having 5 at any given time. The device usage was rotated through different firefighters and trainees at both locations. There was a primary point of contact at each location who was responsible for the devices and oversaw their usage. Both points of contact held leadership roles and were involved in the training departments. Schedule availability allowed the volunteer department to use the devices more frequently than the career department.

During the course of this study, the devices were only used during training. Since the device attached to the face mask, users were wearing full gear including includes a helmet and face shield, gloves, mask, communications receiver, oxygen tank, coat, boots, fire hood, during training exercises. Firefighters had to complete an online profile prior to starting the exercise. A series of obstacles including ladder runs, hose drag, sledge hammers and crawling were set up as a part of routine training called job duty courses. The biometric device was used to monitor heart rate spikes during the course of the exercises. The supervisor was monitoring the results in real time on either a mobile phone or iPad. The results were used as a comparison or ranking tool for fitness levels across the user group. The results were briefly discussed at the end of each exercise, in a classroom setting, providing each individual with a glimpse of their performance.

3.4 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 being introduced to the department 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 participants had used the device at least once. The participants backgrounds and titles were varied along with their respective experience levels. The average fire experience was 15 years in the fire service. Participants from the volunteer department were either active or recently retired career firefighters in different counties; 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 biometric device. 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.

CHAPTER 4. FINDINGS

The 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*, *designing for end users*, and *situations of work*. 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.

4.1 Conflicts with Identity

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” [19]. 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 [30].

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. 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. We're going to do this. We're going to throw this to the window and it's going to put the fire out, 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*." There is a perception that technology might weaken or otherwise disrupt the iconic image of fighting fire.

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. 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. Smart technologies have to meet higher performance requirements in order to overcome the notion that "*We can do our job without technology*" P2.

Opportunity exists within recruit classes to shift firefighter identity. Current firefighters view incoming recruit classes as ill prepared to do the job. P1 describes the struggle as "*newer generations only having technology skills and not being able to adapt to the physical labor of our work.*" This is causing the fire service, like many other industries, to change their entire approach to training and recruiting. It is also forcing the fire service to modernize because they want to attract and retain new talent. For example, P3 says that "*If I take this 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*." P3 continues to describe this shift in culture, "*It's almost you break it down into the blue collar versus the white collar subset in the fire service now where it used to all be blue collar*." Traditionally technology in the fire service meant physical tools and materials, which aligned with blue-collar and came with certain preconceived notions of work and organizational culture [7]. Now technology refers to the digital - computers, iPads, cell phones - viewed as white collar work for leadership or "next generation" firefighters creating a barrier to entry for smart technologies.

4.2 Designing for End Users

Through practices of user centered design, the wearable device reinforces the traditional workplace culture found in firefighting. Explaining the decision to remove a heads-up display unit from an initial prototype, 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. The user feedback aligns with identity of "The Johnny Waynes."

The technologists responded to this feedback by creating a more passive technology for firefighters. P6 states "*They're not really going to care about it besides just putting it on. It automatically turns on when it's on their skin... 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."* While a passive technology may receive the approval of the firefighters, it removes personal accountability and deemphasizes the importance of health and safety.

Shifting away from firefighters as end users signals a change in the technology that aligns with the organizational structure and workplace culture. Current practices, in the field and during training, rely on experienced leaders making judgement calls based on physical appearance. It is the expressed job of leadership to place importance on protecting their crew. Leadership was excited for the technology because it enabled them to have an additional layer of accountability and justification for their decisions - underpinning 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.*" As instructed by a participant, 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 fu*n" 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 [31]. While firefighters would be wearing the device for their own well-being, the enforcement, tracking, and analysis falls on supervision; leadership becomes the end user which is exactly what Grudin warned against [20].

4.3 Situations of Work

The ultimate goal of the device is to become embedded as a part of firefighting culture, to be used on and off of the field. Fitting into the existing structure relegates device usage to the training environment. 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 for like recruits and then for crews when they're PT and to track, is my fitness working? Is what I'm doing, is it 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.

When transitioning to other contexts of use like real emergency response calls, participants were reluctant making statements like P8, "*We don't want to be the ones that go, "Oh man this is hot, we need to back out." It would be a way for chief that he could look and 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.*" In live fire scenarios 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 scenario is to act as watchdog, assuming responsibility for the safety of each firefighter as well as others on the scene. The IC remains sequestered onsite to extensively document each incident via iPad or laptop, giving the IC direct access to the data dashboard. Ultimately, the IC would instruct a firefighter to return to base if their data caused concern. The wearable device could actually prevent a firefighter from doing his job thus eroding the traditional identity of aggressive firefighting and changing the nature of work.

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. Participant conversations turned towards adding a new position to 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. 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. 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 in new workplace environments. Former technologies in the fire service could be measured based on time or cost savings, this wearable biometric device is successful when no lives are lost. Efficiency here means something altogether different.

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 states, "*As we move forward in the fire service, we begin to look for ways to take care of our employees."* Media like firefighter magazines are publishing research on the causes of firefighter deaths. However, as a health and safety advocate one participant states "*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. However, we must recognize the advantages and potential consequences that these technologies introduce by understanding organizational shifts and changes in workplace practices.

CHAPTER 5. DISCUSSION

The unique characteristics of fire departments highlight opportunities for design interventions. The challenge 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 safely and efficiently. A recent study found that wearables exposed firefighters to “unforeseen hazards” and displaced tribal knowledge used to “mitigate workplace risk” [7]. The case study documented the impact of two existing wearable PPE technologies. First, flash hoods, worn under helmets as an additional layer of thermal protection and second, low-air alarms, SCBA regulators vibrate when oxygen levels reach minimum capacity to notify firefighters that it is time to exit. They suggest that the future of smart-firefighting revolves around four critical areas: (1) data types, access, and privacy; (2) information overload and sensory deprivation; (3) trade-offs: trusting and learning systems and (4) organizational factors [7]. Our findings extend this work by documenting the implementation of a new smart wearable technology into fire departments.

As an example of emerging smart technology for firefighting, the wearable device observed in the field, keys into issues of information design, trust, and organizational factors. In our work, the first factor was not a present issue the firefighters were concerned about. Privacy and access are viewed as higher level organizational decisions – NFPA, FEMA etc. To our surprise, privacy concerns were not expressed even when directly asking participants. The device was discussed as a way to ensure the safety of firefighters in the field by reducing obesity internal to departments. When considering access to data, this is a concern expressed by Amidon et al. [7], because fitness data could be used negatively to reprimand firefighters. Participants in our study saw it as a mechanism to make departments stronger and safer. This could partially be attributed to the relative fitness levels of participants and our small sample size. Overall, participant focus was on the at-hand work of how the technology fit into fighting a fire, and less concerned with what might happen pre or post-incident.

5.1 Information Design and Shifting Users

The shift to leadership as end users of the device resulted from the streamlining of data visualization. The wearable device was initially designed to increase visibility for firefighters. A HUD projected warnings and vitals directly to firefighters on their face masks. 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. One of the roles of communication design is to "reduce the cognitive demands on firefighters" [5]. To lessen the information overload, the technologist adapted the prototype to display red, yellow, green indicators for vitals instead of actuals and a messaging application was enabled from the IC to the firefighter. Amidon et al. suggested a similar way of "black boxing" information to increase privacy and reduce cognitive load for firefighters [7]. The concern is that the design can reify institutional hierarchies if a complete understanding of the organization is not present. For example, firefighters continued to provide feedback that embodied the traditional workplace culture stressing their desire to focus on the physical aspects of work. The technologists took the user feedback by shifting where the information became visualized for action. Leadership became the end users reifying organizational hierarchies. In the end, the HUD was replaced entirely by the web-based data dashboard for command. 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.

The creation of more passive technologies is not necessarily a solution to the problem of information overload. Ubiquitous computing supports ideas of calm computing - moving smart technology to the background - but not all environments are suited towards these practices. Do we want these kinds of life-saving devices to blend into the background? Prior work investigating the application of VR/AR for firefighting did not experience the same resistance to data visualization [3]. The VR device was geared towards increasing situational awareness allowing firefighters to see through the fire. The technology aligned with current workplace practices placing value on time savings. Reiterating the importance of situating technology within the structure of the workplace.

5.2 Reliance on Technology

Technology for emergency response is subject to high performance expectations. Firefighters cannot afford to trust devices that do not deliver in the field. Furthermore, technological dependency reduces a firefighter's ability to be self-sufficient when in the heat of the moment. There is a reluctance to adopt new smart technologies because of concerns about reliability in firefighting. Skepticism of new technology is heightened because of past and current issues that affect performance. Like previously mentioned, when technology like GPS goes down "guys freeze up" P2. Being able to rely on technology is a pillar of trust. The relegation of the wearable device to only training environments is a key indicator that trust is missing. Additionally, the oversaturation of devices that claim to be for safety has weakened inherent trust in new products. Training is one mechanism that can restore user trust in health and safety devices.

The fire service relies on front-loaded training that contributes to a culture steeped in tradition. Growing organizational requirements and limited resources, stifle departments abilities to implement new training programs [9]. To realize the vision of smart-firefighting, training practices need to be revamped alongside the implementation of smart technologies. Training encompasses education programs as well. To prioritize health and safety firefighters need to be aware of causes of death related to job duties. A significant portion of the fire service is naïve to the health risks associated with their behavior. Another barrier that wearable devices have to contend with the exposure to individual fitness devices. Experience with FitBit and smart watches is helpful, but it also limits the use of wearable technology because the users only expect a device to do so much. Training programs will have to overcome these perceptions of use including generational derisions surrounding technology by reshaping user's technological frame [24]. Incorporating training throughout a firefighter's career will foster a culture of learning and innovation which is absent in the fire service today.

5.3 Organizational Factors

Organizational factors, including culture and structure, significantly influenced communication design decisions and levels of trust in smart technologies. Fire departments bring together highly trained individuals with diverse backgrounds. Each with their own preconceived notions of the culture of firefighting [5]. Firefighters are competing with the iconic image of heroism that weighs heavily on their identity and influences daily work practices. The experiences of large scale disasters revealed flaws of the widespread differences between departments and the willingness of firefighters to place their own lives on the line for others. The outcome led to new organizational practices including the implementation of the Incident Command System [38]. The IC position was added to combat firefighter's disregard for their own health and safety perpetuated by the culture. The result reinforces the hierarchical structure of fire departments and places the responsibility of health and safety on leadership. This relationship relegates technology to the leadership role as seen through the design process of the wearable device. Technology is entrenching the differences between blue-collar and white-collar work as discussed by Amidon et al. Identifying the prominent influence of workplace culture, we can anticipate that firefighter feedback will continue to reinforce this relationship. Smart technologies present an opportunity to bridge generational and hierarchical divides.

While the structures of fire departments are similar, the implementation varied based on the locality. The career department used the device during an ongoing training program for new rookie firefighters. Previous research supports that the younger generation may be more apt to use technological device. However, device usage at the career department was far less than the volunteer department. Meeting the schedule requirements of the training program made it difficult to introduce a new technology. The fire department was overwhelmed with the size of the class being one of their largest to fill gaps in the workforce. It is unclear how the fire service plans to introduce new smart technologies to the field because the organization is struggling to maintain the status quo [5].

One of the strengths of the volunteer department was its ability to make time for the technology. The volunteer department was more open and willing to try the device because they had considerable downtime on shifts since they respond to less calls than career departments. The cooperative atmosphere encouraged learning although resistance to technology use during live-fire response was still present. The added benefit is that the volunteer firefighters are able to take their experiences and disseminate them across their fulltime career departments. This informal mechanism of technology transfer supports the tight knit community of firefighting. Better cross communication between different department classifications – volunteer, career, combination – would encourage training practices and grow the brotherhood of firefighting. In particular, the diversity present across fire departments means that mandated one size fits all technology solutions may be insufficient. The consequences for smart technologies, particularly wearable devices, in the fire service effects the nature of decision making that translates across organizational hierarchies challenging identity management and changing the social and material arrangement of the organizational structure.

CHAPTER 6. CONCLUSION

The study presented here highlights a number of challenges facing smart technologies and the new categories of organizations that wish to implement these types of 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 and acts as a reminder of the complexities of practice theory and the relationships that enact change in the workplace.

It is understood that practice theory is the analysis and understanding of the "emergent constitution of the sociomaterial world through the micro-dynamics of everyday life in organizations" [16]. Taking this perspective entails that observing technology in practice must continue to be situated within the practical landscape of organizations. And while the structure of organizations is an ongoing process of change related to people, objects, and processes, magnified by the global market, the contexts of work are expanding to include entirely new environments. For successful implementation to occur, we must take into consideration all the complexities of the organizational environment.

Physical labor introduces new ideas about how the sociotechnical relationship interacts with organizational practices. From training to work in dangerous and high-stress environments, smart technology can extend or limit the ability of an employee. Prior work in organizational studies has been focused on the "safety" of office work, so models of change and adoption need to be reevaluated. A clear understanding of the impact of these new types of smart devices in differing workplace setting is necessary and will orient training and education programs for the next generation workforce.

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