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Voices of First Responders: How to Facilitate Adoption and Usage of Communication Technology

An Integrated Analysis of Qualitative and Quantitative Findings

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Voices of First Responders Series

This report is a part of a series of publications amplifying the voices of first responders (VoFR) in four public safety disciplines: Communication Center & 9-1-1 Services (COMMS); Emergency Medical Services (EMS); Fire Service (FF); and Law Enforcement (LE). The VoFR series reports on the experiences of first responders with communication technology, including their needs for, and problems with, communication technology. Publications in this series are primarily intended for designers, developers, vendors, and researchers of public safety communication technology, as well as for public safety administrators and decision-makers.

Published as a part of the VoFR series include NIST reports, conference papers, presentations, posters, articles and blog posts, a book chapter, and a web tool for disseminating the research results and data collected from the interviews with and survey of first responders. The reports from which all published materials are derived are listed below and can be accessed from the *PSCR User Interface/ User Experience Publications* webpage at: https://www.nist.gov/ctl/pscr/user-interface-user-experience-publications. The *PSCR Usability Results Tool*, providing access to results of the large-scale survey and in-depth interviews with first responders across the U.S. about their communication technology use, can be accessed via https://publicsafety.nist.gov/. The datasets from this research project are available via https://doi.org/10.18434/mds2-2820.

Voices of First Responders

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Phase 1: Findings from User-Centered Interviews

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Phase 2: Nationwide Survey

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- ❖ Volume 4 - *Statistical Analysis Results* (NISTIR 8444) https://doi.org/10.6028/NIST.IR.8444

Abstract

The Nationwide Public Safety Broadband Network (NPSBN) is being developed to provide a dedicated network for the use of first responders during incident response. A wave of new communication technologies compatible with the NPSBN is on the horizon, as major research and development efforts continue for these technologies. The National Institute of Standards and Technology's (NIST) Public Safety Communications Research (PSCR) Usability Team investigated the contexts in which first responders work, their experiences with incident response, and their problems with and needs for communication technology. The team conducted an exploratory, sequential, mixed-methods study to gather insights into the experiences and needs of first responders. The multi-phase study included in-depth interviews with 193 first responders in Phase 1, followed by a nationwide survey of 7 182 first responders in Phase 2. This report is the tenth volume published from this data and provides a holistic understanding of the usability of communication technology for first responders. It is unique in that it combines results from both Phase 1 and Phase 2 providing an integrated analysis of both the qualitative and quantitative data. This integration allowed us to develop overarching themes about the problems and needs of first responders, focusing specifically on the barriers and facilitators to the adoption and use of communication technology. In this report, we discuss how adoption and use of communication technology is impacted by first responders' experiences across three themes: technology trustworthiness, user autonomy, and frustration. Overarchingly, there is a lack of technology trustworthiness combined with low autonomy that often results in frustration for first responders. The development of trustworthy technology takes time and relies on first responders knowing that their input and experiences matter (i.e., having autonomy). The lack of trustworthiness and autonomy has an impact on the acceptance and adoption of new technology and the ability of first responders to accomplish their primary tasks. This work can be useful for the researchers, designers, and developers (R&D) community as it works to improve current and develop future communication technology for first responders. It can also aid administrators and decision makers (ADMs) in making purchasing decisions and developing policies related to communication technology for first responders in their departments.

Keywords

Audience

This report is primarily intended for designers, developers, vendors, researchers, and public safety administrators of public safety communication technology.

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1.　　Introduction

The Nationwide Public Safety Broadband Network (NPSBN) is being developed out of the United States Middle Class Tax Relief and Jobs Creation Act of 2012 [10] to provide a high-speed infrastructure for public safety communication. The development of the NPSBN provides a unique opportunity to improve public safety communication technology. However, if such advancements are to be successful, the technology must be usable for first responders to achieve their goals and missions with effectiveness, efficiency, and satisfaction in their specified contexts of use [9]. The challenge for developers and designers of communication technology for public safety is truly understanding first responder contexts of use, along with their current and future technology needs and requirements. This is no easy task given the variability within the first responder population. For example, there are differences across first responder disciplines— Communication (Comm) Center & 9-1-1 Services (COMMS), Emergency Medical Services (EMS), Fire Service (FF), and Law Enforcement (LE)—in the types of tools they use and the purposes of those tools. There are also differences in needs for and problems experienced with communication technology based on where first responders are located, for example in rural, suburban, or urban contexts, in addition to differences in geography and topography. Thus, it is crucial to understand the various public safety user groups and the communication technology they currently use, the problems they experience with current technology, and the technology they believe would be most helpful for the future.

In part to address the goals of the NPSBN, existing and emerging communication technology for public safety is being researched and developed. The National Institute of Standards and Technology (NIST) Public Safety Communications Research (PSCR) program [12] is leading a coordinated, multidisciplinary research effort to facilitate the transition from existing disparate Land Mobile Radio (LMR) networks to NPSBN with the ability to run Long-Term Evolution (LTE) solutions. To provide a greater understanding of users' experiences with and needs for communication technology, the PSCR Usability Team conducted a multi-phase, exploratory, sequential mixed methods study. The goal was to explore communication technology from the perspective of first responders by engaging directly with users (COMMS, EMS, FF, and LE) to understand their experience with communication technology. Ultimately, this multi-phase project sought to discover and provide direct input from first responders about what technology they need to communicate efficiently, effectively, and with user satisfaction.

This project investigates the beliefs, behaviors, and experiences of first responders related to communication technology in order to improve the user experience. Phase 1 of the project was a qualitative exploration of first responders and their contexts of work. It included interviews with 193 first responders across the country, from all four disciplines. Phase 2 was a quantitative nationwide survey that focused on what technology first responders have and use, along with the needs and problems they experience with their communication technology. There were 7 182 responses to the survey. Results from both phases demonstrate that first responders often experience problems with the tools and technologies they currently use for communication. These technologies do not always meet their needs or function as needed in their various contexts of use.

We have published five reports from Phase 1 ([1], [2], [4], [7], [14]) and four reports from Phase 2 ([5], [6], [8], [11]), in which we detail communication technology problems and needs as well

as provide user-centered guidelines based on these findings. This report is unique as it combines results from both phases, providing an integrated analysis of both the qualitative and quantitative data. This integration allows us to examine overarching themes about the problems and needs of first responders, focusing specifically on the barriers and facilitators to the adoption and use of communication technology. In this report, we discuss how the three themes of trustworthiness, autonomy, and frustration are important components in the use and adoption of improved and emergent communication technology.

Technology should not be developed, purchased, or utilized in a vacuum. Before designing, developing, or purchasing new technology, first responder input should be considered — their voices should drive efforts to improve new and existing technology. The results presented here can help technology designers, developers, and researchers to understand and incorporate the experiences of first responders into new and existing technology designed for them. The results can also be useful for administrators and decision makers in public safety as they consider how best to purchase, develop policies for, and implement adoption strategies for first responder communication technology.

2. Study Design and Methods

This study used a sequential, exploratory, mixed methods design [3] with two phases for an in-depth examination of first responders, their work environment, their tasks, and their communication needs. Both phases of the study were approved by NIST's Research Protections Office. All data were collected anonymously. Full methodological details related to study design, data collection, and data analysis can be found in relevant reports for the in-depth interviews [1] and for the survey [8].

For Phase 1 of the study, we designed an interview protocol to explore first responder experiences with communication technology and identified their needs and problems related to this technology. We conducted 193 qualitative interviews with first responders from all four disciplines across the United States, including rural, suburban, and urban areas. We used the results from the interviews to design a survey to be sent to first responders nationwide during Phase 2. We received 7 182 completed survey responses from first responders in all four disciplines. Responses came from all 50 states and the District of Columbia (D.C.) and from urban, suburban, and rural areas. The use of a large-scale, nationwide survey provided for greater representation from more first responders across the country. This allowed for the ability to confirm, clarify, and expand on the findings from Phase 1 of the study. The two phases complemented each other, providing a holistic view of first responders and their experiences related to communication technology. Additional details on the sample and participants for both phases can be found in previous reports ([1], [8]).

Integration has been an important component of the study, bringing together qualitative and quantitative components and approaches to produce a greater understanding of first responder experiences with communication technology. Integration occurred at the design phase through the use of a sequential, exploratory, mixed methods design. Integration also took place during data collection, where results from Phase 1 informed the development of the instrument used in Phase 2. Additionally, integration occurred during analysis when qualitative and quantitative results were examined for points of convergence and divergence. Similarly, findings were

integrated during the process of interpretation in the development of an integrated display of the findings. Figure 1 shows the integrated research design and process.
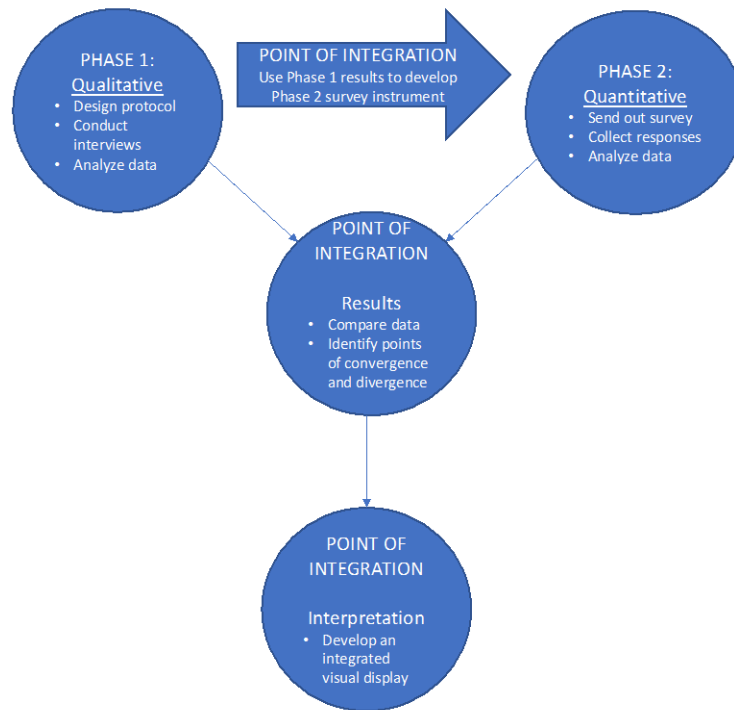
Fig. 1. Integrated Research Design.

2.1.   Phase 1 and Phase 2 Data Integration and Analysis

Once all qualitative and quantitative data were analyzed, the results from the two forms of data were integrated via mixed methods data analysis [3]. This integration involved examining the crossover between the qualitative and quantitative results to determine if and where they were congruent or divergent. This type of mixed methods data analysis allowed the team to make inferences from both the qualitative and quantitative data as well as meta-inferences that cut across both datasets [15].

The goal of integration in mixed methods is to intentionally bring together qualitative and quantitative approaches to provide greater understanding of the data. As previously noted, integration took place at several junctures during the study, from the design through the reporting stages (see Fig. 1 above). At the level of analysis and interpretation, integration occurred as the team reviewed the results from qualitative and quantitative analyses for relationships that were supported by both sets of data. This included thematic, negative case, values, and descriptive exploration of the data and the codes. Team members used analytic memoing to document initial and developing ideas of the relationships and themes. From the analytic memoing, we moved into developing a model of the integrated results. The model captures essential elements that crosscut the full datasets related to barriers and facilitators to the adoption and use of communication technology for first responders.

3.   Results

Three interconnected themes emerged during the integrated analysis of Phase 1 qualitative data and Phase 2 quantitative data: 1) the importance of trustworthiness; 2) the need for autonomy; and 3) the experience of frustration.

When we use the term trustworthiness, we are referring to the trustworthiness of the technology, or its ability to function as intended and when needed. There are certainly other facets of trustworthiness and other components of trust, however, in this report we focus specifically on the trustworthiness of the technology and not on a broader examination of the role of trust for first responders in their context of work (see previous reports, e.g., [1], for a more focused analysis of trust found within the data). Autonomy refers to the control that first responders have over the use and adoption of technology in their work. Frustration is the irritation, annoyance, or dissatisfaction felt when technology gets in the way of first responders being able to accomplish tasks. It is the presence of trustworthiness and autonomy that are important for the successful adoption and use of communication technology by first responders, while minimizing frustration with technology is important for enhanced user satisfaction.

Table 1 below shows how we operationalized the three themes in examining the interview and survey data. Included with the operationalizations are inclusion and exclusion criteria that aided in consistency of understanding and application of the themes. We used these operationalizations to explore the data and ask questions about interrelationships between data sources in support of each theme. For example, in examining the data, we asked ourselves why so many first responders said they "have, but do not use" a particular form of technology, and if/how that frequency of use might be related to both the problems they listed about it and how trustworthy they find it.

Table 1. Operationalization of three major themes.

THEME	OPERATIONALIZATION	INCLUSION	EXCLUSION
Trustworthiness	Technologies that perform as expected and when required, including things such as accuracy, availability, reliability, security, durability, and safety	Attributes of different forms of technology that cause human users to place trust in them because they function as expected and when needed	Not about the trustworthiness of people or policies, but about the devices/technologies themselves
Autonomy	A sense of control and independence over the situation, technology, and/or information; the experience of acting from personal choice rather than from external pressures	Evidence of decision-making capacity; ability to take action, provide input, or problem solve	Something that is out of an individual's control but still has an impact on their ability to achieve a goal (for example: weather causing a COMMS Center to go down)
Frustration	An expression or reaction of annoyance, irritation, or dissatisfaction, due to the inability to achieve a desired outcome	Explicit and/or implicit evidence of a negative emotion or reaction when unable to obtain satisfaction when engaging in a task	Evidence of unrelated emotions or reactions, such as descriptions of how much they love their job or references to challenges that aren't necessarily related to technology, like the weather

The three themes interact in different ways, and all three are important in the adoption and use of improved and emerging communication technology for first responders. The model below (Fig. 2) shows the relationships amongst them and the ways in which these relationships can produce positive or negative outcomes related to the first responder user experience with communication technology. For example, a trustworthy device can allow users greater autonomy in control and use of that technology; a trustworthy device reduces user frustration, while a device that is not seen as trustworthy can increase user frustration.
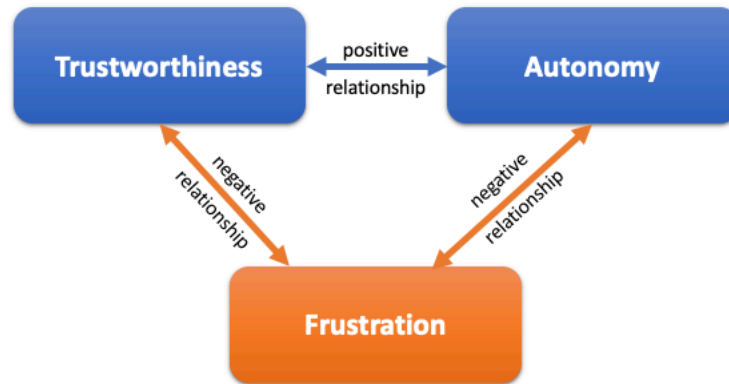
Fig. 2. Relationships of Three Integrated Themes.

In the sub-sections below, we explore each of the themes independently, presenting data that highlight their importance. The section ends with a sub-section that demonstrates the interactions of the three themes and the ways in which they are interconnected.

Throughout this report, we present quotes that serve as strong exemplars of key concepts and ideas found across the data, support the analysis, and highlight the themes. When qualitative data are presented, a notation is included at the end of the quote. This notation represents a particular interview or open-ended survey response. It is composed of four parts: 1) the phase the data is from (INT=Phase 1 interviews; SUR=Phase 2 open-ended survey responses); 2) the discipline of the response (COMMS, EMS, FF, LE); 3) the area in which the respondent works (U=Urban; S=Suburban; R=Rural); and 4) the interview or record ID number. The interview notations are separated by hyphens, while the open-ended survey responses are separated by colons. For example, (SUR:FF:U:1234) represents an open-ended survey response for record ID #1234, from a fire service respondent in an urban area and (INT-LE-R-009) refers to an interview, with a law enforcement participant from a rural location, who is interview participant #009. This notation system provides assurances to the reader of the data's provenance and that the data can quickly and easily be located within the entire data from both phases when necessary.

3.1. The Importance of Trustworthiness

In this report, we use the term trustworthiness to refer to technologies that perform as expected and when required, including things such as accuracy, availability, reliability, security, durability, and safety. In the world of public safety, trustworthiness is a critical characteristic of communication technology, especially in its relation to adoption and usage. When there is a lack

of trustworthiness in a technology, there is often a lack of usage. An EMS interview participant put it very succinctly.

> I mean, the big thing is everything we use, I mean, we don't have time to mess with it, or tweak it, or play with it. It has to work the first time, every time, or people will just to stop using it. They will just refuse to use it and go back to the old way of talking on the radio. (INT-EMS-U-003)

This quote, exemplary of many in the qualitative data, demonstrates the importance of having communication technology that is trustworthy and reliable. Likewise, first responders need technology that is trustworthy and works well within their specific contexts of use.

> Simply having to use my cell phone for a reliable connection. They work better than our radios. (SUR:EMS:S:3987)

> So there's technology that isn't good, or that we don't understand the use for it. It doesn't make our job easier. The goal is safety, but it doesn't really seem to make it safer. (INT-EMS-S-014)

The technology that first responders are asked to use must be both useful for their day-to-day tasks and usable within their contexts of work if first responders are going to perceive it as trustworthy.

On the other hand, trust in technology is eroded when first responders experience problems with their technology. A major barrier to the perception of communication technology as trustworthy is the consistency of the problems that first responders experience with this technology. In the interviews, the code of "problems with technology" was applied to 1 486 different chunks of data. This is the code which had the most data associated with it, highlighting its importance across the Phase 1 data ([1], [4]). Similarly, open-ended survey responses often spoke about the problems associated with technology ([5], [6]). Across both phases, first responders discussed a variety of problems, especially with reliability, usability, interoperability, and cost of communication technology.

When first responders experience problems with their technology, and these problems get in the way of their ability to accomplish primary tasks, it can result in the technology being seen as not trustworthy.

> Our technology at my agency is a joke. It often doesn't work right, and most of my day is spent dealing with crappy I.T. equipment/programs/problems. I accept that technology is an increasing part of my job as a paramedic, but it suffers from poor design & interferes with my patient care. (SUR:EMS:U:3939)

> During a major event, sometimes you cannot depend on technology due to systems being disrupted or overloaded. What we had to [do], it was use non-technical procedures for communications… (SUR:FF:U:9620)

When technology is not seen as trustworthy, first responders may decide not to use particular tools or revert to using "non-technical" tools or workarounds to accomplish their goals.

Similarly, quantitative data from the Phase 2 survey show that most first responders experience problems at least some of the time with their communication technology ([5], [6]). The pervasiveness of these problems may contribute to first responders' lack of trust in the

technology. While not all devices were reported as having problems all the time, problems that occur at some times but not at others may result in even more of a burden for first responders. Technology that only works on occasion is potentially dangerous because the user never knows when it will fail.

> Our portable radios will not get out on most every call we answer. I've told administration many times this will get an officer hurt or killed one day. We are told we do not have the money to update to radios that work. (SUR:LE:R:7589)

As the response above alludes to, untrustworthy coverage during incident response is a major concern for first responders.

While both phases had many examples of situations where technology was not preferred or used due to problems, in the case of personal versus work-issued smartphones there was an interesting example of first responders deciding to use a device due to perceived benefits and lack of problems ([5], [6]). Table 2 shows the overall usage (response options "Use a lot" and "Use occasionally" combined) of smartphones, both personal and work-issued, by discipline.

Table 2. Survey respondents who use smartphones.

	Personal	Work-issued
COMMS	72.24 %	40.91 %
EMS	89.50 %	32.76 %
FF	87.63 %	45.88 %
LE	79.90 %	60.98 %

Across disciplines, nearly two times the number of survey respondents said they use personal smartphones (82.26 %) rather than work-issued smartphones (47.56 %). While some of the difference in usage is due to the fact that not all first responders have access to work-issued smartphones, the qualitative data show that many use their personal smartphones because they are found to be more trustworthy than other work-issued forms of technology.

> So on the squad, our systems are so dated. So Google Maps doesn't really work and they're not precise, so we rely a lot on our phones. So a lot of firefighters-- if I'm driving the squad I'll have the person behind me go, 'Can you map this out and tell me directions over the headsets?' (INT-FF-U-011)

> Our personal smartphones with a software we personally pay for is the most efficient way to receive 911 dispatches, turn by turn directions, and hydrant locations. Work provided means are outdated and lacking. (SUR:FF:S:3765)

For many first responders, using personal smartphones is better than using work-issued devices because they are often more trustworthy. First responders want technology that is trustworthy and works well within their contexts of use.

3.2. The Need for Autonomy

First responders have access to a variety of different forms of communication technology which serve as important tools to facilitate their work. However, many of the first responders who participated in one or both phases of this study articulated ways in which they had little autonomy over the adoption and use of this technology. Autonomy is about the ability to have

control and independence over what technology to use, when to use it, and for what purpose. This lack of autonomy can be due to a variety of factors, including cost, policies governing usage, and/or limited or difficult usability, among others.

An important characteristic of first responder work is the fluid and varied nature of it. Many first responders in both phases of the study spoke about the dynamic nature of their work.

> So that's the thing with being a police officer. You never know really what to expect the day that you go to work. (INT-LE-U-025)

Many also noted how the unpredictable nature of their work meant that communication was especially important—before, during, and after incident response. This makes it even more important for them to have autonomy over the technology they use for communication, since they know best what will work in their specific context of use ([1], [5], [6]).

> And then if you're in that high rise or wherever you are, and you find you don't have coverage, somebody basically has to walk back out to find coverage, use a cellphone, or pick up a landline phone to communicate what they need, if they need help or whatever. (INT-FF-S-040)

As noted by the interview participant above, a first responder often must make decisions about which device will work best in their specific context of use, decisions that often have to be made very quickly. This is one reason it is imperative that first responders have autonomy over the technology they use.

Sometimes, when there is a lack of autonomy, first responders may decide not to use particular tools. An EMS interview participant spoke about how policies sometimes make it difficult to use technology, creating a lack of autonomy.

> Although we have access to a sort of an enterprise level messaging system, it's locked down so tight by IT that it's essentially unusable. So nobody uses it. (INT-EMS-U-003)

The "choice" to use, or not use, particular devices is one way that first responders exert their autonomy over their use of communication technology for their work.

Another example is the use of personal smartphones versus work-issued devices, as discussed in the previous section. Often, first responders choose to use their personal smartphone over other work-issued devices because they provide more autonomy to do what they want, when they want it.

> I use my personal smartphone every day and more often than all the other electronic devices provide to me by the department. It maps better than the Engine laptop/MDT and I can always get CAD info and communicate with someone on it. (SUR:FF:S:5590)

In this case, the work-issued device did provide a mapping function. However, it did not map as well as the participant's personal smartphone, which also worked better overall for their needs.

Even when first responders are discouraged from using their personal smartphones, or when there are policies that prohibit their use, some first responders continue to use them, recognizing that the benefits outweigh the problems.

> The complete irony is that everyone tells you that using your personal cell phone is
> the worst possible idea; however, everybody uses their personal cell phone once
> every 10 minutes in law enforcement. It's a complete joke from the city legal
> department, the administration, all the way down to Prosecutor's are all hitting you on
> your cell phone all the time and yet telling you that it's going to be your downfall.
> (SUR:LE:U:3472)

First responders often recognize the issues that using their personal smartphones present, from possible subpoenas to no financial support ([1], [5]). Their continued use of these devices, which they often recognize as better than other technology they have, is another way they exert autonomy over their work and the technology used to accomplish it.

Another way in which first responders face a lack of autonomy connected to the technology they are asked to adopt and use is related to control over purchasing decisions.

> They're trying to make it better. They keep improving, and that's fine. But we're also
> governed by lowest bidder and other restrictions that prevent you from just getting
> what you want. You may have to get-- well, this vendor has this, this and this. They're
> an approved vendor. And that's what you get. (INT-FF-U-012)
>
> Due to me having to purchase my own earpieces, I typically go with a cheaper option
> which results in lower quality. Therefore, I have frequently had issues with the
> earpiece randomly failing mid-shift. (SUR:LE:S:410)

Often, first responders are asked to use technology that they believe is less than optimal. Sometimes this is due to purchasing policies that do not support autonomy on the part of first responders. For example, this may be due to policies that regulate the use of particular vendors or a "one size fits all" mentality on the part of vendors that does not take into account the varied and dynamic nature of first responder work [1]. Other times it may be purchasing policies that require first responders to purchase their own technology, such as earpieces and microphones ([1], [6]). In these cases, first responders often resort to purchasing lower quality technology in order to minimize their personal costs.

Autonomy, like trustworthiness, is important to first responders who know what technology is likely to work best in their context of use. Once again, the data gathered demonstrate that first responders just want some say in technology they are asked to adopt and use.

3.3. The Experience of Frustration

Across both phases of this study, first responders expressed frustration with their technology. For this study, frustration was defined as an expression or reaction of annoyance, irritation, or dissatisfaction, due to the inability to achieve a desired outcome. Frustration with technology may cause first responders to question the utility and benefits of technology that does not actually help them achieve their primary tasks.

In the Phase 1 data, the code of "frustration" was applied to 412 different chunks of data across all public safety disciplines. As previously noted, the code of "problems with technology" also appeared across the Phase 1 data. These two codes often co-occurred, as in the following exemplar.

> [speaking about how forms do not auto-fill]…it's frustrating and especially when they're trying to get us to finish our reports and get back to the service from the hospital as quickly as possible. It's like they [administration] want us to get all this done real quick, but they don't want to provide us the tools or can have them configured so that we can do it quickly. (INT-EMS-U-017)

Additionally, qualitative data from Phase 2 also highlight the ways in which first responders experience frustration with their communication technology.

> Our mapping software sucks, so does our CAD system. Way to outdated and frustrating. The single biggest frustration dealing with technology is dealing with our IT department. (SUR:FF:U:6501)

> We have peaks where there are higher call volume times and during those moments it can feel overwhelming and frustrating….It would be helpful if all cellular providers sent over accurate locations on a regular basis. (SUR:COMMS:U:3211)

First responders experience frustration when devices, applications, and/or support systems do not function effectively and/or efficiently, which often results in a lack of necessary and accurate information.

First responders want technology that is easy to learn, easy to use, and saves them time ([1], [6]), and they question the utility of technology that do not meet these criteria. Often, frustration was expressed when technology was not seen to save time, or it was difficult to use or manage.

> So it becomes a-- technology becomes a huge time suck and I mean, I just keep saying over and over the promise of technology is awesome but that actual performance is so much less most of the time… I mean, I waste as much time as my technology saves me every day, I think. (INT-EMS-R-008)

> In my opinion, technology should make life easier, not harder. Right? And if the radio doesn't do anything other than just add more weight to your belt—with these new radios, I'm not accessing any new channels that I didn't have privilege for. (INT-LE-U-003)

Frustration is often the result when first responders believe that technology does not provide any value added, when it is just technology for technology's sake [1].

Frustration was also evident when the technology first responders have access to in their personal lives works better than what they have access to at work.

> She [my daughter] goes to a computer and she types in Find My Phone and it pings the GPS signal off of her phone, and she goes, and she finds it underneath the couch or it's on the bus at school or what have you…if everybody in the globe has the technology to find their phone, why can't they find me based on my radio? (INT-FF-U-002)

> I mean, if the regular person running an errand, and then an Uber has to find an address quickly and can do it accurately, then you'd think that it'd be quite important for the ambulances to be able to do that. You can be detailed to an area you're not

> familiar with…So if the average person would do it, it seems crazy that the ambulances don't have it yet, but they don't. (INT-EMS-U-011)

Similarly, some first responders noted they often felt they were behind the private sector in access to the best technology.

> Well, I think in general, law enforcement's always been way behind the curve in terms of technology because we're government. We're lowest-bidder type of government, so the stuff we have is the cheapest. It's usually decades old. (INT-LE-U-003)

Sometimes this sense of being "behind" is due to policies that limit access to and use of devices and/or apps, to purchasing policies and/or mandates, or to cost issues. Although first responders know that existing technology could benefit them, they do not always believe that the technology they are told to adopt and use is what they need in their specific contexts of use. Ultimately, this leads to the experience of frustration as a common and unintended consequence of using communication technology.

3.4. Three Inter-related Themes

In this analysis, we use both narrative and a joint visual display (see Fig. 3 below) as tools for the presentation of results. The joint visual display is a figure that succinctly shows the relationships amongst the three themes. It provides an overarching statement about the relationship between each pair of themes as well as qualitative and quantitative exemplars from the data for each of them. In this way, support for the relationships amongst the themes is highlighted in a single visual representation of the data. Figure 3 below shows how trustworthiness, autonomy, and frustration interact. The narrative allows us to provide a more comprehensive presentation of data supporting the three themes and how they are related.

The relationships amongst these three themes are bidirectional and operate as feedback loops. In addition, these relationships can produce positive or negative outcomes related to the first responder user experience with communication technology. When first responders frequently experience problems with the technology they are expected to use, they become frustrated and come to doubt its trustworthiness. Similarly, when first responders' autonomy in using technology is impeded, trust in that technology is also eroded and frustration is increased. As first responders continue to experience problems with technology, this feedback cycle continues, undermining autonomy, decreasing the perception of trustworthiness, and increasing frustration with technology.

To address this cycle, it is important to address all three themes in conjunction with each other. There is a danger in only addressing one of the themes, rather than recognizing the ways in which these issues intersect. Only focusing on frustration, for example, without addressing the lack of trustworthiness and/or autonomy that contribute to it, may well undermine trustworthiness and autonomy even more. Evidence for these interactions is found in many places in the data. However, in this section, we focus on two specific areas: 1) the cost of technology and 2) the development and use of current versus future technology.
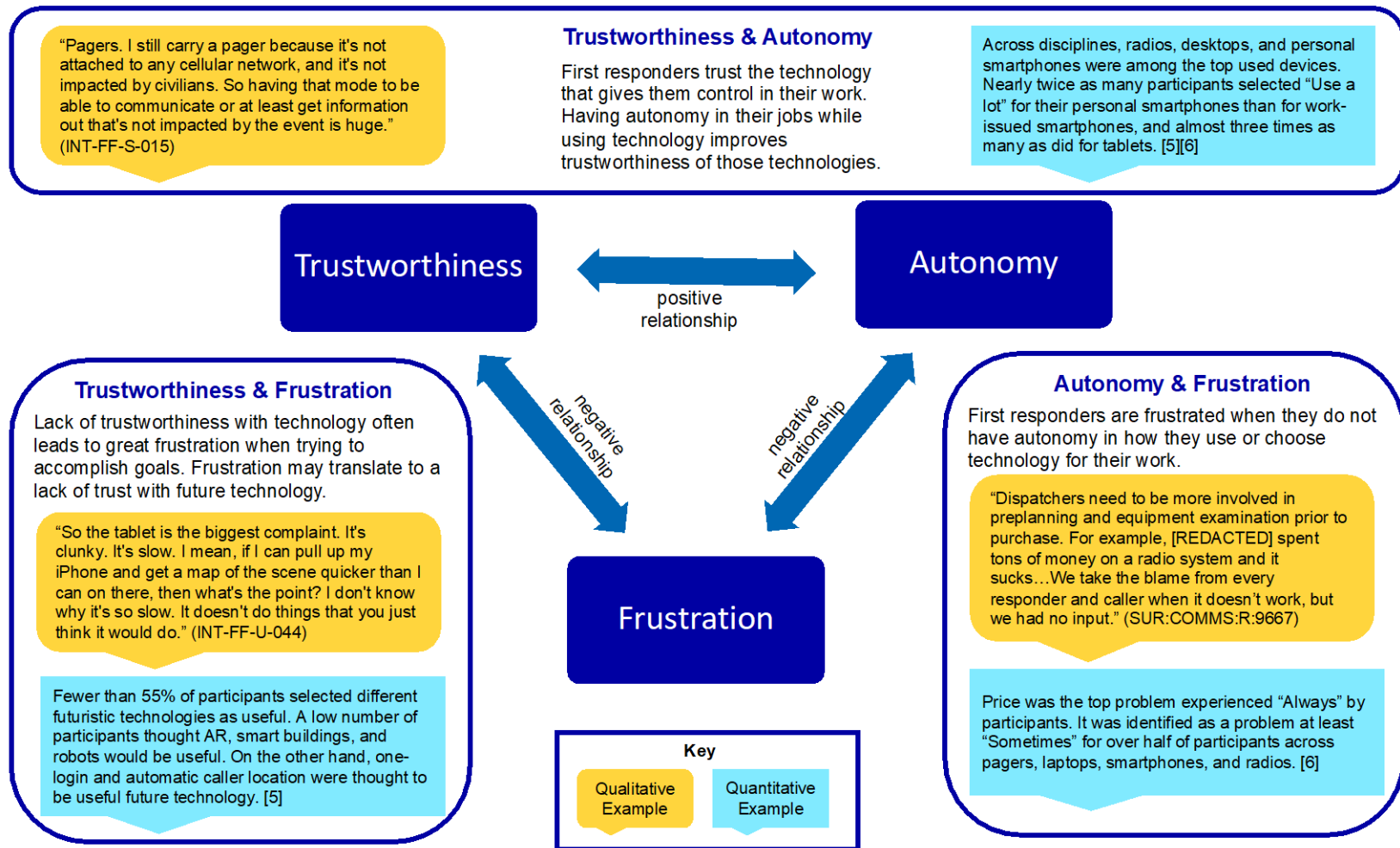
Trustworthiness & Autonomy

First responders trust the technology that gives them control in their work. Having autonomy in their jobs while using technology improves trustworthiness of those technologies.

"Pagers. I still carry a pager because it's not attached to any cellular network, and it's not impacted by civilians. So having that mode to be able to communicate or at least get information out that's not impacted by the event is huge." (INT-FF-S-015)

Across disciplines, radios, desktops, and personal smartphones were among the top used devices. Nearly twice as many participants selected "Use a lot" for their personal smartphones than for work-issued smartphones, and almost three times as many as did for tablets. [5][6]

Trustworthiness

positive relationship

Autonomy

negative relationship

negative relationship

Trustworthiness & Frustration

Lack of trustworthiness with technology often leads to great frustration when trying to accomplish goals. Frustration may translate to a lack of trust with future technology.

"So the tablet is the biggest complaint. It's clunky. It's slow. I mean, if I can pull up my iPhone and get a map of the scene quicker than I can on there, then what's the point? I don't know why it's so slow. It doesn't do things that you just think it would do." (INT-FF-U-044)

Fewer than 55% of participants selected different futuristic technologies as useful. A low number of participants thought AR, smart buildings, and robots would be useful. On the other hand, one-login and automatic caller location were thought to be useful future technology. [5]

Frustration

Autonomy & Frustration

First responders are frustrated when they do not have autonomy in how they use or choose technology for their work.

"Dispatchers need to be more involved in preplanning and equipment examination prior to purchase. For example, [REDACTED] spent tons of money on a radio system and it sucks…We take the blame from every responder and caller when it doesn't work, but we had no input." (SUR:COMMS:R:9667)

Price was the top problem experienced "Always" by participants. It was identified as a problem at least "Sometimes" for over half of participants across pagers, laptops, smartphones, and radios. [6]

Key

Qualitative Example	Quantitative Example

Fig. 3. Joint Visual Display of Integrated Results.

3.4.1. The Impact of Cost on Trustworthiness, Autonomy, and Frustration

In the Phase 2 survey, participants (from EMS, FF, and LE) were asked about problems they experienced with technology they currently have. Although first responders experience many problems with their devices, price is the most frequently experienced problem and is a concern across devices, as well as across disciplines. It was identified as a problem at least "Sometimes" for over half of the participants across disciplines for radios, smartphones, pagers, and laptops. Of the problems categories, problems with price also had the highest rates of occurring "Always." Rates of experiencing price problems at least "Sometimes" are displayed in Fig. 4 below in descending order EMS, FF, and LE.
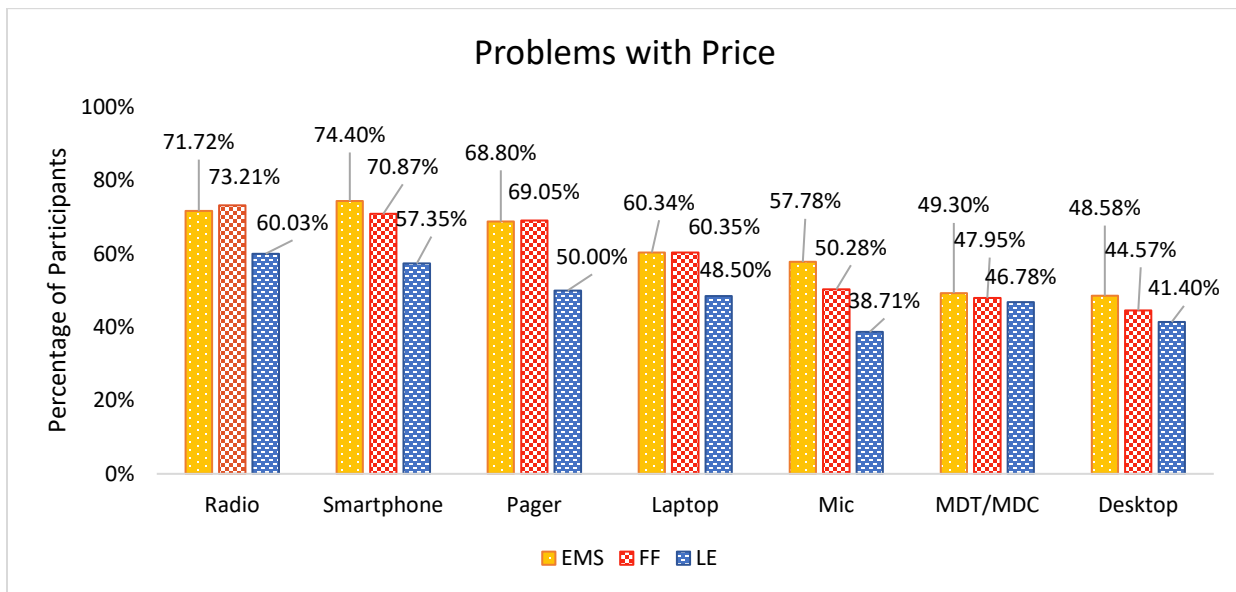

Fig. 4. Price problems by discipline and device for EMS, FF, and LE.

Additionally, in the final open-ended response section participants could share any additional information. Data from this question show that *Cost-Budget-Funding* was the top category of response across all four disciplines— something which shows up consistently in all of the data for this study.

Qualitative data from both phases of the study also highlight first responder concerns about the high cost of communication technology, and how this cost can serve as a barrier to their ability to access the best technology for their needs.

> A lot of technological solutions exist in the current fire service if you can pay for them. And I say this as you don't have to pay for them. So a lot of times, a lot of the technology needs - before I get to the pie in the sky - of most American fire service members is just the state-of-the-art stuff that whatever company is already making. Just it costs 10 grand a member, and they're not going to buy it, right? They have things like thermal imaging cameras that can check heat. Well, they make them now where it can be embedded within your SCBA mask, so you don't have to carry a

> camera. It's like Terminator vision, right? So those kinds of things actually do exist. They're just incredibly cost prohibitive. (INT-FF-U-012)
>
> More compact devices, many are still large and heavy making them [difficult to use]. The cost is also a major factor, there is so many devices that could help speed up the definite care of the sick and injured, but the cost is more than many agencies can afford. (SUR:EMS:S:8480)

Cost problems illustrate that first responders experience a lack of autonomy in deciding what technology is purchased for their use. The cost of technology is outside the control of first responders, and they generally have little say in what their budget is and how that budget will be allocated. As many participants noted, keeping up with ever-changing technology is more than just the cost of the initial investment. Things like maintenance, IT support, and upgrades can also make technology costs prohibitive for first responders.

> The inability to keep up with radio technology because of the cost due to the financial situation of our village to provide an adequate budget to update our portables and squad car radios. (SUR:LE:S:8148)
>
> Technology is very expensive. You don't just buy it and you're good. You've got to maintain it… You've got to upgrade it. (INT-EMS-R-008)

Many first responders recognize there is current technology available that might be more suitable in helping them address their primary tasks, however they do not have access to this technology due to its high cost. One consequence of the lack of autonomy in purchasing technology is that first responders become frustrated with the technology they have and with budgets that constrain their ability to accomplish their tasks effectively and efficiently (not to mention safely). Many respondents lamented at how inadequate funding and budgets put public safety well behind the private sector in terms of access to the most up-to-date technology.

> We are behind the technological advances that occur in the private sector nor do we have the budget necessary to upgrade to the systems and equipment that are becoming increasingly necessary to perform our duties to the expectations of a technologically-reliant public who have no idea how 9-1-1 works. We are short-staffed, working on antiquated systems created when only landlines existed; and, even then they were rarely used to call 9-1-1. Now, everyone calls on their cell phones, overloading the system, to report emergencies that we 'should be able to find' with technology we do not have (if my uber driver can find me, why can't you?) (SUR:COMMS:U:6340)
>
> We try to stay updated but with tight budgets and changing technology and software and govt requirements with no funding for requirements it's not easy for volunteer depts. Radios are something we just can't keep updates on not to mention purchasing new ones. (SUR:EMS:R:3347)

Often, first responders are frustrated that current technology, which is readily available in the private sector and in their personal lives, is either not available for public safety or not available at a price they can afford. As COMMS survey participant #6340 notes above, "if my uber driver can find me, why can't you?"

> It's hard to explain to folks why I can get this cellphone that does all this stuff for a few hundred dollars, but it costs thousands of dollars for a radio that does not near as much as the cellphone does with current technology. (INT-FF-S-040)

It is frustrating when everyday technology available in their personal lives costs less and does more than what they can access at work for public safety.

In many cases, responses identified how the high price of technology often means going without trustworthy technology and using old, used, and/or outdated technology instead. As many participants noted – there is a relationship between the use of outdated technology and the high costs of new technology. When it comes to replacing outdated radios or other devices, cost is often a barrier.

> It has to be affordable, and that's the challenge. Of course, they're loosely related. I mean, there are companies out there that sell all this stuff, but it's never achievable for us. We'll never be able to spend $10,000 on a radio…. right now, I mean, our radios are costing almost 4 grand for radio. And that's why we have older radios because we can't afford the new stuff. (INT-FF-R-019)
>
> For something that we rely so much on, its cost prohibitive for smaller depts. to keep up with technology. And that causes issues for us. We can't afford $7000 for one radio. So we have to settle for used or lesser quality. We make do with technology that other, bigger departments have given up on 20 years ago. (SUR:FF:R:5128)

The use of outdated and/or inappropriate technology can present a serious safety issue for first responders and cause great frustration. As discussed in Sec. 3.2, this may be why first responders in some cases choose to bring and use their own devices to work. They prefer to use technology with functionality that they view as trustworthy.

Another example of the autonomy, trustworthiness, and frustration interplay was seen in COMMS participants' discussion of the shift to aspects of Next Generation 9-1-1 (NG 911). For some call centers, the switch would come with many benefits, but also many negatives [5]. COMMS worker responses, especially in the survey, show that they have had little input into decisions about these changes. In addition, they often believe the technologies used for some components of NG 911 (such as text and video) are not trustworthy and that the negatives will outweigh the positives.

One of the negatives often cited in the data is the increased cost that many of its components (such as receiving texts and/or video) present.

> Increased cost involved with staffing, record retention, and evidence storage. (SUR:COMMS:U:6675)
>
> May not be cost effective, which is why we don't have text to 911 yet. (SUR:COMMS:S:7714)
>
> Currently understaffed, not enough positions. Budget issues for upgrades. Training for (older) staff members. Getting buy-in from the public. (SUR:COMMS:R:2154)

Increased costs for things like additional staff, training, and equipment could be considerable, creating financial difficulties for some call centers. As one respondent asked: "Does the cost

balance the need?" (SUR:COMMS:S:9708). The question of cost versus need is an important one that should be considered carefully as call centers make budget decisions related to NG 911 or technology in general.

However, such decisions about technology adoption and use are largely out of the purview of COMMS workers, and many believe that money is often misspent on technology that they believe is not trustworthy.

> Dispatchers need to be more involved in preplanning and equipment examination prior to purchase. For example, [State agency redacted] spent tons of money on a radio system and it sucks. Now we are left to make excuses for its flaws. We take the blame from every responder and caller when it doesn't work, but we had no input. (SUR:COMMS:R:9667)
>
> I'm not going to have a 30-minute conversation over text whenever I could hear your voice and… and I can really hear are you okay. I can't tell that over here. I can't tell if you're crying or--that's my fear with the Next Generation 911 is are we going to lose that important piece of our communications with technology. (INT-COMMS-R-016)

COMMS workers need to be given autonomy by being included in these discussions, or they are likely to become frustrated with the technology.

The high cost of technology often creates a situation where there is decreased autonomy and decreased trustworthiness, which both contribute to increased frustration on the part of first responders. Providing more opportunities for input and autonomy related to decisions about technology will likely increase the trust that first responders have in that technology and decrease much of the frustration they currently experience.

3.4.2. The Impact of Current versus Future Technology on Trustworthiness, Autonomy, and Frustration

Survey data from both quantitative and open-ended survey responses, along with data from the interviews, show that it is not necessarily new technology that first responders want. Instead, it is the improvement of current technology that they believe is most important. In this report, we refer to current technology as those devices and/or software/applications that participants currently have and use. When referring to "new" technology, we make a distinction between two types of technologies: 1) "new" technologies are those that are already currently available, but that first responders do not often have (such as one-login or high quality mapping programs like those available on personal smartphones) and 2) "futuristic" technologies are those perceived to be more cutting edge, such as smart buildings, self-driving vehicles, or virtual reality (VR).

Data from both phases of the study show that first responders have two key desires: 1) they want their current technology to work better, and 2) they want usable technology that will work with effectiveness, efficiency, and satisfaction. Indeed, in both phases of the study, many first responders noted they would prefer to have their current technology work better rather than buying and investing in newer forms of technology.

> Instead of introducing all this extra new stuff let's, one, make sure what we have actually works better. And then, two, let's not rely on it so much. (INT-FF-U-042)

> Focus on making the technology we currently have work, and work properly before introducing more technology into the L.E. workplace that may bring the same struggles. (SUR:LE:S:3)

The focus on improving current technology grows out of first responders' experience with this technology. In public safety, first responders' primary tasks are to respond to incidents, adapt to new situations, problem-solve, and maintain their own and others' safety [1]. Therefore, most of the time, using technology is not their primary task. Instead, technology is often seen as something to help with their primary task, especially by providing situational awareness and facilitating communication. When first responders know what technology does and how it can help them with their primary tasks, they feel autonomy in using the technology. As a result, trust is built as they integrate technology into their daily work.

However, first responders also recognize that reliance on technology is growing. Sometimes this reliance is about the amount of technology they are required to use, but it is also about how often they need to use technology. In addition, they recognize that technology is rarely problem-free. The data show that in many cases first responders experience problems in which technology does not work at all, or when they need to spend additional time and effort to accomplish primary tasks. When these problems occur, they often have little autonomy in overcoming problems to accomplish the task at hand. They also experience high frustration in not being able to complete their work effectively, efficiently, and safely. Ultimately this results in first responders losing trust in that technology.

> When it works it's great. When it doesn't it's frustrating and time consuming to get it operating. I have found that vendors promise you things they can not deliver and it is expensive. I have found many officers have become too reliant on technology and have no idea how to do their job when technology fails them. (SUR:LE:R:5818)

Because the relationship between autonomy, trustworthiness, and frustration of technology is a cycle, negative experiences with technology have repercussions on first responders' trust in and use of technology in the future. When first responders have a bad experience with one new form of technology, this can have an impact on their perceptions and expectations of the trustworthiness of other technologies. The quantitative survey data illustrates a general lack of support and trust for futuristic technology. On the survey, respondents were presented with a list of new and futuristic technologies and asked to identify those that they believe would also be useful for their day-to-day work. Perhaps more important than the items chosen by a large percentage of respondents, were the items that very few respondents selected. Very few of the truly futuristic capabilities were thought to be useful by a majority of respondents. Over half of the items from each discipline's list were selected by less than 20 % of respondents from that discipline, with many being selected by 5 % of respondents or fewer. For example, "AR (augmented reality)" and "VR (virtual reality)" were in the bottom four items selected by all four disciplines; neither of them was selected by more than 7 % of respondents from any discipline. "Robots," "Smart glasses," and "Smart buildings" were some of the other items that were selected by low percentages of respondents (see Fig. 5 below).
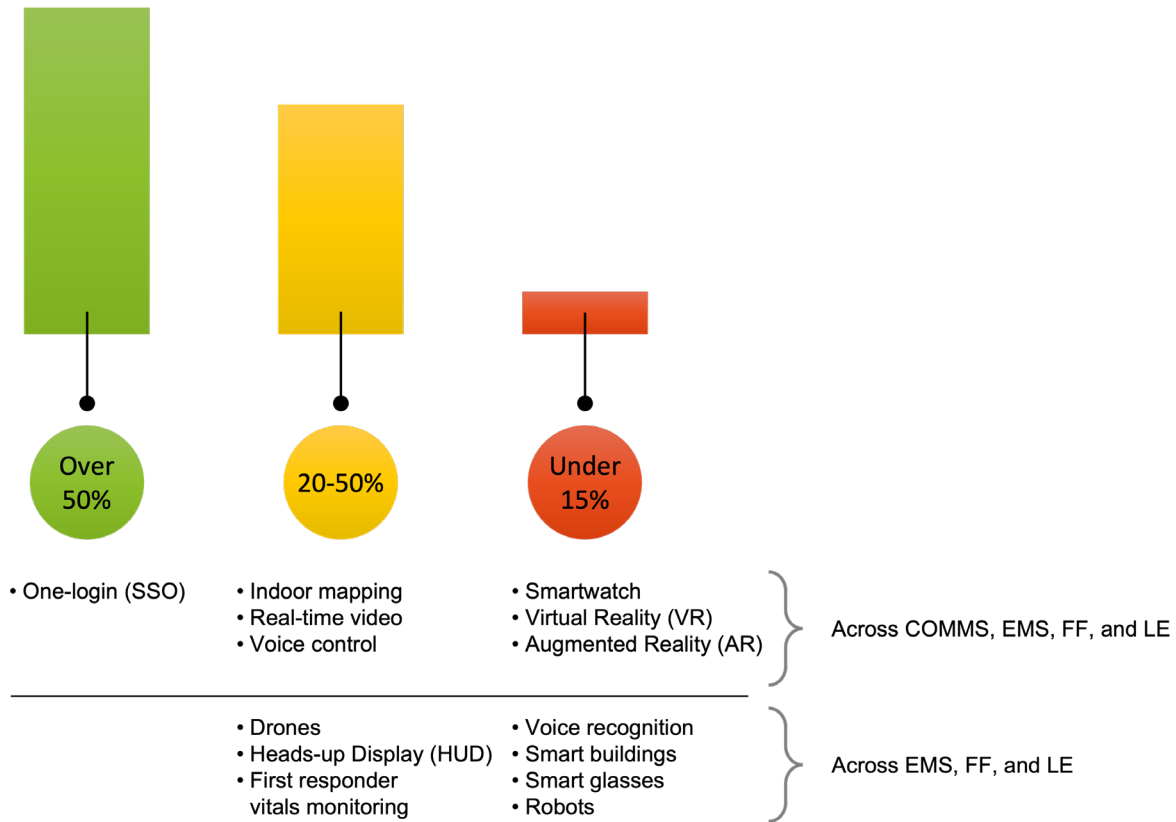
Fig. 5. Percentages of support for futuristic technologies.

This lack of support for futuristic technology may be because first responders have little evidence about how these new technologies will help them with day-to-day incident response. Not having used technology such as AR or smart buildings before, they have no foundation for assessing the trustworthiness of those technologies. In theory, these new forms of technology may be able to provide benefits for first responders. However without demonstrating autonomy and forging trustworthiness of these capabilities, first responders may be reticent to see the benefits and/or adopt new technology.

Another potential explanation for the general lack of interest in futuristic technology is that first responders have little autonomy in what and how technology is developed for them. Sometimes design changes made by developers do not take into account the realities of day-to-day incident response. As noted below, changes and updates often do not facilitate the work of first responders and may actually make it more difficult or less safe.

> But so they keep trying to do these things, and I think they're trying to do it with safety in mind, but they're not really keeping what really your day-to-day job is in mind. So the safety hinders you from doing your job. (INT-EMS-R-007)

While first responders recognize that the research and development community is trying to improve technology, they often think these improvements are done without the input of those who rely on it. This diminishes first responders' autonomy in the development process for technology that they ultimately will have to purchase and use. Given that they have not used this technology before, and had no autonomy in the development of the technology or purchasing decisions, the technology may be perceived as unproven or may come with a huge learning curve

([1], [5]). Moreover, many interview participants noted they are hesitant to depend on newer forms of technology because these technologies come with their own set of new problems: for example, signals can be dropped, cell towers can go down, equipment can break. Thus, new technology is not viewed as trustworthy and is perceived as no better than current technology at helping them accomplish primary tasks.

Developers must work to increase first responders' autonomy with and trust in this new technology, or first responders may choose not to use it. Our data show instances of first responders taking back their autonomy over technology by choosing not to use particular devices or choosing to use alternatives, such as paper and pencil. Qualitative and quantitative results show that many continue to use and rely on older forms of technology. For example, we heard in interviews that many first responders still carry pagers, or "cockroaches" (INT-EMS-U-001) because pagers are always there and never die—first responders can rely on these devices because they know and trust them. Survey results also highlight this. For example, over half of all EMS and FF survey respondents said they have a pager. When asked how frequently they use these devices, 43.76% of EMS and 42.80% of FF survey participants chose "Use a lot." This may be because the problems they experience with pagers (such as battery life) are infrequent [6]; they view pagers as more trustworthy since they can use pagers without experiencing problems.

> Pagers. I still carry a pager because it's not attached to any cellular network, and it's not impacted by civilians. So having that mode to be able to communicate or at least get information out that's not impacted by the event is huge." (INT-FF-S-015)

It is important to note that first responders are not against newer technology – our results illustrate that first responders are interested in some forms of new technology they believe would be helpful for their work. Often, first responders are interested in technology they have already seen and used, whether personally or professionally, and that they know works. First responders are also interested in technology that gives them greater autonomy in their work. One example is first responders' interest in one-login, i.e., single sign-on (SSO), capabilities. Single sign-on was the one item that over 50 % of respondents across disciplines chose from the list on the survey as useful for their work. It was the top item checked for FF and LE, and the second item for COMMS and EMS, demonstrating its importance across all four disciplines. This mirrors the findings from the open-ended survey and interview data where participants noted that having multiple logins and passwords was a major source of frustration for them ([1], [5]).

> I need to purchase an app just to remember all of the id's and passwords I need for each program I need to use. This is very frustrating and time-consuming. Where is the fob that allows me to log into anything I want? Biometrics? Bring it!
> (SUR:FF:S:4460)
>
> One login would be at the top of everybody's list here. It is ridiculous the number of passwords and log-ins that have to be used and waste the time of first responders in their preparation and continuous log-in status. (SUR:LE:R:5075)

If it works consistently and is trustworthy, one-login could provide greater autonomy in their day-to-day work, which could diminish the frustration first responders experience with multiple usernames, passwords, and logins.

Similarly, more than 50% of COMMS survey respondents identified "Automatic caller location" and "First responder tracking" as technologies they think would be useful for their day-to-day work. As with one-login, these technologies are seen as potentially useful for day-to-day incident response and will help COMMS workers accomplish their primary tasks more efficiently and effectively.

> Location is number one. We can dispatch. We can do anything else in the world with that call if we have the location. But getting that location is just paramount. We can't do anything if we don't get a location. (INT-COMMS-R-016)
>
> Better tracking of the deputies, fire fighters, and the public is paramount!! (SUR:COMMS:U:2814)

However, current technology, especially cell phone and texting technology, makes accessing caller location difficult.

> The biggest improvement that all 9-1-1 public safety dispatchers would like to see is the location accuracy of wireless cell phone devices and for the FCC to enforce/fine wireless providers when they fail to meet established mandates on location accuracy. It is literally costing lives whenever a dispatcher cannot locate a caller who is calling in from a wireless device and the location accuracy is poor or non-existent. Wireless calls account for over 80% of our inbound emergency calls. (SUR:COMMS:S:2333)
>
> They think that if they call 911 we know where they are and we don't. We know what cell phone tower your cell phone hit off of and that's it and then if you call on a VoIP phone or a voice over IP phone it's wherever your VoIP was registered to. (INT-COMMS-U-007)

As with one-login, first responder tracking and automatic caller location are seen as potentially useful for day-to-day incident response and can help COMMS workers accomplish their primary tasks more efficiently and effectively.

Technology should facilitate first responders' primary tasks by allowing them to achieve their missions efficiently, effectively, and with satisfaction. First responders do not want technology that takes away their autonomy over their day-to-day work. They are not interested in technology that they cannot trust to be reliable, work as intended, and keep them safe. They want to avoid technology that increases their stress and frustration when in fast-paced emergency situations. To improve the general adoption of current and future technology, it is important to interrupt the negative feedback loop of trustworthiness, autonomy, and frustration, while at the same time recognizing the benefits that the positive part of the feedback loop can contribute (see Fig. 2). Technology could have incredible benefits for first responders. However, they are unlikely to adopt technology that is not trustworthy, does not give them autonomy, and increases frustration.

4. Discussion

The results presented above can help improve communication technology for first responders by providing information for two different sets of partners. First, the results can help technology researchers, designers, and developers (R&D) to understand and incorporate factors that will improve the user experience into new and existing technology for first responders. Second, the

results can be useful for administrators and decision makers (ADM) in public safety as they consider how best to purchase, develop policies for, and implement adoption strategies for first responder communication technology.

For both groups, the focus should be on usability—about providing efficiency, effectiveness, and satisfaction with technology. The goal is to optimize the user experience so that first responders adopt and use technology to its full capacity. Ultimately, it is about providing first responders with the tools they need to accomplish their primary tasks within their specific contexts of use. To provide optimal usability for first responders with communication technology, it is imperative to 1) improve the trustworthiness of the technology, 2) provide autonomy for first responders in the adoption and usage of technology, and 3) minimize first responder frustration when using technology.

The integrated analysis in this report shows that when considering the adoption and usage of communication technology for first responders, the formula is: increased trustworthiness plus increased autonomy equals lower frustration. When this formula is in place, it can have a positive impact on technology usability, adoption, and usage.

There are several ways both the R&D community and ADMs can incorporate these themes into their work to achieve this positive impact. We developed six user-centered design guidelines that are rooted in the empirical data from both phases of this study ([1], [4], [5], [6]). The guidelines provide a foundation that can be useful for how both R&D and ADMs might approach the improvement, development, purchasing, and/or implementation of communication technology in the public safety space. The guidelines serve as a roadmap of best practices, providing guidance rather than requirements, but guidance that is aimed at ensuring the optimal user experience.

- **Improve current technology**
- **Reduce unintended consequences**
- **Recognize 'one size does not fit all'**
- **Minimize 'technology for technology's sake'**
- **Lower product/service costs**
- **Require usable technology**

Below, we discuss each of these guidelines in relationship to the three themes identified in the integrated analysis: the importance of trustworthiness; the need for autonomy; and the experience of frustration.

Improve current technology. Findings from this study clearly show that it is not necessarily new technology that first responders want, but the improvement of current technology that they believe is most important. To improve current technology to be trustworthy, both the R&D community and ADMs should focus on providing greater autonomy for first responders in its design, development, and expectations for use. They should also work to reduce frustration with technology by focusing on problems first responders identify. R&D can do this by conducting user-centered research and design and partnering with public safety organizations and departments when developing technology. ADMs can increase first responders' autonomy by working directly with them when creating policies for adoption and use of technology.

Reduce unintended consequences. Frustration is often the byproduct of poor usability when first responders use communication technology. It is important to develop technology that does not interfere with first responders' attention to their primary tasks–poorly developed technology can cause distraction, loss of situational awareness, cognitive overload, and over-reliance on technology. R&D and ADMs should consider where gaps in autonomy exist and examine where problems could undermine trustworthiness. This can help identify where frustration may develop. Also R&D and ADMs should consider where first responders will not have as much potential for autonomy (e.g., coverage, price, policy development) and make sure the technology itself will not have any issues as this would further erode trustworthiness.

Recognize 'one size does not fit all.' The similarities across the first responder disciplines make standardization important for the consistency, compatibility, and quality of technology. However, technology must accommodate the wide variety of public safety needs across disciplines, personnel, departments, districts, and contexts of use. These contexts can vary greatly, requiring technology to be easily adaptable and configurable to different contexts. Technology should also address context-specific challenges (e.g., coverage and/or connectivity issues). Autonomy and trustworthiness can differ depending on the technology, geographic area, discipline, and other contexts of use. The R&D community should consider these factors when designing technology, and ADMs should also keep these factors in mind when making decisions about what to purchase and how to implement policies for use of technology.

Minimize 'technology for technology's sake.' First responders trust technology that has been proven through experience to be effective, efficient, and satisfactory. Building on this existing trustworthiness is important. They want technology that contributes in a significant way to their ability to accomplish primary tasks—not bells and whistles that take away their autonomy. It is important for the R&D community and ADMs to collaborate closely to ensure that first responders fully understand the benefits of futuristic technologies and how technology can contribute to their primary tasks.

Lower product/service costs. The R&D community should strive to develop technology at price points that departments can afford, lowering the costs for technology. The goal is not just to design trustworthy technology, but to design it at a price-point that makes it feasible and scalable for widespread distribution and usage. By doing this, first responders maintain some control and autonomy over the technology. Solving the cost issue could be an opportunity for the R&D community and ADMs to work together to understand how to provide first responders with the best technology while accounting for the problems associated with costs.

Require usable technology. It is important to understand first responder user characteristics, needs, requirements, and contexts of use in order to develop solutions that make sense to and for them. They want technology that is simple, easy to use, light, fast, and not disruptive. Technology should make it easy for the user to do the right thing, hard to do the wrong thing, and easy to recover when the wrong thing happens. Improved usability that makes sense to first responders and specifically addresses their contexts of use can increase autonomy and trustworthiness and reduce frustration. This is the ultimate goal for both R&D and ADMs if they want to promote adoption and encourage usage. Achieving this guideline is another opportunity for the R&D community and ADMs to work together. While the R&D community knows the technology best and can develop unique and innovative capabilities, on their own they may have little insight into the context of use and challenges of first responders using that technology. On the other hand, ADMs have a thorough understanding of how first responders use technology

and what problems they experience within their specific contexts, but they may not know what existing and emerging technology is available to solve their problems. Only by working together, sharing insights, and coming up with solutions together, can first responders most benefit from new technology.

All six of these user-centered guidelines highlight the importance of listening to first responders and better understanding their contexts of use. What consistently emerges across the datasets is that technology is about more than just the tools. It is also about the myriad of issues associated with those tools. Sometimes these other issues are more important than the technology itself. As noted above, cost is a huge barrier for access to technology, in addition to usability and usefulness, which are also extremely important in the adoption of technology. However, other factors such as the rapid pace of technology change, the lack of clear guidelines and policies, and the need to reduce unintended consequences all influence first responder access to and adoption of technology. It is most important here to listen to the voices of first responders in any of the work to develop and improve communication technology.

> That's the biggest thing with a lot of the stuff is you make it, but you never test it out on the real person who's going to use it. And then will it get lost in translation, and then it becomes useless. You may have thought it was a great idea. And it might be a great idea, but there's a few tweaks that don't make it useful at all. (INT-LE-U-036)
>
> It appears that most changes in technology are not field tested (or at least not tested enough) by end users and are more likely the choice of the technology and the finance departments. (SUR:LE:S:7988)
>
> Simple is better, no technology can ever replace knowledge gained from experience. the more we try to implement technology without seeking the opinion of the people that will be relying on it first we fail. (SUR:FF:S:7798)

Listening to and taking into consideration the voices of first responders could go a long way in increasing trustworthiness and autonomy and decreasing frustration when they interact with existing and newly developed technology. Research of work in general shows that providing autonomy reduces stress and increases engagement [13]. Instead of telling first responders what technology to use, and when, where, and how to use it, first responders should have some latitude and input about what works best within their context of use.

The R&D community should create opportunities for first responders to provide input into what is developed. This may increase first responders' autonomy and their perception of the technology being trustworthy, as well as to help identify the utility and benefits of more futuristic types of technology. ADMs should also involve first responders in their departments when purchasing new technology and/or creating policies for new technology. It is critical to get buy-in from first responders before adopting and implementing new forms of technology. ADMs should find ways to give first responders some autonomy in deciding what new technology is purchased. They should also provide opportunities for first responders to experience the technology first-hand. First-hand experience may provide the opportunity for first responders to see the benefits and identify any unintended consequences that will impact their context of use.

All six of the user-centered guidelines provided above work to improve trustworthiness and autonomy. As trustworthiness and autonomy increase, frustration decreases, creating the optimal user experience.

5. Conclusion

The experiences of the first responders in this study demonstrate the importance of technology trustworthiness, user autonomy, and frustration in the adoption and use of communication technology. Overarchingly, there is a lack of technology trustworthiness combined with low autonomy that often results in frustration for first responders. The development of trustworthy technology takes time and relies on first responders knowing that their input and experiences matter (i.e., having autonomy). Fundamentally, the lack of trustworthiness and autonomy has an impact on the acceptance and adoption of new technology and the ability of first responders to accomplish their primary tasks. The R&D community should work to prioritize the voices of first responders in the technology they develop, while ADMs should work to involve first responders' input into decisions about how technology is implemented and adopted. Importantly, the R&D community and ADMs must work together to fully realize the promise of technology to enhance the effectiveness, efficiency, and satisfaction first responders have with their communication technology.

For more detailed information on methodology, along with additional results from both Phase 1 and Phase 2 of this study, see the nine reports previously published from this study ([1], [2], [4], [5], [6], [7], [8], [11], [14]). Combined, these reports provide a holistic view of first responders and their experiences related to communication technology which can help the R&D community and ADMs to understand the specific contexts, needs, experiences, and beliefs of first responders.

References

[1] Choong, Y.-Y., Dawkins, S., Furman, S., Greene, K., Spickard Prettyman, S., & Theofanos, M. (2018). *Voices of First Responders–Identifying Public Safety Communication Problems: Findings from User-Centered Interviews,* Phase 1, Volume 1. NISTIR 8216. https://doi.org/10.6028/NIST.IR.8216

[2] Choong, Y.-Y., & Salvendy, G. (2021). *Voices of First Responders–Applying Human Factors and Ergonomics Knowledge to Improve the Usability of Public Safety Communications Technology*, Phase 1, Volume 5. NISIR 8340. https://doi.org/10.6028/NIST.IR.8340

[3] Creswell, J. W., & Plano Clark, V. L. (2011). *Designing and conducting mixed methods research* (2nd ed.). Thousand Oaks, CA: Sage.

[4] Dawkins, S., Choong, Y.-Y, Theofanos, M., Greene, K., Furman, S., Steves, M., & Spickard Prettyman, S. (2019). *Voices of First Responders – Examining Public Safety Communication Problems and Requested Functionality, Findings from User-Centered Interviews*. Phase 1, Volume 2.1. NISTIR 8245. http://doi.org/10.6028/NIST.IR.8245

[5] Dawkins, S, Greene, K., & Spickard Prettyman, S. (2020). *Voices of First Responders – Nationwide Public Safety Communication Survey Findings: Mobile Devices, Applications, and Futuristic Technology*, Phase 2 Volume 2. NISTIR 8314. https://doi.org/10.6028/NIST.IR.8314

[6]   Dawkins, S., Morrison, K., & Spickard Prettyman, S. (2021). *Voices of First Responders – Nationwide Public Safety Communication Survey Findings: Day-to-Day Technology*. Phase 2, Volume 3. NISIR 8400. https://doi.org/10.6028/NIST.IR.8400

[7]   Greene, K., Dawkins, S., Theofanos, M., Steves, M., Furman, S., Choong, Y.-Y., and Spickard Prettyman, S. (2019). *Voices of First Responders—Examining Public Safety Communication from the Rural Perspective, Findings from User-Centered Interviews*, Phase 1, Volume 3. NISTIR 8277. http://doi.org/10.6028/NIST.IR.8277

[8]   Greene, K., Dawkins, S., Spickard Prettyman, S., Konkol, P., Theofanos, M., Mangold, K., Furman, S., & Steves, M. (2020). *Voices of First Responders—Nationwide Public Safety Communication Survey Methodology: Development, Dissemination, and Demographic*s, Phase 2, Volume 1. NISTIR 8288. https://doi.org/10.6028/NIST.IR.8288

[9]   ISO 9241-210:2010: *Ergonomics of human-system interaction -- Part 210: Human-centred design for interactive systems*, ISO, Geneva, Switzerland, 2019, http://www.iso.org/

[10]   Middle Class Tax Relief and Job Creation Act of 2021, 112-96 (2012). https://www.govinfo.gov/content/pkg/PLAW-112publ96/pdf/PLAW-112publ96.pdf

[11]   Pintar, A., Buchanan, K., & Choong, Y.-Y. (2022). *Voices of First Responders – Nationwide Public Safety Communication Survey Findings: Statistical Analysis Results*. Phase 2, Volume 4. NISTIR 8444. https://doi.org/10.6028/NIST.IR.8444

[12]   *Public Safety Communications Research*. Research Portfolios. https://www.nist.gov/ctl/pscr/research-portfolios

[13]   Rock, D. (2009, November 08). A sense of autonomy is a primary reward or threat for the *brain: Why employees (and your kids) sometimes lose the plot.* Psychology Today. https://www.psychologytoday.com/us/blog/your-brain-work/200911/sense-autonomy-is-primary-reward-or-threat-the-brain

[14]   Steves, M., Theofanos, M., Choong, Y.-Y., Dawkins, S, Furman, S., Greene, K., & Spickard Prettyman, S. (2020). *Voices of First Responders – Examining Public Safety Communication from the Perspective of 9-1-1 Call Takers and Dispatchers Findings from User-Centered Interviews*, Phase 1, Volume 4. NISTIR 8295. https://doi.org/10.6028/NIST.IR.8295

[15]   Teddlie, C., & Tashakkori, A. (2009). *Foundations of mixed methods research: Integrating quantitative and qualitative approaches in the social behavioral sciences*. Thousand Oaks, CA: Sage.

Appendix A. Glossary

ADM
Administrators and Decision Makers

AR
Augmented Reality

CAD
Computer-Aided Dispatch

COMMS
Communication Center & 9-1-1 Services

EMS
Emergency Medical Services

FCC
Federal Communications Commission

FF
Fire Service, Fire Fighting

GPS
Global Positioning System

HUD
Heads-up Display

LE
Law Enforcement

LMR
Land Mobile Radio

LTE
Long-Term Evolution

MDT/MDC
Mobile Data Terminal/Mobile Data Computer

NG 911
Next Generation 9-1-1

NPSBN
National Public Safety Broadband Network

PSCR
NIST's Public Safety Communications Research Program

R&D
Researchers, Designers, and Developers

SCBA
Self-contained Breathing Apparatus

VR
Virtual Reality