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Voices of First Responders— Nationwide Public Safety Communication Survey Findings:

Statistical Analysis Results
Phase 2, Volume 4

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https://doi.org/10.6028/NIST.IR.8444

NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY
U.S. DEPARTMENT OF COMMERCE

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November 2022

U.S. Department of Commerce
Gina M. Raimondo, Secretary

National Institute of Standards and Technology
Laurie E. Locascio, NIST Director and Under Secretary of Commerce for Standards and Technology

NIST IR 8444
November 2022

NIST Technical Series Policies

Publication History

Approved by the NIST Editorial Review Board on 2022-11-18

How to Cite this NIST Technical Series Publication

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. (National Institute of Standards and Technology, Gaithersburg, MD), NIST Internal Report (IR) NIST IR 8444. https://doi.org/10.6028/NIST.IR.8444

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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

- How to Facilitate Adoption and Usage of Communication Technology: An Integrated Analysis of Qualitative and Quantitative Findings (NISTIR 8443) https://doi.org/10.6028/NIST.IR.8443
- COMMS (NIST SP 1286pt1) https://doi.org/10.6028/NIST.SP.1286pt1
- EMS (NIST SP 1286pt2) https://doi.org/10.6028/NIST.SP.1286pt2
- FF (NIST SP 1286pt3) https://doi.org/10.6028/NIST.SP.1286pt3
- LE (NIST SP 1286pt4) https://doi.org/10.6028/NIST.SP.1286pt4

Phase 1: Findings from User-Centered Interviews

- Volume 1 - *Identifying Public Safety Communication Problems* (NISTIR 8216) https://doi.org/10.6028/NIST.IR.8216
- Volume 2 - *Examining Public Safety Communication Problems and Requested Functionality* (NISTIR 8245) https://doi.org/10.6028/NIST.IR.8245
- Volume 3 - *Examining Public Safety Communication from the Rural Perspective* (NISTIR 8277) https://doi.org/10.6028/NIST.IR.8277
- Volume 4 - *Examining Public Safety Communication from the Perspective of 9-1-1 Call Takers and Dispatchers* (NISTIR 8295) https://doi.org/10.6028/NIST.IR.8295
- Volume 5 - *Applying Human Factors and Ergonomics Knowledge to Improve the Usability of Public Safety Communications Technology* (NISTIR 8340) https://doi.org/10.6028/NIST.IR.8340

Phase 2: Nationwide Survey

- Volume 1 - *Methodology: Development, Dissemination, and Demographics* (NISTIR 8288) https://doi.org/10.6028/NIST.IR.8288
- Volume 2 - *Mobile Devices, Applications, and Futuristic Technology* (NISTIR 8314) https://doi.org/10.6028/NIST.IR.8314
- Volume 3 - *Day-to-Day Technology* (NISTIR 8400) https://doi.org/10.6028/NIST.IR.8400
- Volume 4 - *Statistical Analysis Results* (NISTIR 8444) https://doi.org/10.6028/NIST.IR.8444

Abstract

Public safety is in the midst of a major transition in the communication technology that is used due to the ongoing development and deployment of the Nationwide Public Safety Broadband Network (NPSBN). Once established, the NPSBN will provide dedicated broadband to first responders. Having a dedicated network will allow first responders to leverage technology in performing their jobs safely, effectively, and efficiently. To fully recognize the benefits of having such a network, there have been many efforts to improve and create communication technology for first responders that works with this network. NIST's PSCR Usability team has been contributing to this effort by conducting a multi-year, mixed methods study to examine first responders' needs for and problems with communication technology. The study consisted of two phases: 193 first responders were interviewed in Phase 1, and 7 182 first responders completed a survey of their communication technology experiences in Phase 2. Results of these efforts have been extensively reported on and are publicly available in eight reports.

This report provides an in-depth statistical analysis of the survey data by exploring if and how communication technology problems and needs differ depending on the characteristics of the first responders. Specially, we examined differences by area (rural v. urban/suburban), role (frontline responders v. supervising responder, v. chief/management), and career v. volunteer status for fire service personnel. Two key themes emerged. First, we found that rural and volunteer first responders lack some devices and applications/software that their urban/suburban and career counterparts have, and they experience problems with the price of several devices. Second, we found that chief/management roles have different communication technology problems and needs from frontline first responders. Specifically, they tend to more often use devices and applications/software for coordination and managerial purposes and are very aware of the price of devices.

This report provides rich data and a rigorous analysis for researchers, developers, and designers to use to inform their work developing communication technology for first responders. We also describe how these findings relate to the user-centered guidelines published in previous reports.

Keywords

Communication technology; First responders; Human Factors and Ergonomics; Public safety communications research; Usability; Human-centered design; User needs and requirements; statistical leaning; natural language processing; Bayesian methods.

Audience

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

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Acknowledgments

We would like to thank the many first responders, public safety personnel, and public safety organizations who graciously gave their time and input for this project. We would also like to thank our colleague, Gregory Haber, for his consultations about missing data.

Executive Summary

Background

Public safety is in a period of significant change with the ongoing development and deployment of the Nationwide Public Safety Broadband Network (NPSBN). This network will provide broadband dedicated to first responders as well as create new opportunities for research and development of communication technology for first responders. Since the NPSBN was mandated, researchers, developers, and designers have been researching and developing communication technology. The National Institute of Standards and Technology (NIST)'s Public Safety Communications Research (PSCR) program has been focused on driving research to advance communication technology, identifying six unique research portfolios that explore new advances in communication technology for first responders.

Recognizing the importance of ensuring usable communication technology, the PSCR's User Interfaces/User Experiences (UI/UX) portfolio has focused its efforts on understanding how communication technology can provide effectiveness, efficiency, and satisfaction to the first responders who use it. To achieve this goal, the PSCR Usability team conducted a multi-year research study to identify the communication technology problems, needs, and context of use for first responders across four disciplines: Communication Center & 9-1-1 Services (COMMS), Emergency Medical Services (EMS), Fire Service (FF), and Law Enforcement (LE). This effort has yielded eight reports to date that summarize the key challenges first responders experience with communication technology, and provides insight into how researchers, developers, and designers can improve communication technology.

Methodology

We conducted an exploratory, mixed-methods study to understand first responders and their experiences with communication technology. Phase 1 consisted of in-depth interviews with 193 first responders from across the country. Findings from the interviews were used to develop a nationwide survey with 7 182 responses completed by first responders from four disciplines. The survey focused on day-to-day technology use, including both devices and applications/software, problems with technology, perceived usefulness of futuristic technology, and technology used during major disasters/events.

While previous reports described overall trends emerging from the survey data, the aim of the current report was to use modern statistical techniques to identify differences in experiences with communication technology across meaningful subgroups of first responders. Some of the demographic variables defining these subgroups are the areas first responders work in (rural, urban/suburban), the role they perform (frontline responder, supervising responder, chief/management), and their volunteer status (volunteer, career; a demographic variable for Fire Service first responders only). To do this, we used two different statistical methods, conditional on the question type, multiple choice or the ranking of a list.

Results

Results indicate that communication technology problems and needs differ depending on the areas and roles of first responders as well as whether or not they are career or volunteer FF. Two key themes emerged from our analyses:

- **Rural and volunteer first responders lack resources.** Across all four disciplines, rural first responders were more likely to report not having some of the devices and application/software their urban/suburban counterparts did. Rural first responders were more likely to report not having technology specifically used for incident response, such as mobile data terminals/mobile data computers (MDT/MDC) and computer aided dispatch (CAD). They were also more likely to report having problems with the price of devices, even common and important devices such as radios. A similar pattern was also observed for volunteer FF.
- **Chief/management roles have different communication technology problems and needs from frontline first responders.** First responders in chief/management roles reported using some devices such as MDT/MDC and thermal imaging cameras (TICs) less than frontline first responders. They tended to report using other devices and applications/software such as computers and email more often, likely due to their coordinating and managerial duties. Price was also top of mind for chief/management first responders.

These insights have important implications for researchers, designers, and developers that align with the user-centered design guidelines we have developed [2]. In particular, this report affirms three guidelines and provides additional context and nuance for consideration when developing communication technology for first responders:

- **Improve current technology.** This report suggests that rural first responders across disciplines and FF volunteers may be especially poised to benefit from having access to current technology. Researchers, developers, and designers have a huge opportunity to help first responders in these contexts by providing them with technology that will "catch them up" to current technological innovations.
- **Recognize "one size does not fit all."** Technology problems and needs not only differ between each discipline of public safety, but there are also differences depending on the first responders' area, role, and volunteer status. Researchers, developers, and designers must take these contexts into account when designing technology for first responders.
- **Lower cost of products/services**. The cost of purchasing, training on, and maintaining communication technology has consistently come up as a barrier to first responders' access to technology ([2], [6]). Results from this report illustrate that cost problems and resource challenges are exacerbated for first responders in rural environments and in volunteer services. Keeping costs low may benefit first responders generally but may especially help those in rural and volunteer departments.

Impact

This report underscores the importance of developing communication technology for first responders with their context of use in mind. Researchers, developers, and designers may use the rich data and rigorous analysis presented in this report to inform the problems and needs specific to different types of first responders. Additionally, this report highlights the need for researchers, developers, and designers to work with first responders and involve them in the process of technology development. To fully take advantage of the benefits the NPSBN and new communication technology innovations can provide, it is important such advances are made for and with the voices of first responders guiding the efforts.

1. Introduction

The creation and current deployment efforts for the Nationwide Public Safety Broadband Network (NPSBN) [15] is poised to benefit first responders by providing a dedicated long-term evolution (LTE) network to them. Along with this new network has come an increased focus on research and development of new communication technology for first responders that are intended to work with it. Because it is important that new technology is usable for first responders, user interfaces and user experiences (UI/UX) have been identified as a key area for research as part of NIST's Public Safety Communication Research (PSCR) efforts [20]. The goal of the PSCR usability team's work is to understand how communication technology can provide effectiveness, efficiency, and satisfaction to the first responders who use them.

To achieve this goal, the PSCR usability team conducted an exploratory mixed-methods study to identify first responders needs for and problems with communication technology. In Phase 1, 193 interviews with first responders from across the United States were conducted. Interview findings were then used to create a survey (Phase 2) that was taken by 7 182 first responders. Four disciplines of first responders were targeted for the interviews and survey: Communication Center & 9-1-1 Services (COMMS), Emergency Medical Services (EMS), Fire Service (FF), and Law Enforcement (LE).

The data and insights have been published in a series of reports. The interview results are published in a series of five reports:

- Phase 1 Volume 1: describes first responders' context of use and communication technology needs [2]
- Phase 1 Volume 2.1: an in-depth look at first responders' problems with communication technology [4]
- Phase 1 Volume 3: describes experiences of rural first responders [9]
- Phase 1 Volume 4: describes COMMS first responders [22]
- Phase 1 Volume 5: provides human-factors, user-centered design guidance [3]

To date, the survey data have been published in three reports:

- Phase 2 Volume 1: describes the survey methodology [10]
- Phase 2 Volume 2: reports survey results for mobile device, application/software, future technology needs, and major disaster/large event survey questions [5]
- Phase 2 Volume 3: reports day-to-day experiences of first responders' communication technology use and problems [6]

This report is part of the Phase 2 publications reporting survey results. The goal of the previous three volumes was to provide an overall picture of first responders' experiences with communication technology by presenting survey results using descriptive statistics such as frequencies. The goal of the current work was to identify how different subgroups of first responders have different problems with and needs for their communication technology. Specifically, we examined how experiences with communication technology depend on the area first responders work in (rural, urban/suburban), the role they perform (frontline responder, supervising responder, chief/management), and their volunteer status (volunteer, career; Fire Service only). To do this, we used a statistical learning technique and a Bayesian statistical method (conditional on the question type) to identify subgroups that responded differently to a given survey question from other subgroups.

This report is structured to first provide the reader with an overview of the survey data and subgroups; rationale for our data analysis techniques and how to interpret results follow. Throughout the report we have included graphs to visually depict the results and include extensive examples for how to read and interpret these graphs. We then present the results by discipline (COMMS, EMS, FF, and LE). Within each discipline we report findings for rural compared to urban/suburban and frontline responders compared to supervising and chief/management roles for each survey question. The report concludes with a summary of key results and implications for developers and designers.

2. Methods

A total of 7 182 first responders completed the survey representing first responders across the four disciplines as well as different FEMA regions, ages, and years of service. The development, implementation, recruitment, and full respondent demographics of the survey are extensively described in previous reports ([5], [6], [10]). For this report, it is sufficient to know that the surveys were tailored to each of the four first responder disciplines (COMMS, EMS, FF, LE) and included the following sections:

- Demographics
- Call center information (COMMS only)
- Use of technology in day-to-day work
- Ranking of technology in day-to-day work (EMS, FF, LE only)
- Use of applications/software in in day-to-day work
- Ranking of applications/software in in day-to-day work (EMS, FF, LE only)
- Future technology in day-to-day work
- Problems with day-to-day technology
- Next Generation 9-1-1 (COMMS only)
- Information problems (COMMS only)
- Virtual reality

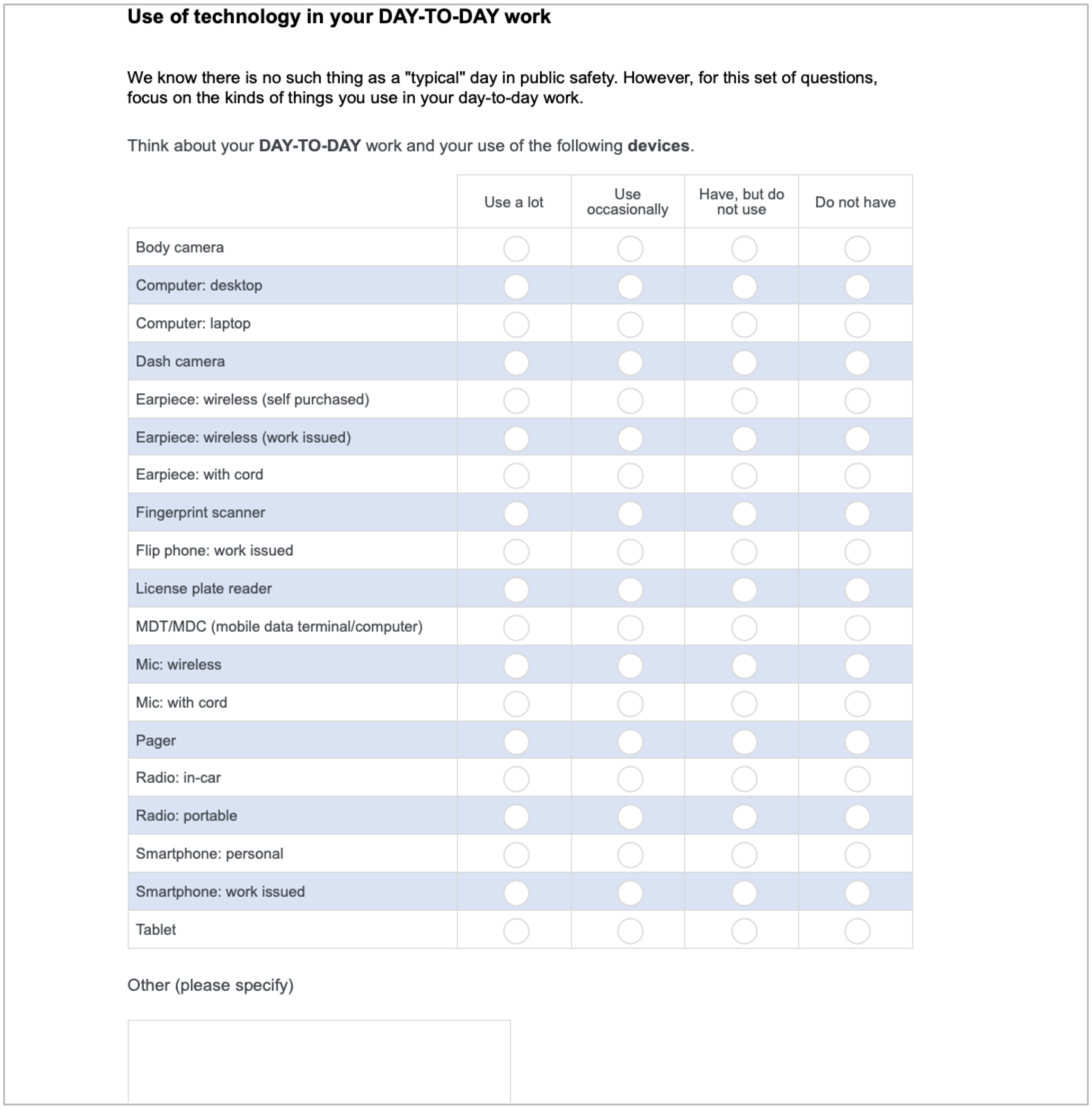
This section focuses on the methods used to analyze the survey data. The purpose of the statistical analyses was to understand how first responders with different experiences compare based on their answers to the survey questions. For example, do rural and urban/suburban respondents have similar access to mobile data terminals/mobile data computers (MDT/MDC)? To answer these questions, the data were first prepared, and then an appropriate statistical analysis was applied depending on the type of answer requested by the survey question. This section describes what considerations were made for preparing the data, what statistical techniques were applied to each type of question, the rationale for choosing these techniques, and how to interpret results from them.

2.1. Data preparation for analysis

This section presents the methods used for preparing the data prior to analysis, including descriptions of question types, identification of subgroups, and the treatment of missing data.

2.1.1. Types of data

In this report, two main types of survey questions were analyzed. The first type is multiple-choice questions. An example block of multiple-choice questions is shown in Fig. 1. In that block, respondents were presented with a device and asked to choose which one of four response options described their daily use of that device: “use a lot,” “use occasionally,” “have, but do not use,” or “do not have.” Although the first three response options (use a lot, use occasionally, and have, but do not use) could be described as being ordered by amount of use, the last category, “do not have,” does not fit nicely into that ordering scheme. Therefore, for analysis, the responses from multiple choice questions were considered to be unordered categorical variables. This has implications for the type of statistical analysis chosen, which is described later in Sec. 2.2.



Use of technology in your DAY-TO-DAY work

We know there is no such thing as a "typical" day in public safety. However, for this set of questions, focus on the kinds of things you use in your day-to-day work.

Think about your **DAY-TO-DAY** work and your use of the following **devices**.

	Use a lot	Use occasionally	Have, but do not use	Do not have
Body camera	○	○	○	○
Computer: desktop	○	○	○	○
Computer: laptop	○	○	○	○
Dash camera	○	○	○	○
Earpiece: wireless (self purchased)	○	○	○	○
Earpiece: wireless (work issued)	○	○	○	○
Earpiece: with cord	○	○	○	○
Fingerprint scanner	○	○	○	○
Flip phone: work issued	○	○	○	○
License plate reader	○	○	○	○
MDT/MDC (mobile data terminal/computer)	○	○	○	○
Mic: wireless	○	○	○	○
Mic: with cord	○	○	○	○
Pager	○	○	○	○
Radio: in-car	○	○	○	○
Radio: portable	○	○	○	○
Smartphone: personal	○	○	○	○
Smartphone: work issued	○	○	○	○
Tablet	○	○	○	○

Other (please specify)

Fig. 1. Example block of multiple-choice survey items.

The second type of data were from questions where respondents provided a **partial ranking** of a list. An example of this type of survey question is provided in Fig. 2. Survey respondents were shown a list of communication devices or applications/software and they were asked to rank up to the five that were the most useful to them. The lists presented to survey respondents were based on their answers up to that point in the survey about the devices or applications/software for which they answered “use a lot,” “use occasionally,” or “have, but do not use”. These rankings provided by the respondents were always partial as opposed to complete, as they only ranked up to their top five items, rather than ranking all of the devices or applications/software from the list they saw. For example, in Fig. 2, the respondent saw a list of 11 applications/software, but was only asked to rank up to the top five most useful.

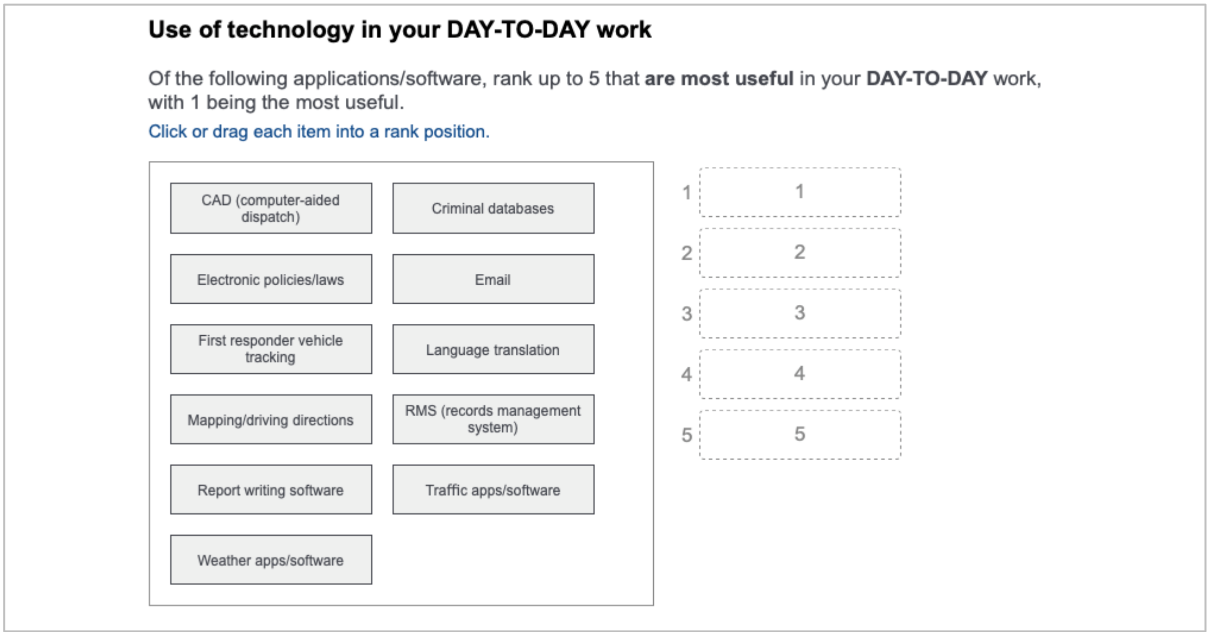


Fig. 2. Example survey item for which respondents were asked to partially rank a list.

2.1.2. Identification of Subgroups and Role Classification

The goal of the statistical analysis was to examine how responses to survey questions differed depending on the experiences of different types of first responders. In order to answer this question, we categorized survey respondents into different subgroups. Subgroups of interest were created using answers to demographic survey questions and subject matter knowledge. How responses to the multiple-choice and partial ranking questions differed across the resulting subgroups was then examined.

The demographic variables defining the subgroups are as follows:

Area. First responders could select if they worked in rural, urban, or suburban areas. For analysis, survey respondents who selected either urban or suburban were categorized as urban/suburban. Statistical comparisons examined if survey responses differed between rural and urban/suburban first responders.

Age. First responders selected their age from an integer list. The selected ages were then categorized into groups (18 – 25, 26 – 35, 36 – 45, 46 – 55, 56 – 65, and over 65), aligning with age categories in previous work [10]. Statistical comparisons examined if survey responses differed between each age category.

Years of service. First responders selected their total years of service in public safety from an integer list. The selected years of service were then categorized into groups: less than 1, 1 – 5, 6 – 10, 11 – 15, 16 – 20, 21 – 25, 26 – 30, 31 – 35, 36 – 40, 41 – 45, 46 – 50, and more than 50, also aligning with categories in previous work [10]. Statistical comparisons examined if survey responses differed between each "years of service" category.

Sex. First responders selected if they were male or female in the survey. Statistical comparisons examined if survey responses differed for male first responders compared to female.

Discipline specific questions. FF, EMS, and COMMS had surveys that included specific demographic questions relevant to their fields:

- FF were asked if they were **volunteer or career** FF. Statistical comparisons examined differences in survey responses for volunteers compared to career FF.
- EMS were asked if they were **private or public**. Statistical comparisons examined differences in survey responses for public compared to private EMS.
- COMMS were asked if they were **civilian or deputized**. Statistical comparisons examined differences in survey responses for civilians compared to deputized COMMS.

Role. The survey asked respondents "*What is your title?*" and allowed respondents to write in a text response, rather than choose from a list of pre-determined categories. Examples of responses from FF respondents are shown in Table 1 to give a sense of the range of responses. Job titles indicating responsibility of performing incident response utilizing communication technology were categorized into three main role categories: **chief/management, supervising responder, and frontline responder**. These three categories were also aligned with the roles of participants we interviewed in Phase 1 [2]. Responses of job titles that did not include performing incident response were not considered to be part of the population of interest in this report.

Table 1. Selected responses from Fire Service respondents to the survey question "What is your title?"

Chief/Management	Supervising Responder	Frontline Responder
Fire Chief	Captain	Firefighter paramedic
Battalion Chief	Lieutenant	Fire Police
Deputy Fire Chief of Operations	Shift Commander	Driver/Engineer

The typical process for categorizing, or coding, open text responses such as these consists of two steps. First, two (or more) people manually code each response. Then, as a group, the final coding is developed by reconciling any differences between the individual codings. Since there were more than 7 000 survey respondents, manually coding the responses would have been onerous. To ease that burden, a machine learning algorithm called a random forest [1] was employed to help with the process.

The first task for this analysis was to randomly select responses and categorize them manually. These coded responses formed the dataset that was used to train the random forest algorithm. To do this, the responses had to be translated into numbers so that the algorithm could categorize them. Such translations are an important part of natural language processing known as word embedding. Algorithms create these translations from large collections of text (examples of algorithms include word2vec [16] and global vectors for word representation (GloVe) [18]). We used an existing word embedding called `glove.840B.300d` from https://nlp.stanford.edu/projects/glove/ (accessed January, 2022), which is based on a large amount of text taken from web pages. These embeddings are based on data from https://commoncrawl.org/ (accessed January, 2022). Additional information on word embeddings for this study can be found in Appendix A.

Once the text was translated into numbers, it was used to predict the role category to which the response should belong, either "chief/management", "supervising responder," or "frontline responder." This classification can be done using a tool called a classification tree. An example of a simple classification tree is found in Fig. 3. In these trees, the circles are called nodes, and the top node or root of the tree encompasses the entire population under study. The nodes then divide the population into finer and finer sub-groups. The basic idea of a classification tree is that at a node in the tree, a decision is made to go down the left or right path if a certain condition is met for the input data point. For example, in Fig. 3, a decision is made to move from the top node based on the condition that one of the input variables is less than or equal to one. If the input variable has a value less than 1, the left path is followed. If the input item is greater than 1, the right path is followed. For the example tree in Fig. 3, the classification would then end, but in more complex trees, there are many levels.

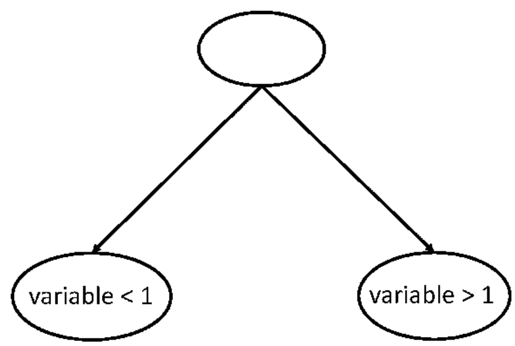


Fig. 3. Example of one node of a classification tree.

Classification trees are known to perform poorly on data that were not used to make them. A classification tree created based on a small subset of manually coded responses is unlikely to perform very well when asked to classify the remainder of over 7 000 responses. For better accuracy, we used random forests, which are made from many individual classification trees. Classifications from the individual trees are combined by majority vote, i.e., the classification selected by most of the trees is the classification from the forest.

Fifty manually coded responses from each of the four disciplines were used to train a random forest classifier for that discipline (200 manually coded responses and four random forests in total). The trained random forests were then used to classify the remaining text responses, and 20 predicted classifications were randomly sampled for each discipline and checked for accuracy. The corrected responses were then combined with the responses used to train the current random forest, and a new random forest was trained. This process was repeated until classification accuracy was found to reach a plateau. COMMS used the highest number of responses, 151 (increments of 20 were not strictly followed).

The use of natural language processing and machine learning techniques led to a substantial saving of human effort and time. Time savings were realized in two places. First, the typical coding process was carried out for only a few hundred open text responses instead of more than 7 000 (the number of survey respondents). Second, while the reconciliation process was still necessary for all of the more than 7 000 responses, the random forest predictions were treated as one individual coding, and it was only necessary for one person to review and revise them instead of two or more.

Table 2 displays the number and percentage of survey respondents in the subgroups of primary focus for this report in each of the four disciplines. The number and percentage of survey respondents in the other subgroups can be found in Appendix B.

Table 2. Respondent Demographics for Area, Role, and Volunteer Status (FF).

Subgroup		COMMS % (n)	EMS % (n)	FF % (n)	LE % (n)
Area	Rural	39 (545)	53 (440)	34 (851)	32 (586)
	Urban/Suburban	58 (797)	44 (368)	64 (1614)	62 (1139)
	(missing data)	3 (42)	3 (21)	2 (60)	6 (101)
Role	Frontline Responder	37 (513)	38 (319)	18 (464)	19 (350)
	Supervising Responder	35 (478)	14 (120)	17 (414)	30 (542)
	Chief/Management	25 (351)	45 (369)	63s (1587)	46 (833)
	(missing data)	3 (42)	3 (21)	2 (60)	5 (101)
Volunteer Status	Volunteer	-	-	31 (798)	-
	Career	-	-	66 (1657)	-
	(missing data)	-	-	3 (70)	-

2.1.3. Types of Missing Data

There were three different ways data were considered missing for analyses: non-respondents, demographic question partial completes, and question partial completes.

Non-respondents. The survey was broadly distributed, providing many first responders with the opportunity to complete it; however, while some of the first responders who received the survey chose to complete it, others chose not to. Those that had the opportunity to complete the survey but ultimately chose not to can be considered non-respondents. It is difficult to estimate how many first responders fall into this group as the total number of first responders that had the opportunity to complete the survey is unknown. Further, the demographic makeup of the entire first responder population is not well characterized, as described in previous work [10]. Since nothing is known about these non-respondents, they were not included in the analyses, and the results are only representative of the information contained in the sample. They do not necessarily generalize to a broader population.

Demographic partial completes. Some survey respondents took the survey but did not complete one or more of the demographic questions. Since the focus of the statistical analyses was on subgroup comparisons, and the subgroups were defined by responses to the demographic questions, survey respondents that did not complete one or more of the demographic questions were not included in the analyses. Additionally, from the definition of the population of interest by subject matter experts, only respondents reporting that they were a frontline responder, supervising responder, chief, or part of management, or was from a rural, suburban, or urban community, were included in the analyses.

Question partial completes. Because all responses to all questions were voluntary, respondents could choose not to answer any of the multiple-choice questions. For analysis of a specific question, respondents that did not answer the question were not included in the analysis. Exclusion decisions were made per question since a respondent could choose to answer some questions but not others.

2.2. Data analysis

We used different statistical analysis techniques to look for group differences on the multiple-choice and the partial ranking survey questions. For multiple choice questions, we used sparse multinomial regression. For partial ranking questions, Plackett-Luce models were utilized ([14], [19]).

Below we discuss the purpose, benefits, and interpretation of results for these two statistical methods. This is to provide readers with a high-level overview of why these methods were used and what the results tell us about first responders and their communication technology. For more detailed statistical methods considerations, please see Appendix A.

2.2.1. Sparse Multinomial Regression for Multiple-Choice Survey Questions

For each multiple-choice question, we applied sparse multinomial regression with the LASSO or L_1 penalty [8]. Sparse multinomial regression is an existing statistical analysis method that can simultaneously, efficiently, and rigorously compare many groups. The glmnet package for the R environment for statistical computing and graphics (R) [21] described in [8] was used for this study.

2.2.1.1. Detecting Group Differences for Multiple Choice Survey Questions

A benefit of using this technique was the ability to compare many groups simultaneously and efficiently. Given that we were interested in comparing first responders across subgroups defined by six demographic variables (i.e., age, years of service, sex, role, discipline-specific, area) each with as few as two (i.e., male, female) and as many as 12 (e.g., years of service) categories, there were a very large number of comparisons to be made. Take for example FF. The number of categories for each variable yield $6 \text{ (age categories)} \cdot 12 \text{ (years of service categories)} \cdot 2 \text{ (genders)} \cdot 2 \text{ (area types)} \cdot 3 \text{ (roles)} \cdot 2 \text{ (career vs. volunteer)} = 1\,728$ groups of interest for comparison.

In each analysis, a baseline group is defined. The baseline group for all disciplines is essentially the same, and consists of male, frontline responders from urban/suburban areas that are 46 – 55 years old with 21 – 25 years of service. The baseline groups differed slightly for FF, EMS, and COMMS, in that the baseline also included the discipline-specific variables. The baseline group for FF also included career, EMS included public, and COMMS included civilian (note there was no discipline-specific item for LE).

The regression models simultaneously compare between each subgroup of interest to determine if there exists evidence of differences[1] between any of them. These models result in estimates called regression coefficients. Generally, regression coefficients are numbers with a directional sign (i.e., positive or negative), and a combination of them indicate if the average outcome for one subgroup increases or decreases in comparison to the average in another. In sparse regression models, a coefficient may be estimated to be exactly zero. In the

[1] The reader is encouraged to note the difference between the phrase "no evidence of a difference between groups" and "no difference between groups." The latter is a much stronger conclusion than the former, and none of the analyses considered in this report are capable of supporting it. In the extreme, for example for FF, if one of the 1728 groups contain no respondents, it cannot be compared to the baseline group. There may truly be a difference between them, but for the available data there is no evidence of it.

case that all coefficients in a combination representing the difference between two subgroups are estimated to be zero, we say that the data do not contain evidence of a difference between the average outcome in the subgroups. In contrast, if at least one coefficient in the combination is estimated to be non-zero, we say that there does exist evidence of a difference in the average outcome between the subgroups. The interpretation of regression coefficients is discussed further in Appendix A.

2.2.2. Plackett-Luce Model for Partial Ranking Survey Questions

In the survey, ranking questions were used to identify which items were most preferred (and least preferred) by respondents. The goal of analyzing ranking data is to identify the preference structure for a collection of items. An important analysis consideration is if the survey items are completely ranked (e.g., respondents are asked to rank all items) or partially ranked (e.g., respondents are asked to rank only their top five). In the survey, respondents were asked to provide a **partial ranking** of both devices and applications/software.

This was taken into consideration when choosing statistical methods to find group differences between the rankings. The Plackett-Luce model was chosen because it is suited for partial ranking data. The Plackett-Luce model ([14], [19]) is a probability model that is capable of quantifying the preference structure for each partial ranking question in the survey. For subgroups of interest (e.g., rural responders), the preference for a device or application was estimated using the `gibbsPLMIX` function in the PLMIX package [17] for R. Group comparisons for the partial ranking questions were done by manually grouping the data, fitting the Plackett-Luce model separately to each group, and then comparing the results for each group separately. For this report, it is sufficient to understand that preference scores were estimated, and credible intervals for those estimates were constructed. The credible intervals enable comparisons between subgroups of interest. More information is available in Appendix A. Previous expertise with this data was used to reduce the number of comparisons of interest.

2.2.2.1. Theoretical Example: Track and Field Competition

To provide some intuition about the Plackett-Luce model, consider a sequence of track-and-field competitions where in each competition, the same five athletes compete against each other. Each race provides a ranking of the five athletes, e.g., (athlete E, 1), (athlete A, 2), (athlete D, 3), (athlete B, 4), and (athlete C, 5). The rankings between two races may differ, introducing randomness. To put it a different way, athlete E may not always win, athlete A may not always finish second, and so on. The Plackett-Luce model postulates that each runner possesses an underlying strength, p_{A} for athlete A, p_{B} for athlete B, and so on. The athlete strengths may be assumed to be numbers between zero and one that sum to one, i.e., probabilities. For one race, the ranking proceeds sequentially. The winner is chosen first, and the probability that athlete i wins is p_i. After the winner is chosen, there remain four athletes from which second place is selected. The remaining four strengths are scaled so that they again sum to one, and second place is selected randomly using those probabilities. Note that scaling the remaining four strengths so that they sum to one preserves the order of strengths, e.g., the largest of the remining four strengths maps to the largest probability. The process proceeds until all five athletes are ranked.

The five athletes may not all participate in every race in the sequence. This could happen if some of the athletes choose not to participate in or do not qualify for the race under study for a particular track meet. Such situations are handled by partial rankings. If two of the five runners participate, only the first and second ranks are assigned. If three of the five runners participate, the first three ranks are assigned, etc. Partial rankings require the implicit assumption that the unranked items would have received lower ranks than the items that were ranked, but otherwise they are unknown. For the track-and field example, this means that if three of the athletes participate in a race, and two do not, the two athletes that do not participate would receive a rank lower than 3. This may or may not be a realistic assumption for some situations, but it is an assumption of the Plackett-Luce model.

The goal of analyzing ranking data like these is to take a sequence of complete or partial rankings and estimate the athlete strengths. If athlete E won half of the races the estimated strength of athlete E should be about 0.5. On the other hand, if athlete C lost all of the races the estimated strength of athlete C should be about 0. For other situations, say an athlete that did not win any races, but finished second many times, the value of the estimated athlete strength is more difficult to intuit.

The track-and-field example maps to our current example of ranking public safety communication technologies in the following way. The races are the survey respondents because each survey respondent provides one set of rankings. The athletes are the communications technologies because each survey respondent ranks their top five technologies. All rankings are partial because survey respondents rank their top five technologies from more than five choices. Lastly, the communication technologies do not possess an underlying strength, like an athlete, but an underlying perception of usefulness. That is, technologies that consistently receive a higher ranking than others are perceived to be more useful by users.

2.2.2.2. Detecting Group Differences in Partial Ranking Data and Uncertainty

To identify group differences of interest for the ranking questions, the survey responses were first divided into the subgroups of interest, and then perceptions of usefulness were estimated separately for each group. For each estimate of perceived usefulness, a 95% credible interval was generated. This interval provided a range of plausible values for the estimate, and so is a quantification of uncertainty. Between group comparisons of estimated perceptions of usefulness were based on the 95% credible intervals. If the credible intervals for the estimated perceived usefulness for each group overlapped, this indicated there was no evidence of a difference between the groups. In contrast, if the two credible intervals did not overlap, this indicated there was evidence of a difference between groups.

The reader should note that identifying group differences in this way ignored potential interactions between subgroups. For example, comparing rural versus urban/suburban FF may reveal that urban/suburban FF perceive desktop computers to be more useful than rural FF. However, if there was an important interaction between subgroups, it could be the case that the differences in perceived usefulness between urban/suburban and rural FF depend upon other subgroups (e.g., volunteer status). Unfortunately, it was impossible to compare the very large number of subgroups identified in Section 2.2.1 in the manner described for the partial ranking data. It would have been far too onerous, but more importantly, many of the subgroups identified in Section 2.2.1 did not contain any respondents, so direct comparison was impossible. Based on the results of the sparse multinomial regression analyses, we do not believe that ignoring potential interactions for the ranking data substantively affected our conclusions.

3. Results

3.1. How to Interpret the Results

This section presents analyses of the differences between subgroups for each discipline focused on:

- Area: rural compared to urban/suburban first responders
- Role: chief/management compared to frontline responders and supervising responders compared to frontline responders
- Volunteer (FF only): volunteer compared to career status FF

For each subgroup of each discipline, effects are organized into the following categories:

- Device usage and ranking
- Problems with technology
- Application/software usage and ranking
- Futuristic technology and VR

The COMMSs section does not include ranking items. Instead, area and role comparisons for the call center information, Next Generation 9-1-1, and information problem questions are considered.

Although the sparse multinomial regression models reveal many potential effects, this section details effects that were the focus of prior work and **correspond to estimated coefficients that are greater than 0.2.** These choices help to focus the discussion on effects that have the largest estimated impact, and which are important to subject matter experts. All coefficients with a non-zero estimate can be found in Appendix B. This includes coefficients representing differences between sex, age group, years of experience, public/private status of EMS, and civilian deputized status for COMMS.

In each section, the most important and relevant effects are described in the text and are accompanied by graphs showing the differences between subgroups. There are two types of graphs. One type shows the sparse multinomial regression results, and the other shows the results of the Plackett-Luce models for examination of the ranking data. Next, we walk-through an example of how to interpret the graphs.

3.1.1. Graphs Displaying Sparse Multinomial Regression Results for Multiple-Choice Survey Questions

The sparse multinomial regression results include two different types of effects: main effects and interactions. Each type of result has a different graph depicting it.

Main effects describe the average difference between subgroups, where averaging occurs across all of the other subgroups not under consideration. An example of a graph showing a main effect is displayed in Fig. 4.

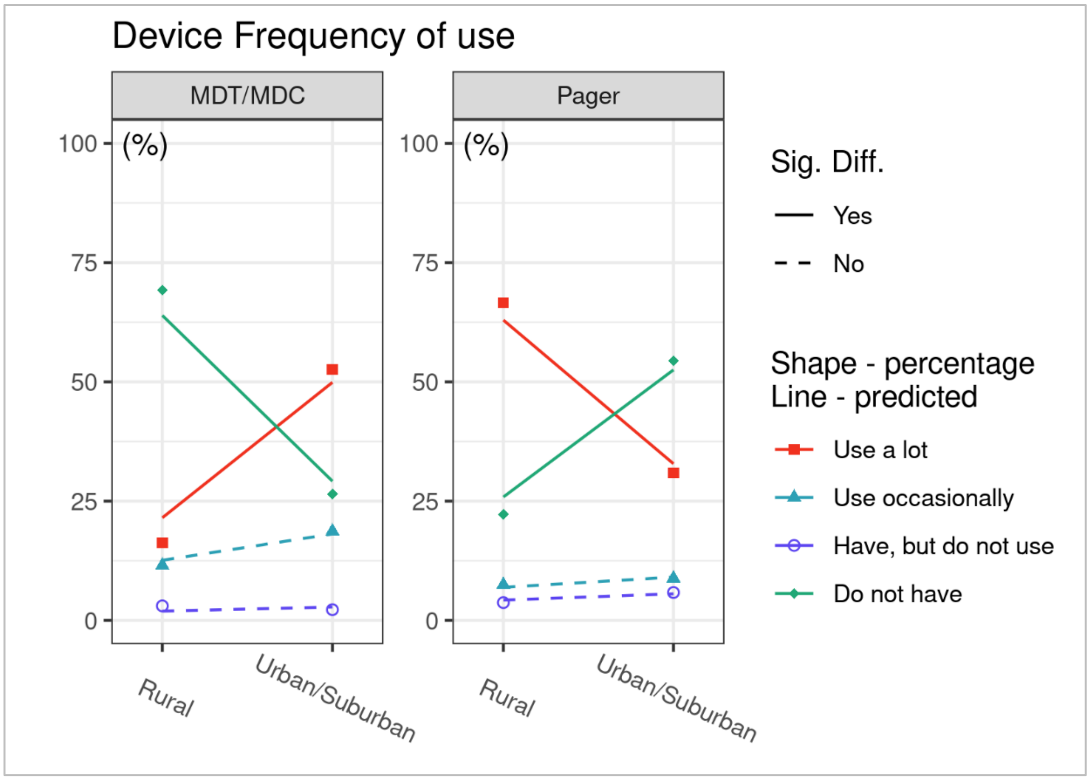


Fig. 4. Example of a main effects graph. Percentages, reported and predicted, for each frequency of use category, for selected devices, separated by rural and urban/suburban FF.

To orient the reader, the **title** describes the survey section, and the **gray boxes** indicate the device subgroups were compared on. Within each box, the **horizontal axis** identifies the subgroups being considered. The **vertical axis** indicates the percentage of respondents ranging from 0 % to 100 %. In the example of Fig. 4, the left graph displays the results of the analysis for the multiple-choice question about day-to-day frequency of use of MDT/MDC by FF. For both devices, the graph is showing the comparison of rural to urban/suburban FF.

Each graph has a collection of **shapes and colors** that correspond to the survey response options. The red squares are the percentage of respondents who selected they used their devices “a lot”, the blue triangles are the percentage of respondents who used their devices “occasionally”, and so on. For example, the red square in the MDT/MDC graph indicates that slightly over 50% of urban/suburban FF indicated that they used their MDT/MDC “a lot”.

The ends of the **colored lines** are each subgroup’s average predicted percentages, where the averaging is done across all other subgroups not under consideration. In some cases, the shape and the end of the line are similar. This indicates that the reported percentage of first responders selecting the response option was similar to the percentage predicted by the regression model. However, in some cases, the shape and the end of the line are different. For example, for MDT/MDC, the percentage of rural FF reporting they “do not have” an MDT/MDC (the green diamond) was higher than the percentage predicted by the model (end of the green line). The mismatches are most pronounced when there is a relatively large difference between subgroups, but the number of respondents (sample size) for one or more of the subgroups is small.

The **lines** connect each subgroup's average predicted percentages, where the averaging is done across all other subgroups not under consideration. The **slope of the lines** indicates the estimated difference between the subgroups. A **solid line** depicts estimated differences that are statistically significant (estimated regression coefficients greater than zero). For example, the red line connecting rural to urban/suburban for the pager graph indicated that there was a significant difference between rural and urban/suburban FF for the response option "use a lot" on the frequency of use question for pagers. We can see that rural FF had higher rates of using their pagers "a lot" (over 60% for both predicted and reported as indicated by the red shape and the end of the red line) compared to urban/suburban FF (just slightly over 25% for both predicted and reported as indicated by the red square and the end of the red line).

Main effect plots for the role factor, which has three categories, chief/management, frontline responder, and supervising responder, show three possible significant differences. The lines connecting average predicted values are drawn as solid lines if any of the three differences are statistically significant. This convention is consistent with identifying that a factor as a whole is important to predicting the response.

A **dashed line** depicts differences that are not statistically significant (estimated regression coefficients that are exactly zero). For example, the difference between rural and urban/suburban FF for response option "have, but do not use" for MDT/MDC is not significant. The line is nearly horizontal, and the reported and predicted values are just over 0% for both rural and urban/suburban FF. Dashed lines may not always be perfectly horizontal due to imbalance in the subgroups (e.g., different numbers of rural and urban/suburban FF) and the constraint that probabilities sum to one. Solid lines may appear nearly horizontal for similar reasons. Appendix A discusses these issues further.

In summary, the graph in Fig. 4 shows that rural and urban/suburban FF reported using MDT/MDC at different rates. We see that fewer rural FF reported using their MDT/MDC "a lot" and more reported that they "do not have" an MDT/MDC compared to urban/suburban FF. Fig. 4 also shows that rural and urban/suburban FF reported using pagers at different rates. We see more rural FF reporting using pagers "a lot" and fewer reporting "do not have" compared to urban/suburban FF. Rural and urban/suburban FF did not significantly differ on having but not using these devices nor reporting that they use them "occasionally."

A graph of interactions between subgroups has similar elements as the main effects graphs, but there are some important differences. An **interaction** describes the situation where a main effect between two subgroups is dependent on the values of other subgroups. An example of a graph depicting results of an interaction is displayed in Fig. 5.

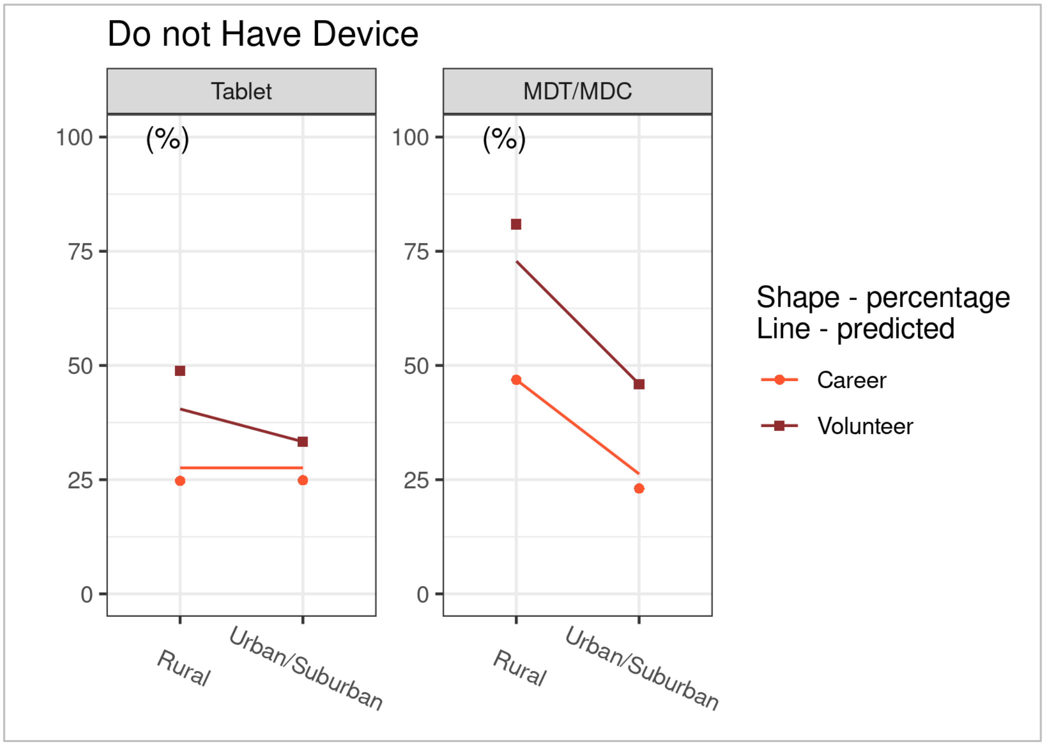


Fig. 5. Example of an interaction. Reported and predicted percentages of the "Do not have" response for the identified devices separated by areas and career/volunteer status.

The **title** and **gray boxes** orient the reader to the survey question, responses being examined and device or application/software. Fig. 5 shows the results for the survey response option "do not have" for the frequency of use question about tablets and MDT/MDC. The **horizontal axis** and the **colored shapes** together show what interaction effect is displayed. Here, the graph shows the interaction effect of area (rural and urban/suburban on the horizontal axis) and volunteer status (light red circles for career FF and dark red circles for volunteer FF). The ends of the **colored lines** represent the average prediction for the identified subgroup, and the **shapes** represent the reported percentages. Similar to the graphs of main effects, the lines connect average predicted percentages where averaging is done across all other subgroups not under consideration. The degree to which the lines are not parallel represents the estimated interaction. In this case, rural respondents "do not have" an MDT/MDC at a higher rate than urban/suburban respondents on average (a main effect), but the difference between (the effect of) rural and urban/suburban respondents is greater for volunteer FF than for career FF. The same interpretation is true for tablets.

3.1.2. Graphs Displaying Plackett-Luce Model Results for Partial Ranking Survey Questions

The second form of graphic depicting main effects is for the ranking data. Fig. 6 displays results comparing rural to urban/suburban FF on the perceived usefulness of devices. The **horizontal axis** displays all the devices that could be ranked in the survey, and the **vertical axis** is the perceived usefulness, such that higher values indicate greater perceived usefulness. **Colors and shapes** delineate the subgroups being compared, with blue circles for rural FF and orange triangles for urban/suburban FF. The **shapes** represent the perceived usefulness estimates for the groups.

The **lines** on each symbol represent the 95% credible intervals for the estimates of perceived usefulness. When the lines surrounding the shapes do not overlap for the two groups, this means the credible intervals for the estimates do not overlap and that there is evidence of a difference between groups. For example, the estimated perceived usefulness of desktop computers is about 0.19 for urban/suburban FF, and it is about 0.11 for rural FF. The 95% credible interval for urban/suburban FF is about [0.18, 0.2], and for rural FF it is about [0.1, 0.12]. Since the 95% credible intervals do not overlap, we say that there is a statistically significant difference in the perceived usefulness of desktop computers for rural and urban/suburban FF, such that urban/suburban FF perceived desktop computers to be more useful than rural FF. In contrast, the credible intervals do overlap for the two groups on perceived usefulness of portable radios. This is interpreted as no evidence of a difference in the perceived usefulness of portable radios between rural and urban/suburban FF. In fact, both groups perceived portable radios to have relatively high usefulness.

Before continuing, the reader is reminded that it is assumed that unranked items would have been assigned lower ranks than ranked items. Thus, a low score for perceived usefulness could be due to an actual low perception of usefulness, or it could be due to a broad lack of availability. The latter is likely driven by resource constraints. Consider the low perceived usefulness score for MDT/MDC for rural FF in Fig. 6. This could be due to inaccessibility of MDTs/MDCs for rural FF, not necessarily because rural FF would not find them useful if they were available.

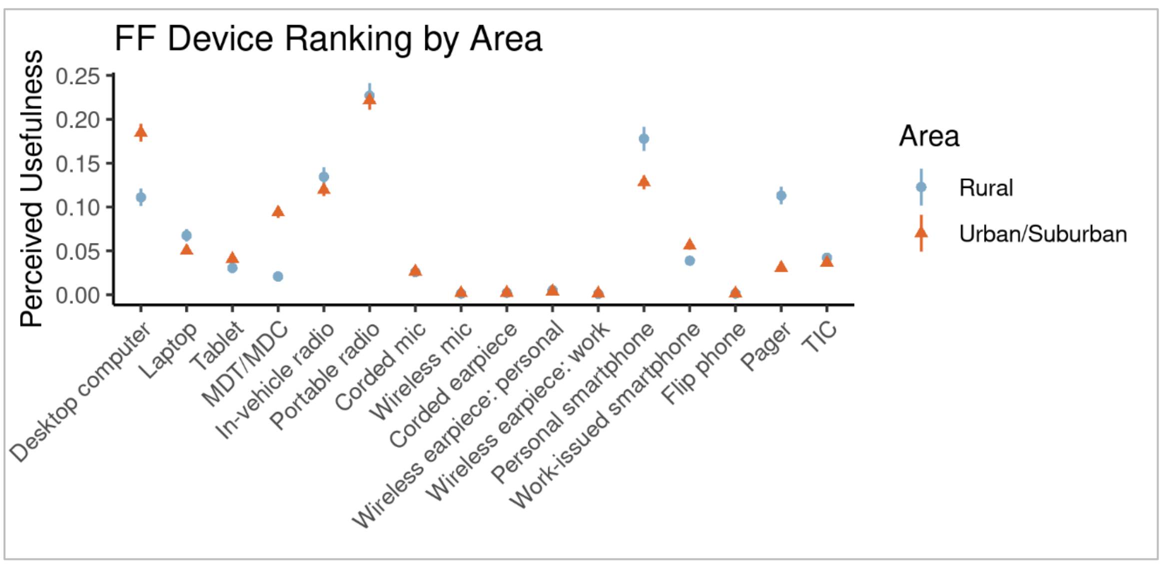


Fig. 6. Example of FF Device Ranking by Area.

3.2. COMMS

This section presents the selection of COMMS subgroup comparisons.

3.2.1. Rural compared to Urban/Suburban

Overall, key differences between rural compared to urban/suburban COMMS illustrated that rural COMMS were:

- Less likely to use language apps/software "a lot"
- More likely to report not having first responder vehicle tracking

3.2.1.1. Application/Software Frequency

Rural COMMS were more likely to not have first responder (FR) vehicle tracking (Fig. 7). Nearly half of rural COMMS respondents 47 % (37 % predicted) reported not having first responder vehicle tracking while 22 % (28 % predicted) of their urban/suburban counterparts reported the same. In addition, rural COMMS were less likely to use language translation applications/software "a lot" compared to urban/suburban COMMS (Fig. 7). Only 10 % (15 % predicted) of rural COMMS reported using these apps "a lot" compared to 32 % (28 % predicted) of urban/suburban COMMS.

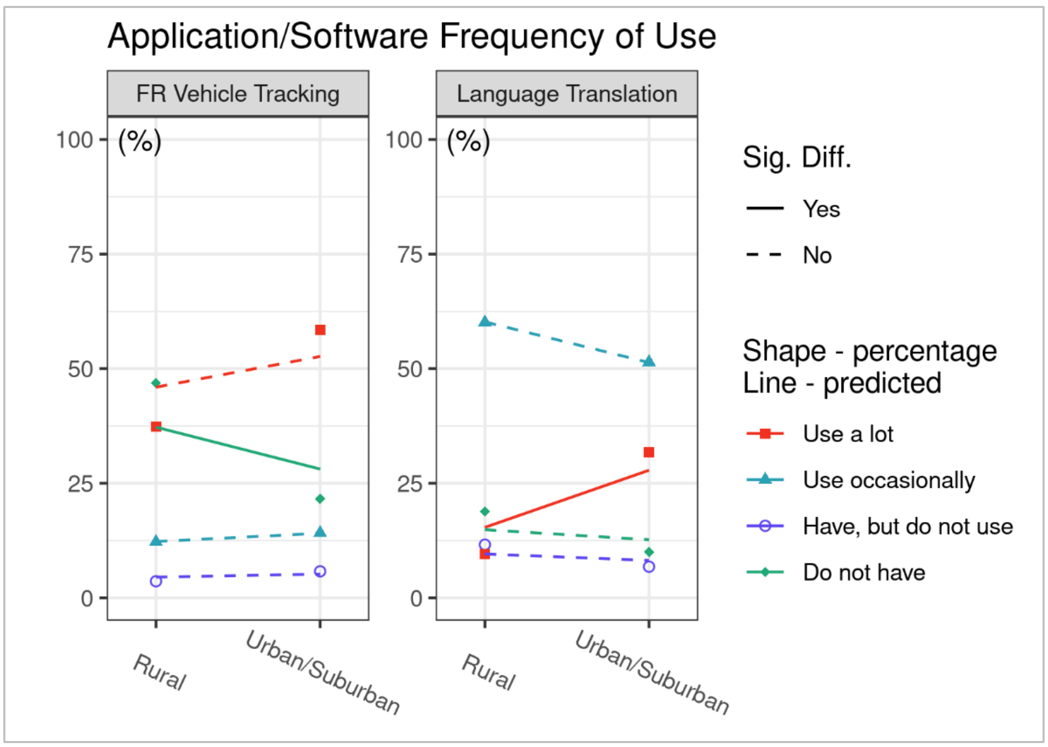


Fig. 7. Percentages, reported and predicted, for each frequency of use category, for applications/software listed, separated by rural and urban/suburban COMMS.

3.2.2. Chief/Management and Supervising Responders compared to Frontline Responders

Overall, key differences between frontline compared to chief/management and supervising COMMS illustrated that supervising and chief/management COMMS were:

- More likely to use work and personal smartphones "a lot"

- More likely to use email “a lot”
- More likely to think receiving texts at call centers would be beneficial
- More likely to have heard of Next Generation 9-1-1 (NG911)

3.2.2.1. Device Frequency

Both supervising COMMS and chief/management COMMS were more likely to report using personal and work smartphones “a lot” compared to frontline COMMS (Fig. 8). Chiefs/management COMMS used work smartphones “a lot” the most frequently (60 % reported and 54 % predicted) followed by supervising COMMS (35 % reported and 31 % predicted). Only 5 % (13 % predicted) of frontline COMMS reported using work smartphones “a lot.”

Whether or not COMMS had a work smartphone also differed by role (Fig. 8). Frontline COMMS were more likely to report not having a work smartphone (86 % reported and 78 % predicted), while far fewer supervising COMMS (50 % reported and 54 % predicted) and chief/management COMMS (26 % reported and 32 % predicted) report not having a work smartphone. Chief/management COMMS and supervising COMMS were also more likely to use a personal smartphone “a lot” compared to frontline responders (Fig. 8).

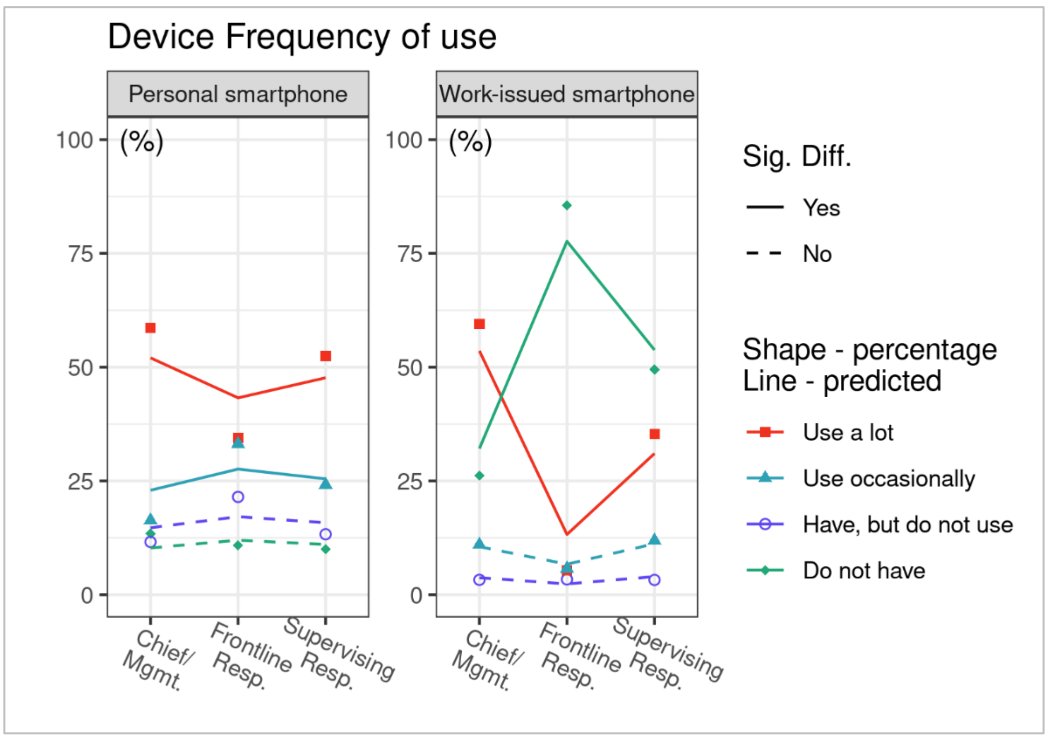


Fig. 8. Percentages, reported and predicted, for each frequency of use category, for devices listed, separated by the COMMS roles chief/management, frontline responder, and supervising responder.
* Management is abbreviated mgmt. and responder is abbreviated resp.

3.2.2.2. Application/Software Frequency

Both supervising COMMS and chiefs/management COMMS were more likely to use email “a lot” compared to frontline COMMS (Fig. 9). A majority of all roles used email in their day-to-day work “a lot,” but while 70 % (79 % predicted) of frontline COMMS used email “a lot,” over 90% of supervising COMMS and chief/management did (89 % and 85 % predicted, respectively).

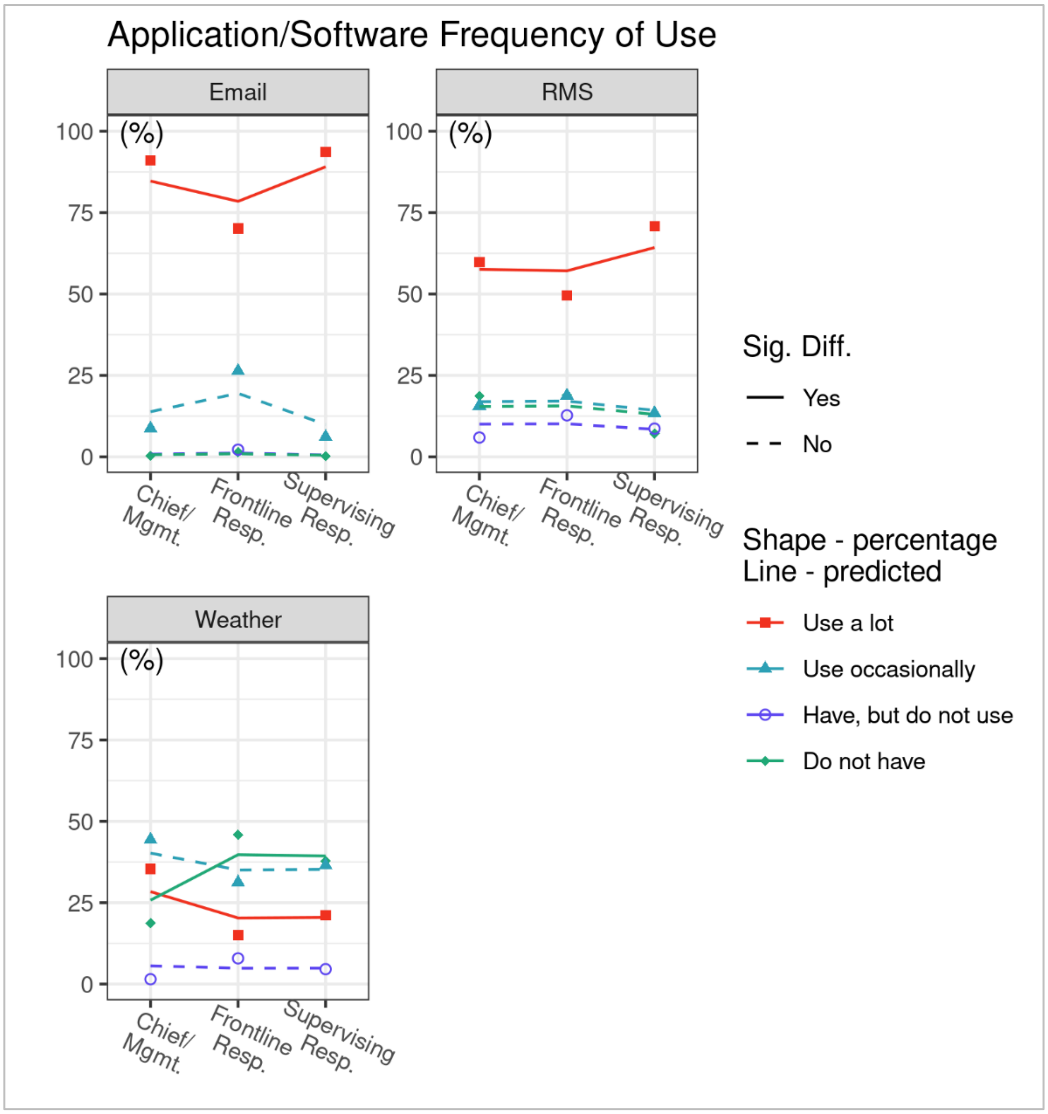


Fig. 9. Percentages, reported and predicted, for each frequency of use category, for applications/software listed, separated by the COMMS roles chief/management, frontline responder, and supervising responder.
* Management is abbreviated mgmt. and responder is abbreviated resp.

Supervisors were more likely to use Records Management System (RMS) “a lot” compared to frontline COMMS (Fig. 9). Nearly 50 % (57 % predicted) of frontline COMMS used RMS “a lot,” but over 70 % (64 % predicted) of supervising COMMS did.

Chief/management COMMS were more likely to use weather apps “a lot” and less likely to not have weather apps compared to frontline responders (Fig. 9). Over a third of chief/management reported using their weather app “a lot” (35 % reported and 28 % predicted), while only 15 % (20 % predicted) of frontline COMMS reported using it “a lot”.

3.2.2.3. Call Center Information and Next Generation 9-1-1

Both chief/management and supervising COMMS were more likely than frontline COMMS to indicate that receiving texts at call centers would be beneficial (Fig. 10). While 62 % (70 % predicted) of frontline responders believed this would be beneficial, 79 % (74 % predicted) of supervising responders and 85 % (79 % predicted) of chief/management COMMS did.

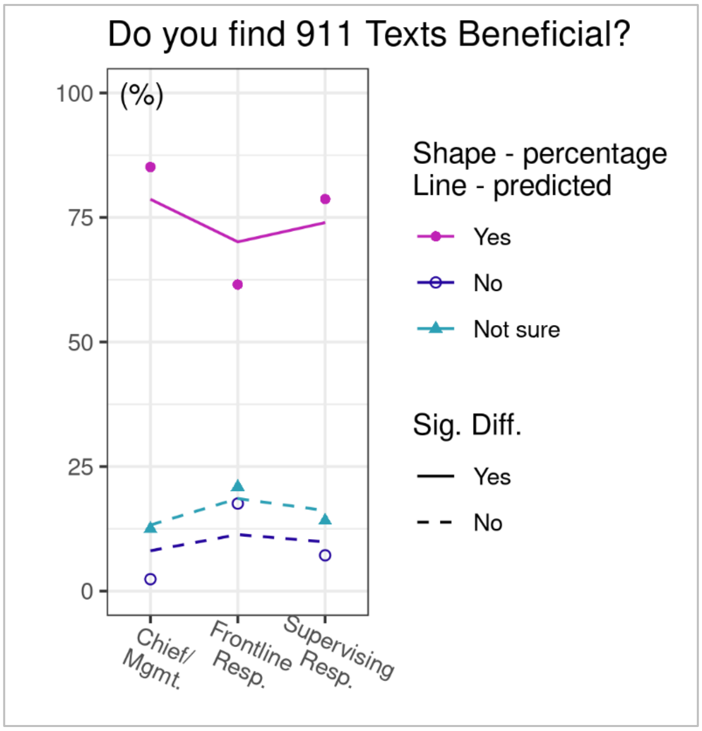


Fig. 10. Percentages, reported and predicted, of respondents identifying 9-1-1 text messages as beneficial separate by the COMMS roles chief/management, frontline responder, and supervising responder.

* Management is abbreviated mgmt. and responder is abbreviated resp.

Both chief/management and supervising COMMS were also more likely to have heard of NG911 compared to frontline COMMS (Fig. 11). While 78 % (85 % predicted) of frontline had heard of NG911, over 90 % (reported and predicted) of supervising responders had, and nearly all (93 % predicted) of chief/management COMMS had.

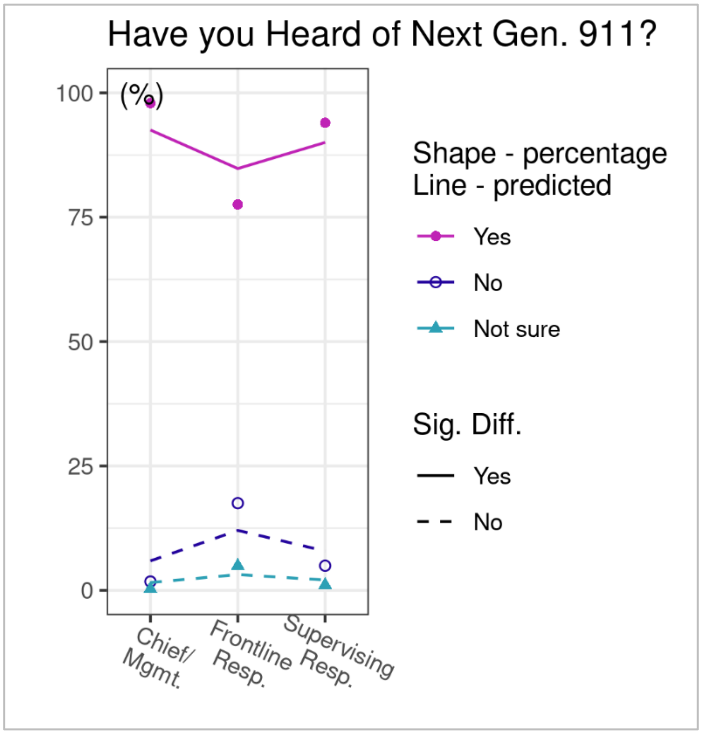


Fig. 11. Percentages, reported and predicted, of respondents identifying that they had heard of next generation 9-1-1 separated by the COMMS roles chief/management, frontline responder, and supervising responder.
* Management is abbreviated mgmt. and responder is abbreviated resp.

3.3. EMS

This section presents the selection of EMS subgroup comparisons.

3.3.1. Rural compared to Urban/Suburban

Overall, key differences between rural compared to urban/suburban EMS illustrated that rural EMS were:

- More likely to report not having tablets, corded mics, and MDT/MDC
- More likely to report using pagers, but less likely to use MDT/MDC "a lot"
- More likely to report not having first responder vehicle tracking and traffic apps
- More likely to have computer price problems

And, rural EMS:

- Ranked pagers as more useful and MDT/MDC and tablets as less useful
- Found Automatic External Defibrillator (AED), Emergency Response Guide (ERG), and weather apps to be more useful but Computer-Aided Dispatch (CAD), Records Management System (RMS) and traffic apps to be less useful

3.3.1.1. Device Frequency

Rural EMS were less likely to use MDT/MDC "a lot" (Fig. 12). Over 40 % (39 % predicted) of urban/suburban EMS used MDT/MDC in their day-to-day work "a lot," But only 14 % (20 % predicted) of rural EMS used MDT/MDC "a lot." Rural EMS were also less likely than urban/suburban EMS to report using tablets "a lot," (Fig. 12). Rural EMS reported using tablets "a lot" 30 % (35 % predicted) of the time, but urban/suburban EMS reported the same 44 % (39 % predicted) of the time. Rural EMS were also more likely to report they "do not have": tablets, corded mics, and MDT/MDC compared to urban/suburban EMS (Fig. 12).

Rural EMS were more likely to use pagers "a lot" (Fig. 12). Nearly twice as many rural EMS selected that they use their pagers "a lot" (57 % reported and 48 % predicted) as urban/suburban EMS (29 % reported and 40 % predicted).

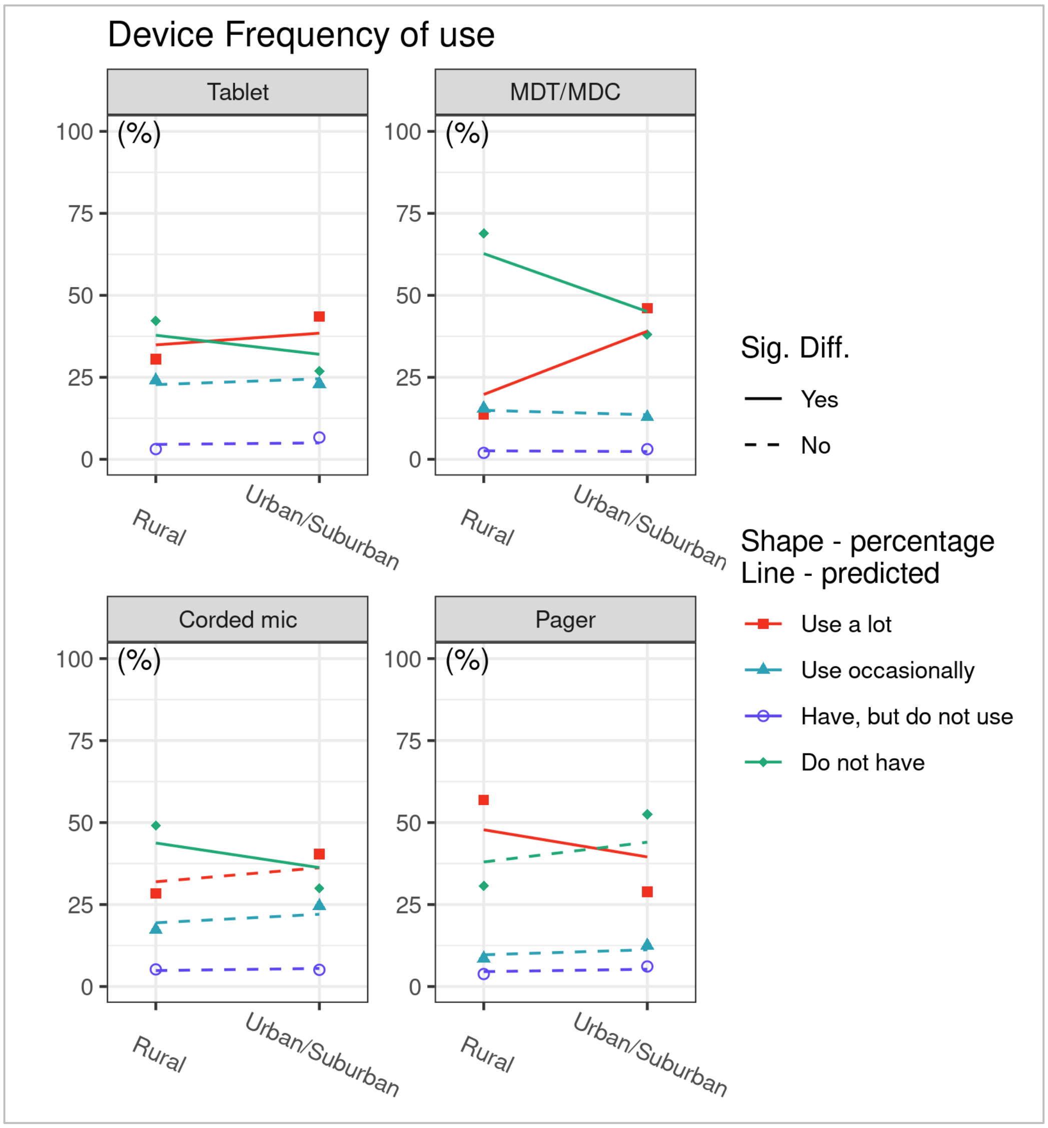


Fig. 12. Percentages, reported and predicted, for each frequency of use category, for devices listed, separated by rural and urban/suburban EMS.

3.3.1.2. Device Ranking

For most devices, there is not a statistically significant difference between the estimated preferences for rural and urban/suburban EMS (the lines overlap; Fig. 13). There are three exceptions: tablets, MDT/MDC, and pagers. Rural EMS perceive pagers as far more useful than their urban/suburban counterparts, and they perceived MDT/MDC as less useful (Fig. 13). Urban/suburban EMS perceived tablets to be slightly more useful than rural EMS (Fig. 13).

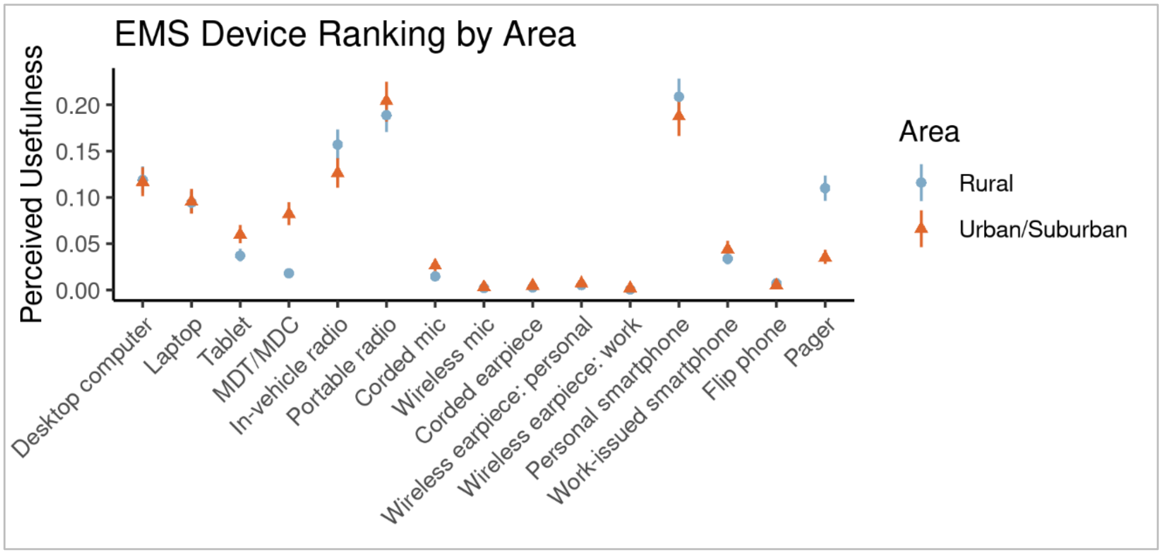


Fig. 13. Estimated perceived usefulness and 95 % credible intervals for those estimates of devices, separated by rural and urban/suburban EMS.

3.3.1.3. Problems with Technology

Rural EMS were more likely to have problems with computer price "always" or "most of the time" (Fig. 14). Only 5 % (9 % predicted) of urban/suburban EMS "always" experienced problems with computer price, while nearly three times as many rural EMS "always" experienced these problems (14 % reported and 11 % predicted). Further, 25 % of rural EMS experienced computer price problems "most of the time" (22 % predicted) compared to only 11 % (15 % predicted) of urban/suburban EMS. Relatedly, rural EMS were less likely to state that computer price "does not apply" (Fig. 14).

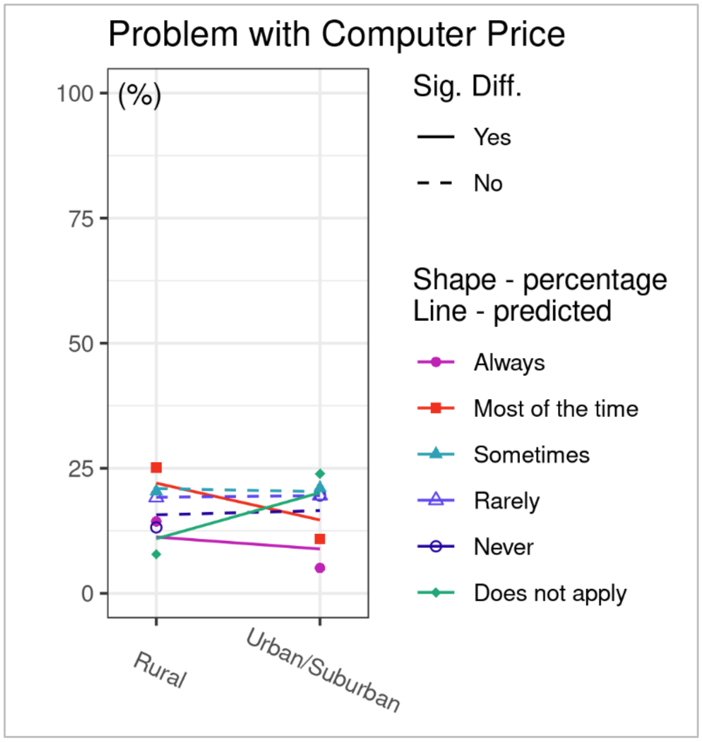


Fig. 14. Percentages, reported and predicted, for each category of the frequency of experiencing a problem with computer price, separated by rural and urban/suburban EMS.

3.3.1.4. Application/Software Frequency

Rural EMS were more likely to report not having first responder vehicle tracking and traffic apps (Fig. 15). While nearly 41 % (52 % predicted) of urban/suburban EMS did not have traffic applications/software, that percentage jumped to 66 % (57 % predicted) for rural EMS. Similar percentages of reporting “do not have” are found for FR vehicle tracking applications/software. Rural EMS were more likely to use ERG “occasionally” and less likely to say they had but did not use ERG compared to their urban/suburban counterparts (Fig. 15).

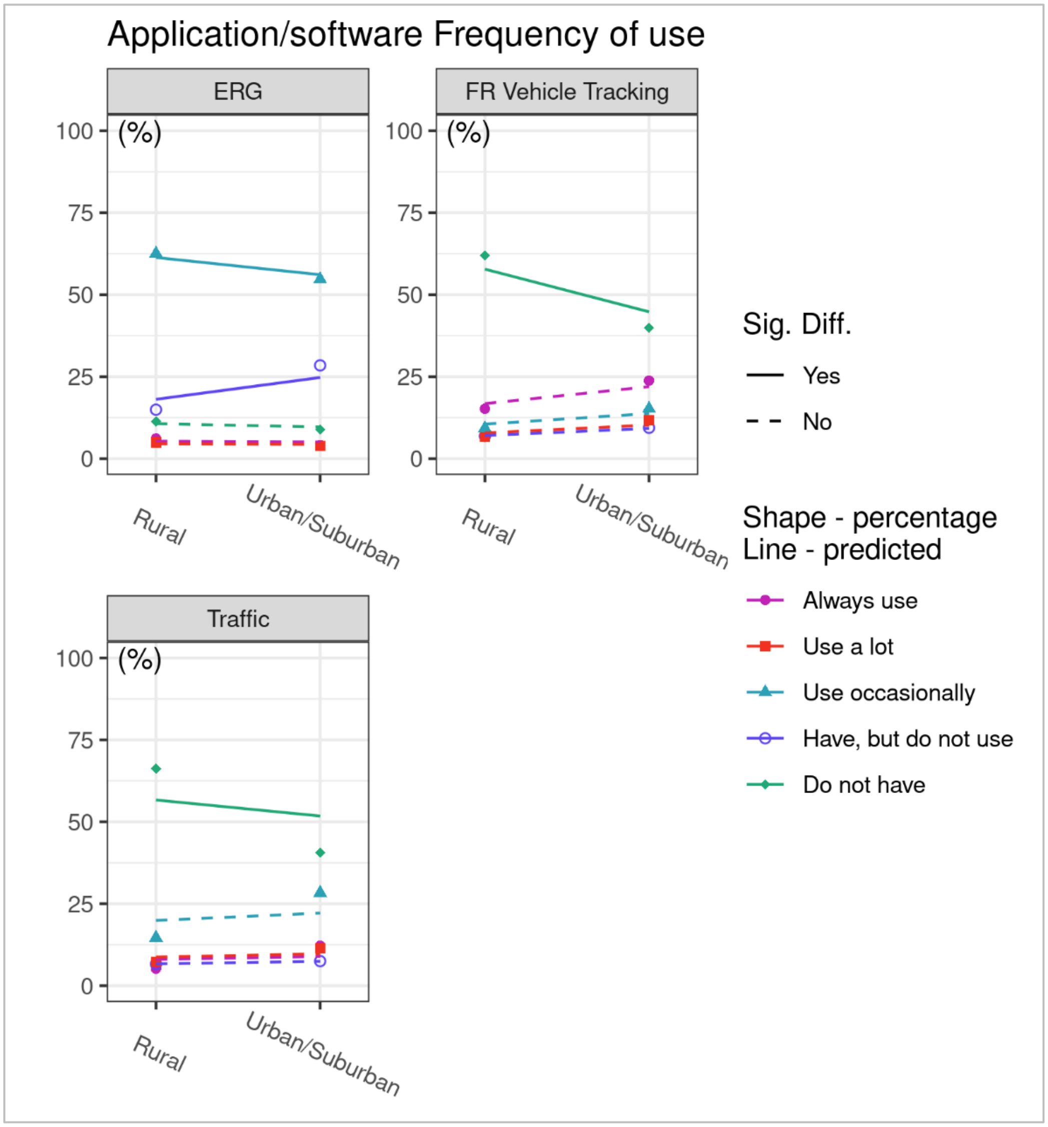


Fig. 15. Percentages, reported and predicted, for each frequency of use category, for applications/software listed, separated by rural and urban/suburban EMS.

3.3.1.5. Application/Software Ranking

For several applications/software there are statistically significant, yet small, differences in perceived usefulness between rural and urban/suburban EMS (Fig. 16). Rural EMS perceived AED, ERG, and weather applications/software as slightly more useful than their urban/suburban counterparts (Fig. 16). On the other hand, urban/suburban EMS perceive RMS and traffic applications/software as slightly more useful than their rural counterparts (Fig. 16). There is a large difference in the perceived usefulness of CAD applications/software (Fig. 16) between rural and urban/suburban EMS, with urban/suburban EMS perceiving CAD as far more useful than rural EMS.

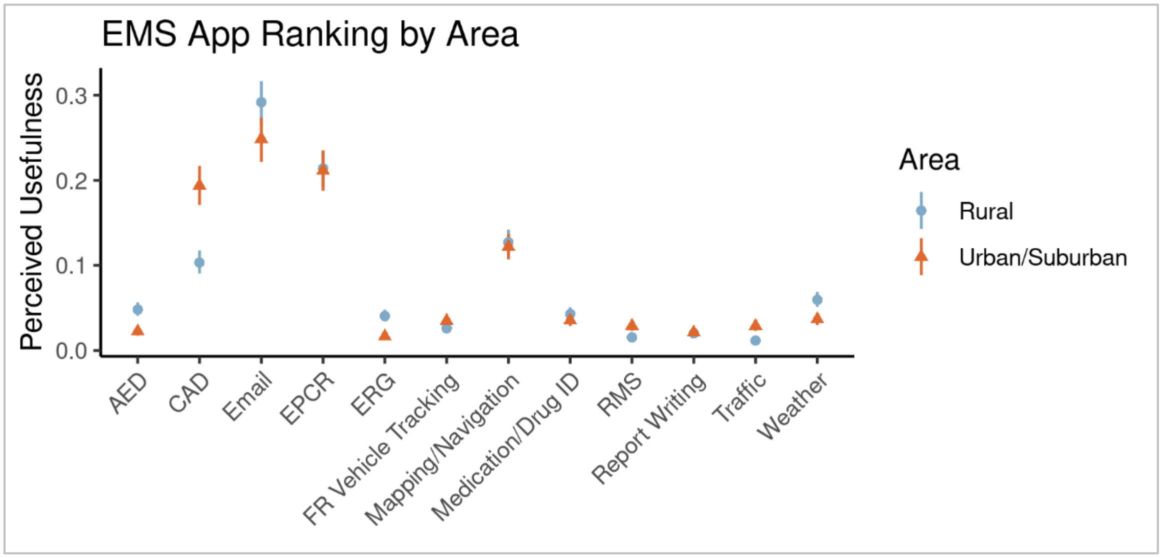


Fig. 16. Estimated perceived usefulness and 95 % credible intervals for those estimates of applications/software, separated by rural and urban/suburban EMS.

3.3.2. Chief/Management and Supervising Responders compared to Frontline Responders

Overall, key differences between chief/management, supervising responders, and frontline responders for EMS illustrated that chief/management EMS were:

- More likely to use work smartphones and computers "a lot"
- More likely to use email, ERG, and weather applications
- More likely to select Automatic Vehicle Location (AVL) as a useful futuristic technology
- More likely to have problems with MDT/MDC and radio price

And, chief/management EMS:

- Ranked work issued smartphones as more useful but personal smartphones as less useful
- Ranked email as more useful and Electronic Patient Care Reporting (EPCR) and CAD as less useful

3.3.2.1. Device Frequency

Chief/management EMS were more likely than frontline and supervising responders to use computers and work smartphones "a lot" (Fig. 17). Over 50% of chief/management, frontline, and supervising EMS used computers "a lot", but rates were significantly higher for chiefs/managers (73 % reported and 66 % predicted) compared to frontline (51 % reported and 60 % predicted) and supervising responders (65 % reported and 60 % predicted). With respect to work issued smart phones 43 % (33 % predicted) of chief/management EMS used them "a lot," but only 13 % (21 % predicted) of frontline responders, and 17 % (21 % predicted) of supervising responders did.

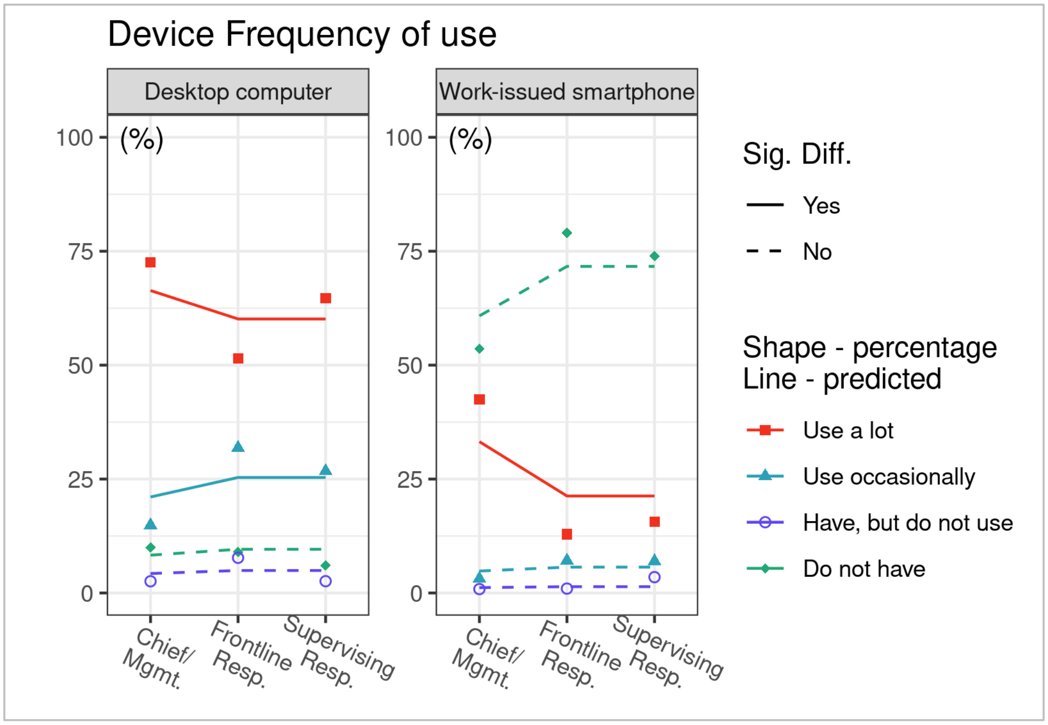


Fig. 17. Percentages, reported and predicted, for each frequency of use category, for devices listed, separated by the EMS roles chief/management, frontline responder, and supervising responder.
* Management is abbreviated mgmt. and responder is abbreviated resp.

3.3.2.2. Device Ranking

There were only two devices for which there were statistically significant differences in the estimated perceived usefulness of the device between chief/management roles and both frontline and supervising responders (Fig. 18). Chief/management perceived work issued smartphones as more useful than both frontline and supervising responders did. Presumably relatedly, chief/management perceived personal smartphones as less useful than both of frontline and supervising responders did. There are no statistically significant differences in the estimated perceived usefulness of devices between frontline and supervising responders.

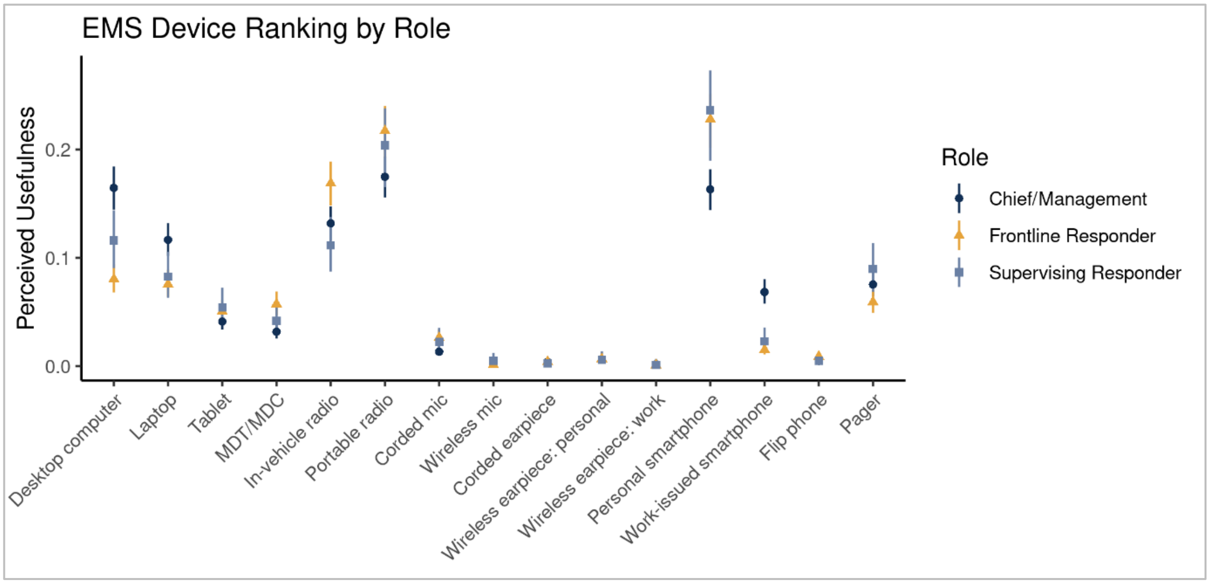


Fig. 18. Estimated perceived usefulness and 95 % credible intervals for those estimates of devices, separated by the EMS roles chief/management, frontline responder, and supervising responder.

3.3.2.3. Problems with Technology

Chief/management EMS experienced price problems with several devices more frequently than frontline and supervising responders (Fig. 19). Chief/management were more likely than frontline and supervising responders to have price problems "most of the time" for MDT/MDC and "always" for radios (Fig. 19). Most strikingly, chief/management EMS were less likely to indicate that price problems "does not apply" for computers, laptops, MDT/MDC, and radios. For computers, more than one in four frontline and supervising responders indicated that price problems "does not apply" (24 % reported and 25 % predicted), but one in fifteen chief/management (9 % predicted) said the same.

This suggests that price problems are experienced by chief/management for a range of devices used by EMS in their day-to-day work.

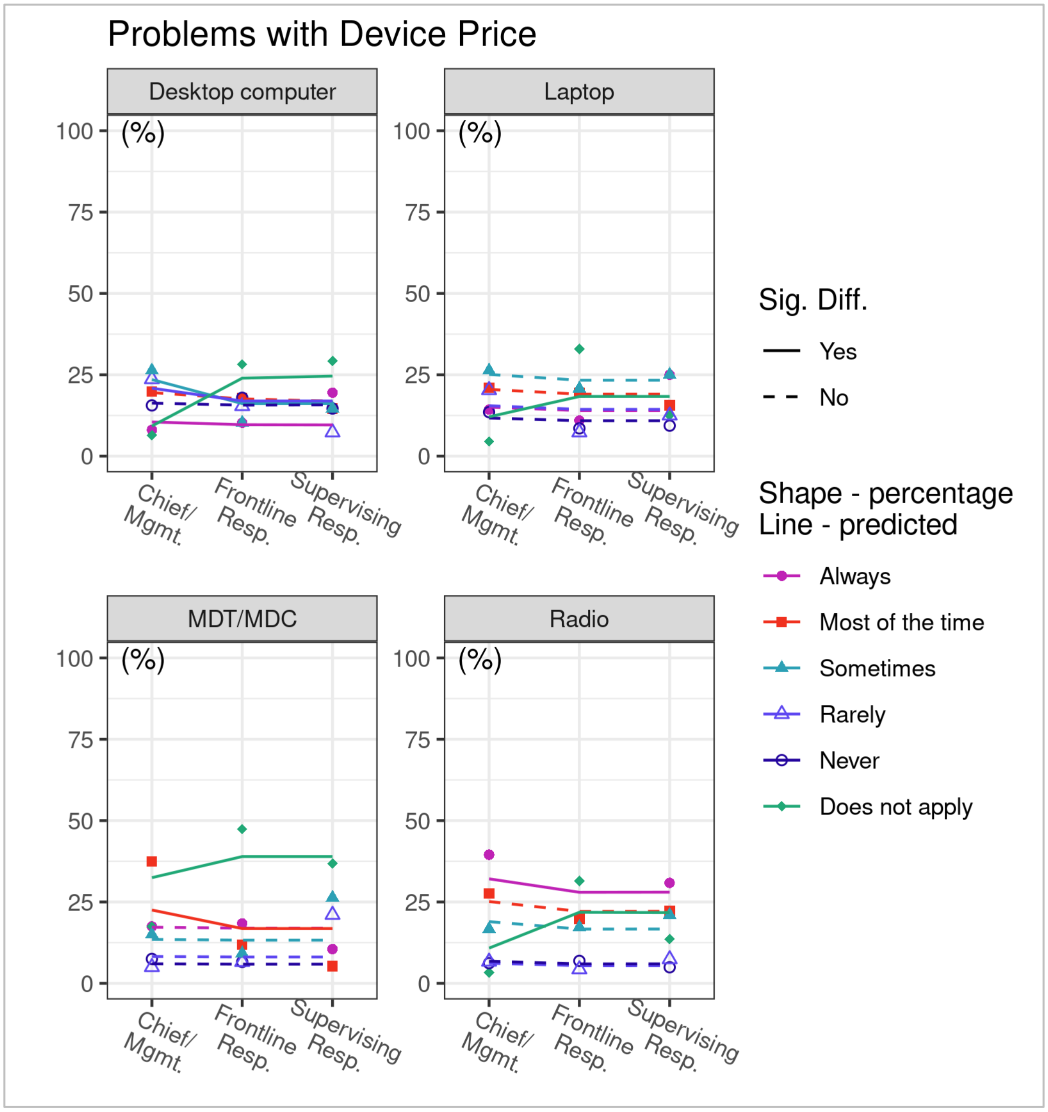


Fig. 19. Percentages, reported and predicted, for each category of the frequency of experiencing a problem with the price of the devices listed, separated by the EMS roles chief/management, frontline responder, and supervising responder.
* Management is abbreviated mgmt. and responder is abbreviated resp.

3.3.2.4. Application/Software Frequency

Chief/management EMS were more likely to use email "always" and ERG "occasionally" compared to frontline and supervising EMS (Fig. 20). About half of frontline EMS use email "always" (53 % reported and 63 % predicted), and 70 % of supervising EMS used email "always" (63 % predicted), but the percentage of chiefs/management using email "always" was 85 % (78 % predicted). Chief/management EMS were also more likely to use weather applications "a lot" and were less likely to report not having weather apps compared to frontline and supervising EMS (Fig. 20).

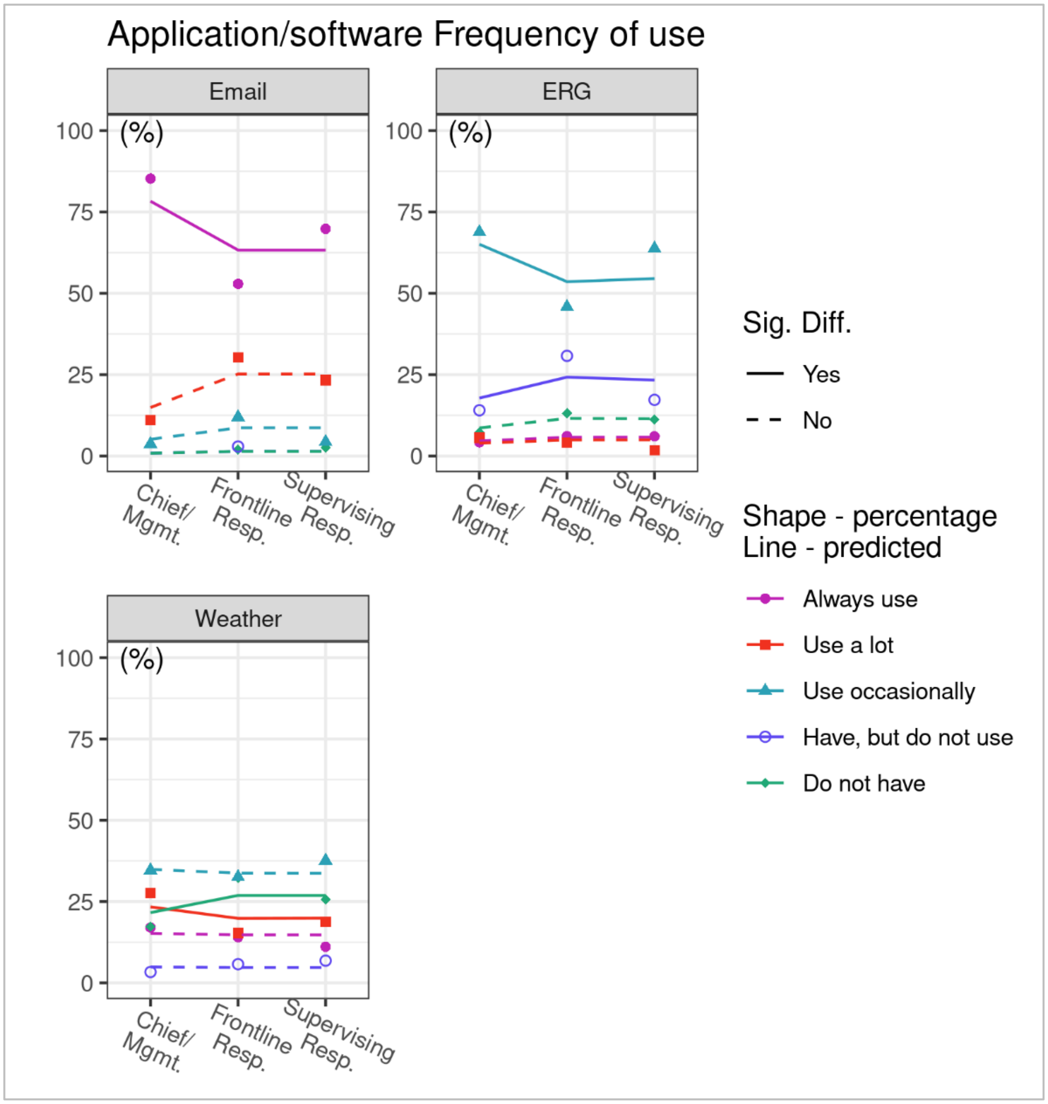


Fig. 20. Percentages, reported and predicted, for each frequency of use category, for applications/software listed, separated by the EMS roles chief/management, frontline responder, and supervising responder.
* Management is abbreviated mgmt. and responder is abbreviated resp.

3.3.2.5. Application/Software Ranking

Fig. 21 shows the perceived usefulness estimates for applications/software separated by the EMS roles chief/management, frontline responder, and supervising responder. The most pronounced difference in estimated perceived usefulness between the three roles is for email, with chiefs/management and supervising responders ranking email as the application/software that they perceived as most useful, and much more so than frontline responders. Frontline responders perceived EPCR as the most useful application/software, followed closely by CAD (Fig. 21). For EPCR and CAD, the differences between estimates of perceived usefulness were statistically significant between frontline responders and chief/management, but not between frontline and supervising responders, and not between chief/management and supervising responders.

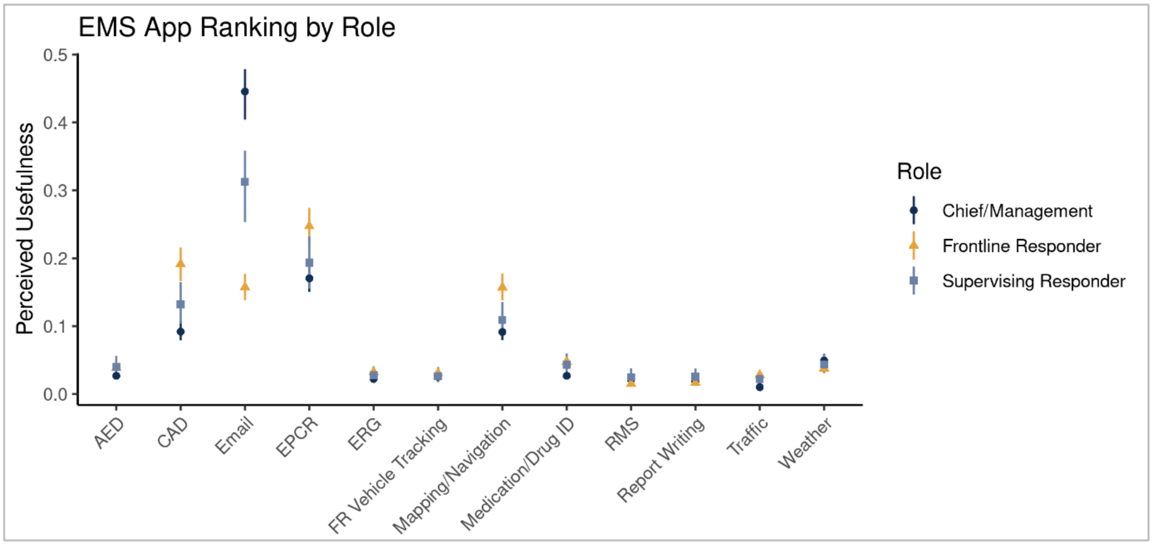


Fig. 21. Estimated perceived usefulness and 95 % credible intervals for those estimates of applications/software, separated by the EMS roles chief/management, frontline responder, and supervising responder.

3.3.2.6. Futuristic Technology and VR

Compared to frontline and supervising EMS, chief/management EMS were more likely to select AVL as a useful technology for their day-to-day work (Fig. 22). About half of chief/management EMS selected AVL and as a useful futuristic technology (46 % predicted), while only 30 % (35 % predicted) of frontline responders and 32 % (35 % predicted) of supervising responders did.

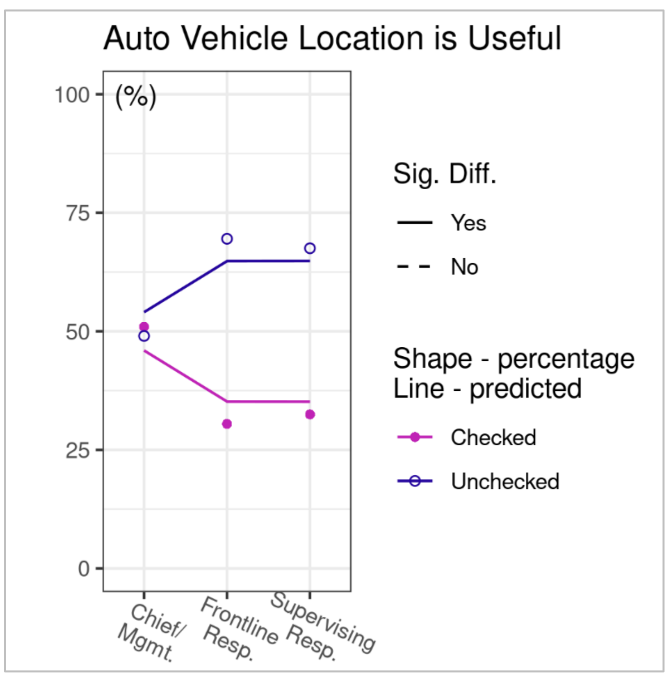


Fig. 22. Percentages, reported and predicted, for indicating AVL as a useful futuristic technology, separated by the EMS roles chief/management, frontline responder, and supervising responder.
* Management is abbreviated mgmt. and responder is abbreviated resp.

3.3.3. Rural and Chief/Management Interactions

For EMS, there was an interaction between area and role for "always" experiencing problems with pager price (Fig. 23). The estimated difference in the proportion of rural and urban/suburban reporting that pager price is "always" a problem is 0 %, or no effect, for frontline and supervising responders but is 4 % for chiefs/management EMS. The line depicting the average predicted values for frontline responders is obscured by the line for supervising responders.

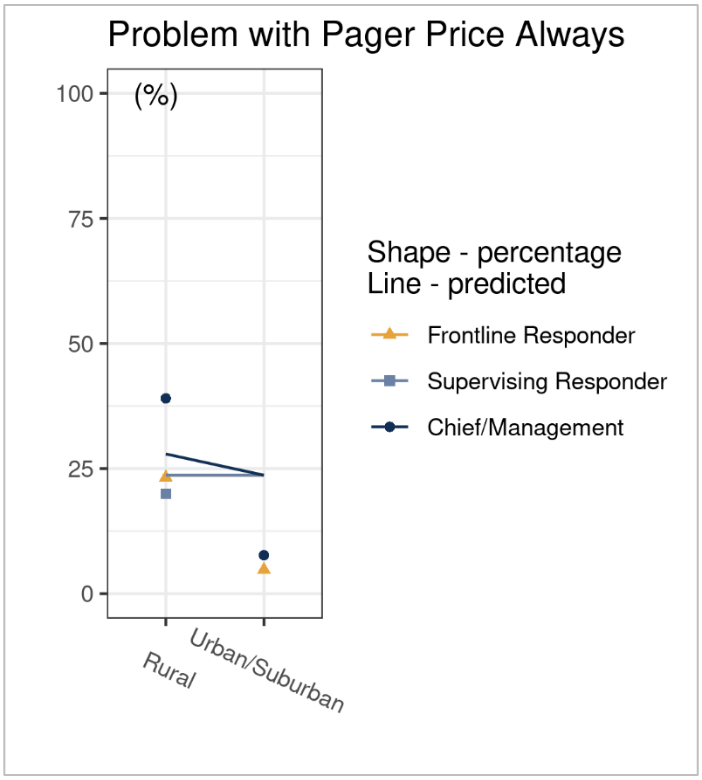


Fig. 23. Percentages, reported and predicted, of "always" experiencing problems with pager price, separated by rural and urban/suburban EMS and the EMS roles frontline responder, supervising responder, and chief/management.

* The line for frontline responders is covered by the line for supervising responders.

3.4. Fire Service

This section presents the selection of FF subgroup comparisons. In addition to area and role differences, and their interactions, volunteer and career FF are also compared.

3.4.1. Rural compared to Urban/Suburban

Overall, key differences between rural and urban/suburban FF illustrated that rural FF were:

- More likely to use pagers "a lot", but less likely to use MDT/MDC "a lot"
- More likely to report they did not have CAD, EPCR, language translation, and RMS
- More likely to have problems with the price of radios and computers
- More likely to have radio coverage problems

And, rural FF:

- Ranked personal smartphones, pagers, and email as more useful than urban/suburban FF

3.4.1.1. Device Frequency

Rural FF were more likely to use pagers “a lot” in their day-to-day work compared to urban/suburban FF (Fig. 24). Over 65 % (63 % predicted) of rural FF reported using pagers “a lot” compared to about 30 % (31 % predicted) of urban/suburban FF. Relatedly, 54 % (53 % predicted) of urban/suburban respondents reported that they “do not have” a pager, but only 22 % (26 % predicted) of rural respondents reported the same.

Rural FF were less likely to use MDT/MDC “a lot” (Fig. 24). While over 50 % of urban/suburban FF used their MDT/MDC “a lot” (50 % predicted), only around 15 % of rural FF did (21 % predicted). Rural FF were also more likely to report not having MDT/MDC compared to their urban/suburban counterparts (Fig. 24). Nearly 70 % (64 % predicted) of rural FF did not have an MDT/MDC compared to about 25 % (30 % predicted) of urban/suburban FF.

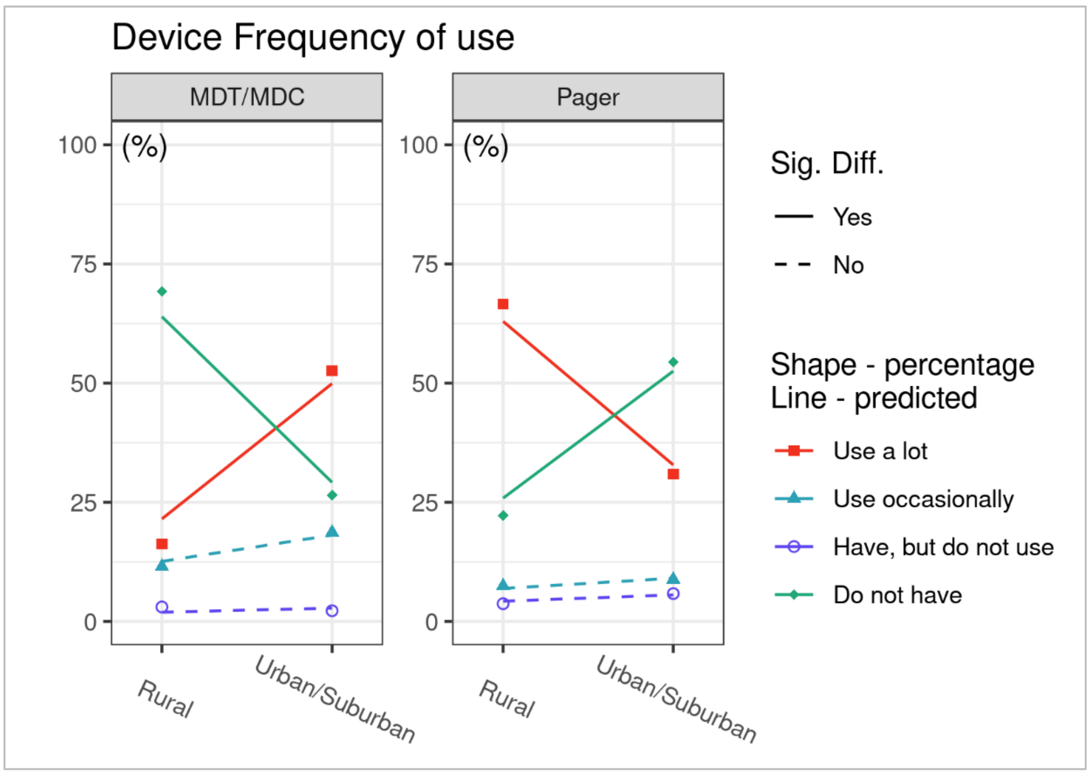


Fig. 24. Percentages, reported and predicted, for each frequency of use category, for devices listed, separated by rural and urban/suburban FF.

3.4.1.2. Device Ranking

The perceived usefulness of many devices for rural and urban/suburban FF were similar (Fig. 25). For example, both rural and urban/suburban FF ranked portable radio as the most useful device. However, preferences for some devices did differ between rural and urban/suburban FF: urban/suburban FF ranked desktop computers and MDT/MDC as more useful than rural FF, and rural FF ranked personal smartphones and pagers as more useful than urban/suburban FF.

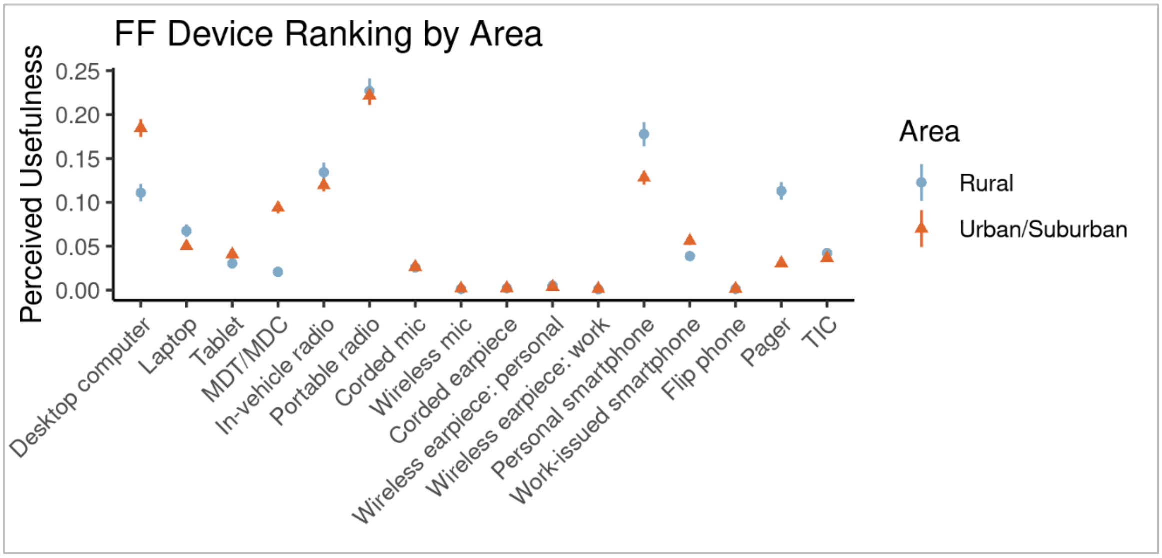


Fig. 25. Estimated perceived usefulness and 95 % credible intervals for those estimates of devices, separated by rural and urban/suburban FF.

3.4.1.3. Problems with Technology

Rural FF were more likely than urban/suburban FF to "always" have problems with the price of desktop computers and radios (Fig. 26). They were also more likely to have these problems "most of the time" (Fig. 26). While only about 6 % (7 % predicted) of urban/suburban FF had problems "always" with computer price, about 16 % (13 % predicted) of rural FF did. About 26 % (27 % predicted) urban/suburban FF had problems with radio price "always" compared to 40 % (38 % predicted) of rural FF.

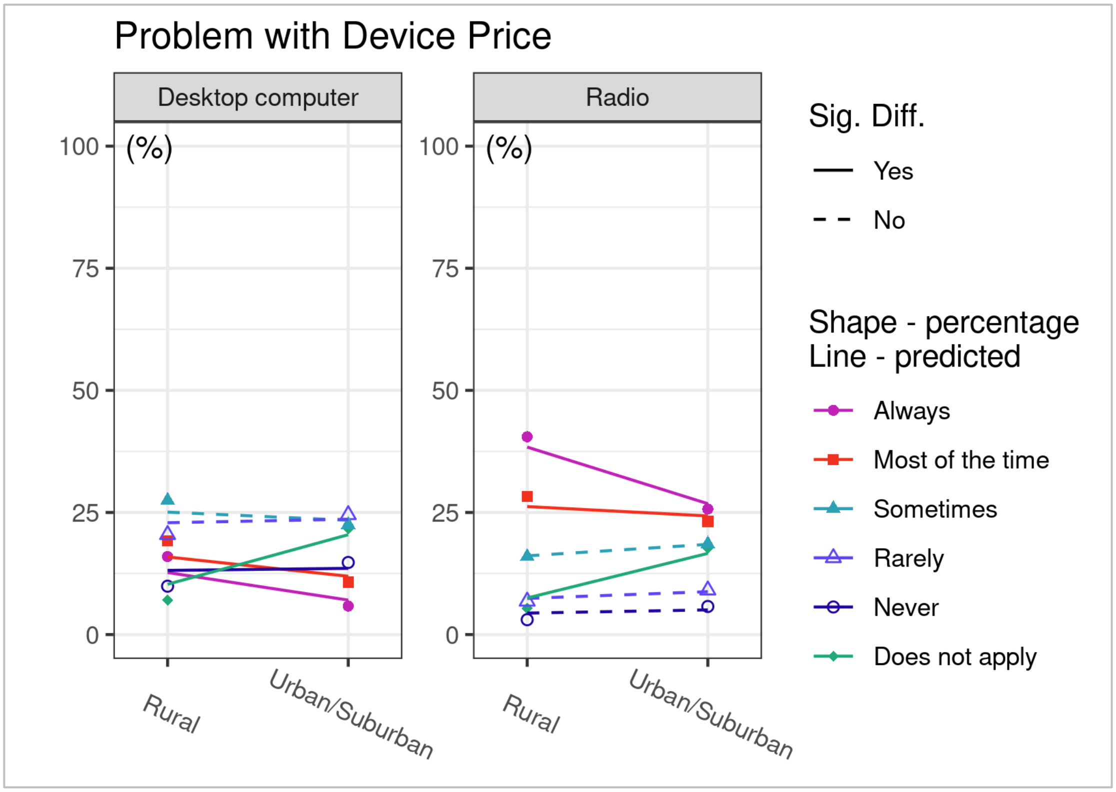


Fig. 26. Percentages, reported and predicted, for each category of the frequency of experiencing a problem with the price of the devices listed, separated by rural and urban/suburban FF.

Rural FF also reported problems with radio coverage at a higher rate than their urban/suburban counterparts (Fig. 27). While 21 % (14 % predicted) of rural FF reported that they "always" experienced this problem, only 6 % (10 % predicted) of urban/suburban FF did. Note the filled circle in Fig. 27 representing the reported percentage (6 %) of urban/suburban FF "always" having radio coverage problems is obscured by the other symbols in the figure.

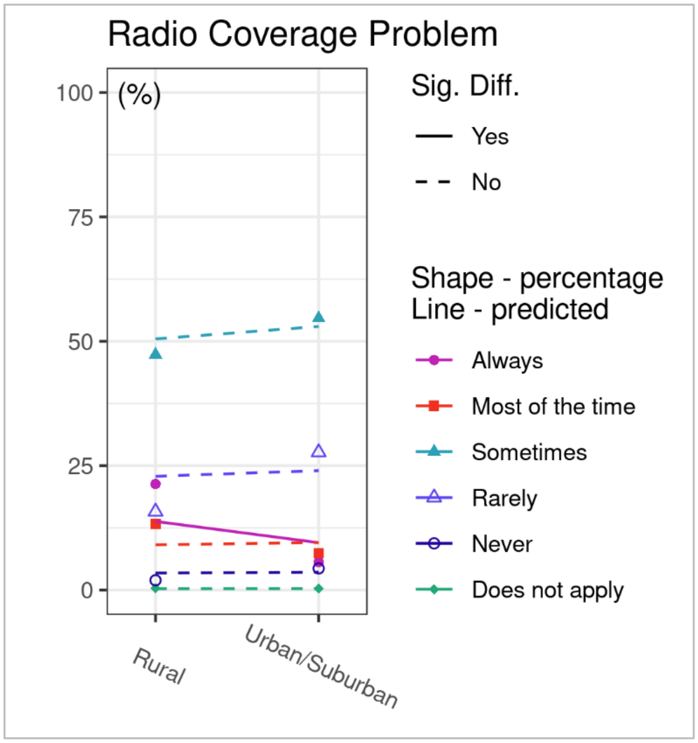


Fig. 27. Percentages, reported and predicted, for each category of the frequency of experiencing problems with radio coverage, separated by rural and urban/suburban FF.

3.4.1.4. Applications/Software Frequency

Rural FF were more likely than urban/suburban FF to report that they did not have some applications/software, including, CAD, EPCR, language translation, and RMS (Fig. 28). Differences between rural and urban/suburban FF are especially pronounced for CAD and EPCR. While nearly 40% (33 % predicted) of rural FF did not have CAD, only 11 % (14 % predicted) of urban/suburban FF did not. The filled diamond in Fig. 28 representing the reported percentage of the "do not have" CAD response for rural FF (40 %) is obscured by the filled square symbol. Similarly, 26 % (27 % predicted) of urban/suburban FF did not have EPCR, but nearly 60 % (56 % predicted) of rural FF did not. Rural FF were also less likely to use CAD "a lot" compared to urban/suburban FF (Fig. 28). Of urban/suburban FF, 68 % (65 % predicted) used CAD "a lot," but only 39 % (45 % predicted) of rural FF did.

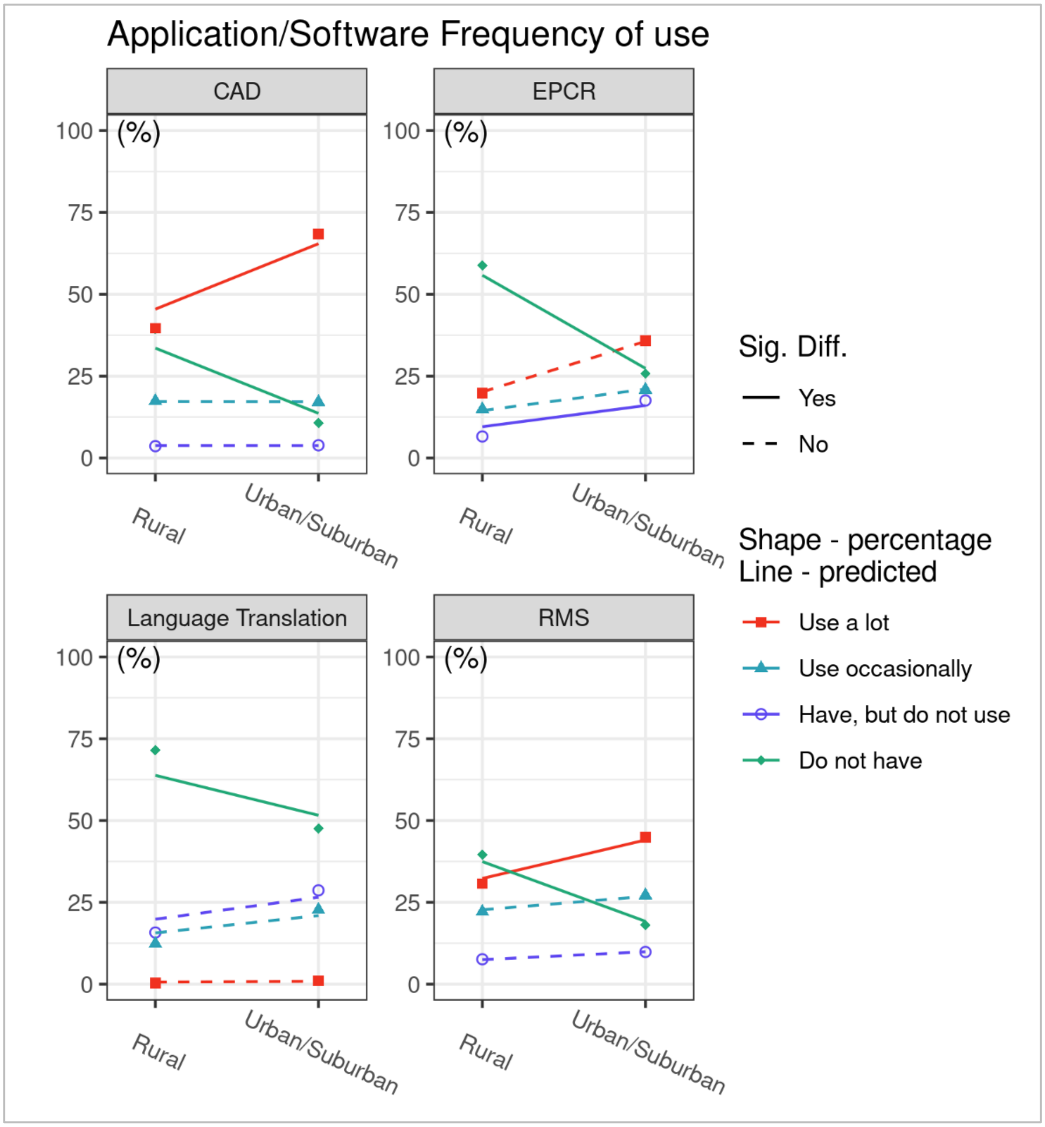


Fig. 28. Percentages, reported and predicted, for each frequency of use category, for applications/software listed, separated by rural and urban/suburban FF.

3.4.1.5. Applications/Software Ranking

As shown in Fig. 29, the perceived usefulness of most applications/software for rural and urban/suburban FF are similar, with two exceptions. Urban/suburban FF ranked CAD as more useful than rural FF, and rural FF ranked email more useful than urban/suburban FF (Fig. 29). The former may be a result of rural FF reporting that they "do not have" CAD more often than urban/suburban FF (Fig. 28).

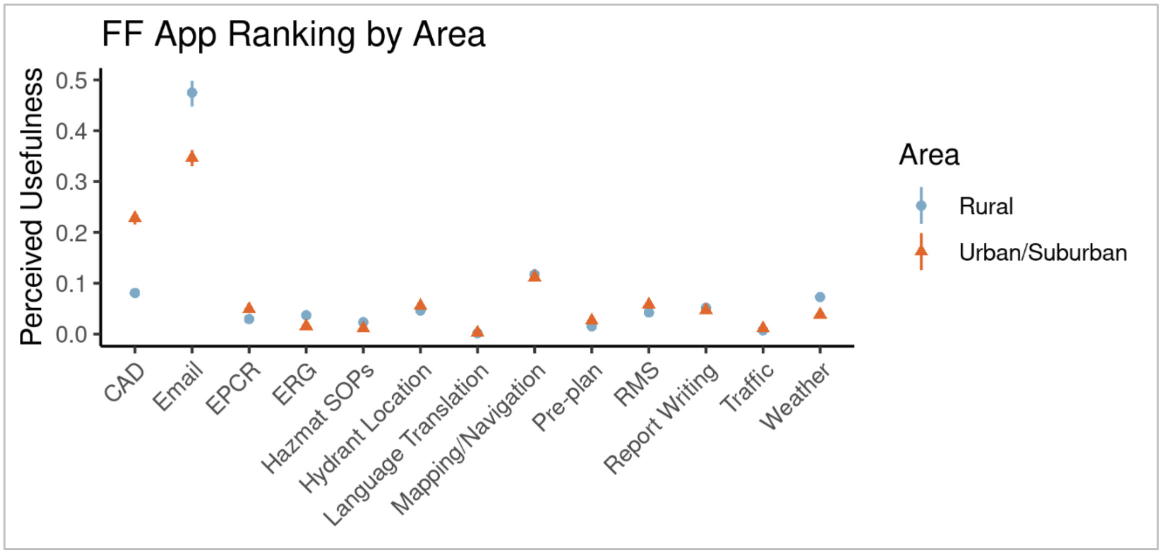


Fig. 29. Estimated perceived usefulness and 95 % credible intervals for those estimates of applications/software, separated by rural and urban/suburban FF.

3.4.2. Volunteer compared to Career FF

Overall, key differences between volunteer and career FF illustrated that volunteer FF were:

- More likely to use pagers, but less likely to use MDT/MDC and computers
- More likely to report they "do not have" MDT/MDC, work smartphones, in-vehicle radios, and tablets
- More likely to report they "do not have" RMS, CAD, language translation, and EPCR
- More likely to think pagers would be useful futuristic technology
- More likely to have problems with radio and computer prices

And, volunteer FF:

- Ranked personal smartphones and pagers as more useful and CAD as less useful than career FF

3.4.2.1. Device Frequency

Volunteer FF were less likely to use computers and MDT/MDC "a lot" (Fig. 30). While over 50 % (53 % predicted) of volunteer FF used computers "a lot", nearly 85 % (83 % predicted) of career FF did. Similarly, over half of the career FF used MDT/MDC "a lot", but only 13 % (19 % predicted) of volunteer FF did. In fact, more volunteer FF reported that they did not have MDT/MDC compared to career FF. Additionally, more volunteer FF reported that they did not have work smartphones, in-vehicle radios, and tablets (Fig. 30).

Volunteer FF were more likely to use pagers "a lot" compared to career FF (Fig. 30). Nearly 75 % (71 % predicted) of volunteer FF used their pagers "a lot", while only 28 % (30 % predicted) of career FF did.

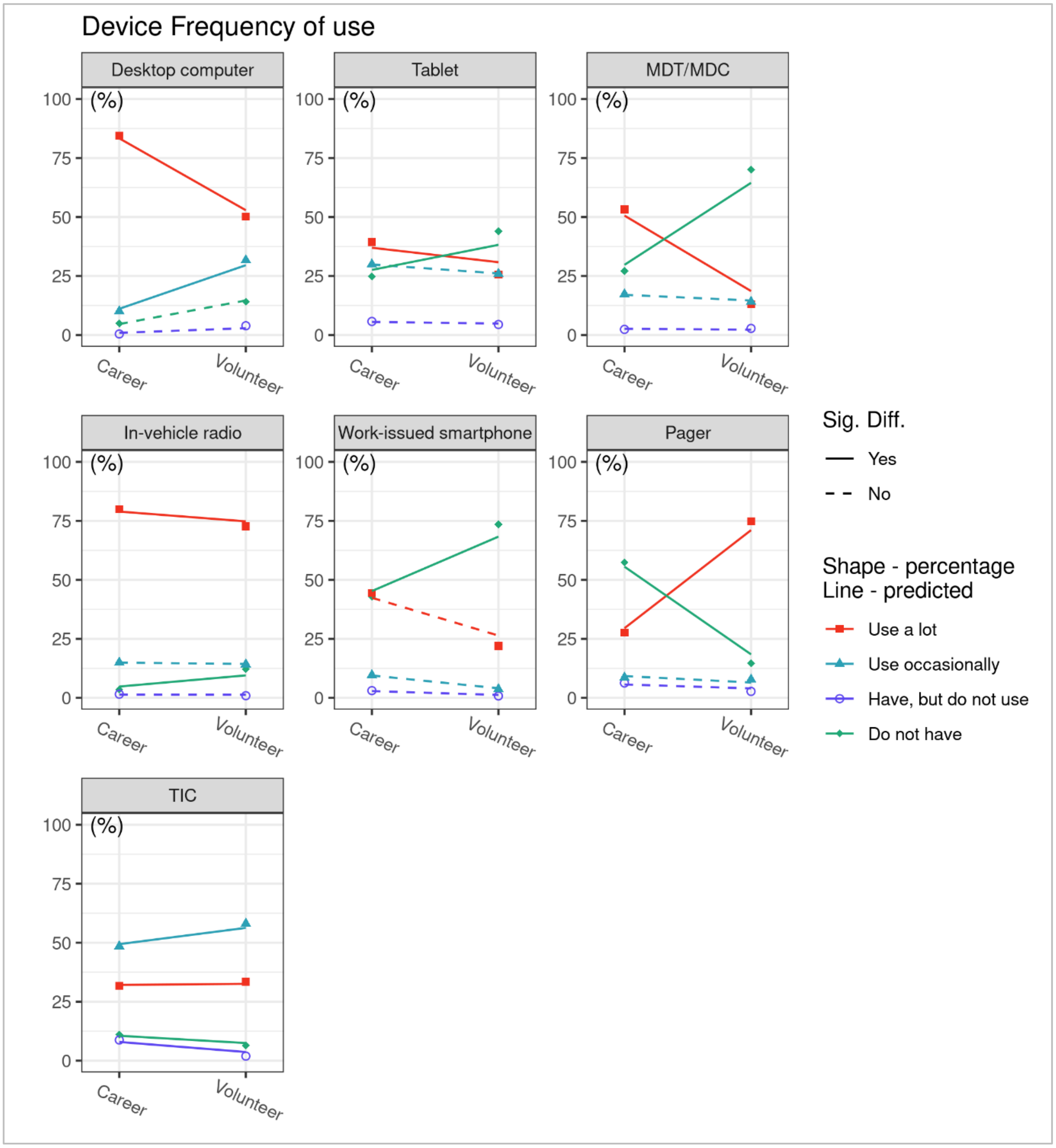


Fig. 30. Percentages, reported and predicted, for each frequency of use category, for devices listed, separated by career and volunteer FF.

3.4.2.2. Device Ranking

The perceived usefulness of many devices for career and volunteer FF were similar (Fig. 31). For example, both career and volunteer FF rank the portable radio as one of the most useful devices. But perceived usefulness of some devices did differ for volunteer compared to career FF. Career FF ranked desktop computers, MDT/MDC, and work-issued smartphones as more useful than volunteer FF, but volunteer FF ranked personal smartphones and pagers as more useful than career FF.

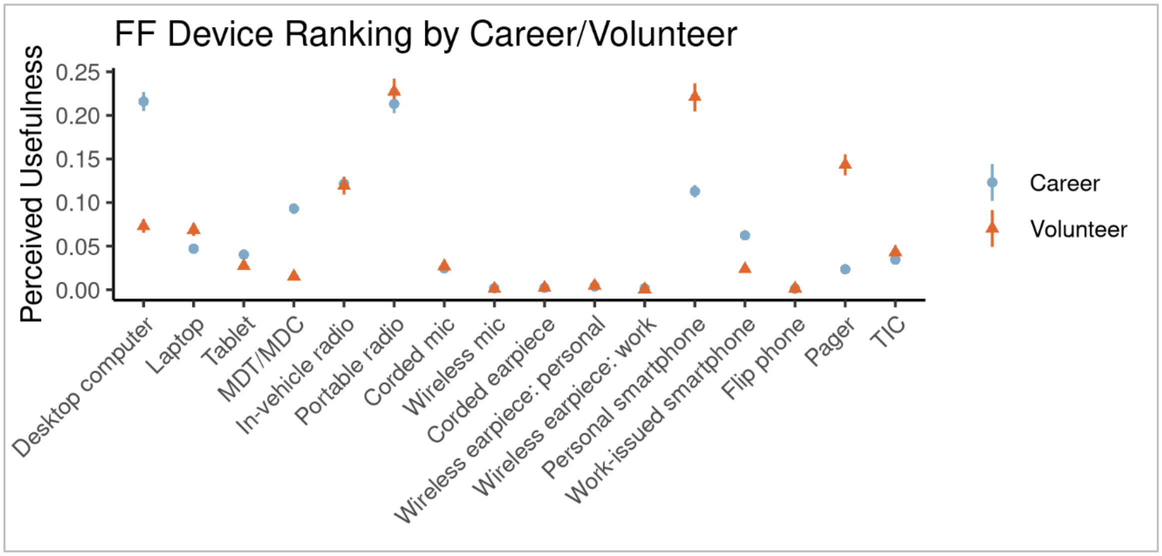


Fig. 31. Estimated perceived usefulness and 95 % credible intervals for those estimates of devices, separated by career and volunteer FF.

3.4.2.3. Problems with Technology

While both volunteer and career FF experienced problems with device prices, volunteer FF were more likely to have problems with the cost of some devices. For example, volunteers were more likely to have problems with computer prices (Fig. 32). Volunteer FF experienced problems with computer prices "always" 16 % of the time (11 % predicted) compared to about 7 % (8 % predicted) of career FF. Volunteers were also less likely to indicate that radio and computer price "does not apply" (Fig. 32). Volunteer FF reported problems with radio price "always" 40 % of the time (38 % predicted) compared to 26 % (27 % predicted) of career FF.

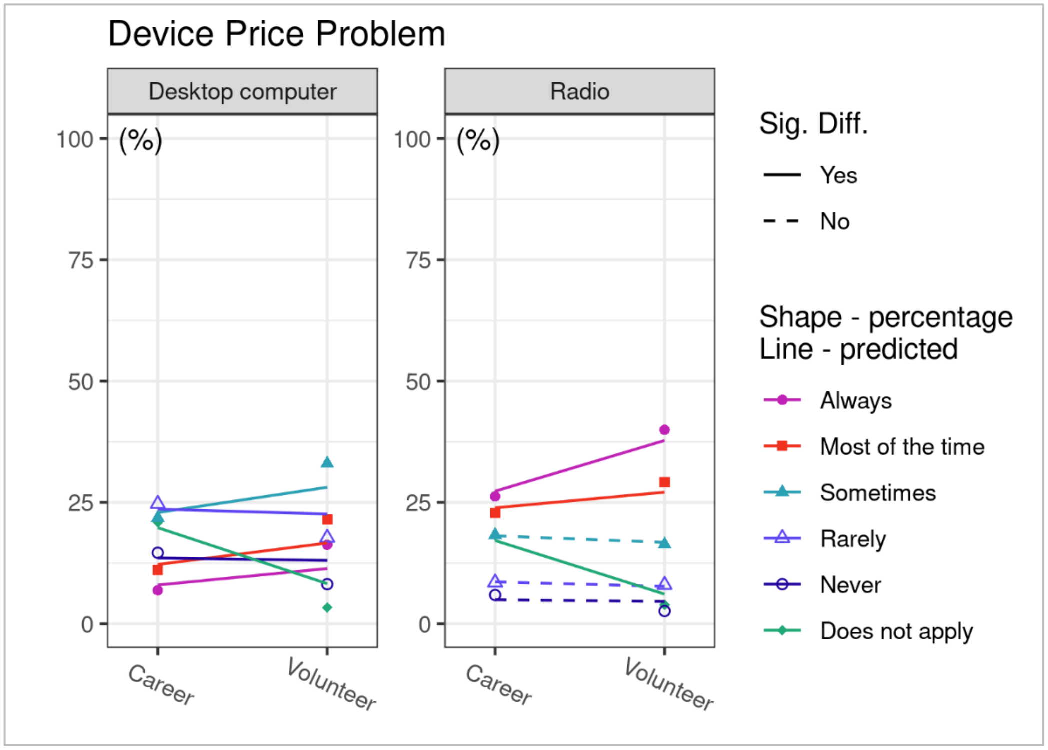


Fig. 32. Percentages, reported and predicted, for each category of the frequency of experiencing problems with the price of the devices listed, separated by career and volunteer FF.

3.4.2.4. Applications/Software Frequency

Volunteer FF were more likely to report that they "do not have" CAD, email, EPCR, language translation, and RMS (Fig. 33). Only 12 % (15 % predicted) of career FF reported they "do not have" CAD, while nearly 40 % (33 % predicted) of volunteer FF did. Volunteer FF were less likely to use email "a lot" compared to career FF (Fig. 33); although, both volunteer and career FF reported using their email "a lot" very frequently (over 85 % reported, 90 % predicted, for both groups). Additionally, over 20 % (23 % predicted) of career FF reported that they did not have EPCR, but almost 70 % (66 % predicted) of volunteer FF said the same. Of career FF, 47 % (51 % predicted) did not have a language translation application. That number jumped to 74 % (66 % predicted) for volunteer FF.

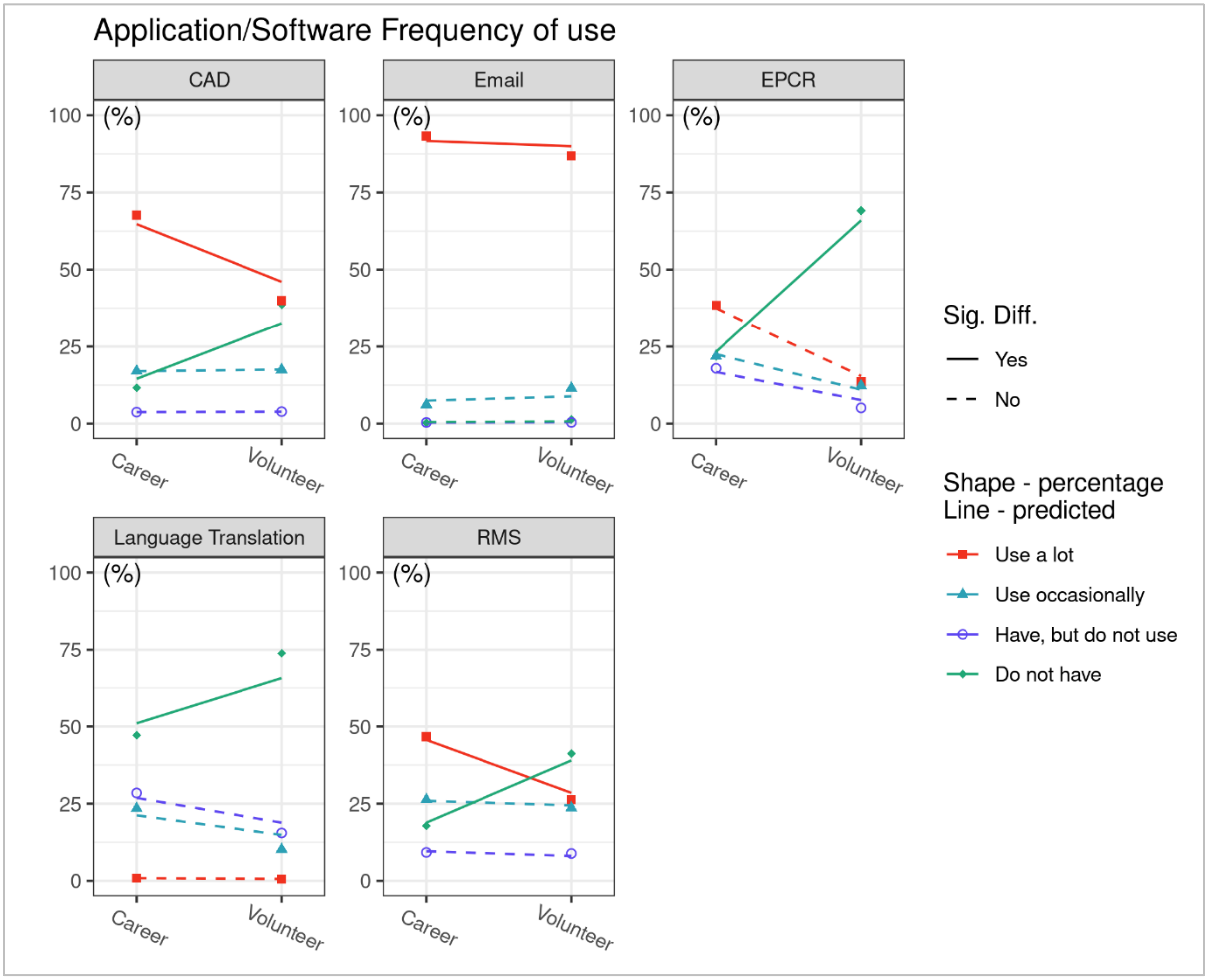


Fig. 33. Percentages, reported and predicted, for each frequency of use category, for applications/software listed, separated by career and volunteer FF.

3.4.2.5. Applications/Software Ranking

Fig. 34 shows many relatively small statistically significant differences between volunteer and career FF with respect to their perceived usefulness of applications/software. For example, volunteer FF perceived Email and ERG as slightly more useful than career FF, but career FF perceived EPCR to be slightly more useful than volunteer FF. There is one application for which the difference is not small, CAD. Career FF perceived CAD to be far more useful than volunteer FF, presumably because a higher percentage of volunteer FF do not have access to CAD (Fig. 33).

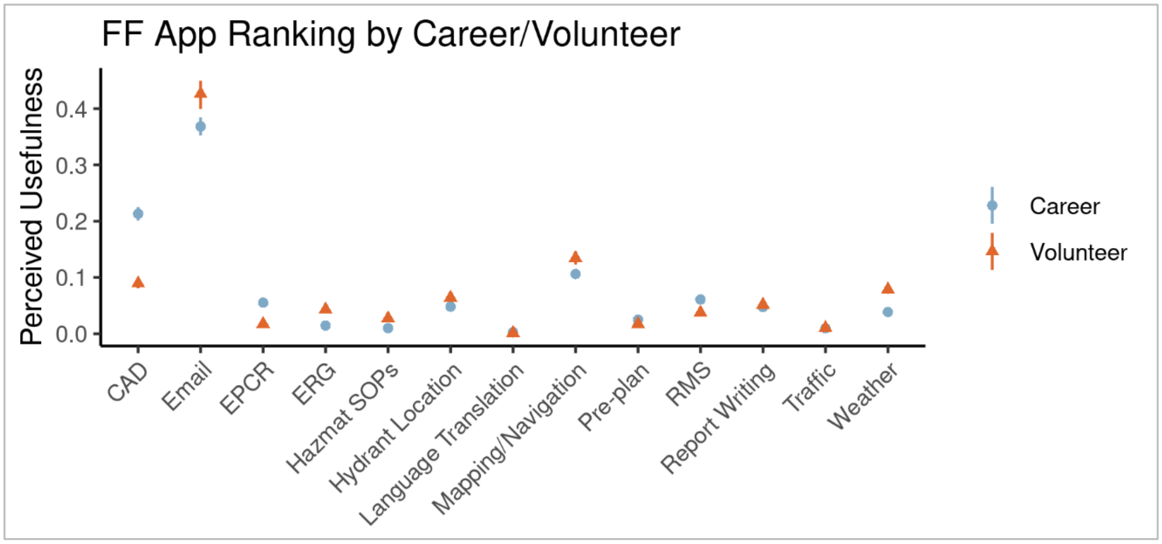


Fig. 34. Estimated perceived usefulness and 95 % credible intervals for those estimates of applications/software, separated by career and volunteer FF.

3.4.2.6. Futuristic Technology and VR

Volunteers were more likely to check "pager" as a device that would be useful to them from the list of futuristic technology (Fig. 35). Although the 15 % (5 % predicted) that selected this option is a small percentage of volunteer first responders, it is much larger than the very small percentage of career FF that saw pagers as useful futuristic technology (1 % reported and 3 % predicted).

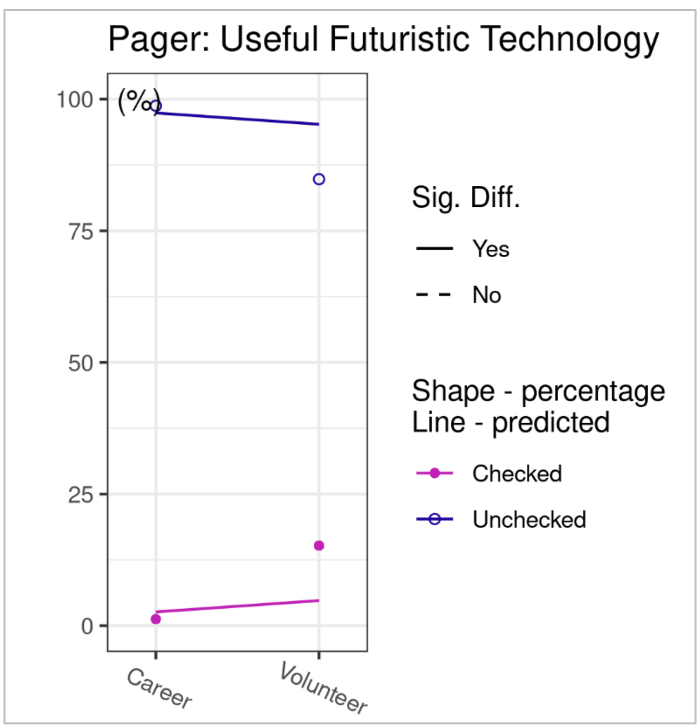


Fig. 35. Percentages, reported and predicted, for indicating pager as a useful futuristic technology, separated by career and volunteer FF.

3.4.3. Chief/Management and Supervising Responders compared to Frontline Responders

Overall, key differences between chief/management, supervising responders and frontline responders for FF illustrated that chief/management FF were:

- More likely to use pagers, work smartphones, and laptops “a lot”
- Less likely to use TIC, corded mics, and MDT/MDC “a lot” and more likely to report they “do not have” TIC, personal smartphone, MDT/MDC, and flip phones
- More likely to use weather, RMS, and email “a lot”, but less likely to use mapping/navigation apps, EPCR, and CAD “a lot”
- More likely to have radio price problems and were more aware of price problems for devices such as computers and MDT/MDC
- Less likely to have smartphone subsidy problems

And, chief/management FF:

- Ranked portable radios, MDT/MDC, and TIC as less useful, and laptops, work-issued smartphones, and pagers as more useful
- Ranked email as more useful but CAD, EPCR, hydrant location and mapping/navigation as less useful

Supervisors did not tend to differ from frontline responders, with a few exceptions:

- Supervisors were more likely to use RMS “a lot”
- Supervisors perceive email as more useful, but perceive CAD as less useful

3.4.3.1. Device Frequency

Chief/management roles were more likely than frontline and supervising FF to use laptops, work smartphones, and pagers “a lot” (Fig. 36). The greatest difference was for work smartphones and pagers. While nearly 50 % (47 % predicted) of chief/management used work smartphones “a lot,” only 11 % of frontline responders (20 % predicted), and 20 % of supervising responders (20 % predicted) said the same. Similarly, while 54 % (52 % predicted) of chief/management roles used pagers “a lot,” only 21 % of frontline responders (27 % predicted) and 26 % of supervising responders (26 % predicted) did.

Fig. 36 also shows that chief/management roles were less likely to use MDT/MDC, corded mics, and TIC “a lot.” The biggest difference was for MDT/MDC, with 58 % of frontline responders (56 % predicted) and 65 % of supervising responders (57 % predicted) using this device “a lot,” whereas only 29 % of chief/management (31 % predicted) said the same. Supervising responders were the most likely to use TIC “a lot” (44 % reported and 40 % predicted) followed by frontline responders (34 % reported and predicted), and chief/management were the least likely to use TIC “a lot” (29 % reported and 30 % predicted). Not only were chief/management roles less likely to use MDT/MDC and TIC “a lot,” but they were also more likely to report “do not have” for these devices. They were also more likely to not have a personal smartphone or flip phone. A potential reason is that they have work smartphones instead.

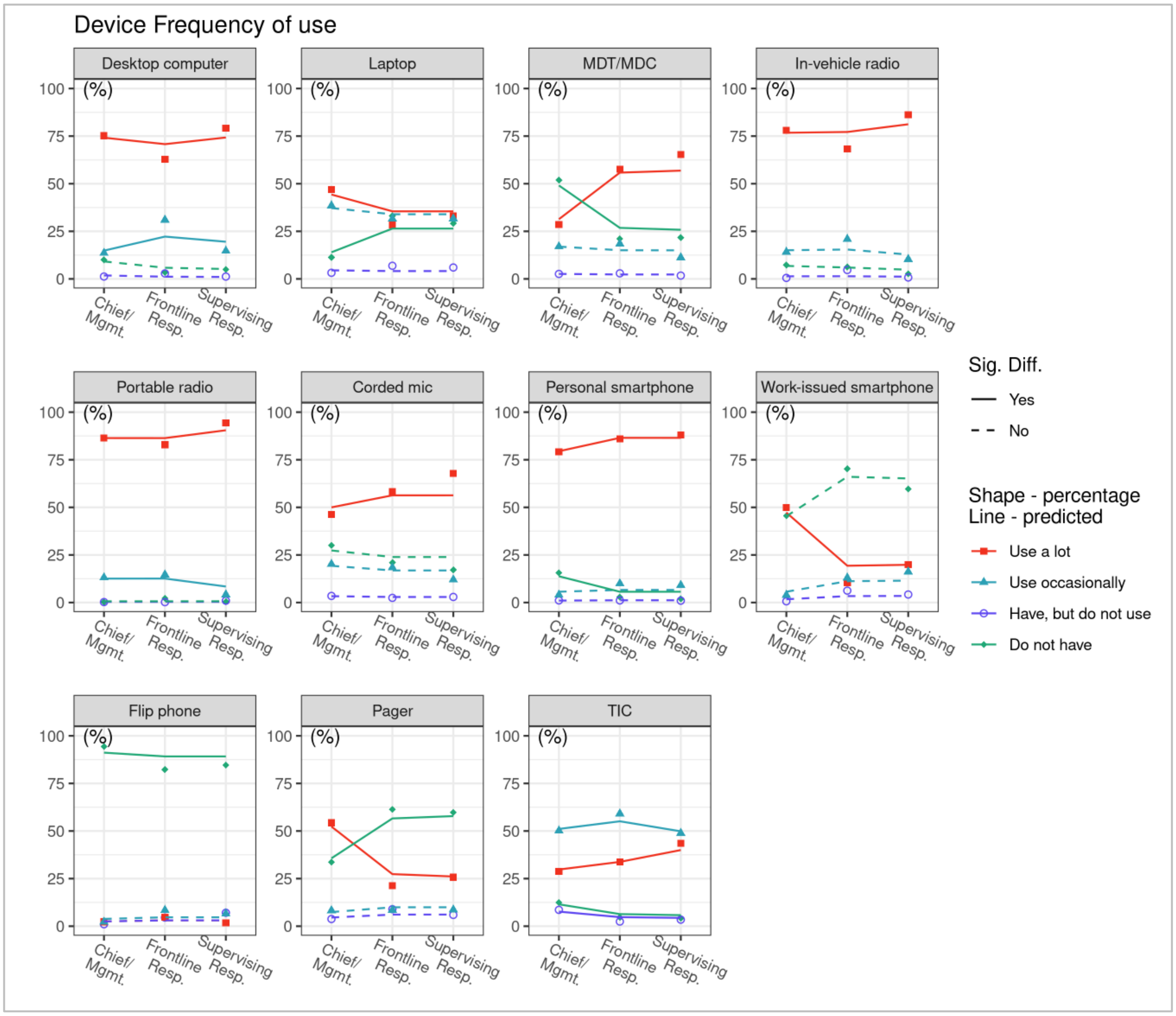


Fig. 36. Percentages, reported and predicted, for frequency of use category, for devices listed, separated by the FF roles chief/management, frontline responder, and supervising responder.
* Management is abbreviated mgmt. and responder is abbreviated resp.

3.4.3.2. Device Ranking

As shown in Fig. 37, the difference between frontline and supervising responders in perceived usefulness for all devices except for the desktop computer was not statistically significant. Frontline responders ranked desktop computers as less useful than supervising responders.

On the other hand, for chief/management roles, perceived usefulness significantly differs from that of frontline and/or supervising responders for several devices. Chief/management FF ranked MDT/MDC, portable radios, and TIC as less useful than frontline and supervising responders. Chief/management FF also ranked laptops, work-issued smartphones, and pagers as more useful than frontline and supervising responders.

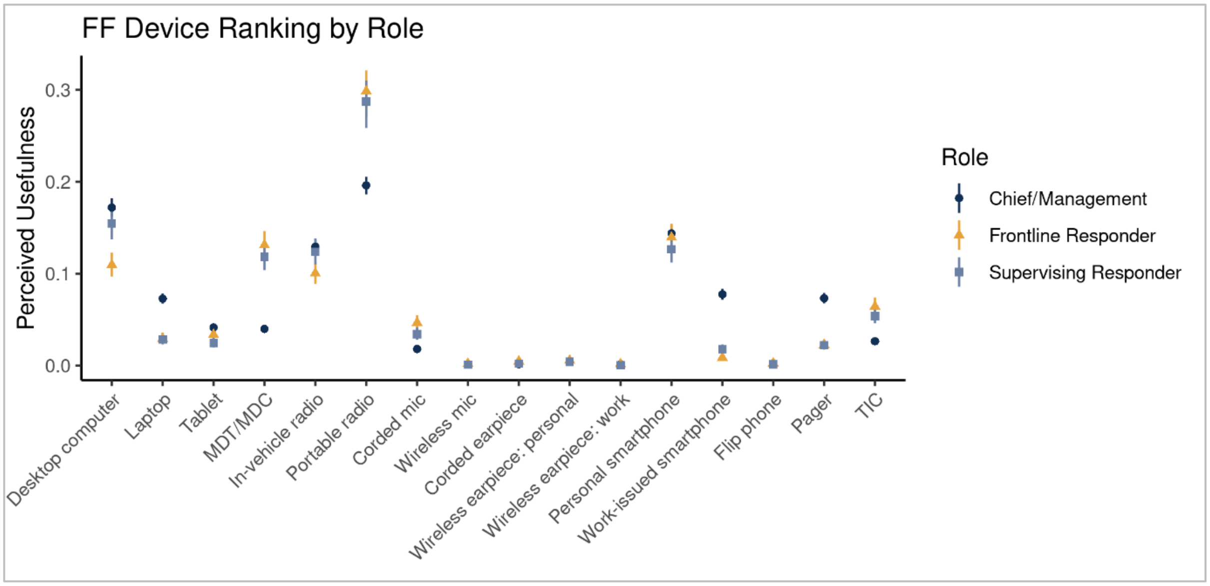


Fig. 37. Estimated perceived usefulness and 95 % credible intervals for those estimates of devices, separated by the FF roles chief/management, frontline responder, and supervising responder.

3.4.3.3. Problems with Technology

Chief/management roles were more likely to "always" have radio price problems (Fig. 38) and less likely to "always" have smartphone subsidy problems (Fig. 39) compared to frontline and supervising responders. Nearly twice as many chief/management roles (39 % reported and 37 % predicted) compared to frontline (18 % reported and 22 % predicted) and supervising (22 % reported and predicted) responders "always" experienced radio price problems. About half as many chief/management (15 % reported and 18 % predicted) roles "always" experienced smartphone subsidy problems compared to frontline (30 % reported and 22 % predicted) and supervising (same percentages as frontline) responders. This is potentially due to chief/management roles using work smartphones more often than personal smartphones to which a subsidy would apply.

The results also suggest that chief/management roles are more aware of price problems generally compared to frontline and supervising responders. Chief/management roles were less likely to say that a price problem "does not apply" to computers, MDT/MDC, and radios (Fig. 38). Frontline and supervising responders indicated a price problem "does not apply" at significantly higher rates than chief/management roles. The low rates of the response "does not apply" for computer, MDT/MDC, and radio price problems for chief/management roles indicates that these problems, albeit not occurring "a lot" for devices except for radios, were something they experienced in their day-to-day work.

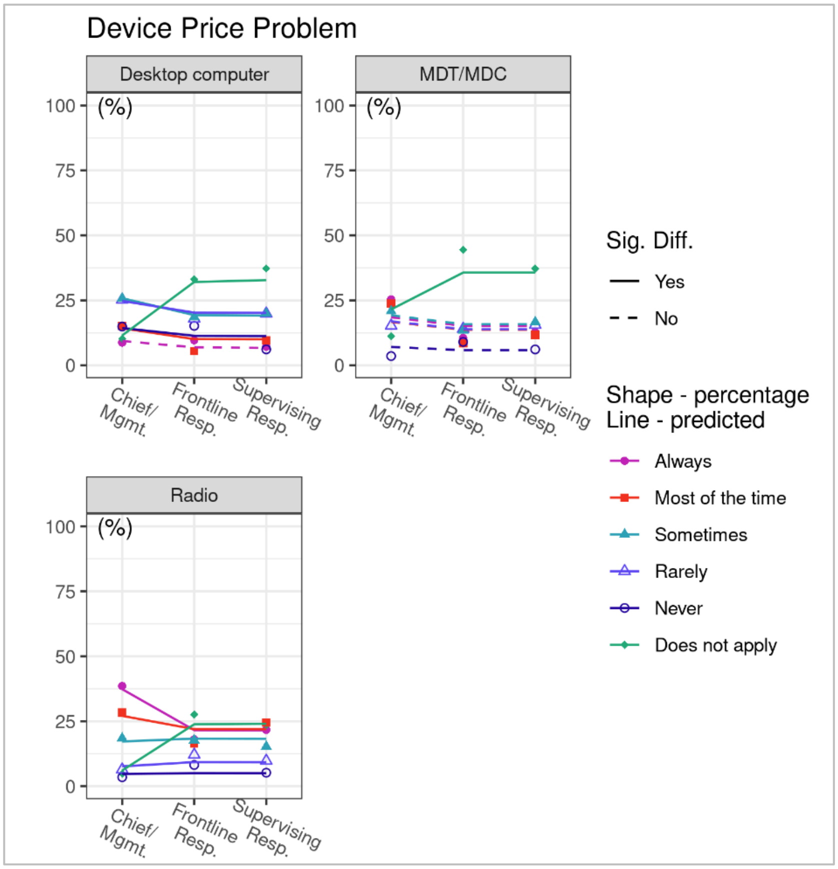


Fig. 38. Percentages, reported and predicted, for each category of the frequency of experiencing problems with the price of the devices listed, separated by the FF roles chief/management, frontline responder, and supervising responder.
* Management is abbreviated mgmt. and responder is abbreviated resp.

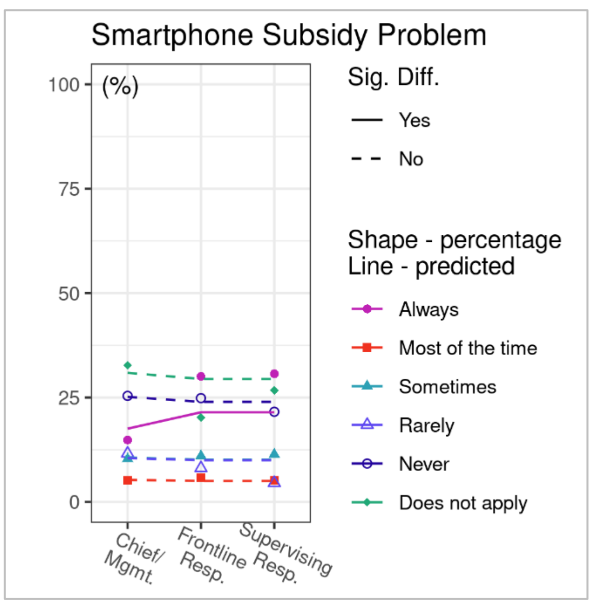


Fig. 39. Percentages, reported and predicted, for each category of the frequency of experiencing problems with smartphone subsidies, separated by the FF roles chief/management, frontline responder, and supervising responder.
* Management is abbreviated mgmt. and responder is abbreviated resp.

3.4.3.4. Applications/Software

As shown in Fig. 40, for many apps, reported and predicted percentages of using "a lot" were similar for frontline and supervising responders, with chief/management roles having different usage rates. Chief/management roles were more likely to use email and a weather application "a lot," but they were less likely to use CAD, EPCR, and a mapping/navigation application "a lot." Chief/management roles were also less likely to say they "do not have" a weather application. A different pattern emerged for RMS, such that both chief/management roles (44 % reported and 43 % predicted) and supervising responders (42 % observe and 38 % predicted) responders were more likely to use RMS "a lot" compared to frontline responders (24 % reported and 31 % predicted).

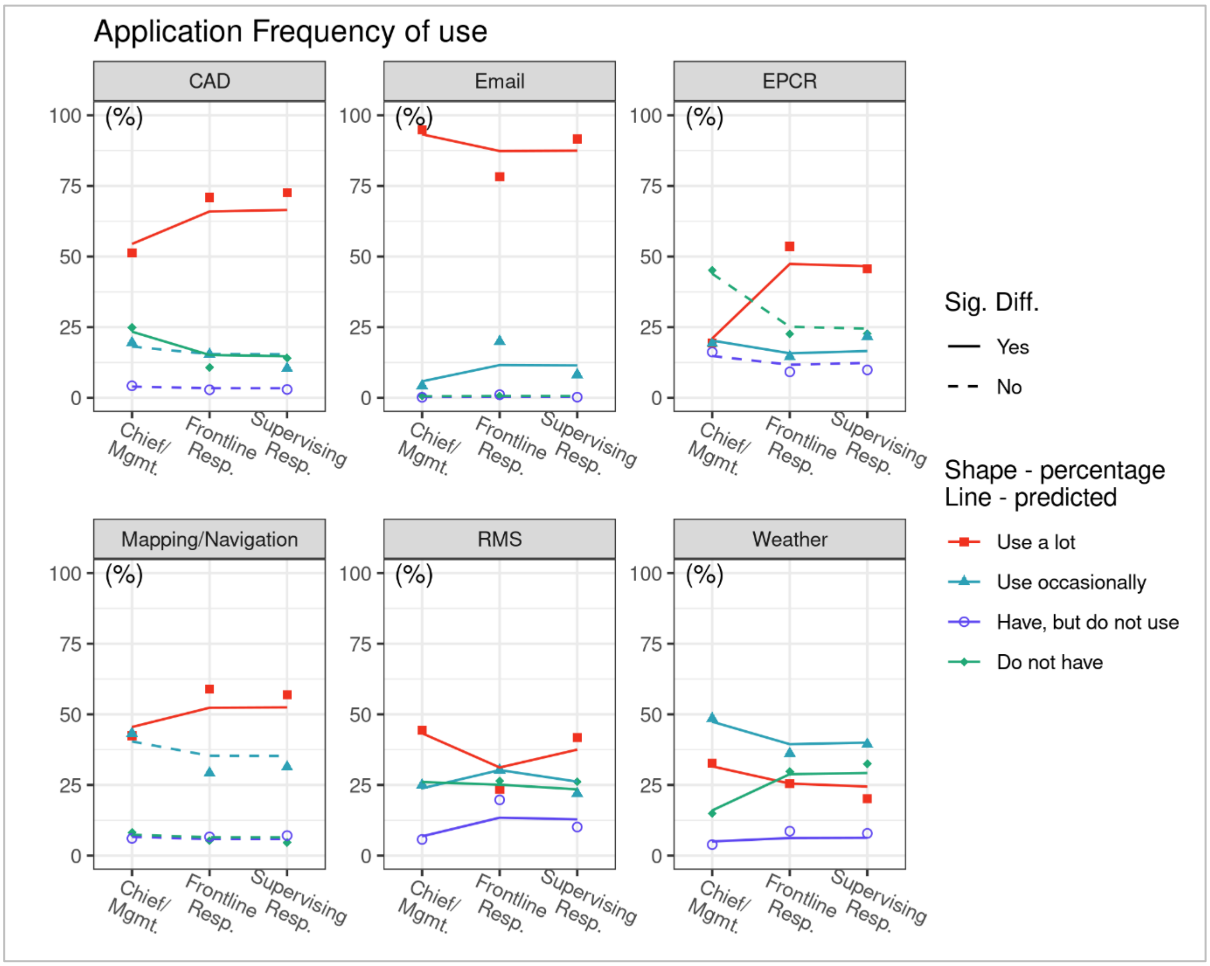


Fig. 40. Percentages, reported and predicted, for each frequency of use category, for applications/software listed, separated by the FF roles chief/management, frontline responder, and supervising responder.
* Management is abbreviated mgmt. and responder is abbreviated resp.

3.4.3.5. Application/Software ranking

Fig. 41 displays the estimates of perceived usefulness of applications/software asked about on the survey separated by the FF roles chief/management, frontline responder, and supervising responder. Frontline and supervising responders ranked most applications/software similarly, except for CAD and email. Supervising responders ranked email as more useful but CAD as less useful than frontline responders.

From Fig. 41 there were several applications/software for which the perceived usefulness by chief/management is statistically significantly different from both frontline and supervising responders. Chief/management ranked email as the most useful application/software, far more useful than frontline and supervision responders. On the other hand, chief/management ranked CAD, EPCR, hydrant location and mapping/navigation as less useful than frontline and supervising responders.

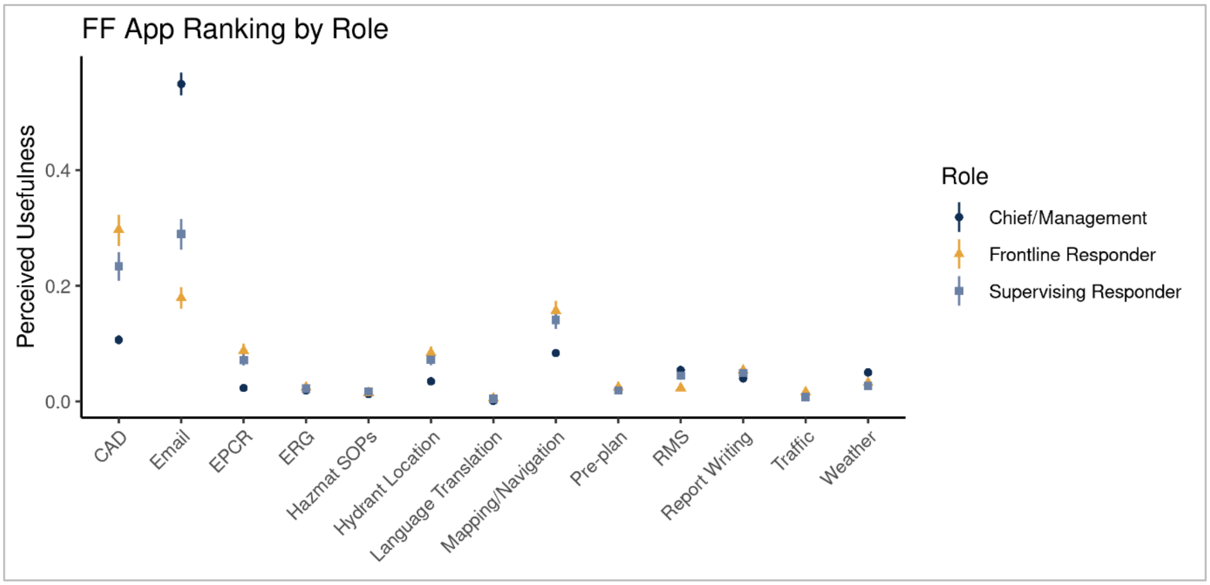


Fig. 41. Estimated perceived usefulness and 95 % credible intervals for those estimates of applications/software, separated by the FF roles chief/management, frontline responder, and supervising responder.

3.4.4. Area and Career Status Interactions

Results in this section show interactions between area and career/volunteer status, comparing results for four groups: rural career FF, rural volunteer FF, urban/suburban career FF, and urban/suburban volunteer FFs. The interpretation of an interaction is different than the interpretation of main effects; main effects may be thought of as average effects (e.g., averaging across all other subgroups, how much more likely are rural FFs to say that they "do not have" an MDT/MDC than urban/suburban FFs). On the other hand, an interaction between area and career/volunteer status answers questions such as whether the area main effect differs between career and volunteer FF.

3.4.4.1. Device Frequency

As described in Sec. 3.4.1 (and displayed in Fig. 24), rural FF were more likely than urban/suburban FF to say they "do not have" MDT/MDC and as described in Sec. 3.4.2 (Fig. 30) volunteer FF were more likely to report "do not have" for both MDT/MDC and tablets. By adding those main effects together, rural volunteers would naturally be the most likely to respond "do not have" for both MDT/MDC and tablets. If there were no interaction between area and career/volunteer status for the survey question about the frequency of using MDT/MDC or tablets, the lines in Fig. 42 would be nearly parallel. From Fig. 42, it can be noted that rural and urban/suburban career FF report that they “do not have” a tablet at essentially identical frequencies, so an estimated effect of 0 %. However, rural volunteers are more likely to report that they “do not have” a tablet compared to urban/suburban volunteers. For career FF, the average predicted difference between rural and urban/suburban FF reporting “do not have” for a tablet is nearly 0 % (i.e., the estimated area effect is 0 %), but the average predicted difference was 7 % for volunteers (the estimated area effect is 7 %). A similar pattern was observed for MDT/MDC. The average predicted difference between rural and urban/suburban for career FF reporting “do not have” an MDT/MDC is 21 % (i.e., the estimated area effect is 21 %), but for volunteers this difference was 27 % (i.e., the estimated area effect is 27 %).

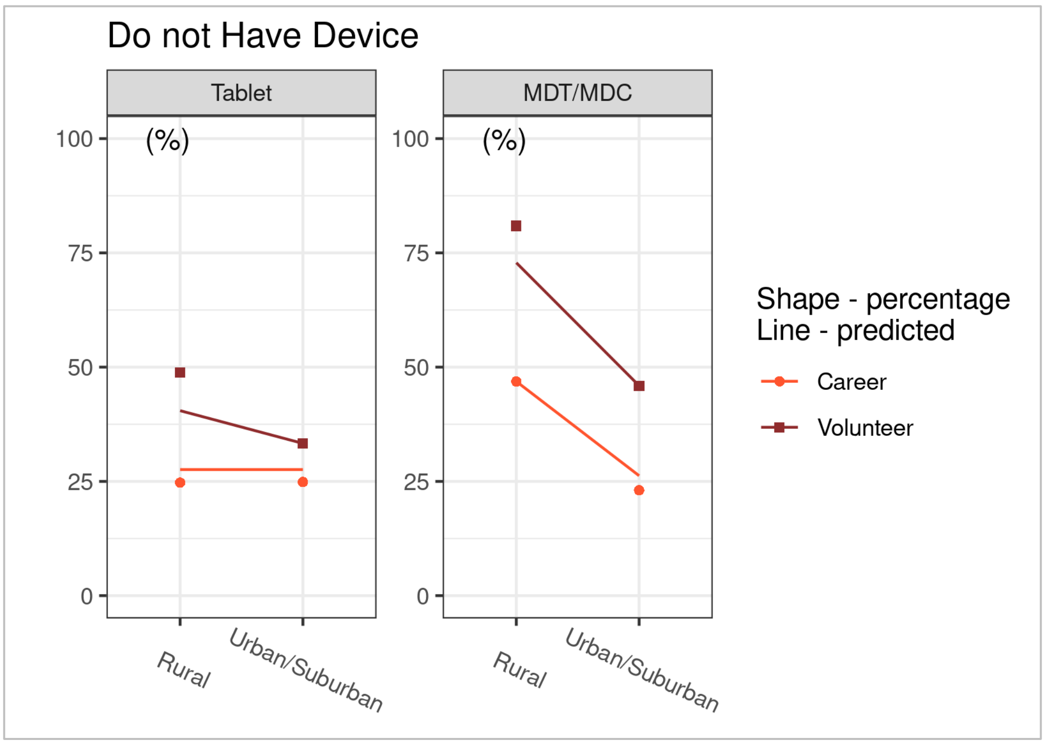


Fig. 42. Percentages, reported and predicted, of the “do not have” response for the devices listed, separated by areas and career/volunteer FF.

3.4.4.2. Problems with Technology

Both rural and volunteer FF experienced problems with radio and computer prices (see Fig. 26 in Sec. 3.4.1 and Fig. 32 in Sec. 3.4.2 for rural and volunteer findings, respectively). As Fig. 43 shows, for radio price, for the response, “most of the time” there was a statistically significant interaction between area and career/volunteer status. The estimated area effect for career FF reporting a problem with radio price “most of the time” was about -1 %. However, for volunteer FF, the estimated effect was about 2 %. Note the opposite signs – rural career FF were predicted to have lower rates of experiencing radio price problems “most of the time” compared to urban/suburban career FF, while rural volunteer FF had a higher predicted rate than urban/suburban volunteer FF.

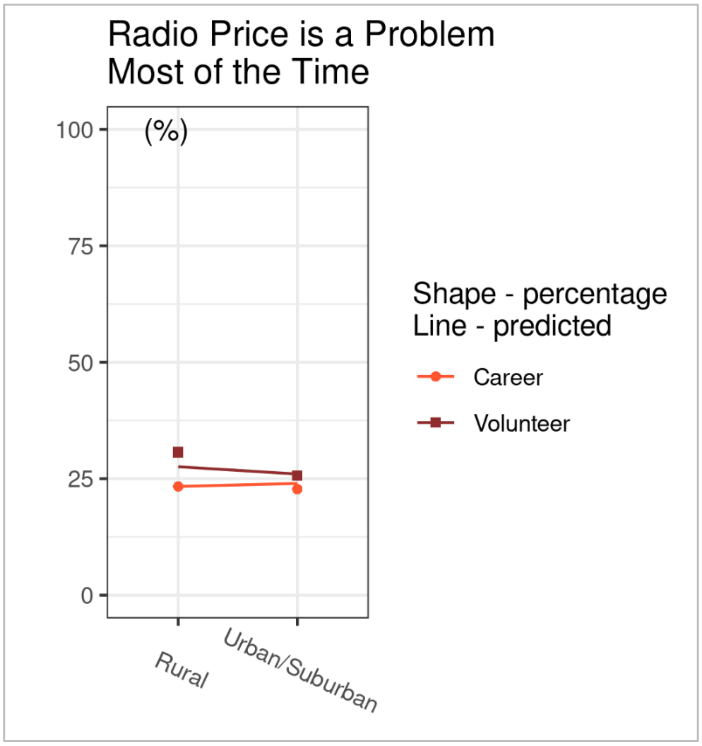


Fig. 43. Percentages, reported and predicted, of experiencing problems with radio price "most of the time," separated by areas and career/volunteer FF.

3.4.4.3. Application/Software

In Section 3.4.1.4 it was found that rural FF were more likely than urban/suburban FF to respond that they "do not have" several applications/software (Fig. 28). Similar results were observed for volunteer FF in Section 3.4.2.4 (Fig. 33). Fig. 44 shows that there were also interactions between area and career/volunteer status for the "do not have" response for several applications. The interaction with the largest estimated magnitude was for the pre-plan application/software. The estimated area effect for reporting "do not have" pre-plan was 0 % for career FF, but for volunteer FF, it was 20 %. Put another way, rural and urban/suburban career FF reported that they "do not have" the pre-plan application/software at about the same rate, but the sparse regression model predicts that 20 % more rural volunteer FF would report that they "do not have" the pre-plan application/software than urban/suburban volunteers.

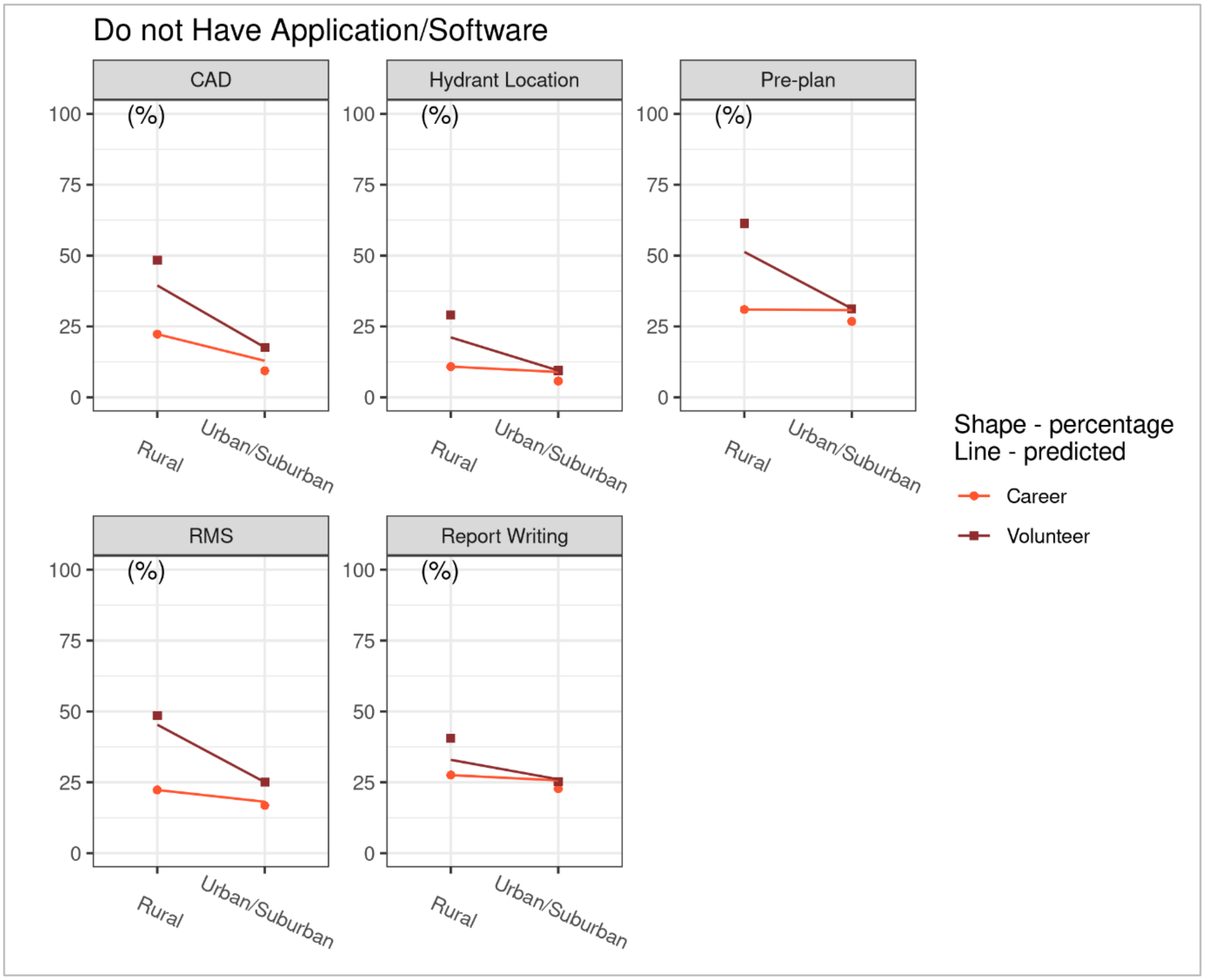


Fig. 44. Percentages, reported and predicted, of the “do not have” response for the applications/software listed, separated by areas and career/volunteer FF.

There was also an interaction between area and career/volunteer status for using mapping/navigation software “a lot” (Fig. 45). The same pattern is observed; the estimated area effect of reporting using mapping/navigation software “a lot” is greater for volunteer FF than career FF.

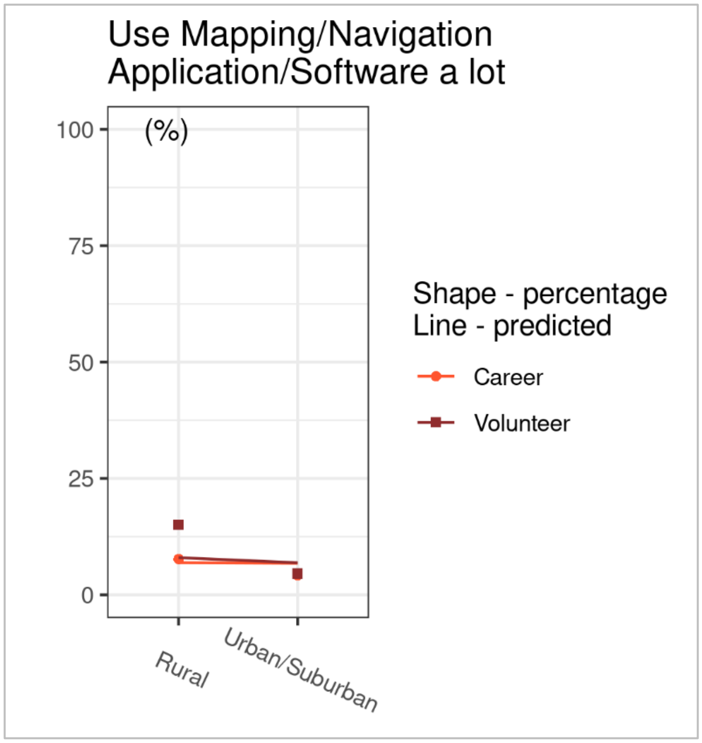


Fig. 45. Percentages, reported and predicted, of the "use a lot" response for the mapping/navigation applications/software, separated by areas and career/volunteer FF.

3.4.5. Area and Role Interactions

There was a significant interaction between area and role for FF for "always" experiencing problems with TIC price (Fig. 46). The estimated area effect of FF reporting that TIC price is "always" a problem was greater for chief/management (8 %) than it was for frontline and supervising responders (2 %). As shown in the Fig. 46, rural chief/management FF reported "always" having TIC price problems about 60 % of the time.

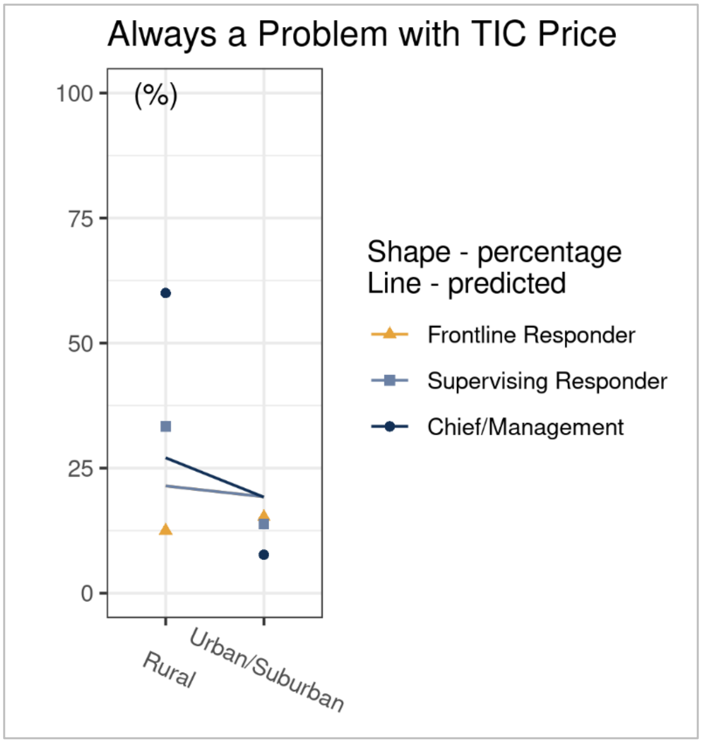


Fig. 46. Percentages, reported and predicted, of "always" experiencing problems with TIC price, separated by areas and the FF roles frontline responder, supervising responder, and chief/managements.

* The line for frontline responders is covered by the line for supervising responders.

There was also a significant interaction between area and role for FF responding they "do not have" a traffic applications/software (Fig. 47). The estimated effect of rural FF reporting they "do not have" traffic applications/software is also about 2 % for frontline and supervising responders and 8 % for chiefs/management. As shown in Fig. 47, of the six subgroups being compared, rural chief/management FF had the highest rate of reporting they did not have traffic applications/software.

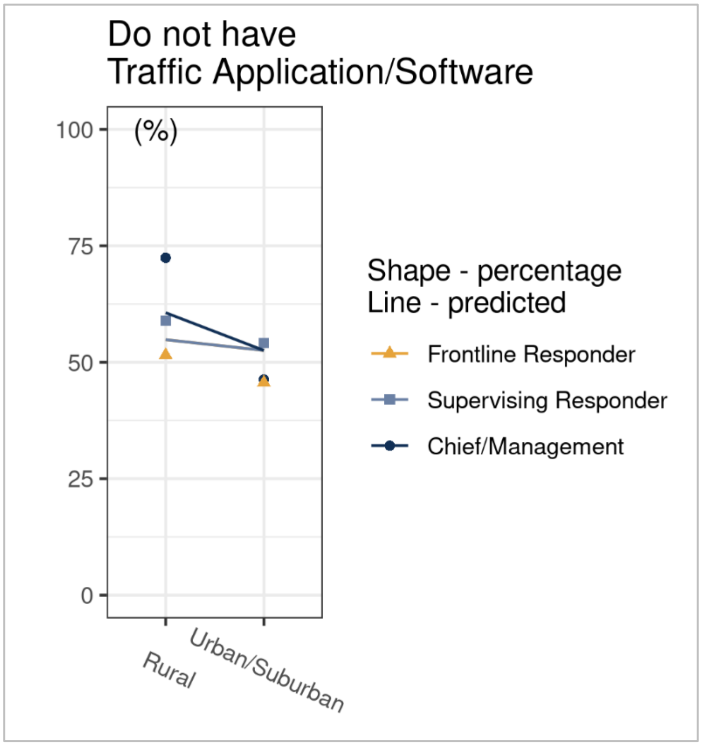


Fig. 47. Percentages, reported and predicted, of the "do not have" response for the traffic applications/software, separated by areas and the FF roles frontline responder, supervising responder, and chief/managements.

* The line for frontline responders is covered by the line for supervising responders.

3.4.6. Career Status and Roles Interactions

Fig. 48 through Fig. 51 display significant interactions between career/volunteer status and role for FF.

Fig. 48 shows an interesting pattern where the career/volunteer status effect changes direction, depending on the FF role: the effects of career/volunteer status for frontline and supervising responders follow the same direction, but the direction of the effect is different for chief/management. To put this effect in context, recall that career and volunteer FF reported "use a lot" for TIC similarly on average (Sec. 3.4.2, Fig. 30), and chief/management FF reported using TIC "a lot" less often on average than frontline and supervising responders, with supervising responders using TIC the most (Sec. 3.4.3, Fig. 36). Fig. 48 shows the following more complex pattern: volunteer frontline and supervising responders were less likely to report using TIC "a lot" compared to their career counterparts, but volunteer chiefs/management were actually more likely to use TIC "a lot" compared to their career counterparts. For both frontline and supervising responders, the effect of career/volunteer status is about -6 %, but for chiefs/management, it is about 5 %.

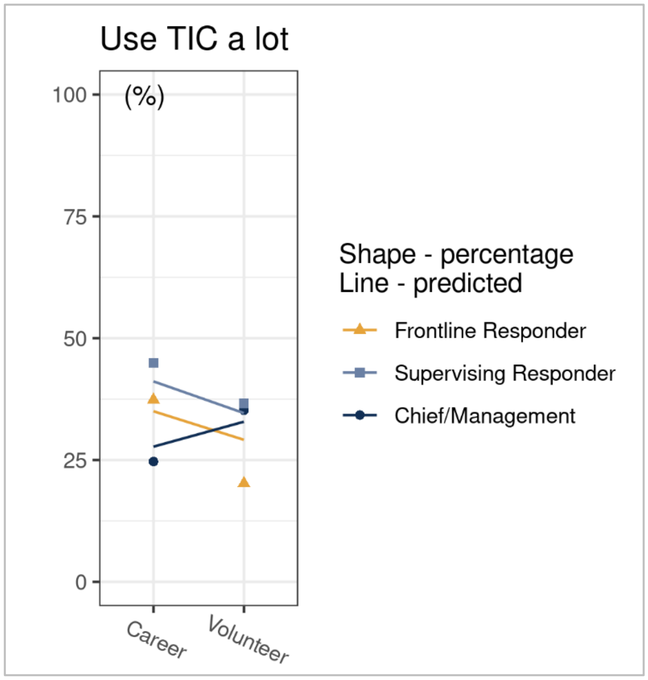


Fig. 48. Percentages, reported and predicted, of the "use a lot" response for TIC, separated by career/volunteer FF and the FF roles frontline responder, supervising responder, and chief/management.

Fig. 49 shows the interaction of career/volunteer status and role for the response "have but do not use" for TIC. The effect of career/volunteer status was greater for chief/management roles than the other roles for reporting that they "have but do not use" TIC. With the exception of career chief/management roles, there were pretty low rates of reporting "have but do not use" TICs.

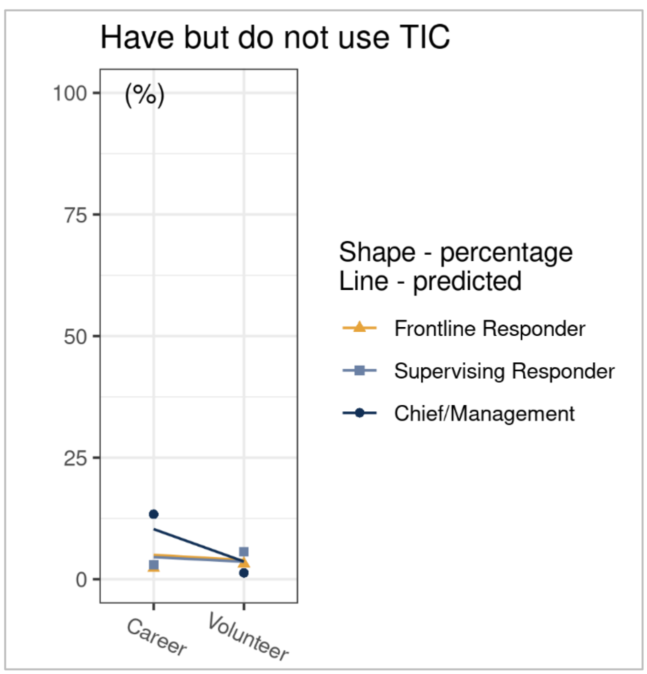


Fig. 49. Percentages, reported and predicted, of the "have, but do not use" response for TIC, separated by career/volunteer FF and the FF roles frontline responder, supervising responder, and chief/management.

Fig. **50** shows the interaction between career/volunteer status and role for selecting automatic vehicle location as a useful futuristic technology. The effect of career/volunteer status was much greater for chief/management roles than the other roles (20 % effect for chief/management; 5 % effect frontline and supervising responders).

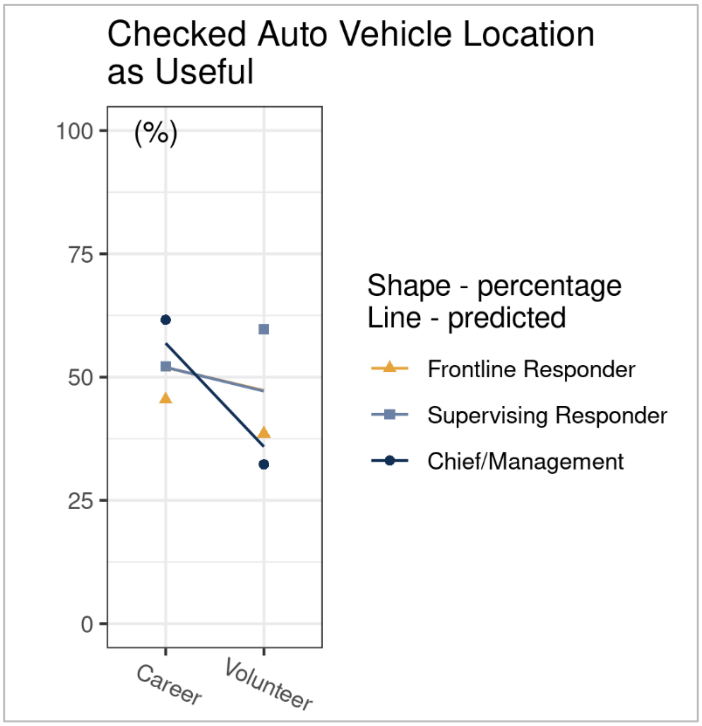


Fig. 50. Percentages, reported and predicted, for indicating AVL as a useful futuristic technology, separated by career/volunteer FF and the FF roles frontline responder, supervising responder, and chief/management.

* The line for frontline responders is covered by the line for supervising responders.

Fig. 51 shows the interaction between career/volunteer status and role for the response "do not have" for RMS and weather applications/software. For selecting "do not have" RMS, the effect of career/volunteer status was greater for the chief/management role than the other roles (23 % versus 12 % for frontline and 14 % for supervising responders). For selecting "do not have" a weather application/software, the effect of career/volunteer status changed direction depending on the role. Career frontline and supervising responders were more likely to respond that they "do not have" a weather application/software than their volunteer counterparts, but career chief/management FF were less likely than their volunteer counterparts to respond that they "do not have" a weather application/software.

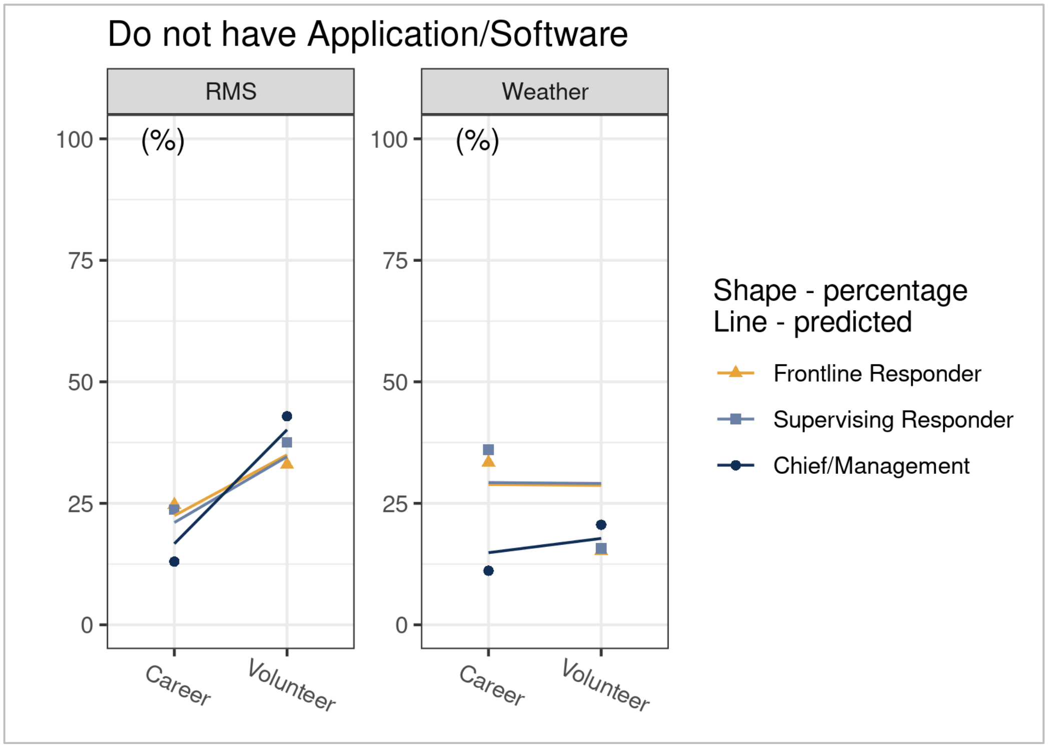


Fig. 51. Percentages, reported and predicted, of the "do not have" response for the applications/software listed, separated by career/volunteer FF and the FF roles frontline responder, supervising responder, and chief/management.

3.5. LE

This section presents the selection of LE subgroup comparisons.

3.5.1. Rural compared to Urban/Suburban

Overall, key differences between rural compared to urban/suburban LE illustrated that rural LE were:

- More likely to use in-vehicle radio
- More likely to report not having MDT/MDC and License plate reader (LPR)
- More likely to report not having CAD
- More likely to have radio price problems

And, rural LE:

- Ranked in-vehicle radio more useful and MDT/MDC as less useful than urban/suburban LE

3.5.1.1. Device Frequency

Rural LE were more likely to use in-vehicle radio "a lot" compared to urban/suburban LE (Fig. 52). While a majority of both rural and urban/suburban LE used in-vehicle radio frequently, 86 % (80 % predicted) of rural LE reported using in-vehicle radio “a lot” compared to only 65 % (68 % predicted) of urban/suburban LE.

Rural LE were more likely to report that they “do not have” MDT/MDC and LPR (Fig. 52). Where 20 % (22 % predicted) of urban/suburban LE did not have MDT/MDC, 35 % (31 % predicted) of rural LE did not. Both rural and urban/suburban LE had high rates of reporting they “do not have” LPR, but while 71 % (76 % predicted) of urban/suburban LE did not, over 90 % (80 % predicted) of rural LE did not.

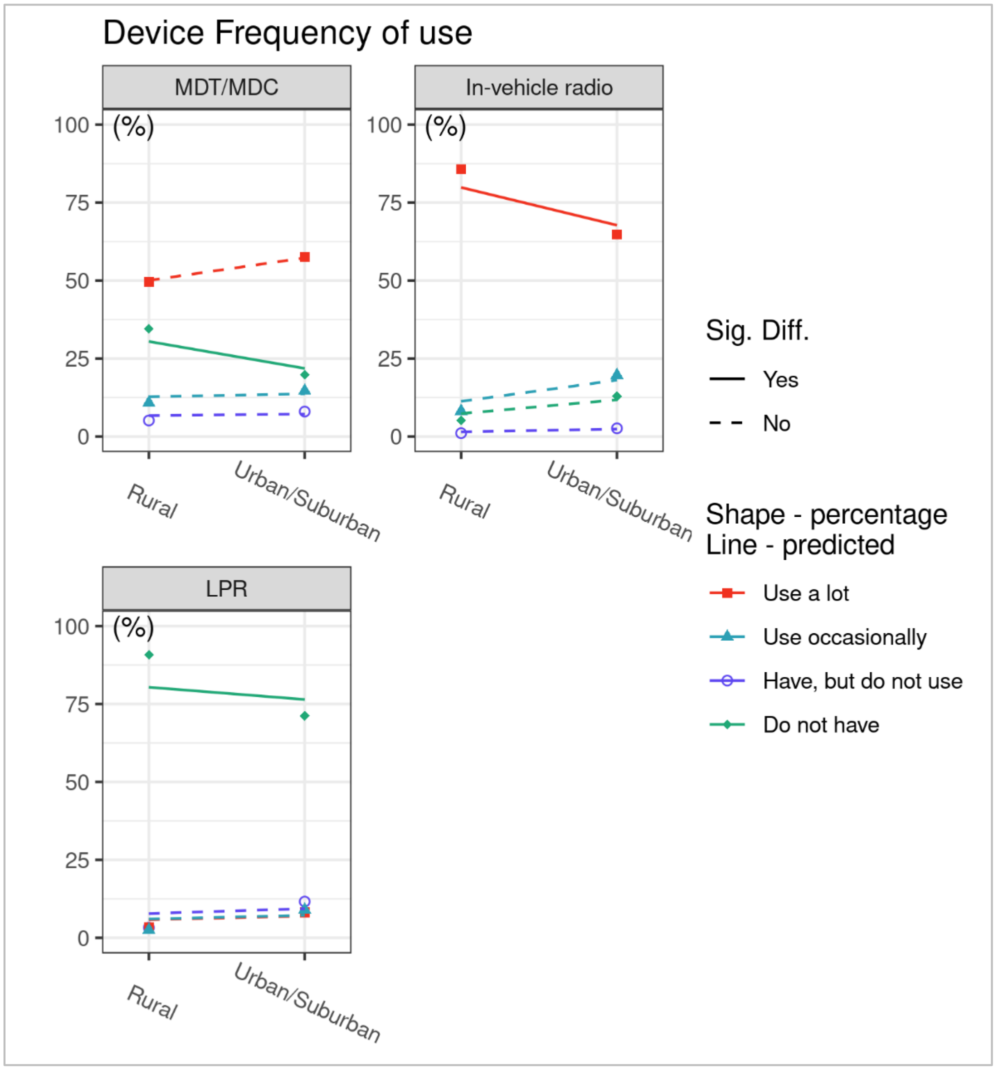


Fig. 52. Percentages, reported and predicted, for each frequency of use category, for devices listed, separated by rural and urban/suburban LE.

3.5.1.2. Device Ranking

There was a statistically significant difference between rural and urban/suburban LE for perceived usefulness of MDT/MDC and in-vehicle radio (Fig. 53). While urban/suburban LE ranked MDT/MDC as slightly more useful than rural LE, rural LE ranked in-vehicle radios as far more useful than urban/suburban LE. The difference in perception about MDT/MDC may be due to the differences between rural and urban/suburban LE in having MDT/MDC (Fig. 52).

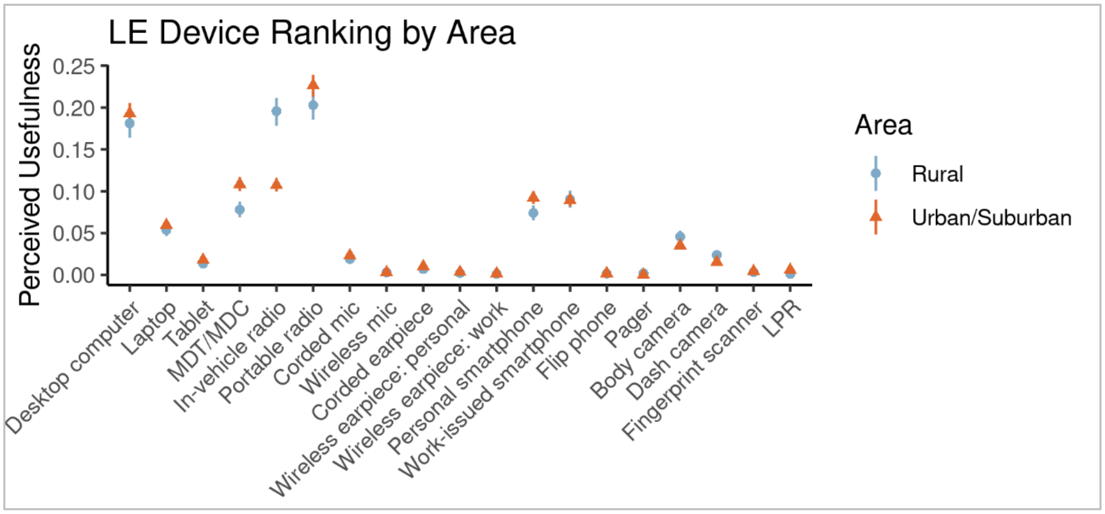


Fig. 53. Estimated perceived usefulness and 95 % credible intervals for those estimates of devices, separated by the rural and urban/suburban LE.

3.5.1.3. Problems with Technology

Rural LE were more likely to experience problems with radio prices "always" and "most of the time" (Fig. 54). While 19 % (21 % predicted) of urban/suburban LE had a problem "always" with radio price, 33 % (30 % predicted) of rural LE did.

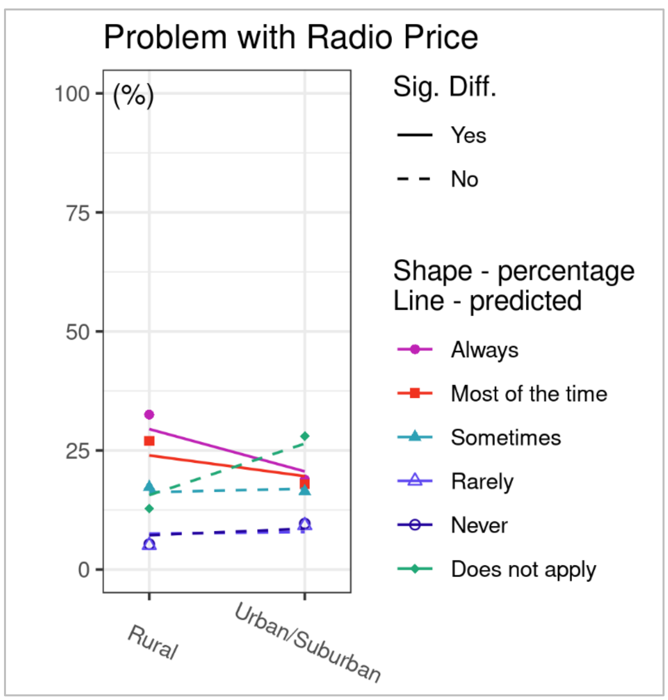


Fig. 54. Percentages, reported and predicted, for each category of the frequency of experiencing problems with radio price, separated by rural and urban/suburban LE.

3.5.1.4. Application/Software Frequency

Rural LE were more likely to report that they "do not have" CAD (Fig. 55). Twice as many rural LE (20 % reported and 18 % predicted) reported not having CAD compared to urban/suburban LE (9 % reported and 10 % predicted).

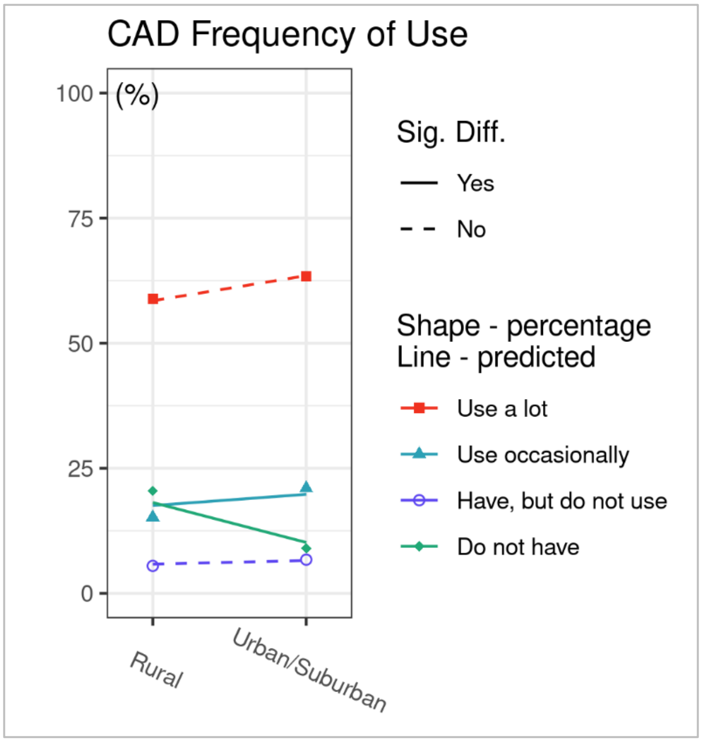


Fig. 55. Percentages, reported and predicted, for each frequency of use category, for the application/software CAD, separated by rural and urban/suburban LE.

3.5.2. Chief/Management and Supervising Responders compared to Frontline Responders

Overall, key differences between roles for LE illustrated that chief/management and supervising LE were:

- More likely to use work smartphones and computers and less likely use MDT/MDC
- Less likely to report "not applicable" for problems with the price of radios and laptops
- More likely to report not having CAD

And, chief/management and supervising LE:

- Ranked MDT/MDC and portable radios as less useful but desktop computers and work-issued smartphones as more useful
- Ranked CAD, criminal databases, reporting writing applications/software as less useful and email, RMS, and policies as more useful

Chief/management LE were:

- More likely to report not having tablets and laptops
- Less likely to report “not applicable” for problems with the price of computers, smartphones, body cameras, and MDT/MDC.
- More likely to use RMS and more likely to not have report writing applications/software

And, chief/management LE:

- Ranked in-vehicle radios as more useful and personal smartphones as less useful

3.5.2.1. Device Frequency

Chief/management and supervising LE were more likely than frontline LE to use computers and work smartphones “a lot.” (Fig. 56). Chief/management and supervising LE had high rates of using desktop computers: over 80 % (reported and predicted) used their computers “a lot,” while 60 % (74 % predicted) of frontline responders did. While over half of chief/management and supervising LE used their work smartphones “a lot,” (63 % reported and 51 % predicted) only 25 % (45 % predicted) of frontline LE did. Chiefs/management were also more likely than supervising and frontline LE to use in-vehicle radios “a lot” (Fig. 56).

Chief/management and supervising LE were also less likely to use MDT/MDC compared to frontline LE (Fig. 56). Over 75 % of frontline LE (63 % predicted) used their MDT/MDC “a lot” compared to only about half of chiefs/managers and supervising LE (51 % and 56 % predicted, respectively).

There were also differences between the three roles in the devices they reported not having (Fig. 56). Chiefs/management were less likely to report that they “do not have” laptops, tablets, and work-issued smartphones compared to frontline and supervising LE (Fig. 56). While nearly 30 % (22 % predicted) of frontline LE reported they “do not have” a laptop, and 24 % (22 % predicted) of supervising LE reported the same, only 12 % (16 % predicted) of chief/management LE reported this. While over 85 % (70 % predicted) of frontline LE reported they “do not have” a tablet, and 70 % (69 % predicted) of supervising LE reported the same, only 51 % (57 % predicted) of chief/management LE did. The percentages of reporting “do not have” for work-issued smartphones are: chief/management – 29 % reported and 31 % predicted; frontline responders – 63 % reported and 49 % predicted; supervising responders – 35 % reported and 41 % predicted.

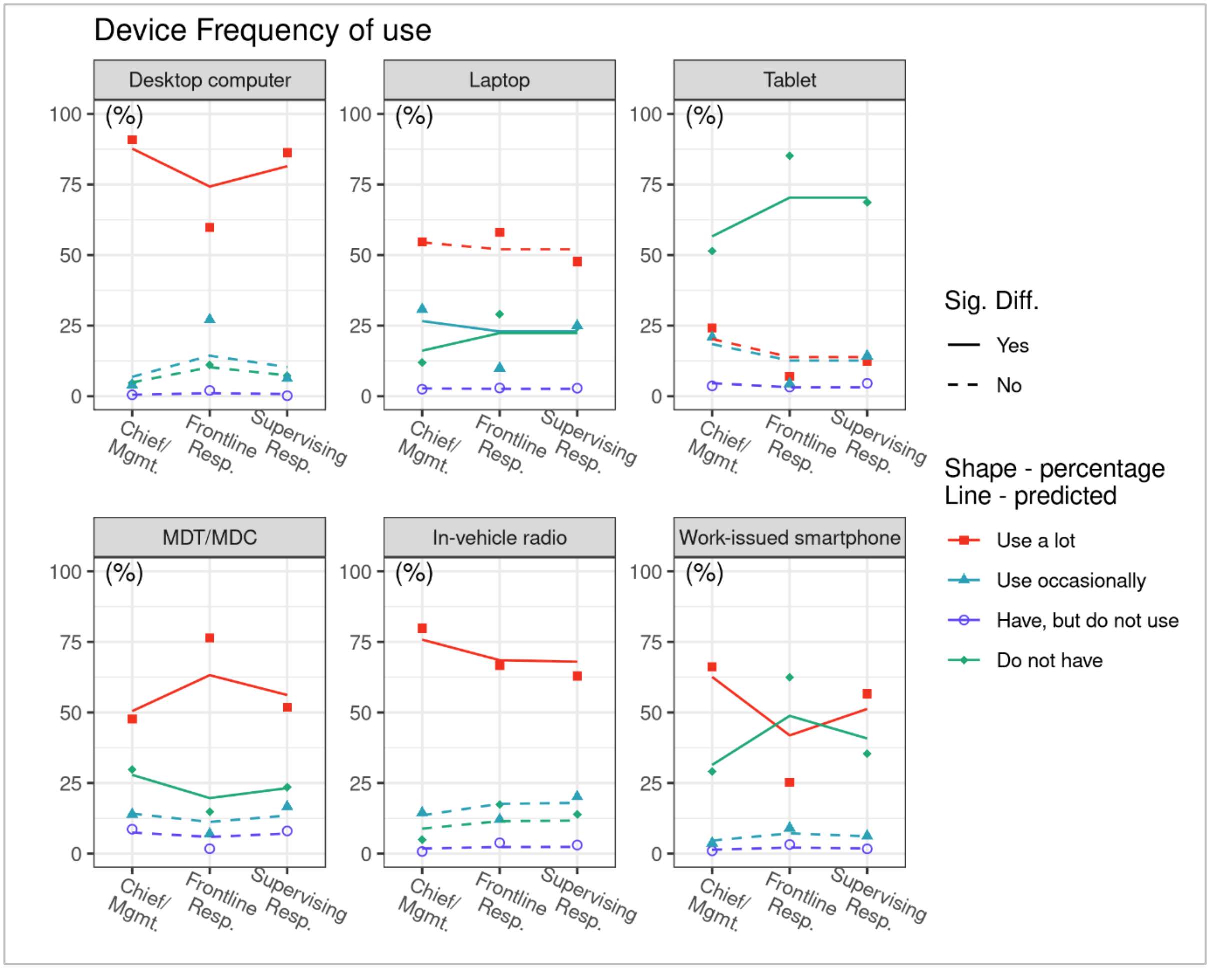


Fig. 56. Percentages, reported and predicted, for each frequency of use category, for devices listed, separated by the LE roles chief/management, frontline responder, and supervising responder.
* Management is abbreviated mgmt. and responder is abbreviated resp.

3.5.2.2. Device Ranking

Fig. 57 displays the estimated perceived usefulness of devices for chief/management, frontline responder, and supervising responder LE roles. Frontline responders ranked MDT/MDC and portable radios as being more useful than chief/management and supervising responders. On the other hand, frontline responders ranked desktop computers and work-issued smartphones as less useful than either chief/management or supervising responders. One potential explanation for frontline responders reporting work-issued smartphones as less useful is that frontline responders were more likely to report that they “do not have” a work-issued smartphone (Fig. 56). Chief/management LE also ranked in-vehicle radios as more useful than either frontline or supervising responders, while they ranked personal smartphones as less useful (Fig. 57).

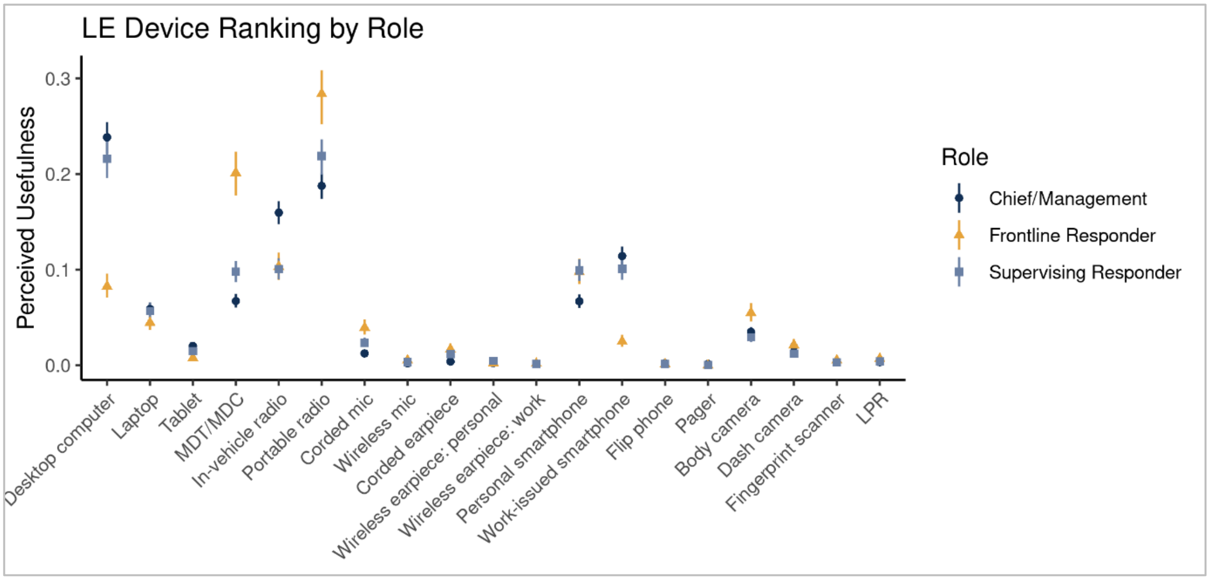


Fig. 57. Estimated perceived usefulness and 95 % credible intervals for those estimates of devices, separated by the LE roles chief/management, frontline responder, and supervising responder.

3.5.2.3. Problems with Technology

Frontline LE were more likely to report that laptop and radio price problems "did not apply" compared to chiefs/management and supervising responders (Fig. 58). Further, frontline and supervising responders were more likely to report that desktop computer, MDT/MDC, smartphone, and body camera price problems "did not apply" compared to chiefs/management LE. For all of the devices listed in Fig. 58, except body cameras, fewer than 10 % (predicted and reported) of chiefs/management indicated that price problems did not apply. For body cameras, 4 % of the surveyed chiefs/managers indicated that price problems "do not apply," but 18 % was predicted by the multinomial regression model. The larger discrepancy between the reported and predicted values is due to the very large percentage (almost 75 %) of frontline responders indicating that the price of body cameras "does not apply." This may suggest that chief/management LE are sensitive to different problems in their day-to-day work than frontline and supervising responders.

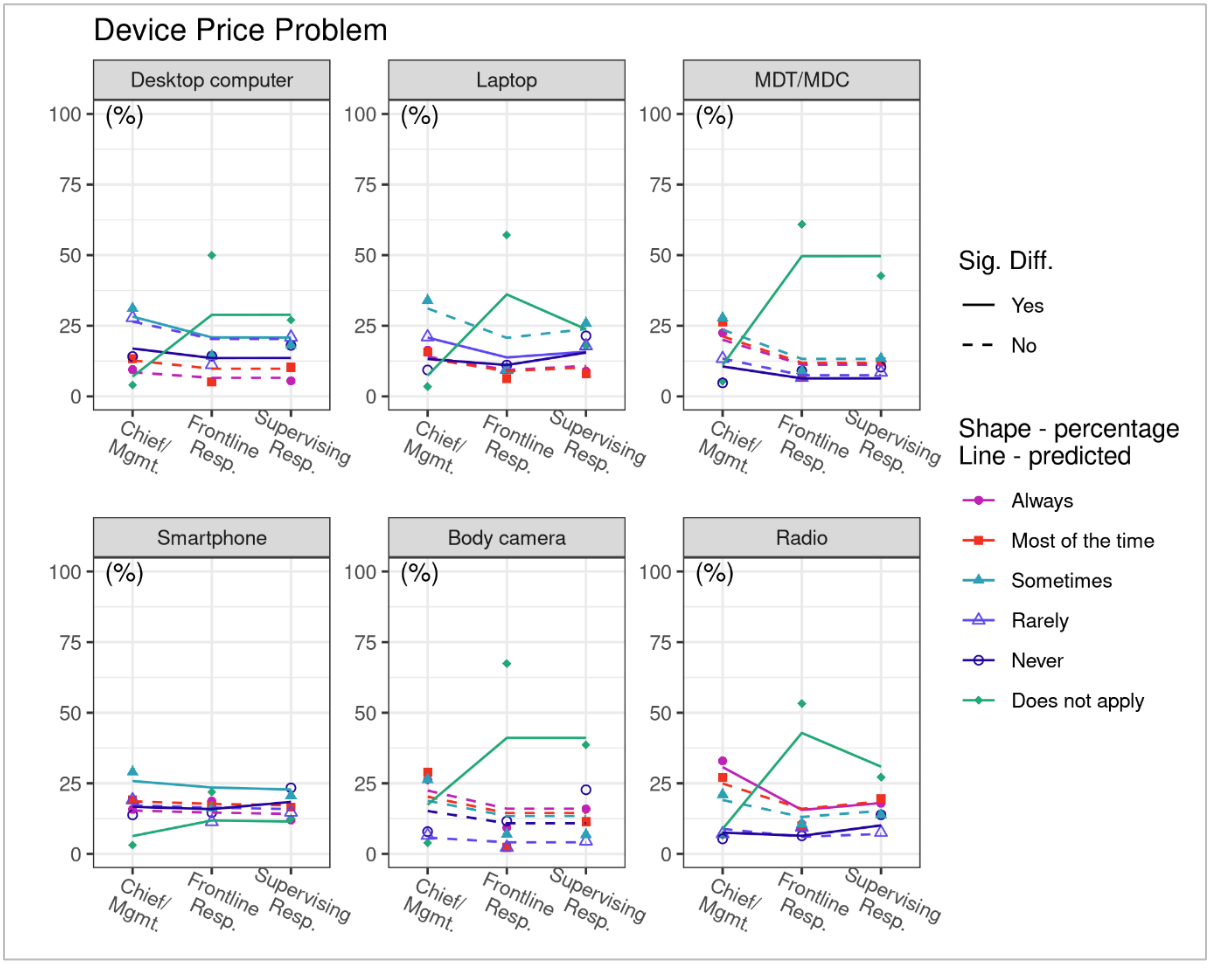


Fig. 58. Percentages, reported and predicted, for each category of the frequency of experiencing problems with the price of devices listed, separated by the LE roles chief/management, frontline responder, and supervising responder.
* Management is abbreviated mgmt. and responder is abbreviated resp.

Frontline and supervising LE also experienced problems with the portability of MDT/MDC at a higher rate than chief/management LE (Fig. 59). Frontline and supervising LE infrequently reported problems with the portability of MDT/MDC "always" (20 % and 15 % reported, and 14 % predicted, respectively), but chief/management LE were still less likely to report this (3 % reported and 9 % predicted). Further, 41 % (35 % predicted) of chief/management LE reported a problem with MDT/MDC "rarely", but 22 % (28 % predicted) of frontline LE reported the same, and 27 % (28 % predicted) of supervising LE did.

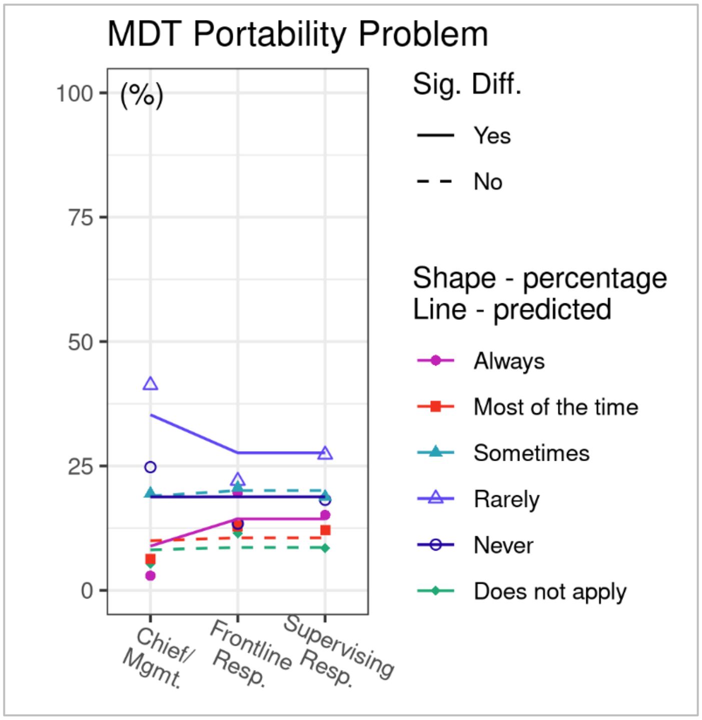


Fig. 59. Percentages, reported and predicted, for each category of the frequency of experiencing problems with MDT/MDC portability, separated by the LE roles chief/management, frontline responder, and supervising responder.
* Management is abbreviated mgmt. and responder is abbreviated resp.

3.5.2.4. Application/Software Frequency

Both supervising responders and chief/management LE were less likely to use CAD "a lot" (Fig. 60). Over 70 % (66 % predicted) of frontline LE used CAD "a lot" compared to about 60% (reported and predicted) of supervising responders and chief/management.

Chief/management were more likely to use RMS compared to frontline and supervising responders (Fig. 60). Over 75 % of chief/management used RMS "a lot" (72 % predicted) whereas only 50 % (64 % predicted) of frontline responders and 66 % (64 % predicted) of supervising responders did. Chief/management were also more likely to report they "do not have" report writing applications/software compared to frontline and supervising LE (Fig. 60).

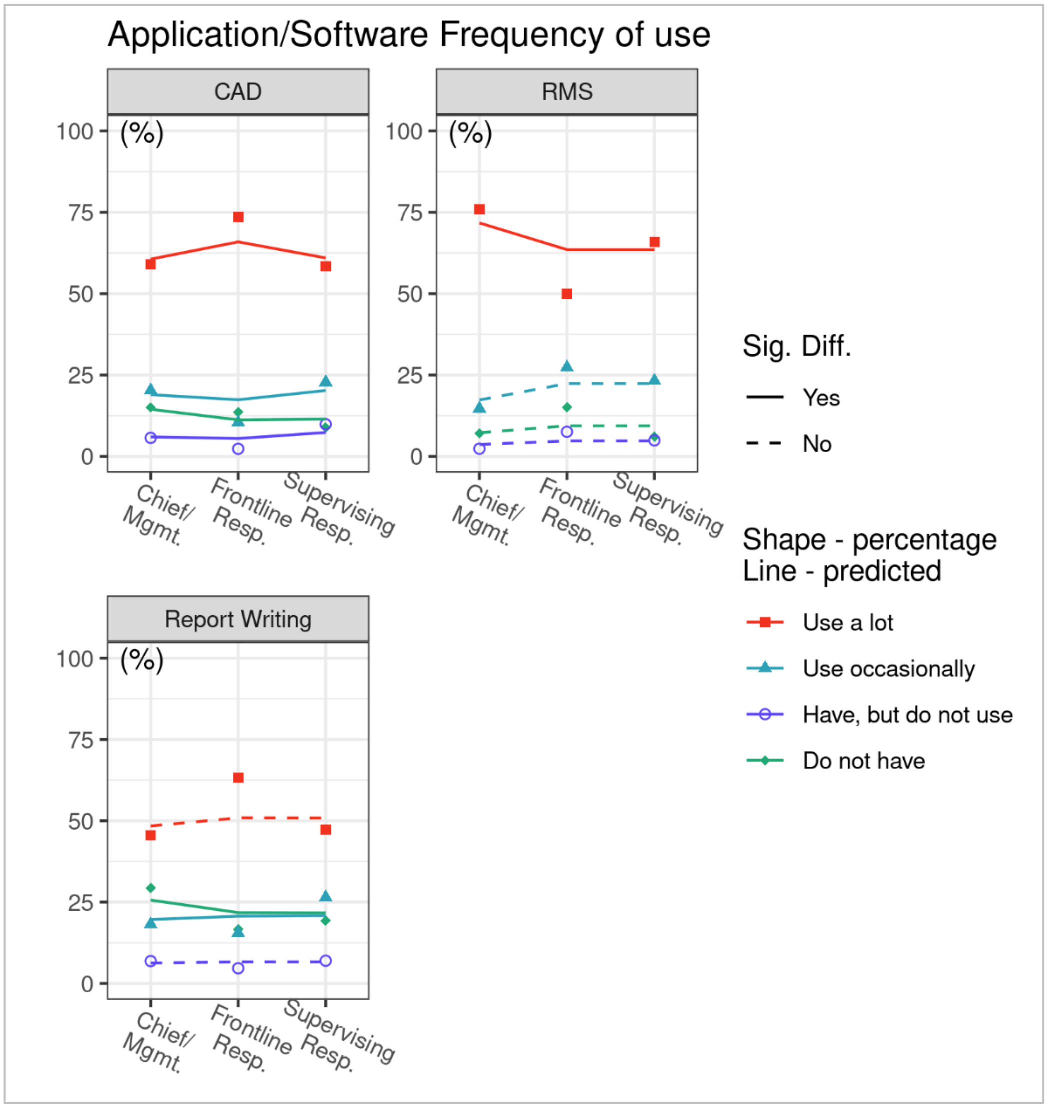


Fig. 60. Percentages, reported and predicted, for each frequency of use category, for applications/software listed, separated by the LE roles chief/management, frontline responder, and supervising responder.
* Management is abbreviated mgmt. and responder is abbreviated resp.

3.5.2.5. Application/Software Ranking

Fig. 61 displays the estimated perceived usefulness of applications/software for chief/management, frontline responder, and supervising responder LE. Frontline responders ranked CAD as being more useful than chief/management and supervising responders, and email as being less useful. To a lesser extent, frontline responders also ranked criminal databases and report writing software as more useful, and RMS and Electronic Policies to be less useful than chief/management and supervising responders.

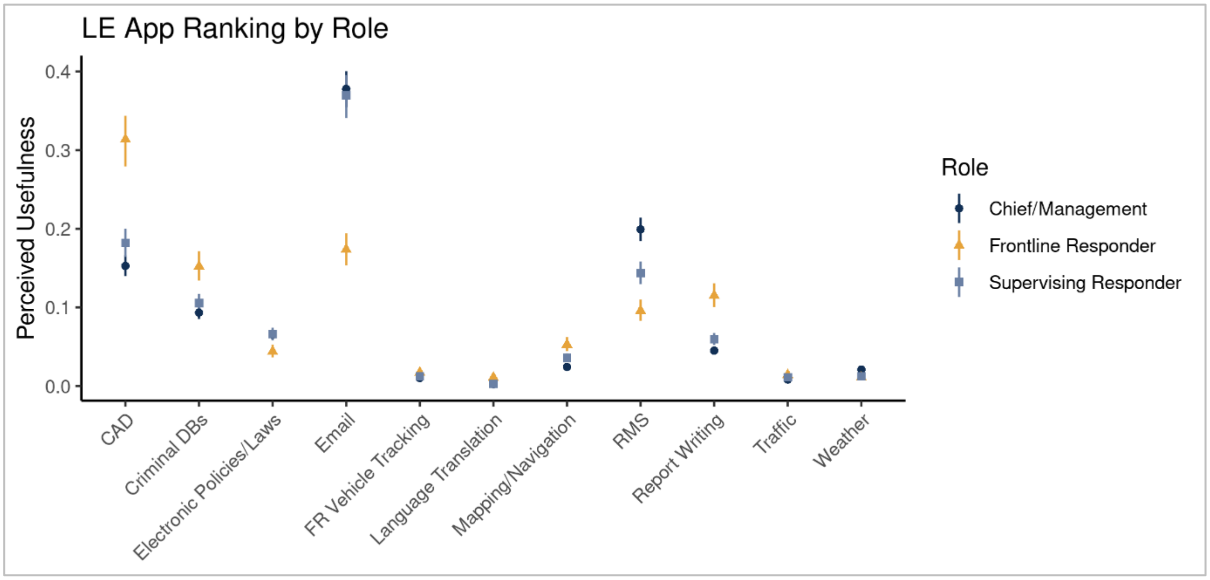


Fig. 61. Estimated perceived usefulness and 95 % credible intervals for those estimates of applications/software listed, separated by the LE roles chief/management, frontline responder, and supervising responder.

4. Discussion and Future Directions

With increased focus on improving first responders' communication technology through efforts such as NPSBN and PSCR, there are many opportunities to develop communication technology to greatly benefit first responders. As highlighted in our previous volumes ([2], [4]), there are several problems and needs that exist across first responders and disciplines. Although those reports describe important considerations and insights that are likely to benefit first responders generally, this report takes a different approach and highlights where specific considerations must be made for the communication technology used by particular subgroups of first responders. Specifically, we describe the unique problems and needs of first responders in different areas, roles, volunteer status, and combinations of these characteristics informed by rigorous statistical analyses. The following sections conclude this report with overarching themes of the results, implications for user-centered guidelines, and future directions and opportunities for improvement of communication technology for first responders.

Throughout this section, respondent quotes from the open-ended sections of the survey are included. These quotes are verbatim from the survey and are not connected to specific respondents. The notation for the quotes includes the discipline, area, and survey ID (e.g., FF:R:1234).

4.1. Overarching Themes from Data Analysis

Our previous reports highlighted that first responders across disciplines lack resources for the communication technology they need ([2], [4], [6], [9]). The statistical analysis in this report supports these findings, and further illustrates that a lack of resources is especially an issue for first responders in rural environments and for volunteers (FF only). Across disciplines, rural first responders were more likely to report not having some devices and applications/software compared to their urban/suburban counterparts. For example, EMS, FF, and LE in rural areas were less likely to have MDT/MDC and CAD. In some cases, they were also more likely to use devices that are considered older technology; for example, rural EMS were more likely to report using pagers in their day-to-day work. Rural first responders also were more likely to report problems with the price of their devices. Price problems often arose for radios, which is concerning as radios are commonly used and ranked as highly useful by first responders (Fig. 13, Fig. 25, and Fig. 53)[6]. These problems also appeared in the open-ended responses in the survey.

> The county is in the process of planning a change over from our current analog system to a digital system. This changeover will be extremely financially difficult for my department along with most of them in the county. The county is not offering any assistance with this project to provide any radio equipment to the end users as has been completed in at least 2 of the counties that we border and is planned in 1 other county we touch. For my department alone we are looking at a cost of over $60,000. This to be completed on a budget of around $30,000 with us paying all of our own bills, insurance, fuel, water, sewer, electric, phone, etc… (FF:R:2562)

> Being a small agency, funds are very limited. The cost of equipment such as radios and MDCs are very costly. Assistance in purchasing these would be helpful or even refurbished items, possibly donated to smaller agencies would help with department costs. Agencies like ours are using technology that is anywhere from 5 years to 25 years old. (LE:R:9245)

A similar lack of resources was also found for volunteer FF. This group was more likely to report “do not have” for some devices and applications/software, such as MDT/MDC and CAD. They also reported having price problems with radios and computers more often. This is not to say that urban/suburban and career FF do not lack resources – our prior work shows that resource challenges occur across first responders. Rather what our results suggest is that the resource problems that plague public safety more broadly are especially problematic for rural first responders and volunteers.

We also found evidence that communication technology use and problems differ depending on first responders’ roles. Chief/management first responders tended to have specific needs for their technology that differed from those of frontline responders. Chiefs tended to report using certain devices for incident response (e.g., MDT/MDC, TIC) less frequently than frontline responders. This was supported by chief/management responses to the open-ended survey questions as well.

> Note: As the Fire Chief I use my POV and typically do not respond to emergency incidents. However all suppression personnel in my department are issued their own radios, all of our apparatus have MDCs, TICs, and we have computers throughout our staions [*sic*]. (FF:S:6193)

> As the Chief of Police I do not use some of the technology listed in my daily job. Our agency does have some of the technology in our patrol cars such as MDT's and dash cameras. I noted that we have them but that I do not personally use them. (LE:S:4909)

Chief/management roles used some communication technology more frequently than others; they were more likely to use devices and apps such as computers, laptops, smartphones, and email that are conducive to their managerial and coordination duties. We also found evidence that the price of communication technology is top of mind for chief/management first responders. This makes sense as chief/management first responders are often decision-makers for their departments, which may include deciding what communication technology to buy and train on.

While chief/management first responders had unique technology usage and needs, we also found different patterns for supervising responders. For EMS and FF, supervising responders' technology use and problems tended to pattern similarly to frontline responders. This was not the case for COMMS and LE, where frontline responders differed from both supervising responders and chief/management roles. For COMMS, chief/management and supervisors reported using similar devices and reported similar considerations on receiving texts and NG911. For LE, chief/management and supervising responders reported using similar devices such as work smartphones, and they tended not to use MDT/MDC and CAD. They were also both aware of price problems; however, chief/management LE still have some specific price concerns and used different devices.

We also found evidence of interactions between our primary factors of interest, area, role, and volunteer status for FF. For example, rural FF were more likely than urban/suburban FF to report a problem with TIC price, but that difference was increased for chief/management FF (Fig. 46). Several respondents described problems with lack of resources in the open-ended responses.

> ambulance services especially rural services that do not get any financial support as most in [state redacted] do not; cannot afford to purchase these communications as well as the equipment with the technology that can make a difference in patient outcomes. I find it disheartening that even though EMS is as vital public safety entity as fire services and police services and should be treated as equals but does not get the financial support from the government (state/local/federal) as police and fire does with multiple grants and tax base support (EMS:R:524)

> We are technology hamper, mostly because of the rural area we live and work in. We usually can't afford the technological equipment that most big departments have. We use what is available to us, such a TIC's, and Desk top computers and some software. Our infrastructure of our community is usually a few years behind mostly because of funding. (FF:R:3054)

We also found evidence that the difference between rural and urban/suburban responders for reporting a lack of some devices and software/apps was larger in magnitude for volunteer compared to career FF. A similar pattern was observed for reporting problems with the price of some devices.

4.2. User-Centered Design Guidelines

We have previously published six user-centered design guidelines for improving communication technologies for first responders [2]:

1. Improve current technology

2. Reduce unintended consequences
3. Recognize 'one size does not fit all'
4. Minimize 'technology for technology's sake'
5. Lower product/service costs
6. Require usable technology

While we believe these guidelines will benefit all first responders, some of these guidelines have particular meaning in the context of this report.

Improve current technology. Our previous reports describe first responders' desires for their current technology to be fixed and updated rather than for development of entirely new communication technologies ([2], [6]). Such improvements may especially benefit rural and volunteer first responders, who currently lack some basic devices, applications, and software.

> Technology advances for this industry are great and vast, the problem is we are unable to use any of the technology due to the connectivity being unreliable. We are currently better off using old school methods such as paper maps, because of the inability to stay connected to any network or service in our mountainous terrain. (FF:R:4503)

> Due to our rural and remote location we are forced to use mobile repeaters, and they are less than reliable. Also, due to the restrictions of narrow-band radios and the low power output of the ones our agency can afford, actually reaching our dispatch center (which is several miles away) is hit-and-miss at best. There are higher-powered radios available, we just cannot afford them, and it seems that when the Federal government mandated the switch to narrow-band transceivers, it exacerbated an already bad situation for small and rural agencies like ours. (LE:R:8193)

When current technology is improved for rural and volunteer first responders, it is vital that it be developed with existing infrastructures and limitations in mind.

Recognize "one size does not fit all". Communication technology is often not well-suited to the specific needs first responders have given their unique contexts of use: a device developed for one discipline may not be well-suited to another. Our previous work has identified that different disciplines have unique needs based on the context of use ([4], [22]); within a discipline, first responders in rural contexts also have unique needs [9]. Findings reported here support this, showing that first responders in rural environments reported more resource needs compared to their urban/suburban counterparts. This suggests technology developed for urban/suburban first responders may not be suited to the needs of rural first responders who have very limited budgets and infrastructure considerations. This report adds to our previous work by also identifying volunteers and chief/management as having specific problems and needs. For example, we found evidence that volunteer FF do not use the same communication technology as their career counterparts, and this finding was also voiced in the open-ended responses.

> as a volunteer I wouldn't use much of these things, but sometimes others might (FF:R:5507)

> Volunteers have limited access to internet at best, in many cases must use paper and later enter into personal computer double work and I know several calls do not get

> logged Mapping is hit and miss some times directions take us to another state 500 miles away (FF:R:7795)

As evidenced by the quotes, needs and problems are further complicated for rural volunteer first responders.

Similarly, technology should be developed with first responders' roles in mind and be flexible to meet their needs. Our findings suggest that communication technology for chief/management roles should support their communication and coordination needs. For some disciplines, such as COMMS and LE, the frontline responders' day-to-day work and duties may require very different technology than those in supervising and chief/management positions. Technology that supports incident response as well as the unique roles and duties of chief/management first responders is important to consider when developing new technology.

Lower cost of products/services. Cost and resource concerns are unfortunately common in first responders' experiences ([2], [4], [6]). But technology costs are especially prohibitive for rural and volunteer first responders (Fig. 14, Fig. 23, Fig. 26, Fig. 32, Fig. 46, Fig. 54). Developers creating technology for rural and volunteer first responders must keep this in mind, and aim to create technology that is affordable to purchase, train on, maintain, and update. Results from this study suggest that chief/management first responders are very conscious of price considerations and could be a useful resource for developers in understanding these issues.

4.3. Future Directions and Opportunities

There are several opportunities for research and development of communication technology to benefit first responders in different areas and roles and who have career or volunteer status. Results of this report highlight that there are inequities in communication technology between subgroups of first responders; inequities for the rural and volunteer first responder subgroups were highlighted in this report. They are currently lacking some devices and applications, and this lack of technology is likely related to a general lack of funding and resources. Researchers and developers have an opportunity to develop affordable technology for these groups to catch them up to the benefits current and emerging technologies can provide for incident response. However, it is important to consider how technology may be used by first responders who fall into the intersection of rural, volunteer, and/or chief/management subgroups. More research is needed to identify how to solve the unique problems experienced by specific intersections of these groups. Work is also encouraged to explore how other factors such as age, sex, and years of service could also interact with existing subgroups to produce unique challenges and needs to address.

Another opportunity is for technology designers and developers to work directly with chief/management first responders when developing technology. Such consultations would be helpful as chief/management roles are often decision-makers for what technology is used. Working directly with chief/management may also be helpful for developing technology that is suited to the duties and needs of chief/management roles, which can be quite different from those of frontline responders.

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Appendix A. Additional Statistical Methods Details

Because the Methods section focuses on the rationale rather than the mechanics of conducting our analyses, we provide additional details here. First, we include a general description of word embeddings, which were used to categorize first responder roles (see Sec. 2.1.2). Then we include a description of sparse multinomial regression and the specific considerations that went into our models (see Sec. 2.2.1). This includes exemplar equations to illustrate our technique. Finally, we include Bayesian specific details about the analyses involving the Plackett-Luce models (see Sec. 2.2.2).

A.1. Word Embeddings

Word embeddings translate words into vectors of numbers, in this work vectors of dimension 300. Since each word is represented by 300 numbers (300 dimensions), if a response is composed of more than one word, the entire response is represented by a vector with dimension equal to the number of words in the response times 300. Take the response "Deputy Fire Chief of Operations," which is composed of 5 words, and would be represented by a vector with 1500 numbers (1500 dimensions). So that all the responses are translated to vectors of the same dimension, each response is translated into a vector large enough for the longest response. The vectors representing shorter responses are padded with zeros to fill the unused dimensions. Word embeddings are meaningful in the sense that related words will tend to yield translations that are closer together than unrelated words. For example, "captain" and "commander" are closer together than "captain" and "firefighter." Word embeddings contain other meaningful structure, but a broader discussion of their attributes is out of scope.

A.2. Sparse multinomial regression model considerations

The least absolute shrinkage and selection operator (LASSO) (or L_1 penalty) was introduced for ordinary regression by Tibshirani (1996) [23]. Multinomial regression with the L_1 penalty (sparse multinomial regression) has been discussed in [12] and [8].

A sparse multinomial regression model is used for the multiple-choice questions because a respondent's answer to a question can be assumed to follow a multinomial distribution (see for example Chapter 30 of [7]). Consider the first question in Fig. 1 regarding a respondent's use of a body camera. The respondent has a choice between four alternatives, "use a lot," "use occasionally," "have, but do not use," and "do not have." The assumption of a multinomial distribution imposes that the respondent will choose between the alternatives according to the probabilities p_1, p_2, p_3, and $p_4 = 1 - p_1 - p_2 - p_3$ (among other assumptions). In the extremes, when $p_i = 0$, alternative i will certainly not be chosen, and when $p_i = 1$, alternative i will certainly be chosen. The probabilities have a natural interpretation. They are the proportion of respondents in a subgroup of interest that would choose alternative i.

The choice made by a respondent for a multiple-choice question may be encoded as a row vector of zeros and ones containing only a single one. If a respondent chose "use a lot" for the body camera question in Fig. 1, the row vector encoding that response would be (1, 0, 0, 0). This type of encoding is also known as one-hot encoding in the field of machine learning.

A row vector, or horizontal stacking of numbers, contrasts with a column vector, or vertical stacking. The difference can be important in linear algebra operations and so is made here.

The predictor variables are all categorical, so they may be encoded by row vectors of zeros and ones. A predictor variable with two categories may be encoded by a single zero or one, a predictor variable with three categories may be encoded by a row vector of zeros and ones of length two, etc. Since male is the gender of the baseline category, male is encoded as a single zero, and female is encoded as a single one. For FF, there are three roles, chief/management, supervising responder, and frontline responder. They are encoded as (1, 0), (0, 1), and (0, 0), respectively, since frontline responder is a part of the baseline group. The remaining predictor variables are encoded similarly. By concatenating the row vectors that encode each predictor variable into a very long row vector, each of the 1728 groups (for FF) may be represented by a row vector of zeros and ones. The row vector for the baseline group contains all zeros. This type of encoding for predictor variables is known as baseline encoding in analysis of variance (see for example [13]) because the regression coefficients represent comparisons to the chosen baseline group.

It is instructive to write out a simplified version of the mathematical form of the regression equation used to analyze the multiple-choice questions. For FF, for each $p_i, i = 1, 2, \dots, K$, where K is the number of response categories,

$$
\begin{gathered}
p_i = \frac{e^{\mu_i}}{\sum_{j=1}^{K} e^{\mu_j}}, \\
\mu_i = \beta_{0i} + \boldsymbol{\beta}_{Ai}\boldsymbol{A}' + \boldsymbol{\beta}_{Yi}\boldsymbol{Y}' + \beta_{Gi}G + \beta_{Ci}C + \boldsymbol{\beta}_{Ri}\boldsymbol{R}' + \beta_{Vi}V.
\end{gathered} \tag{A.1}
$$

In Equation (A.1), $\boldsymbol{A}$ represents a row vector of 0's and 1's that indicates the age group to which a respondent belongs, and $\boldsymbol{A}'$ is the corresponding column vector (transpose of the row vector in the terminology of linear algebra). Similarly, $\boldsymbol{Y}$ and $\boldsymbol{R}$, are row vectors indicating a respondent's category for years of service and role. Bold symbols delineate vectors from scalar quantities. Since gender, community (rural or urban/suburban), and volunteer versus career status take on only two categories, a single 0 or 1 is sufficient. In contrast, role takes on three categories, so a row vector of two 0's and 1's is needed. Age requires a row vector of length five, and years of service length eleven. The β symbols represent regression coefficients to be estimated, and again bold delineates a vector from a scalar. A row vector multiplied by a column vector follows the usual rules of matrix multiplication. For example

$$
\boldsymbol{\beta}_{Ai}\boldsymbol{A}' = (\beta_{A1i} \quad \cdots \quad \beta_{A5i})\begin{pmatrix} A_1 \\ \vdots \\ A_5 \end{pmatrix} = \beta_{A1i}A_1 + \cdots + \beta_{A5i}A_5
$$

In Equation (A.1), the p_i are said to be the logistic transformation of the μ_i, and inversely, the μ_i are said to be the logit transformation of the p_i.

The regression coefficients in Equation (A.1) (β symbols) are directly interpretable as differences between groups. Consider any of the 1728/2 = 864 groups of interest for FF that have gender as male (which includes the baseline group). Based on Equation (1), the difference in the value of μ_i between one of those groups and the corresponding group with only gender changed to female is exactly β_{Gi} (or $-\beta_{Gi}$ depending on the order of the difference). When a predictor variable has more than two categories, the interpretation is slightly more complicated. Consider any of the 1728/6 = 288 groups with the age category 18 – 25. Based on Equation (1), the difference in the value of μ_i between one of those groups and the corresponding group with the age category switched to 26 – 30 is $\beta_{A1i} - \beta_{A2i}$ (or $\beta_{A2i} - \beta_{A1i}$ depending on the order of the difference). If changing from the age category 18 – 25 to 46 – 55, which is the baseline, the difference would be just β_{A1i} (or $-\beta_{A1i}$).

It should be emphasized that the coefficients represent differences between the μ_i, not the p_i. Further, there is not a direct interpretation of the magnitude of a regression coefficient on p_i. This may come as a surprise to the reader that is familiar with logistic regression with only two categories for the response variable. In that case the regression coefficients are directly interpreted as a change in the odds ratio. In multinomial logistic regression, with more than two categories for the response variable, that interpretation is not maintained. The sign of the coefficient may still be interpreted as leading to an increase (positive) or decrease (negative) in the p_i.

The L_1 penalty is selected separately for each question by 10-fold cross-validation as recommended by [11], but with an important deviation. In 10-fold cross-validation, the dataset is randomly partitioned into 10 equal parts. The regression coefficients are then estimated using 9 of the 10 parts, and those coefficients are used to predict each response in the 10th part. This provides an estimate of the out-of-sample prediction error for the regression model. The procedure is repeated 9 more times, leaving each part out once. The 10 estimates of the out-of-sample prediction error are typically averaged together, and the value of the L_1 penalty that leads to the smallest estimate of the out-of-sample prediction error is chosen. However, it was noticed that the selected penalty was not stable. That is, two different random partitions could lead to two different selected penalties. To correct this instability, 10-fold cross-validation was repeated 20 times, leading to 200 estimates of the out-of-sample prediction error. Averaging these 200 estimates and selecting the penalty leading the smallest average led to stable estimates of the L_1 penalty.

It was mentioned earlier, but is highlighted now, that Equation (A.1) is a simplified version of the regression equation that was actually employed in this work. Equation (A.1) contains only main effects. That means, for example, that the difference between a group with gender set to male and the corresponding group with only gender changed to female is always the same, no matter the pair of groups being considered. The regression equation actually employed allowed for the possibility of two-factor interactions. That means, for example, that the difference between a group with gender set to male and the corresponding group with only gender changed to female can indeed depend upon the pair of groups being considered. Higher order interactions (higher than two) were not considered.

With respect to figures such as Fig. 4, the reader might have expected the dashed lines to be perfectly horizontal since their slope represents a difference that is not statistically significant. That does not occur for two reasons: 1) the regression coefficients represent differences between the μ_i, not the p_i, but the p_i must sum to 100 %, so when the average prediction for one response goes up when moving from rural to urban/suburban in Fig. 4, the average prediction for at least one of the other responses must go down; 2) the groups are unbalanced, so in Fig. 4 the average for the rural group weighs alternate subgroups differently than the urban/suburban group. For example, relatively, there are more rural volunteers than urban/suburban volunteers, so volunteers contribute more heavily to the rural average prediction than to the urban/suburban average prediction. Solid lines representing statistically significant differences may appear nearly horizontal for similar reasons. One great advantage of using a sparse regression model to screen for statistically significant group differences is that it can control for these imbalances as long as the model is an accurate reflection of the group differences that exist in the underlying population.

A.3. Plackett-Luce Considerations

The output of the function `gibbsPLMIX` are samples from the joint posterior distribution of the perceived usefulness of all communications technologies being ranked (devices and applications are separated). The 95% credible intervals are calculated as the 2.5^{th} percentile and the 97.5^{th} percentile of those samples. The underlying statistical inference paradigm for the PLMIX package is Bayesian, so the selection of prior distributions is necessary. The default flat prior distributions are used here to express a lack of knowledge *a priori*. A detailed discussion of the computational methods of the PLMIX package, and more broadly Bayesian statistical methods, is out of scope for this report.

Appendix B. Supplemental Results

This section includes detailed demographics and all results from the sparse multinomial regression models. First, we present an example walkthrough of the graphs used in this section. Then we present demographics and results for each of the four disciplines:

- COMMS
- EMS
- FF
- LE

B.1. Example Graph

Figure B.0 displays an example result. It is the analysis for the multiple-choice question about day-to-day pager use by FF.

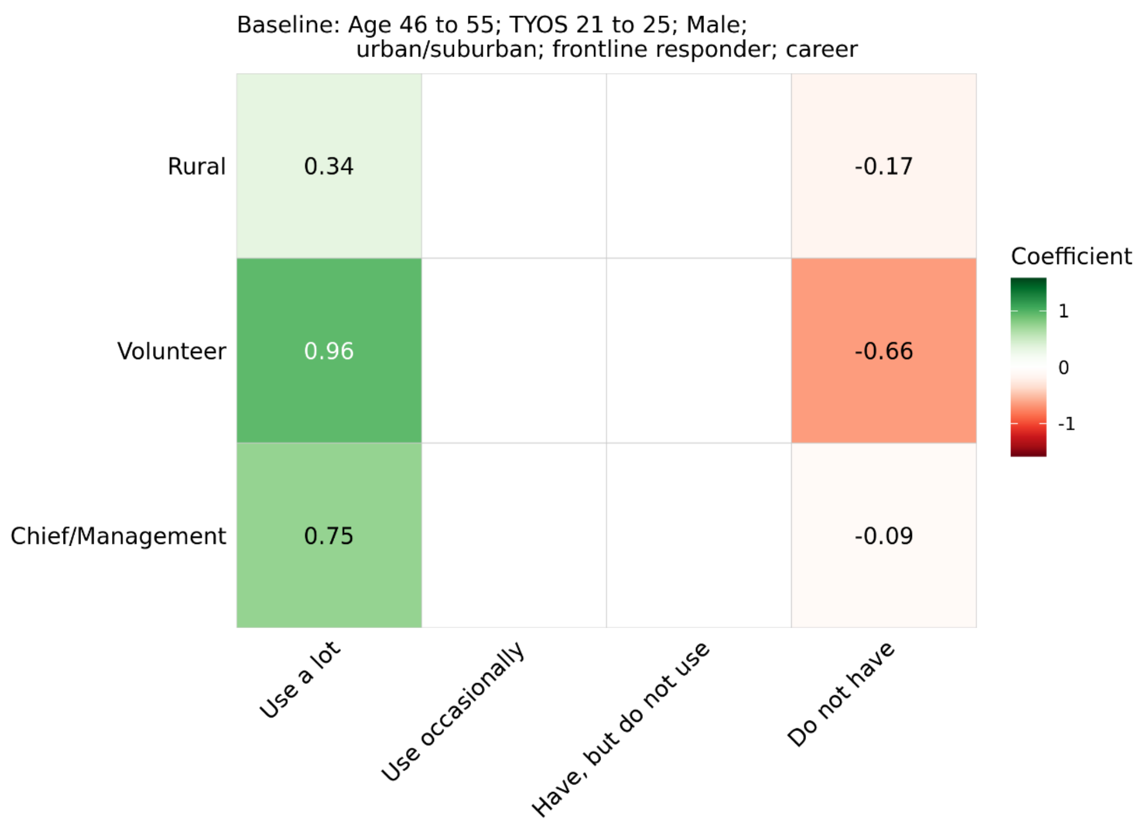

Fig. B.0 Example. Estimated regression coefficients for FF from the pager daily use question.

The horizontal axis displays the four response options for the survey question, and the vertical axis displays three comparison groups. Each cell of the grid represents the regression coefficient for comparing each group to the baseline group on a particular response option. Each cell is either blank or displays a number and color. Blank cells represent estimated coefficients that are exactly zero. For example, the blank cell in the rural row and "use occasionally" column indicates there was no evidence of a difference between the proportions of rural and urban/suburban FF reporting that they use pagers "occasionally." Some cells are missing, e.g., (Use a lot, Female). Missing cells also represent estimated coefficients that are exactly zero.

Colored cells with numbers indicate non-zero estimates of regression coefficients, which indicate evidence of a difference between the comparison group and the baseline group for that response item. Green coloring is used for positive coefficients, and orange is used for negative coefficients. The positive and negative sign indicates the direction of the effect in comparison to the baseline, with positive coefficients corresponding to a group being more likely to have a response compared to the baseline group, and a negative coefficient corresponding to a group being less likely. For example, volunteers were more likely to use pagers a lot compared to career FF, but they were also less likely to select that they did not have pagers compared to career FF. Darker colors depict larger magnitudes (farther from zero), and lighter colors depict smaller magnitudes (closer to zero).

Taken together, from Fig. B.0 it may be concluded that volunteer FF report that they use a pager a lot, more often than career FF. Similar statements can be made for chief/management roles compared to frontline responders and rural compared urban/suburban FF. It may also be seen from Fig. B.0 that volunteer FF are less likely than career FF to say that they do not have a pager.

B.2. COMMS

List of tables and figures

B.2.1. Subgroup Demographics

Table B.2.1.1 COMMS Demographics

Subgroup		%	n
Area	Rural	39	545
	Urban/Suburban	58	797
	(missing data)	3	42
Role	Frontline Responder	37	513
	Supervising Responder	35	478
	Chief/Management	25	351
	(missing data)	3	42
Age	18-25	4	51
	26-35	19	263
	36-45	28	387
	46-55	30	416
	56-65	14	197
	Over 65	1	15
	(missing data)	4	55
Years of Service	Less than 1	2	32
	1-5	11	152
	6-10	12	172
	11-15	15	208

	16-20	15	202
	21-25	16	226
	26-30	12	167
	31-35	8	108
	36-40	4	51
	41-45	1	16
	46-50	0	6
	More than 50	0	1
	(missing data)	3	43
Sex	Female	55	761
	Male	41	565
	(missing data)	4	58
Civilian Status	Civilian	89	1226
	Deputized	8	114
	(missing data)	3	44

B.2.2. Device Frequency

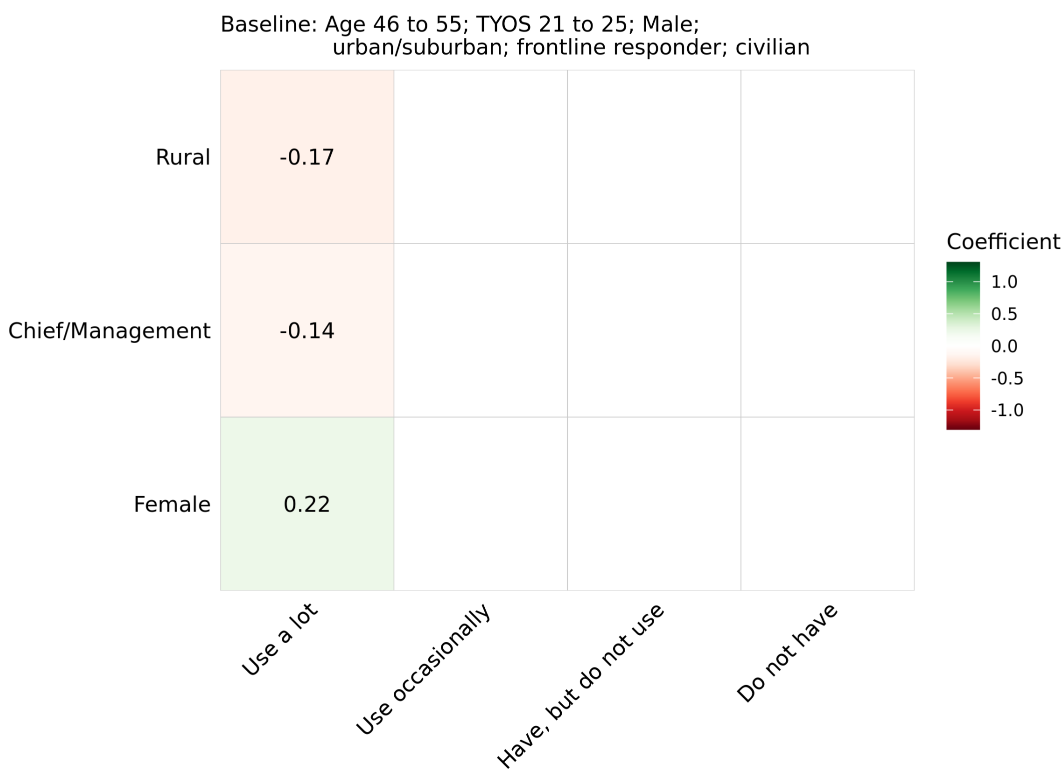

Fig. B.2.2.1 COMMS Device Usage Frequency: Foot Pedal

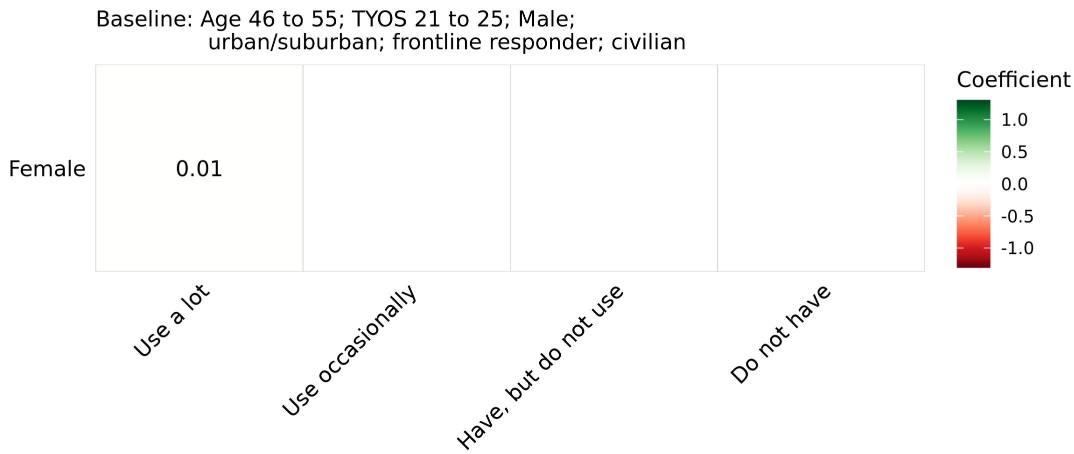

Fig. B.2.2.2 COMMS Device Usage Frequency: Headset

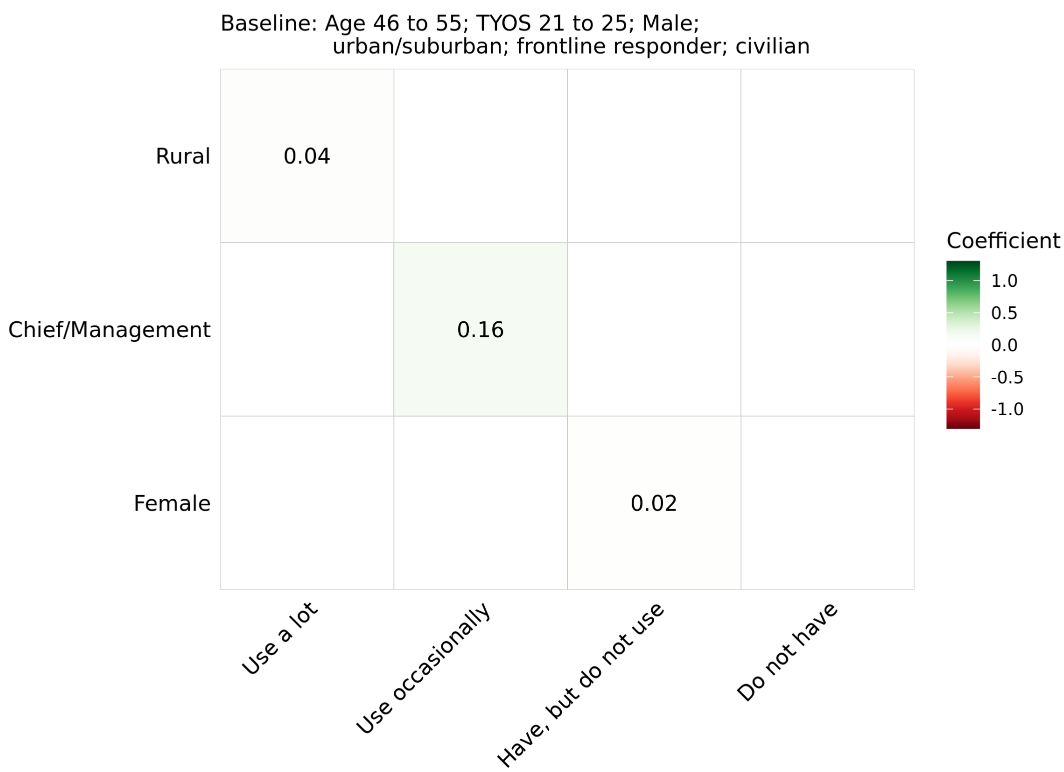

Fig. B.2.2.3 COMMS Device Usage Frequency: Desktop Microphone

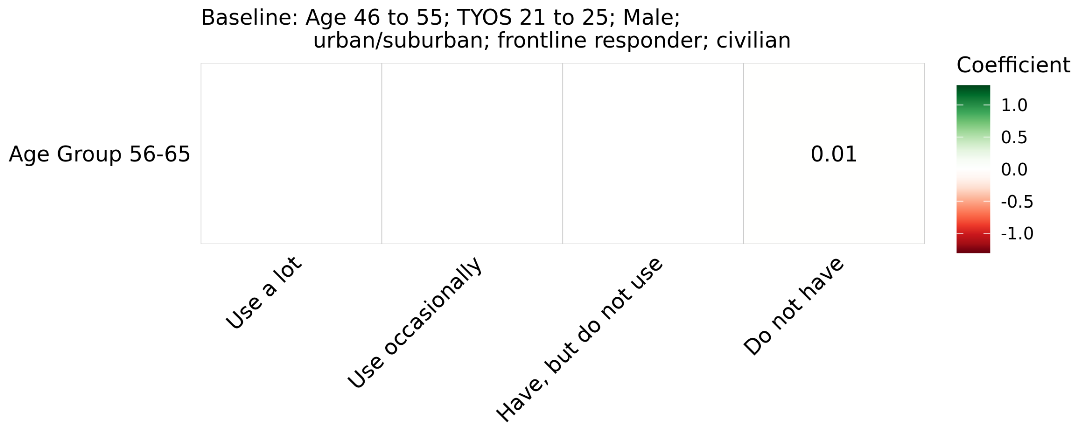

Fig. B.2.2.4 COMMS Device Usage Frequency: Microphone Clip

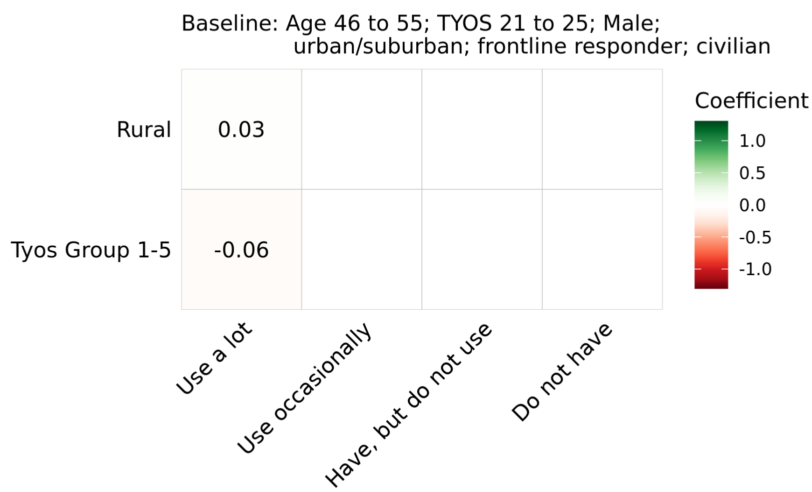

Fig. B.2.2.5 COMMS Device Usage Frequency: Landline

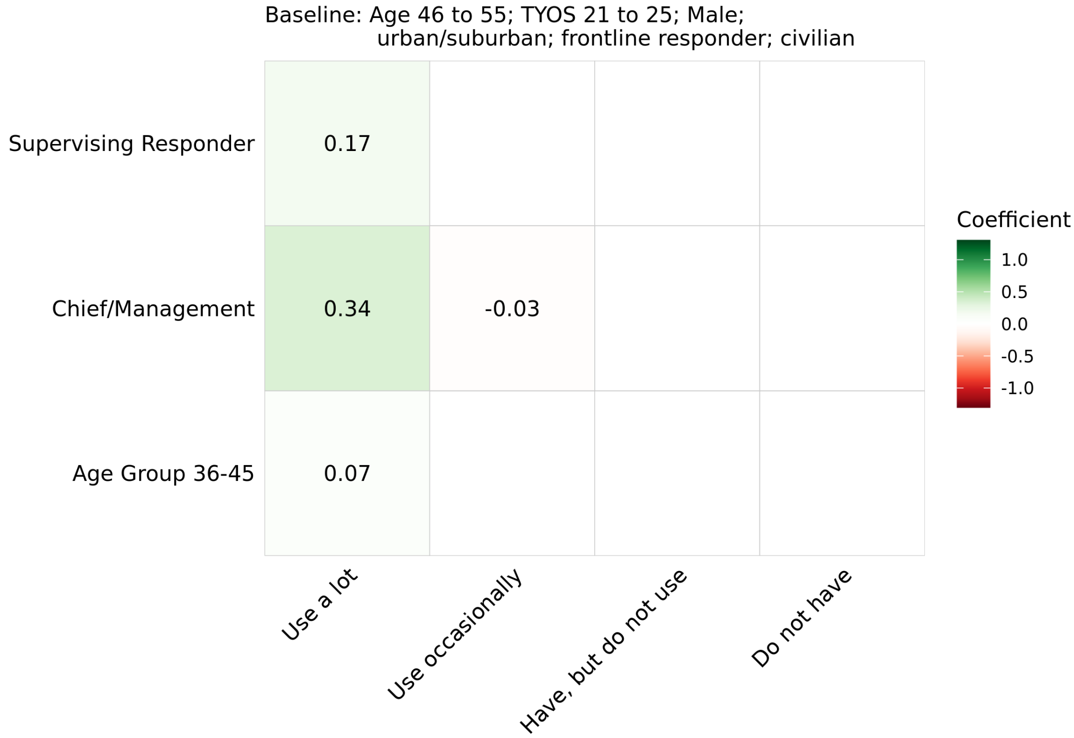

Fig. B.2.2.6 COMMS Device Usage Frequency: Personal Smartphone

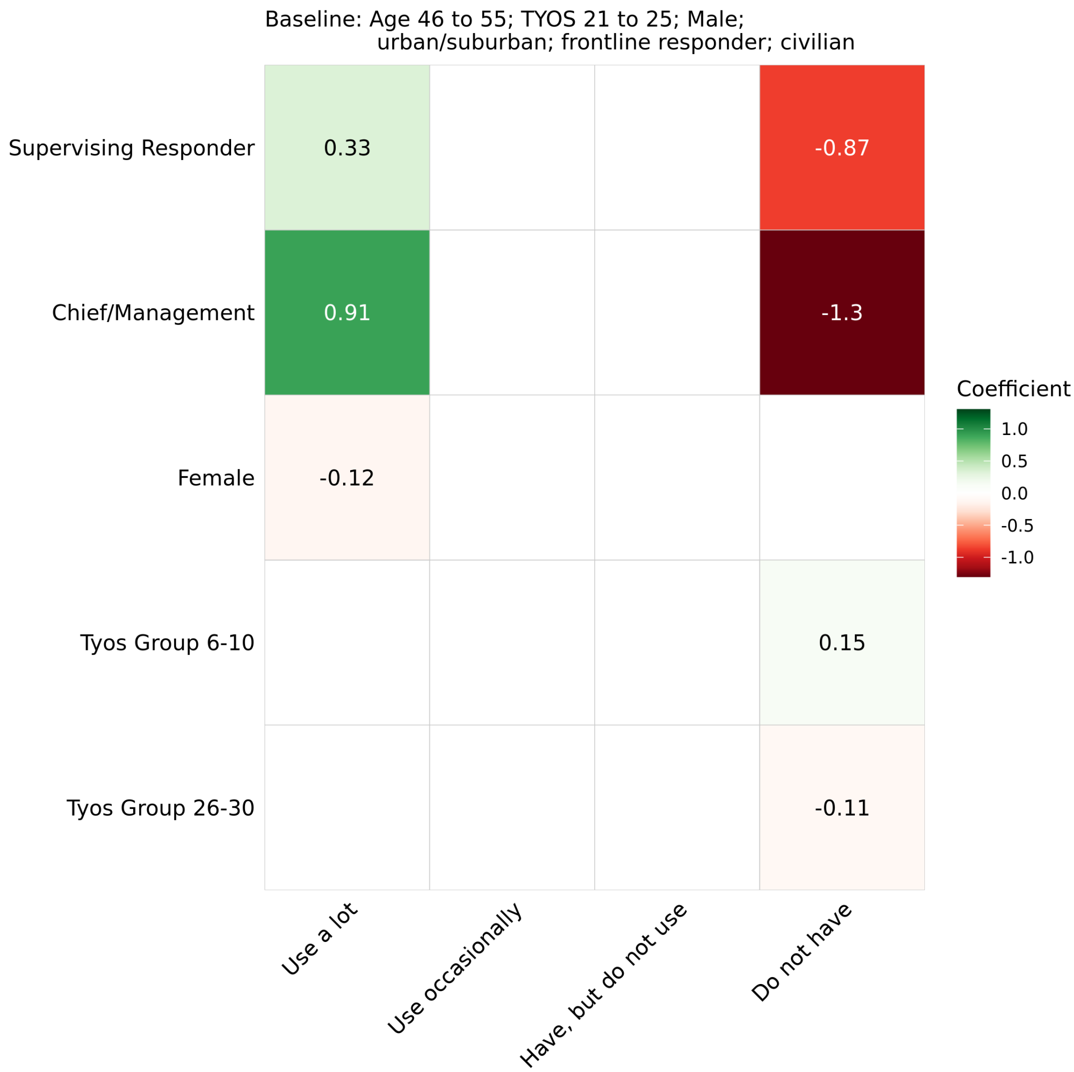

Fig. B.2.2.7 COMMS Device Usage Frequency: Work-issued Smartphone

B.2.3. Application/Software Frequency

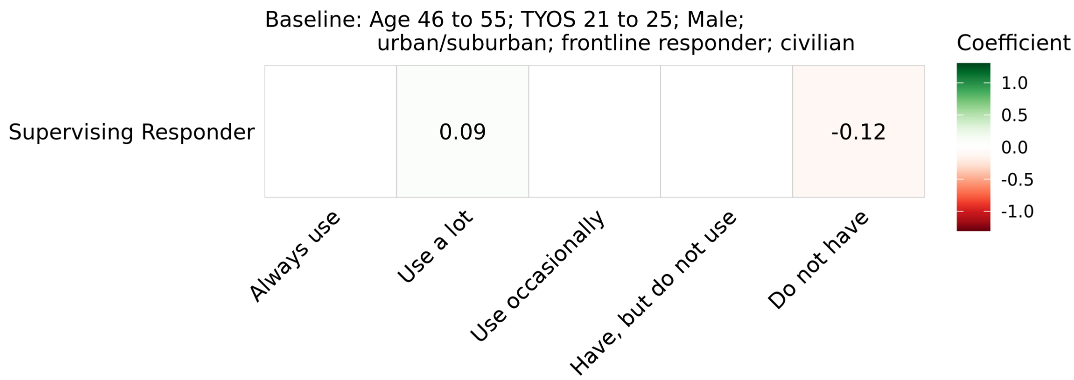

Fig. B.2.3.1 COMMS Apps/Software Usage Frequency: Electronic Policies/Laws

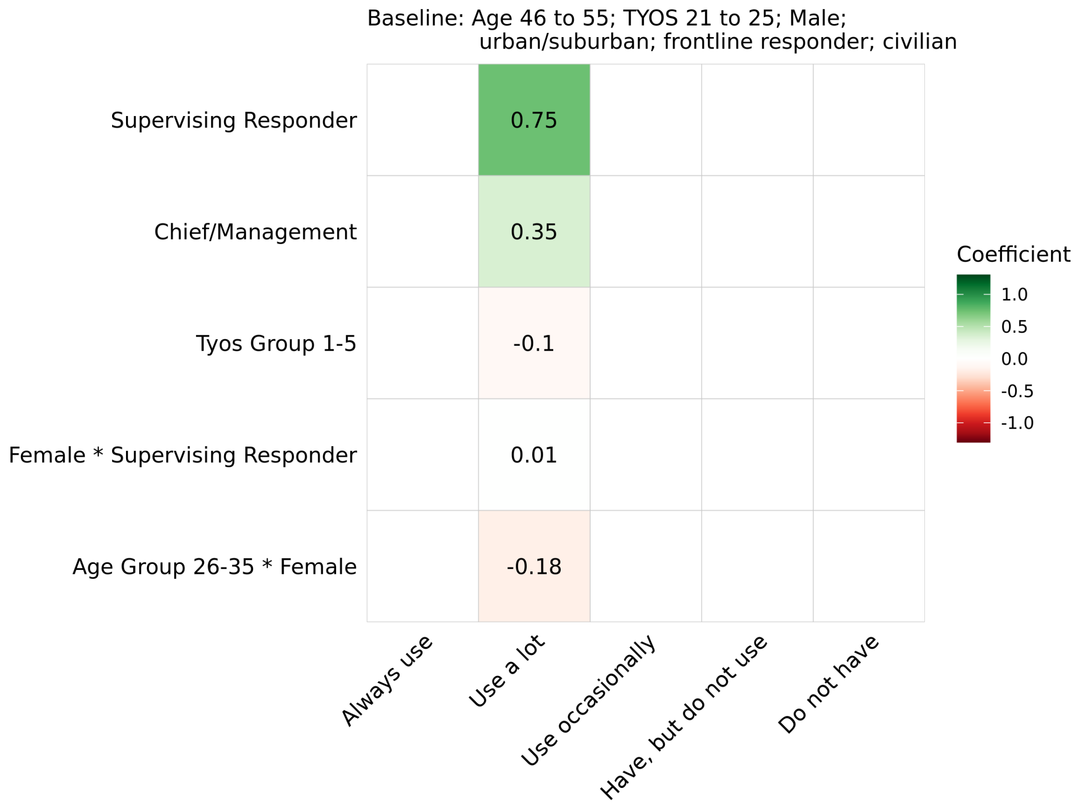

Fig. B.2.3.2 COMMS Apps/Software Usage Frequency: Email

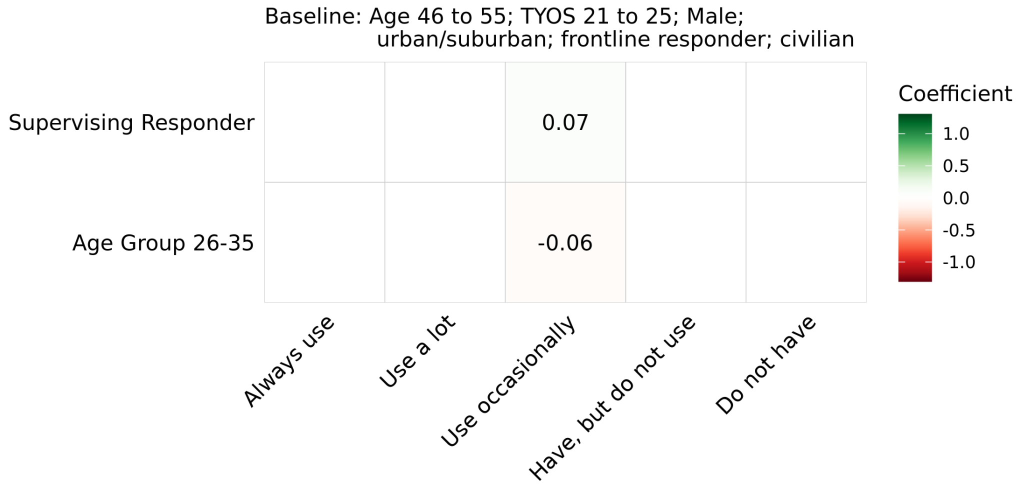

Fig. B.2.3.3 COMMS Apps/Software Usage Frequency: Alert System

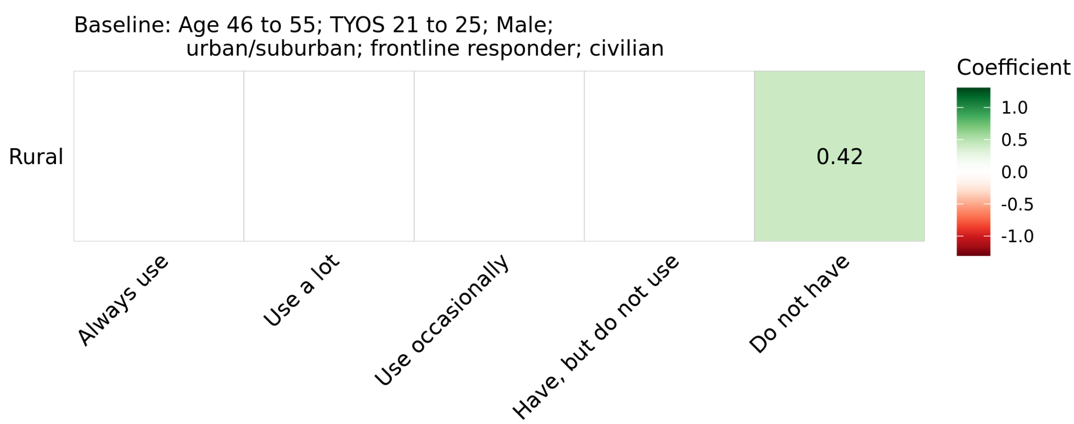

Fig. B.2.3.4 COMMS Apps/Software Usage Frequency: FR Vehicle Tracking

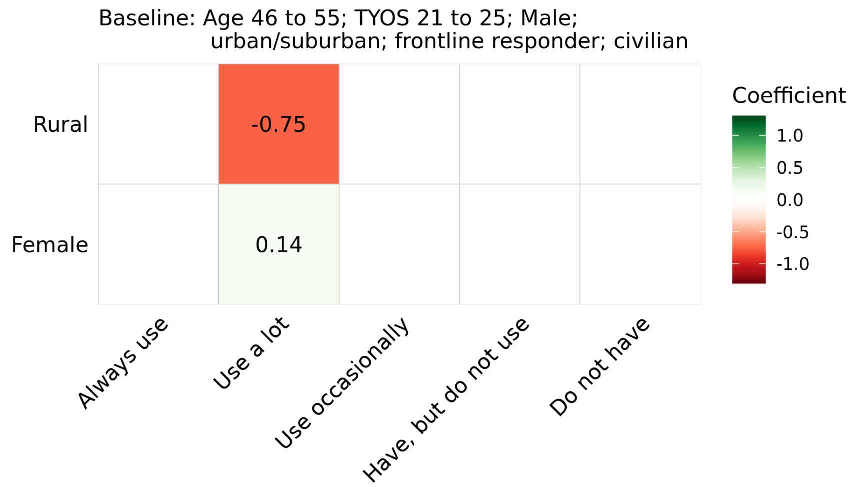

Fig. B.2.3.5 COMMS Apps/Software Usage Frequency: Language Translation

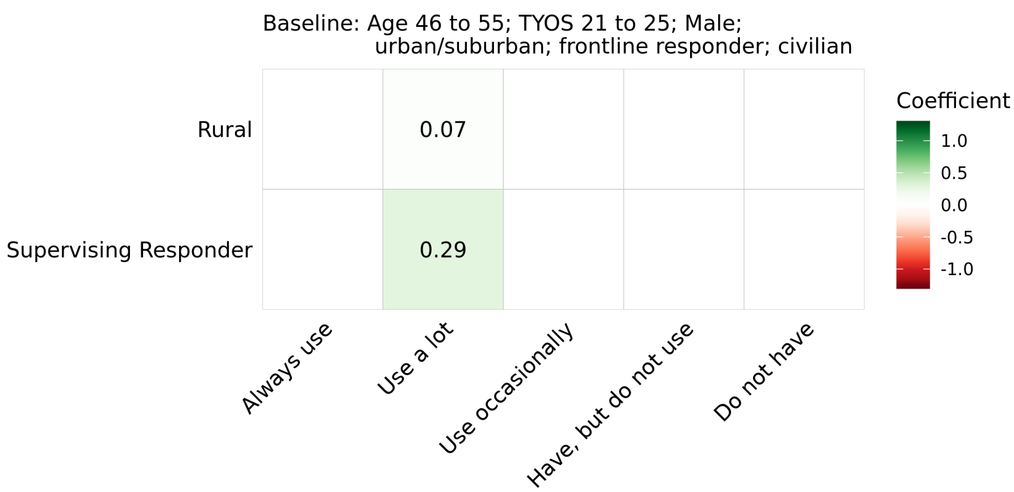

Fig. B.2.3.6 COMMS Apps/Software Usage Frequency: RMS

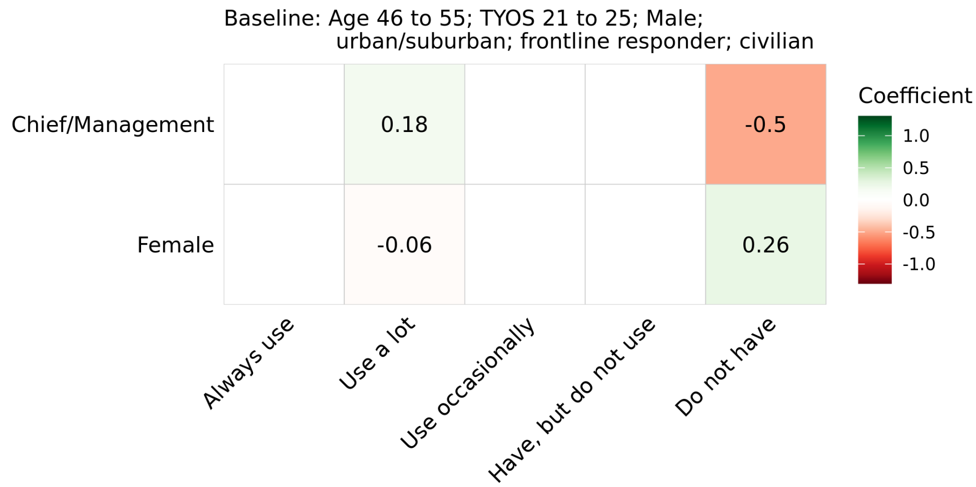

Fig. B.2.3.7 COMMS Apps/Software Usage Frequency: Weather

B.2.4. Information Problems

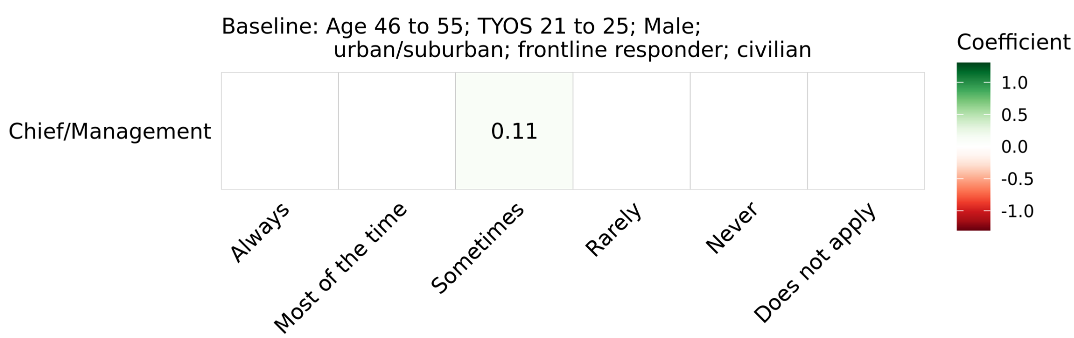

Fig. B.2.4.1 COMMS Information problems: Callers - inaccurate or missing information

B.2.5. Futuristic Technology

Figure B.2.5.1 COMMS Perceived Usefulness of Futuristic Technology: Indoor Mapping

B.2.6. Call Center Information

Fig. B.2.6.1 COMMS 911 Text Messages

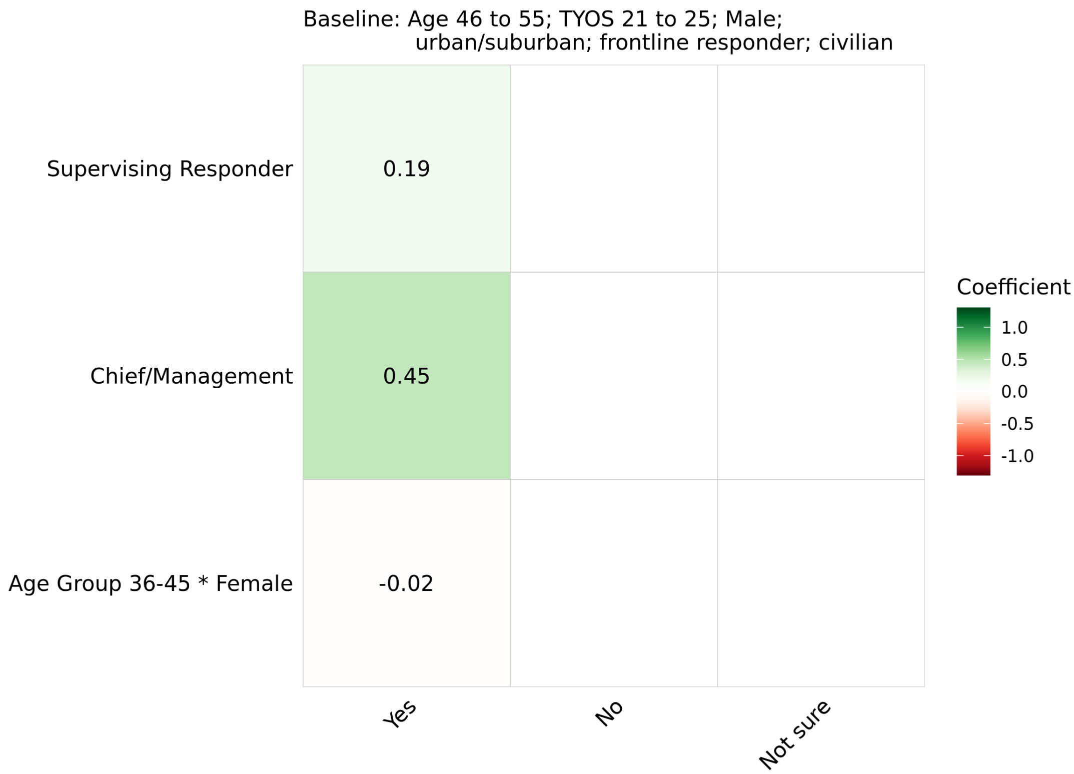

Fig. B.2.6.2 COMMS 911 Text Messages Beneficial?

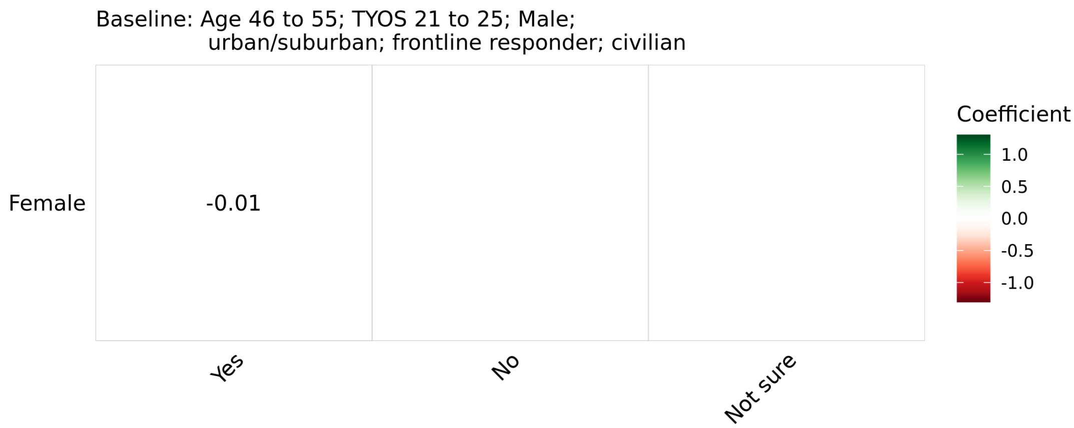

Fig. B.2.6.3 COMMS Pictures and Videos Beneficial?

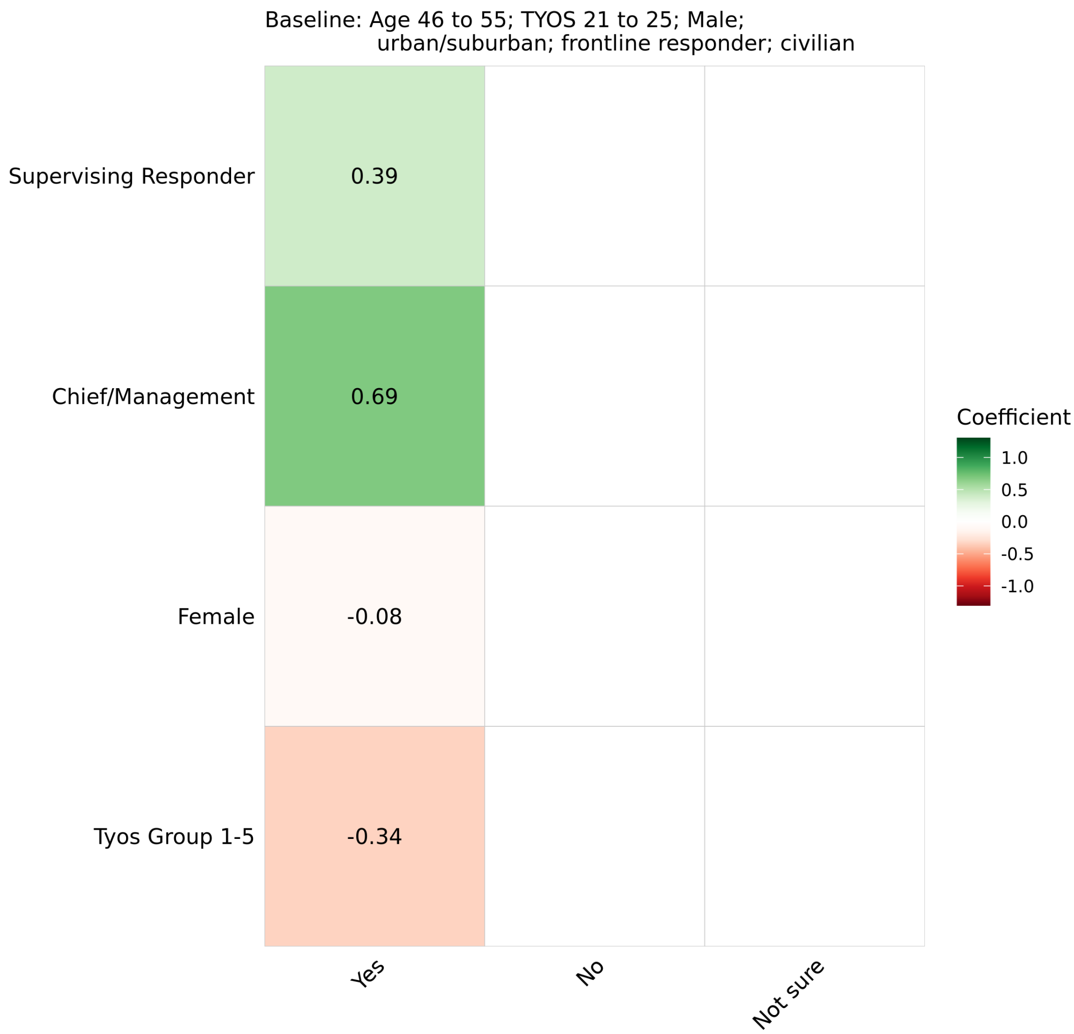

Fig. B.2.6.4 COMMS Heard of Next Gen. 911?

B.2.7. Virtual Reality

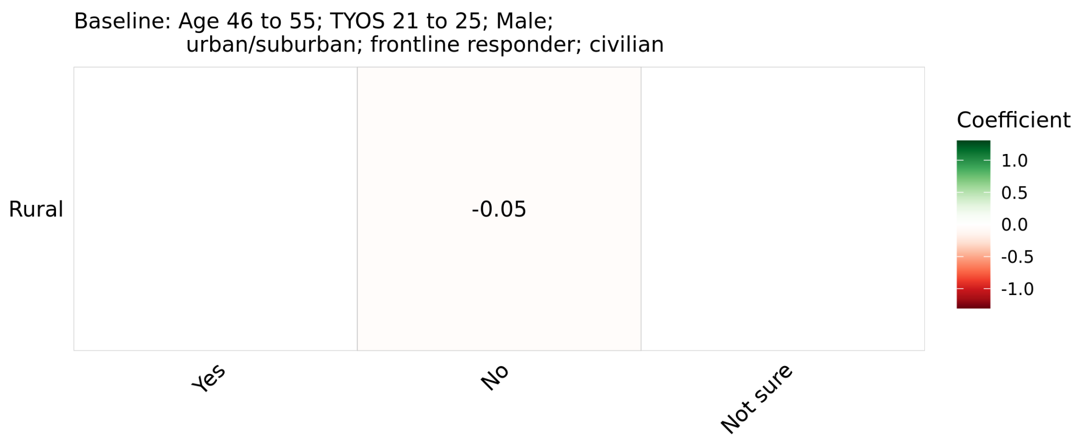

Fig. B.2.7.1 COMMS VR Training Useful

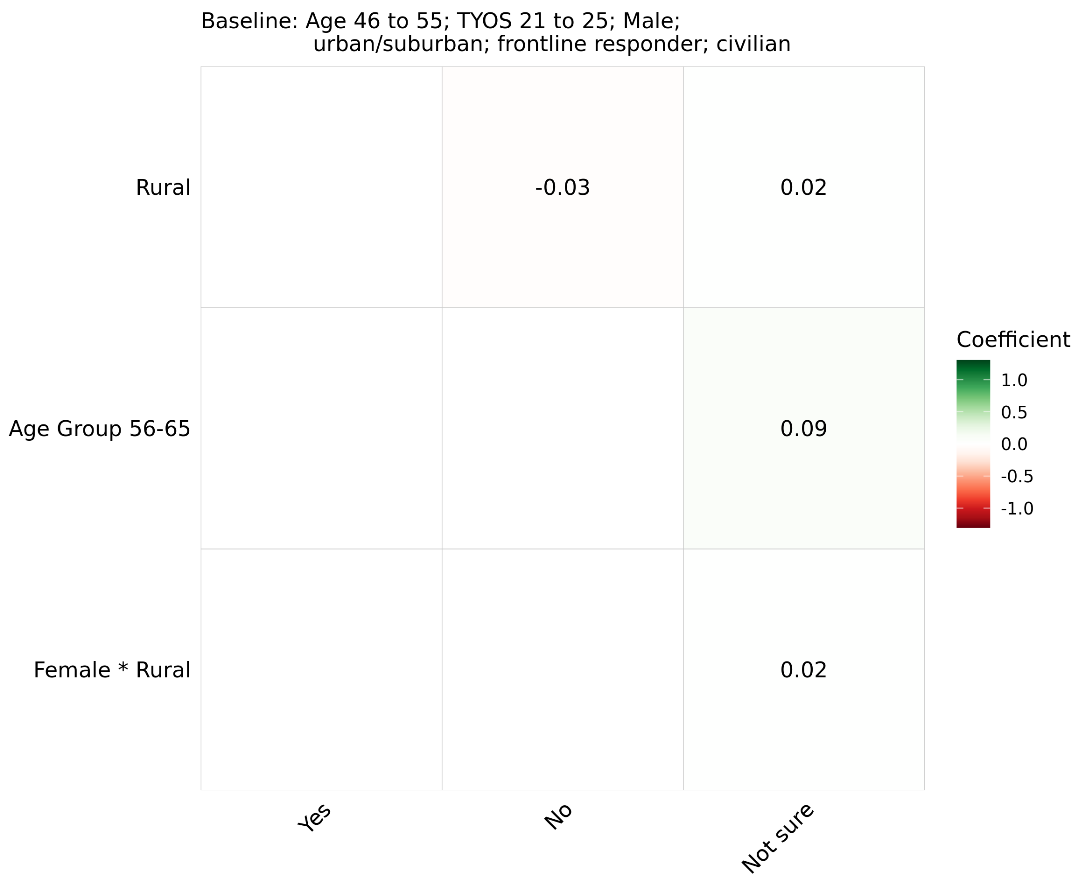

Fig. B.2.7.2 COMMS VR other than Training

B.3. EMS

List of tables and figures

B.3.1. Subgroup Demographics

Table B.3.1.1 EMS Demographics

Subgroup		%	n
Area	Rural	53	440
	Urban/Suburban	44	368
	(missing data)	3	21
Role	Frontline Responder	38	319
	Supervising Responder	14	120
	Chief/Management	45	369
	(missing data)	3	21
Age	18-25	6	50
	26-35	14	113
	36-45	22	184
	46-55	26	218
	56-65	22	184
	Over 65	6	52
	(missing data)	3	28
Years of Service	Less than 1	0	6
	1-5	10	86
	6-10	11	92
	11-15	11	92
	16-20	12	102
	21-25	14	112
	26-30	13	108
	31-35	11	93
	36-40	7	60
	41-45	5	40
	46-50	1	12
	More than 50	0	3
	(missing data)	3	23
Sex	Female	20	169
	Male	77	634
	(missing data)	3	26
Public/Private Status	Private	32	262
	Public	65	543
	(missing data)	3	24

B.3.2. Device Frequency

Fig. B.3.2.1 EMS Device Usage Frequency: Personal Smartphone

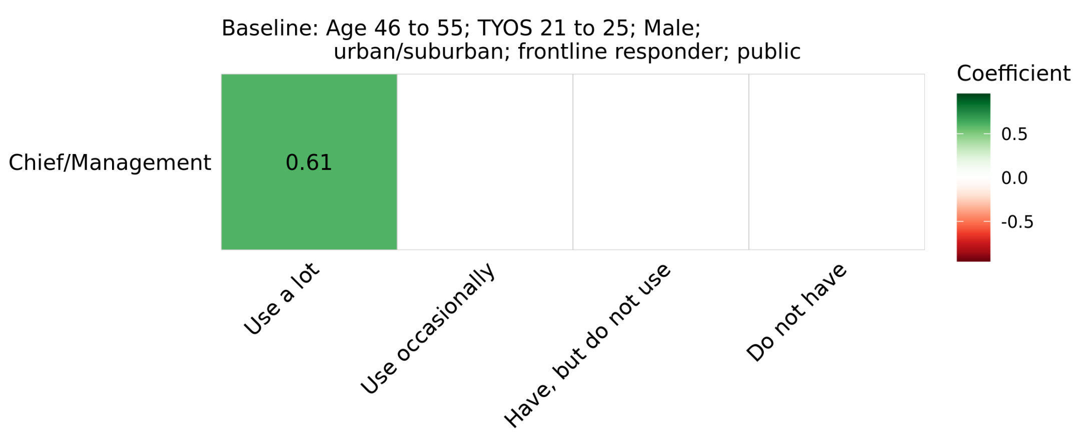

Fig. B.3.2.2 EMS Device Usage Frequency: Work-issued Smartphone

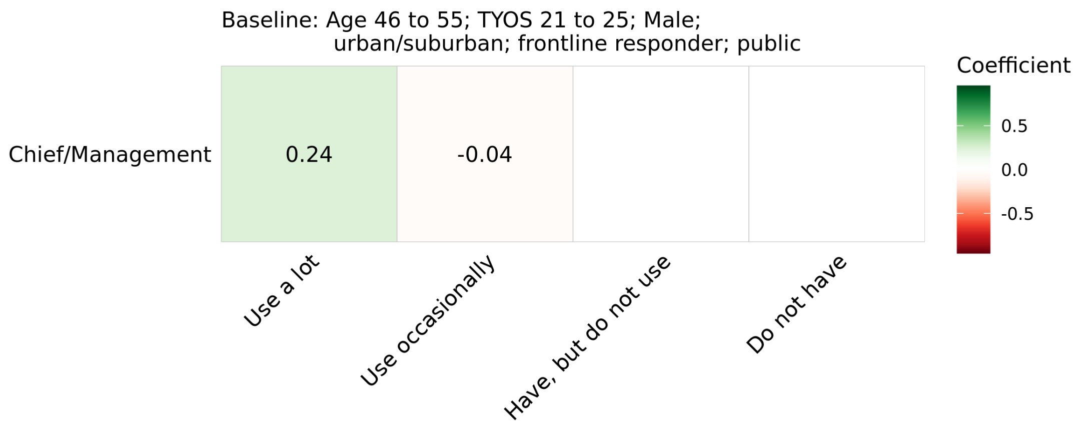

Fig. B.3.2.3 EMS Device Usage Frequency: Desktop Computer

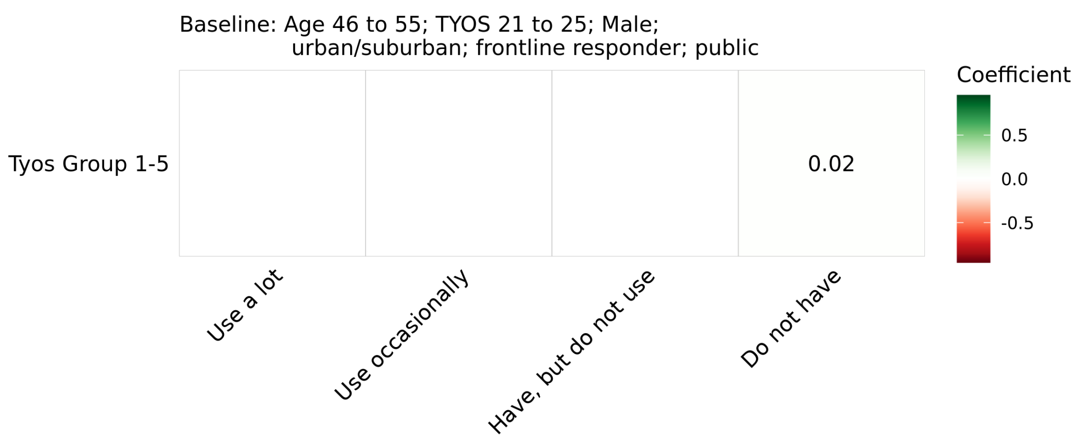

Fig. B.3.2.4 EMS Device Usage Frequency: Wireless Earpiece: Personal

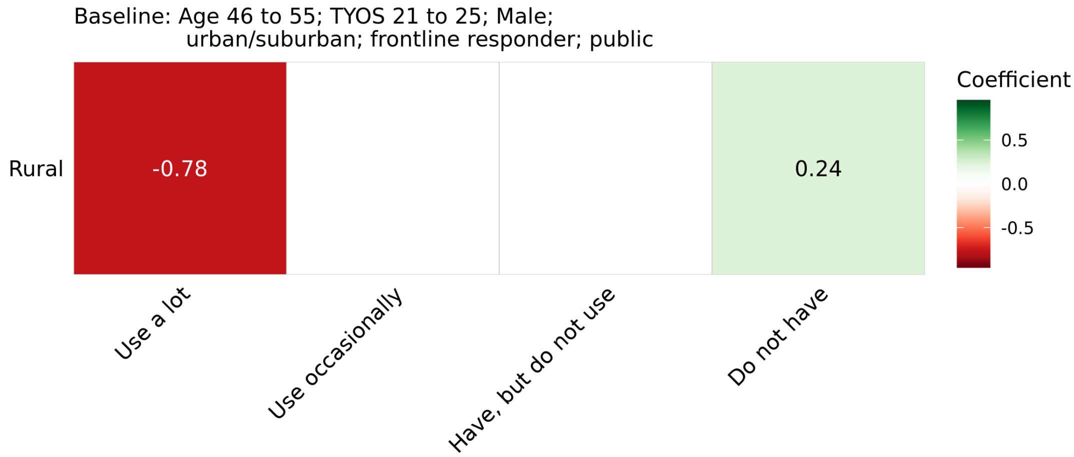

Fig. B.3.2.5 EMS Device Usage Frequency: MDT/MDC

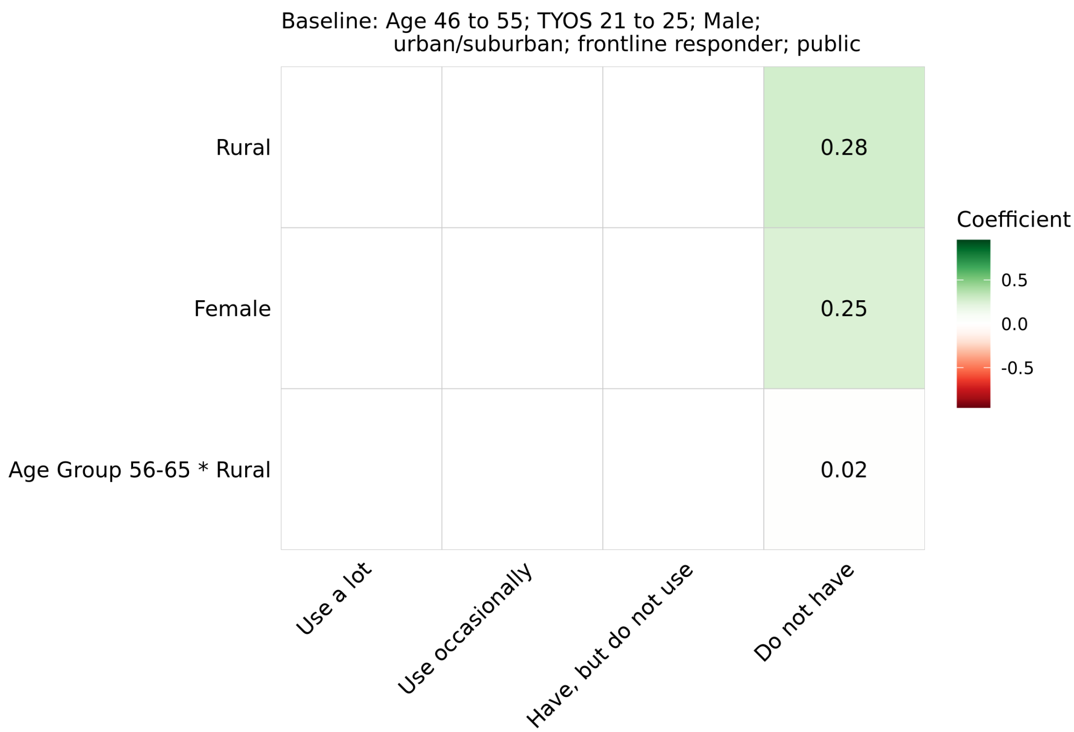

Fig. B.3.2.6 EMS Device Usage Frequency: Corded Microphone

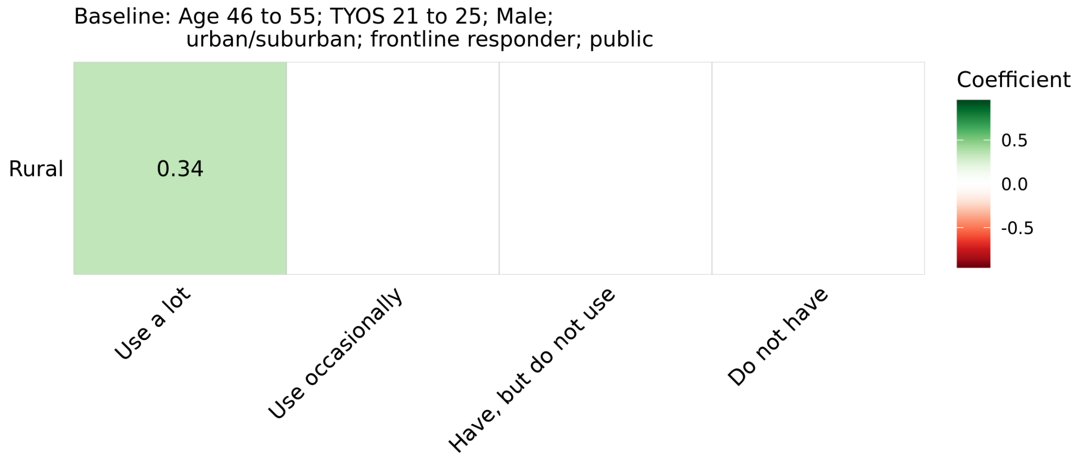

Fig. B.3.2.7 EMS Device Usage Frequency: Pager

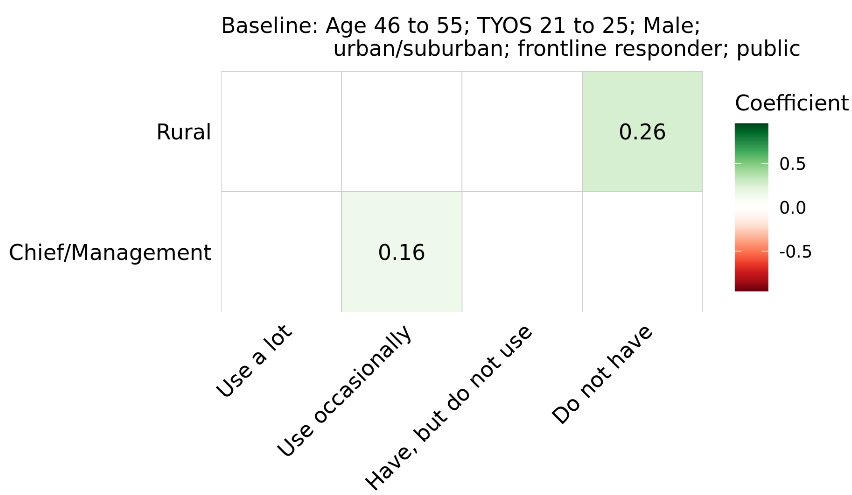

Fig. B.3.2.8 EMS Device Usage Frequency: Tablet

B.3.3. Problems with Technology

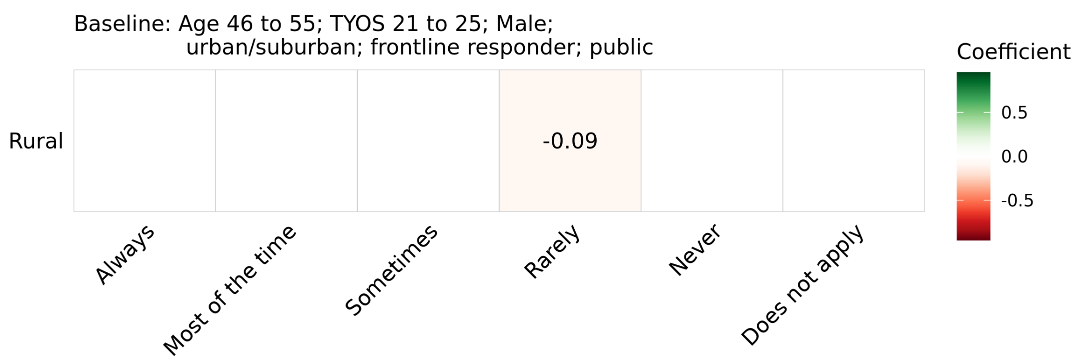

Fig. B.3.3.1 EMS Problems with Smartphone: Dropped Call

Fig. B.3.3.2 EMS Problems with Smartphone: One Login

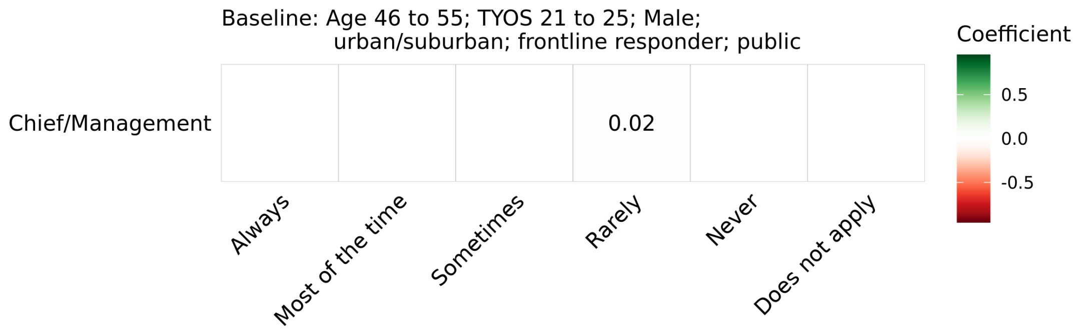

Fig. B.3.3.3 EMS Problems with Desktop Computer: Old

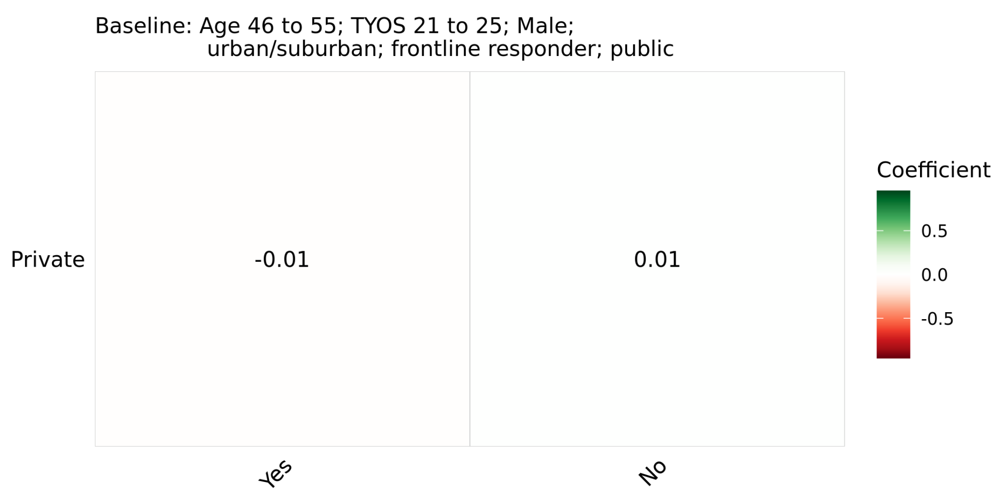

Fig. B.3.3.4 EMS Problems with Desktop Computer: Other

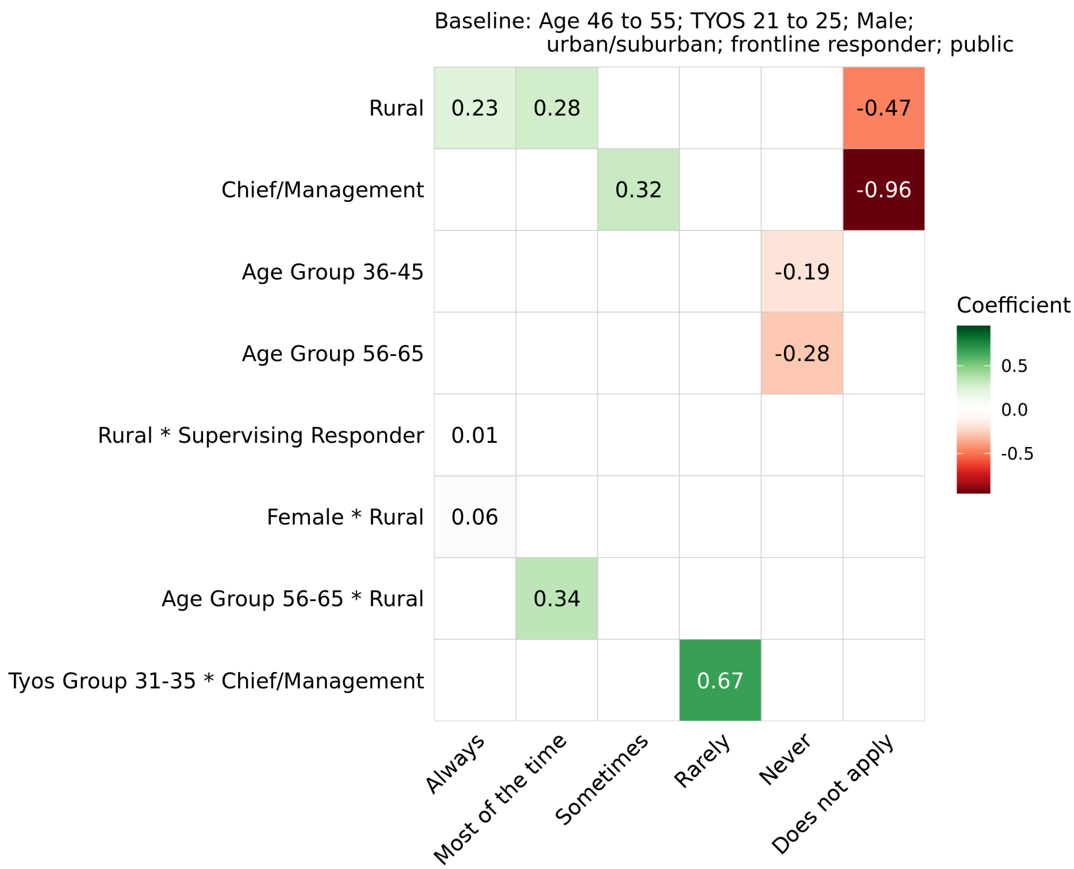

Fig. B.3.3.5 EMS Problems with Desktop Computer: Price

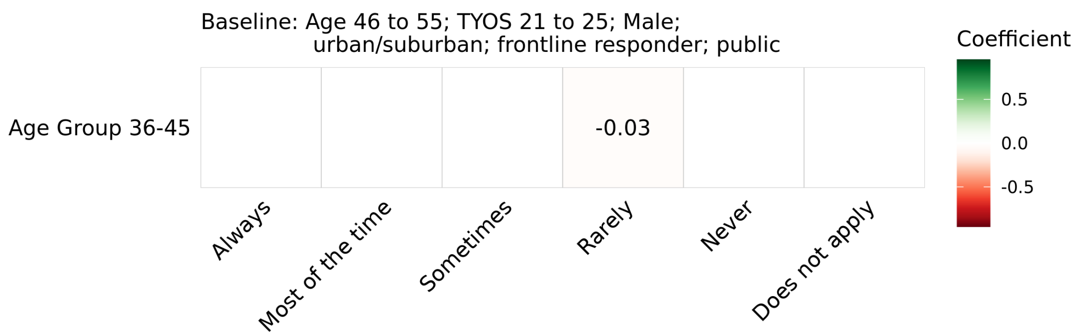

Fig. B.3.3.6 EMS Problems with Desktop Computer: Software Crash

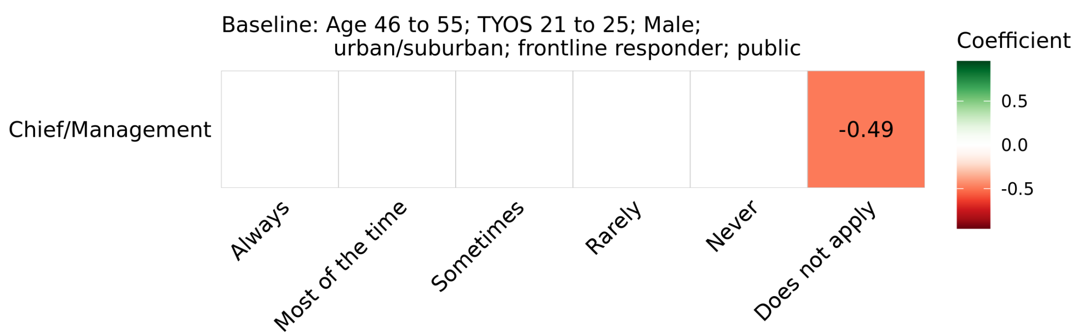

Fig. B.3.3.7 EMS Problems with Laptop: Price

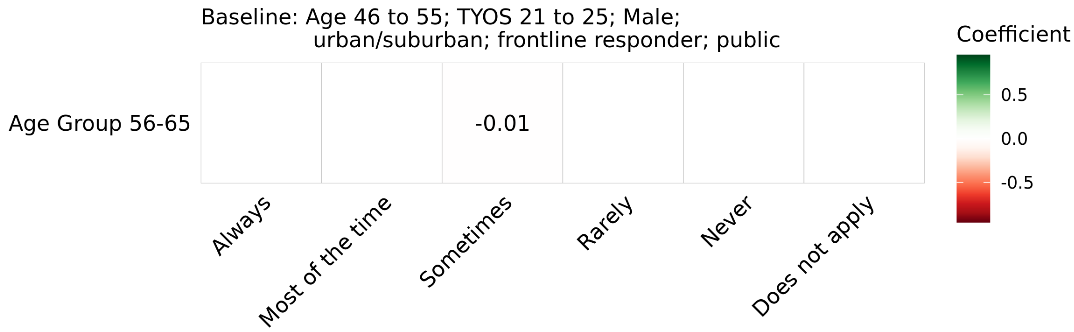

Fig. B.3.3.8 EMS Problems with Laptop: Recharge

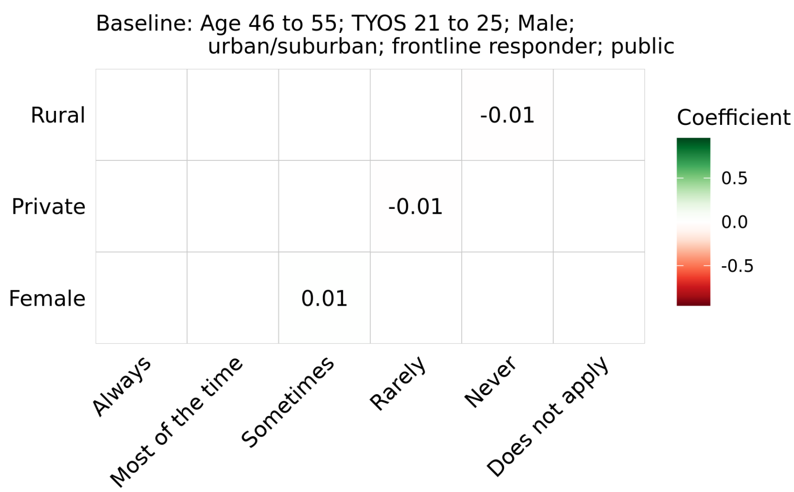

Fig. B.3.3.9 EMS Problems with Laptop: Weight

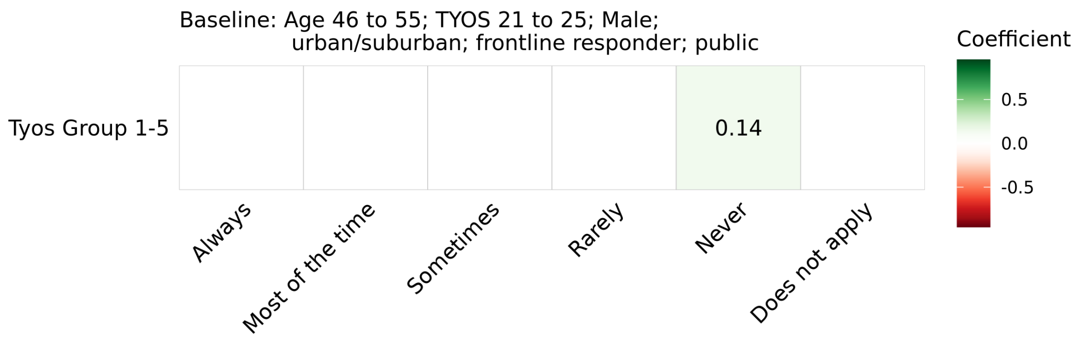

Fig. B.3.3.10 EMS Problems with MDT/MDC: Durability

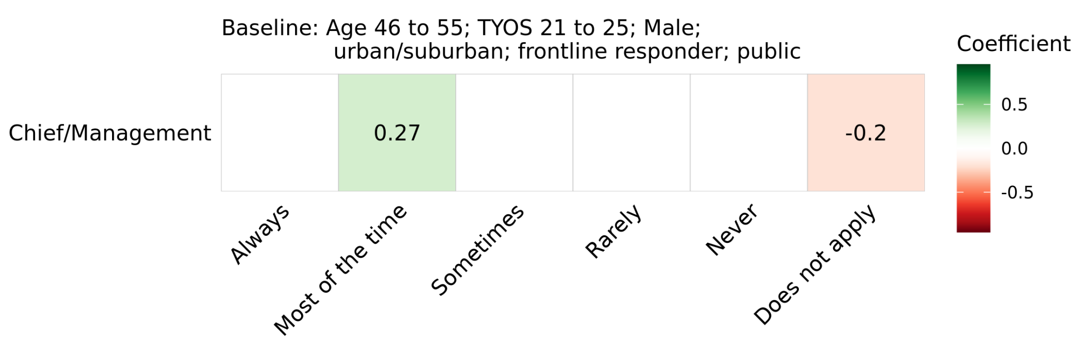

Fig. B.3.3.11 EMS Problems with MDT/MDC: Price

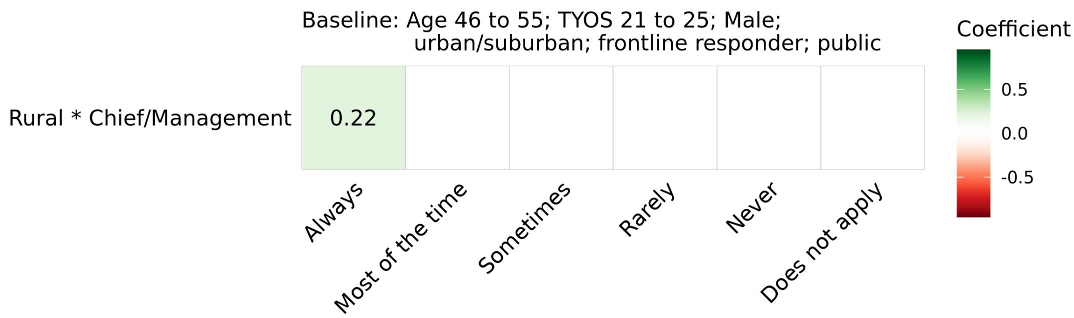

Fig. B.3.3.12 EMS Problems with Pager: Price

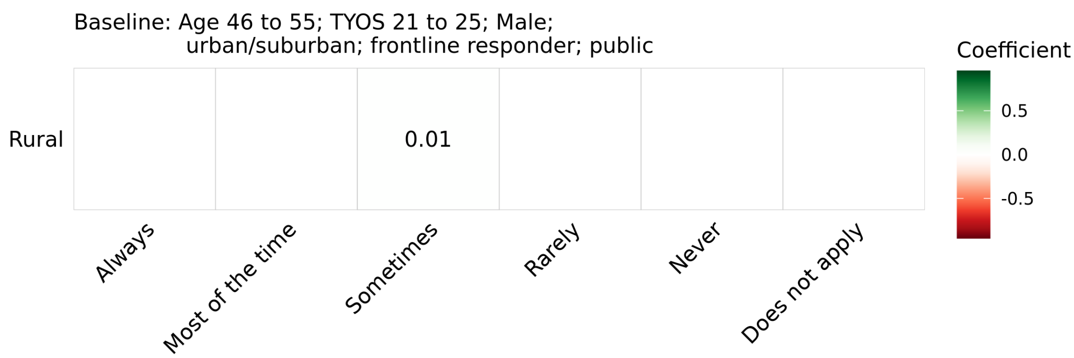

Fig. B.3.3.13 EMS Problems with Radio: Old

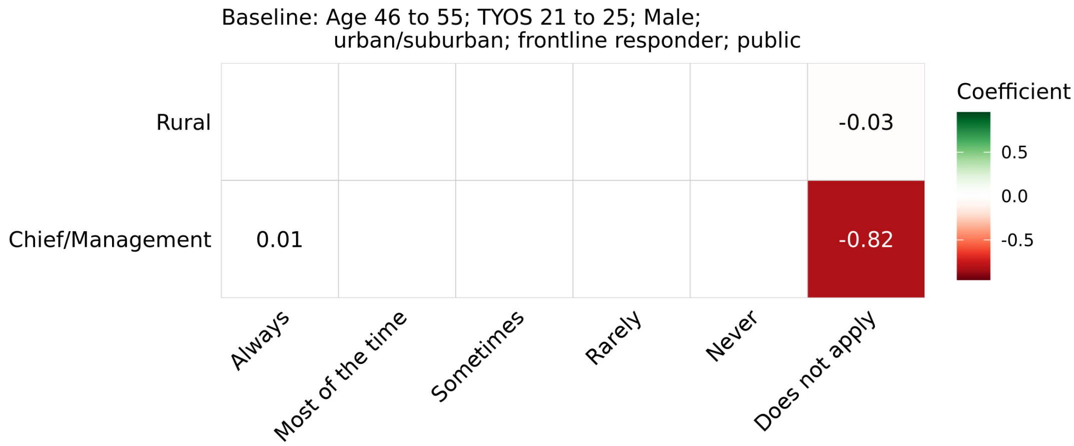

Fig. B.3.3.14 **EMS Problems with Radio: Price**

B.3.4. Application/Software Frequency

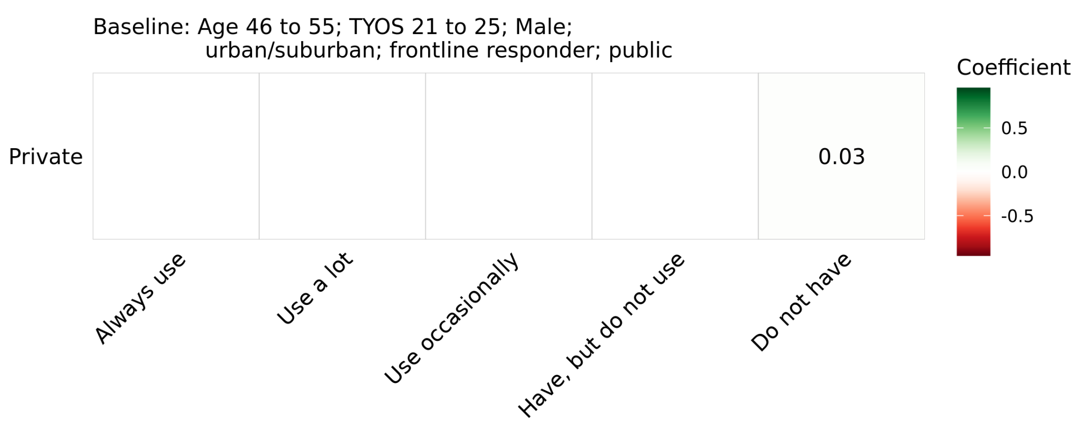

Fig. B.3.4.1 EMS Apps/Software Usage Frequency: AED

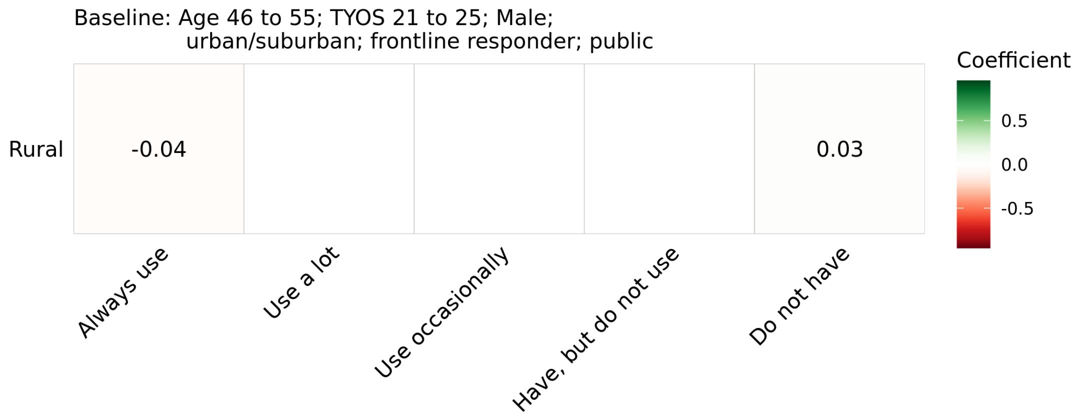

Fig. B.3.4.2 EMS Apps/Software Usage Frequency: CAD

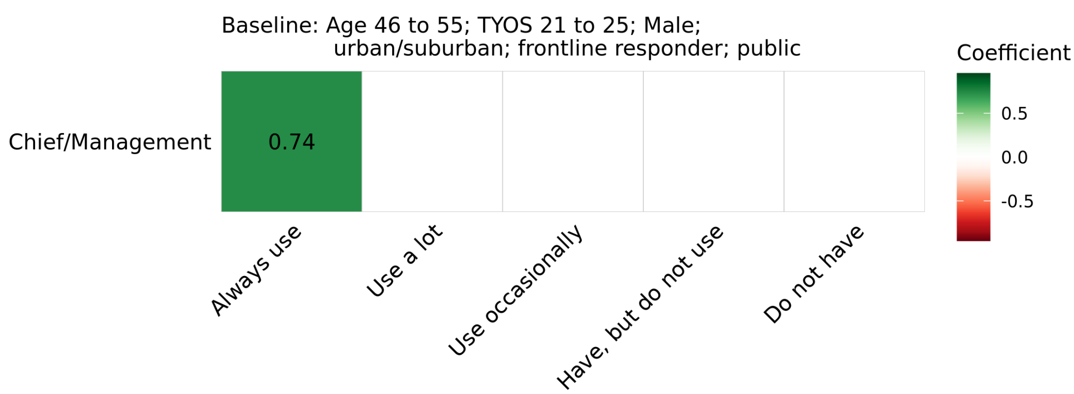

Fig. B.3.4.3 EMS Apps/Software Usage Frequency: Email

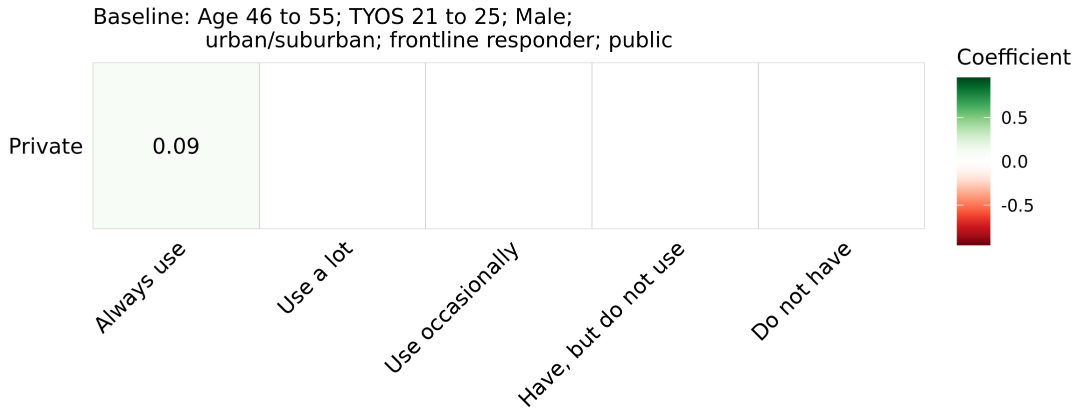

Fig. B.3.4.4 EMS Apps/Software Usage Frequency: EPCR

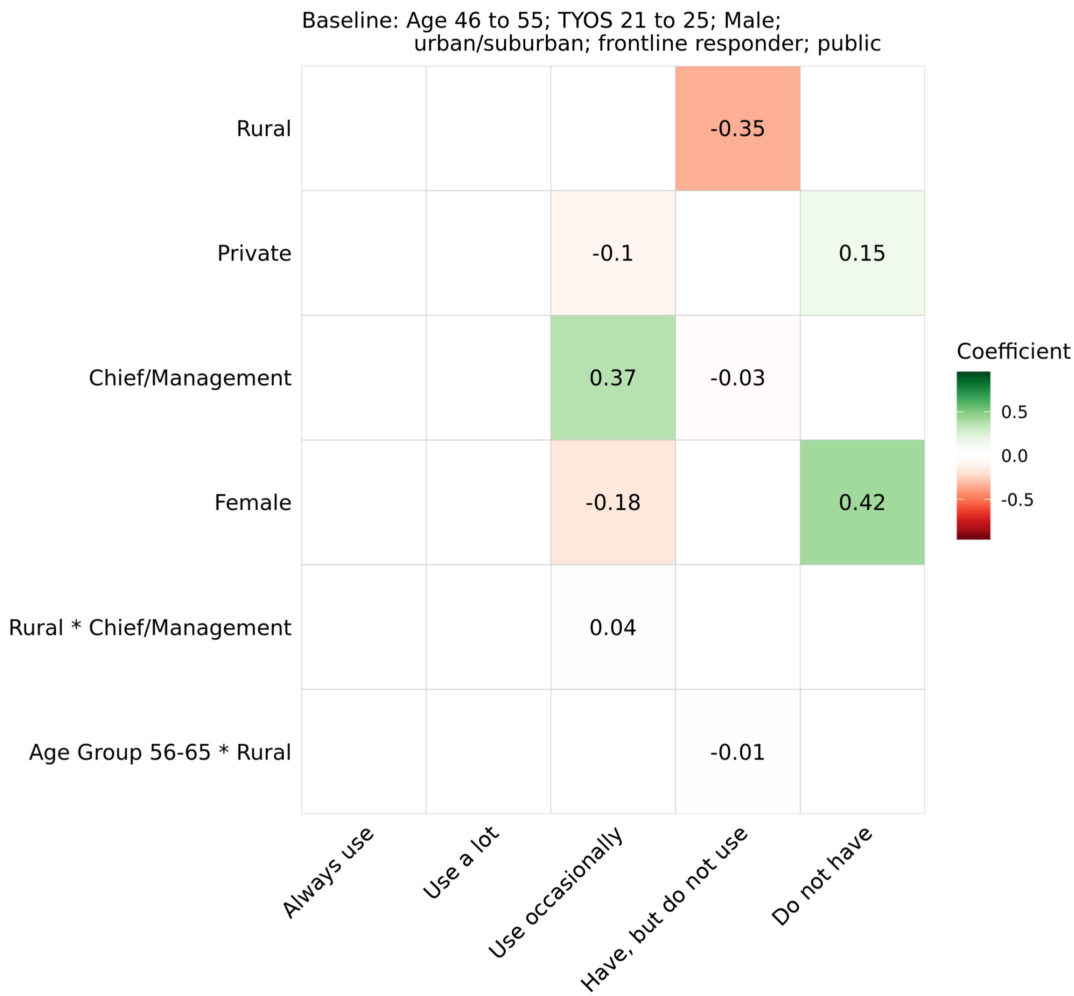

Fig. B.3.4.5 EMS Apps/Software Usage Frequency: ERG

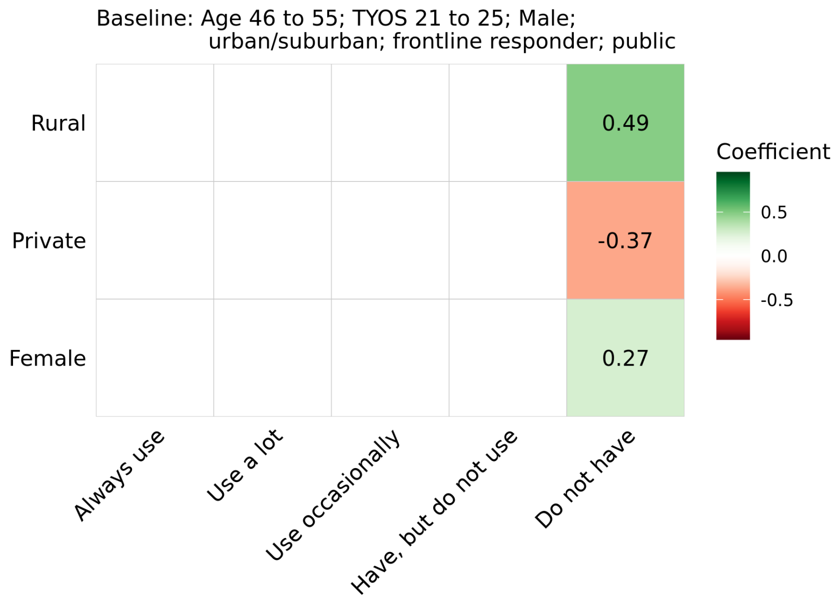

Fig. B.3.4.6 EMS Apps/Software Usage Frequency: FR Vehicle Tracking

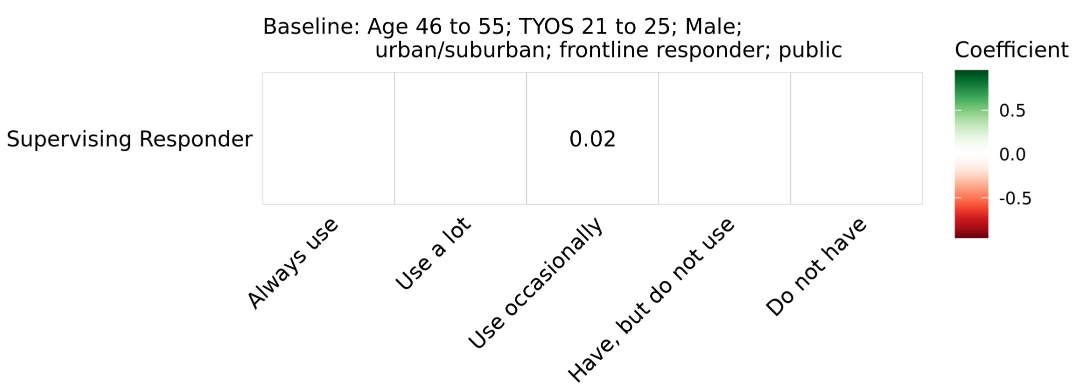

Fig. B.3.4.7 EMS Apps/Software Usage Frequency: Medication/Drug ID

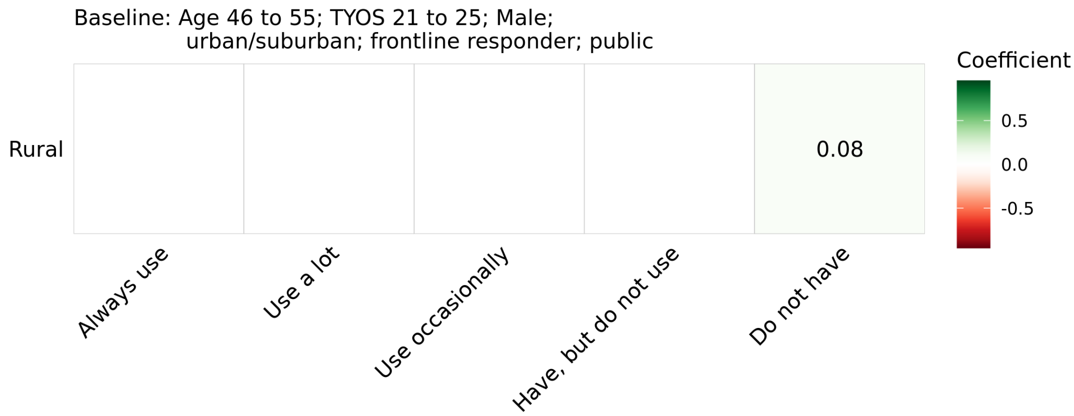

Fig. B.3.4.8 EMS Apps/Software Usage Frequency: RMS

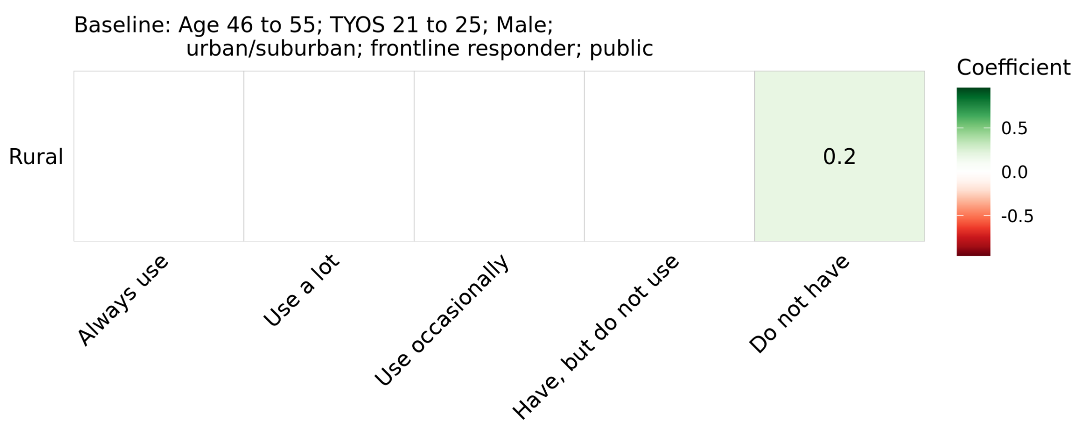

Fig. B.3.4.9 EMS Apps/Software Usage Frequency: Traffic

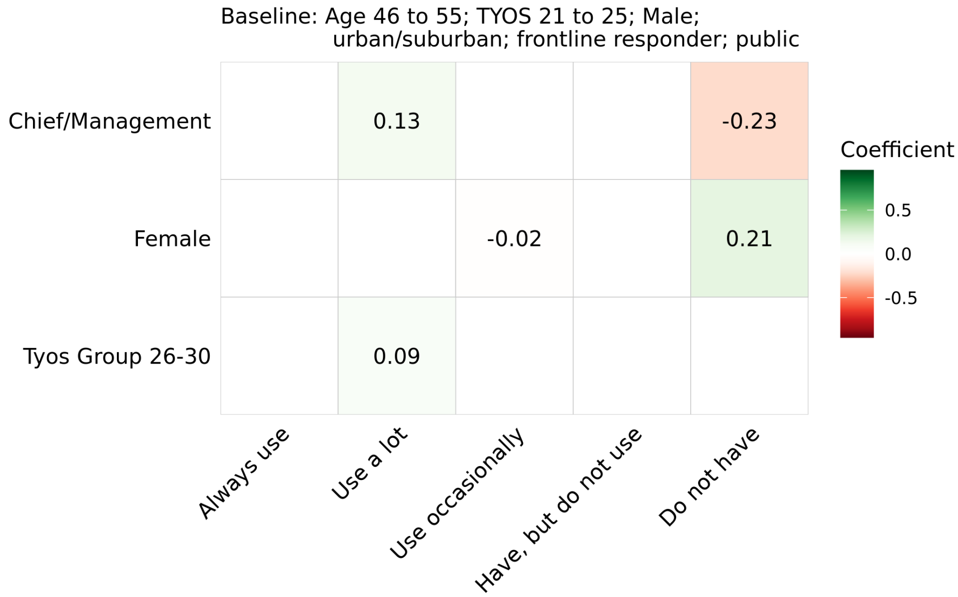

Fig. B.3.4.10 EMS Apps/Software Usage Frequency: Weather

B.3.5. Futuristic Technology

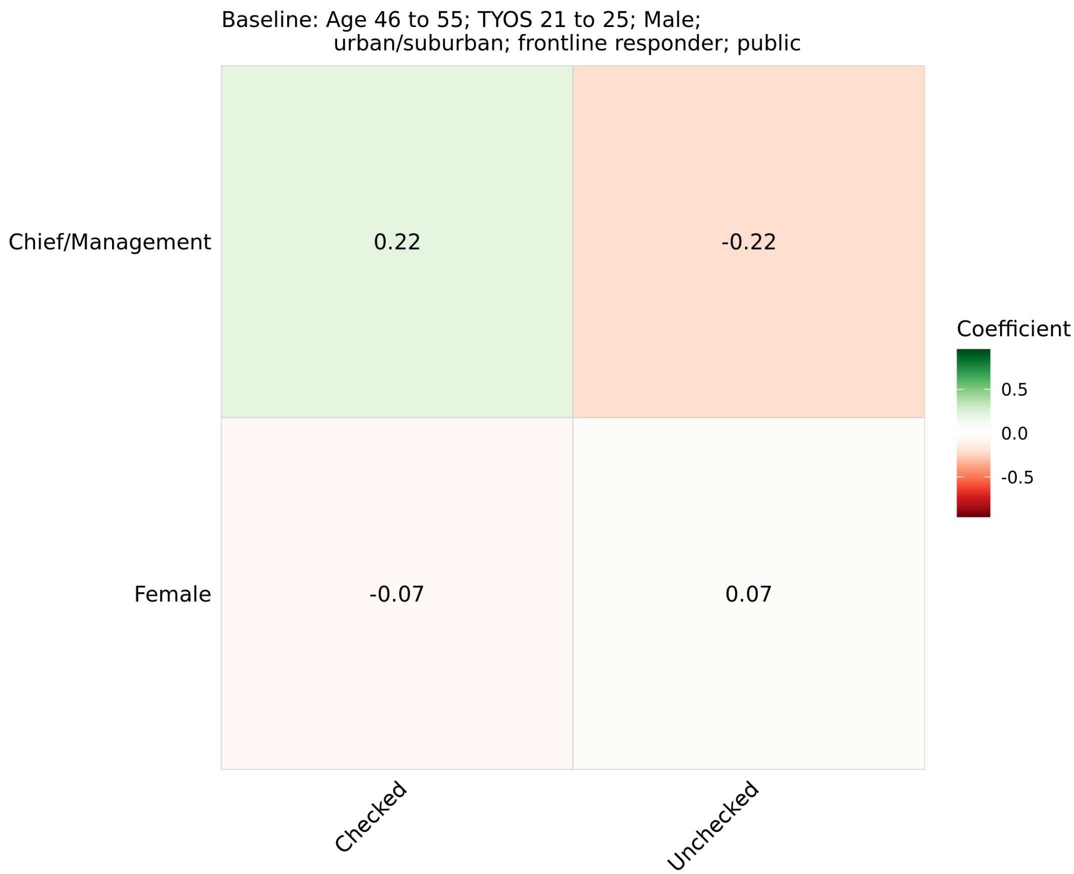

Fig. B.3.5.1 EMS Perceived Usefulness of Futuristic Technology: Auto. Vehicle Loc.

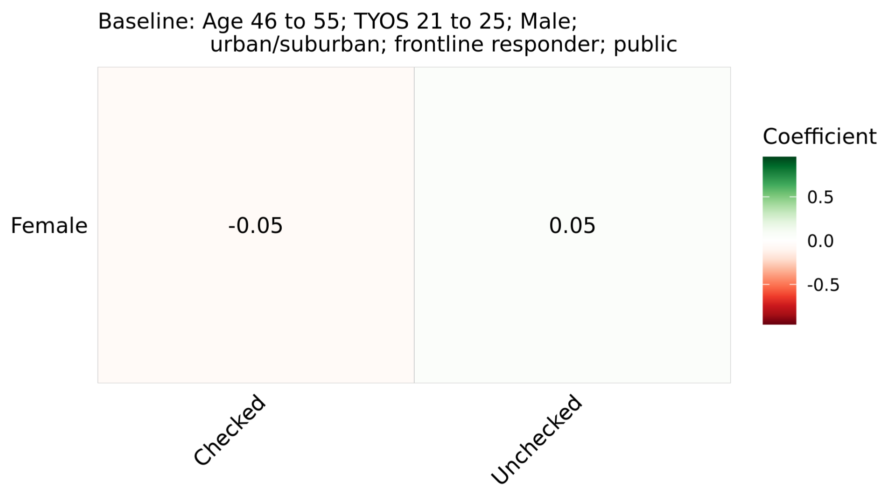

Fig. B.3.5.2 EMS Perceived Usefulness of Futuristic Technology: Drones

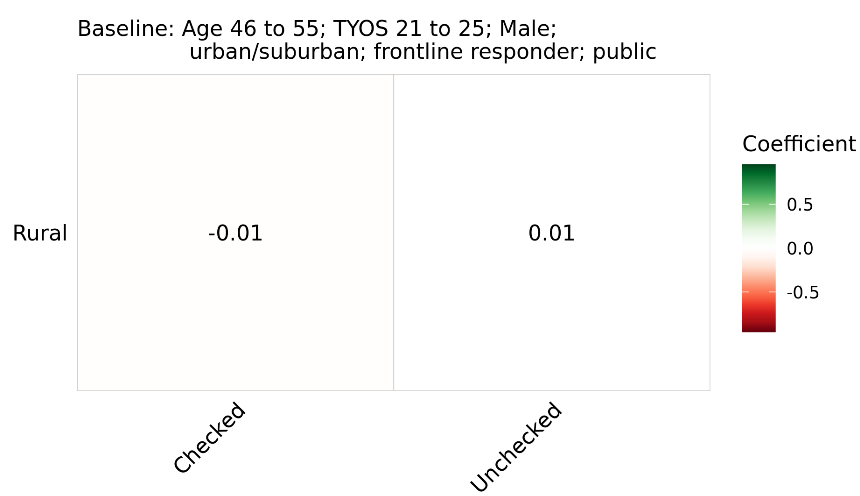

Fig. B.3.5.3 EMS Perceived Usefulness of Futuristic Technology: HUD

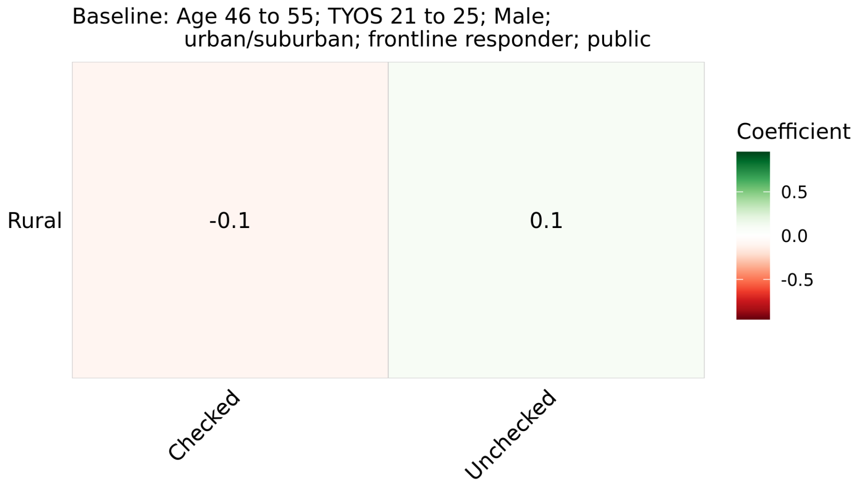

Fig. B.3.5.4 EMS Perceived Usefulness of Futuristic Technology: Indoor Mapping

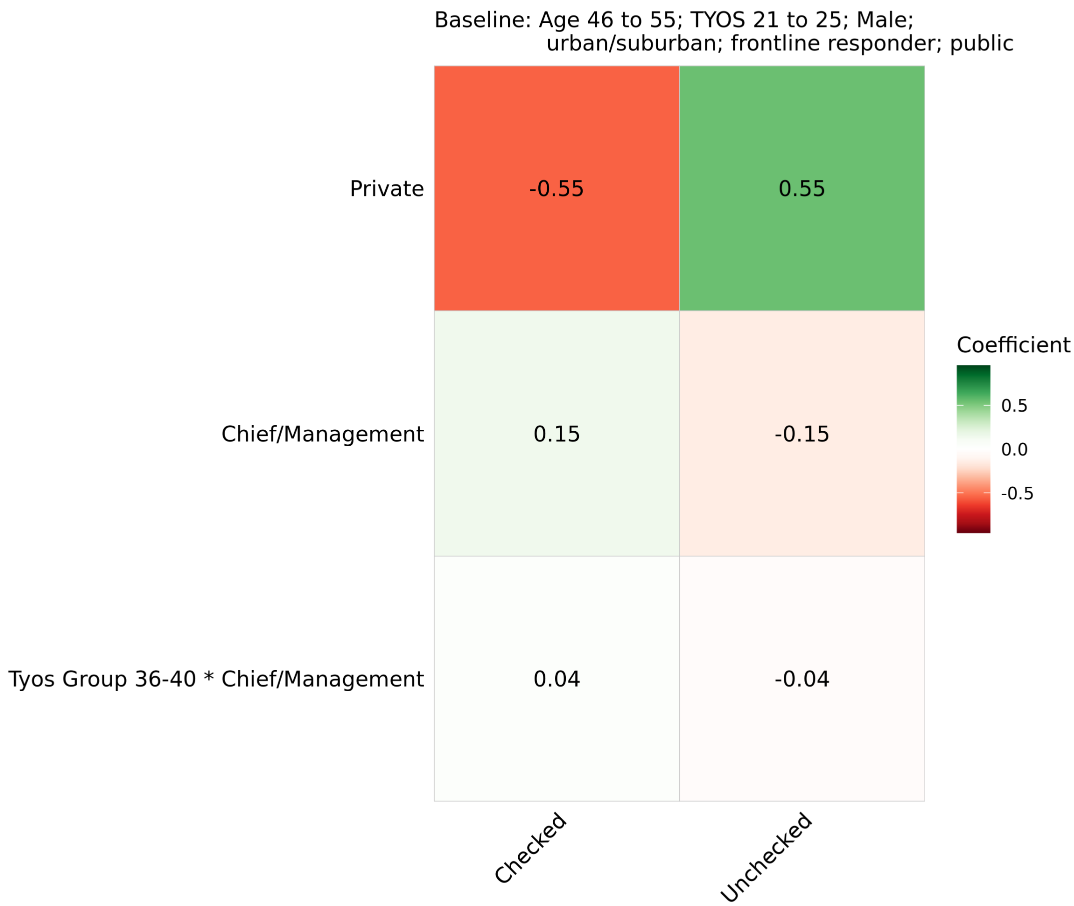

Fig. B.3.5.5 EMS Perceived Usefulness of Futuristic Technology: Laptop

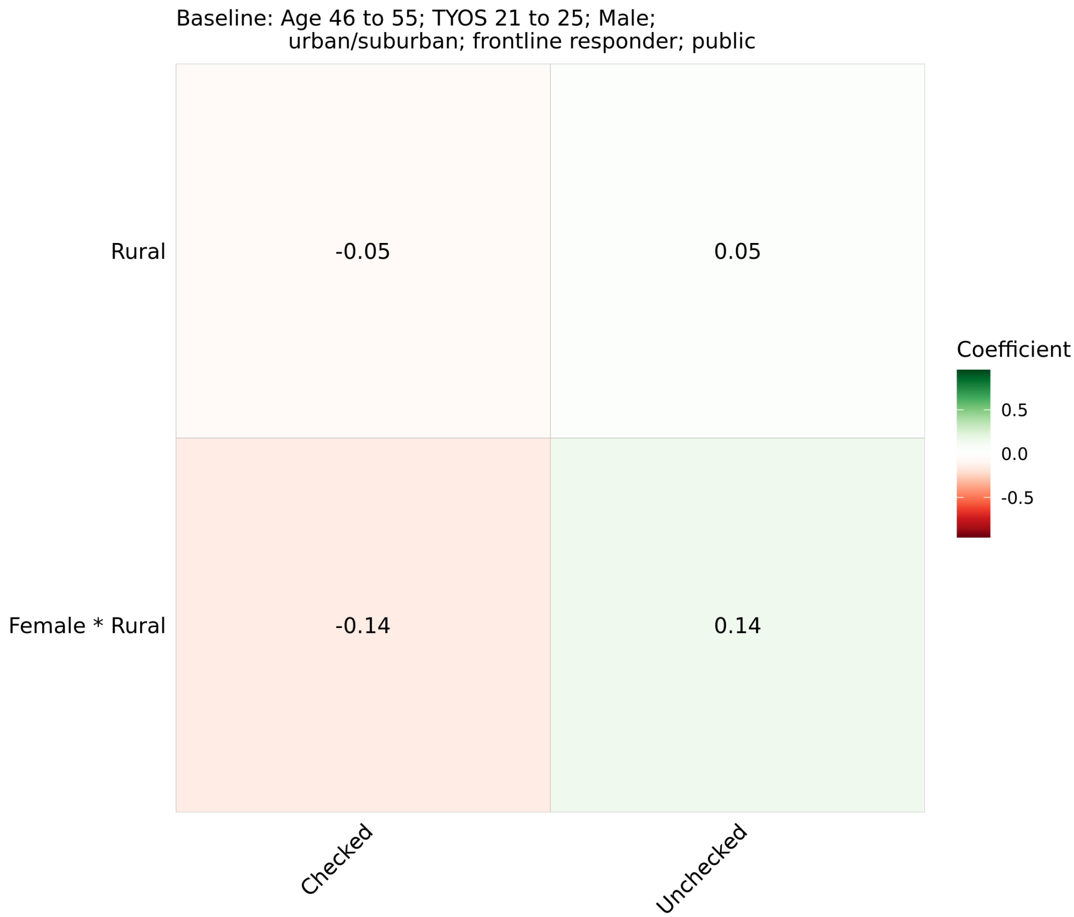

Fig. B.3.5.6 EMS Perceived Usefulness of Futuristic Technology: MDT/MDC

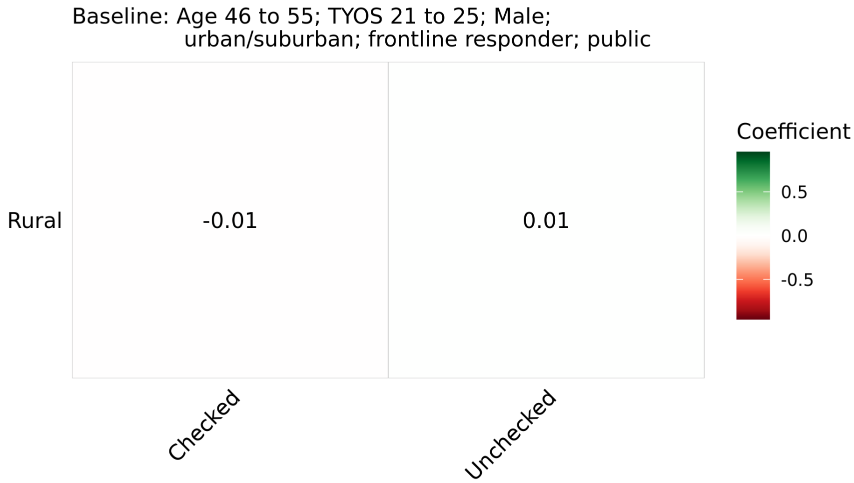

Fig. B.3.5.7 EMS Perceived Usefulness of Futuristic Technology: Smart Buildings

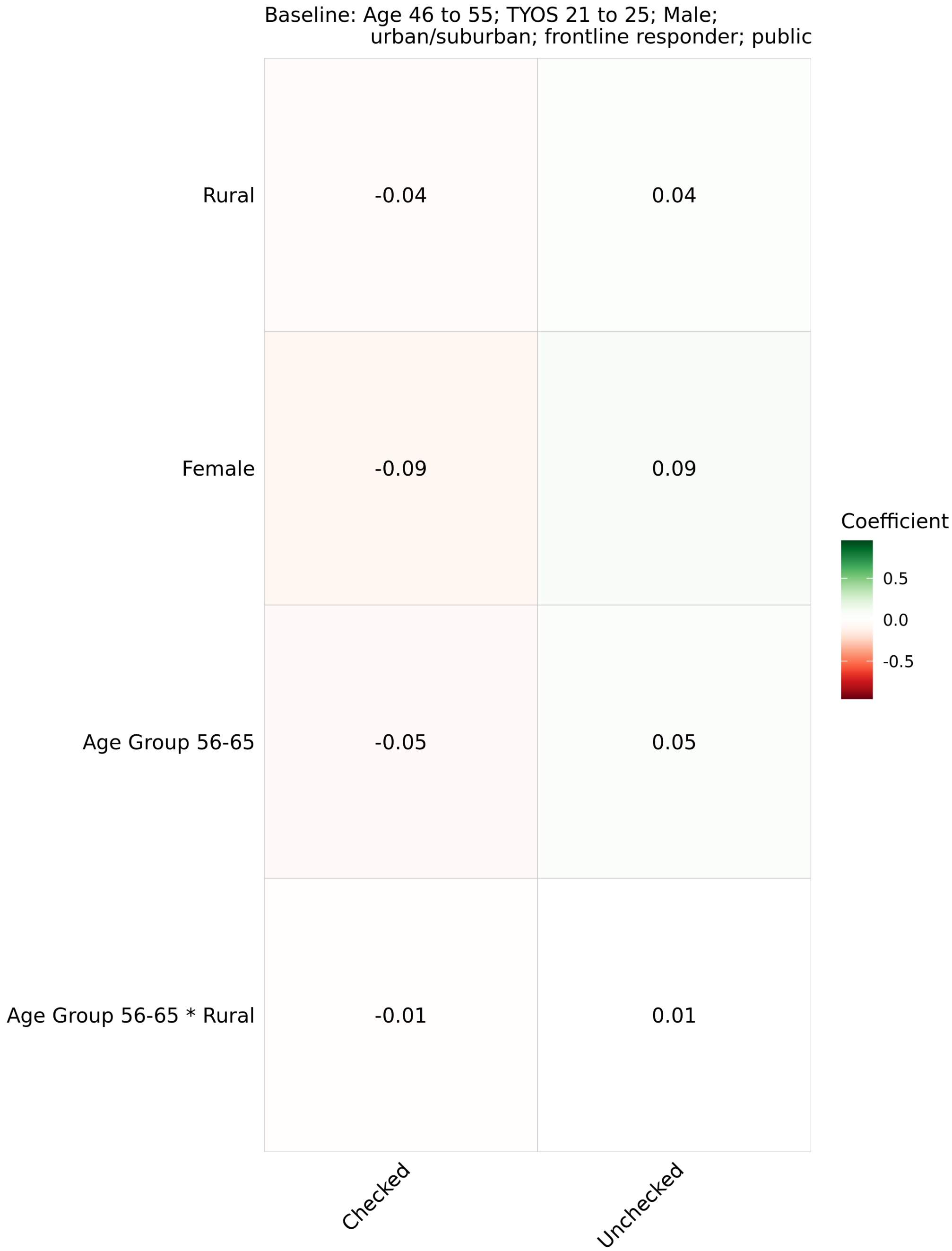

Fig. B.3.5.8 EMS Perceived Usefulness of Futuristic Technology: Smart Glasses

B.4. FF

List of tables and figures

B.4.1. Subgroup Demographics

Table B.4.1.1 FF Demographics

Subgroup		%	n
Area	Rural	34	851
	Urban/Suburban	64	1614
	(missing data)	2	60
Role	Frontline Responder	18	464
	Supervising Responder	17	414
	Chief/Management	63	1587
	(missing data)	2	60
Age	18-25	1	36
	26-35	11	272
	36-45	22	568
	46-55	36	899
	56-65	22	564
	Over 65	4	110
	(missing data)	3	76
Years of Service	Less than 1	0	12
	1-5	3	70
	6-10	5	130
	11-15	9	223
	16-20	15	367
	21-25	16	390
	26-30	16	414
	31-35	14	358
	36-40	10	260
	41-45	7	168
	46-50	2	48
	More than 50	1	22
	(missing data)	2	
Sex	Female	2	58
	Male	95	2384
	(missing data)	3	83
Volunteer Status	Volunteer	31	798
	Career	66	1657
	(missing data)	3	70

B.4.2. Device Frequency

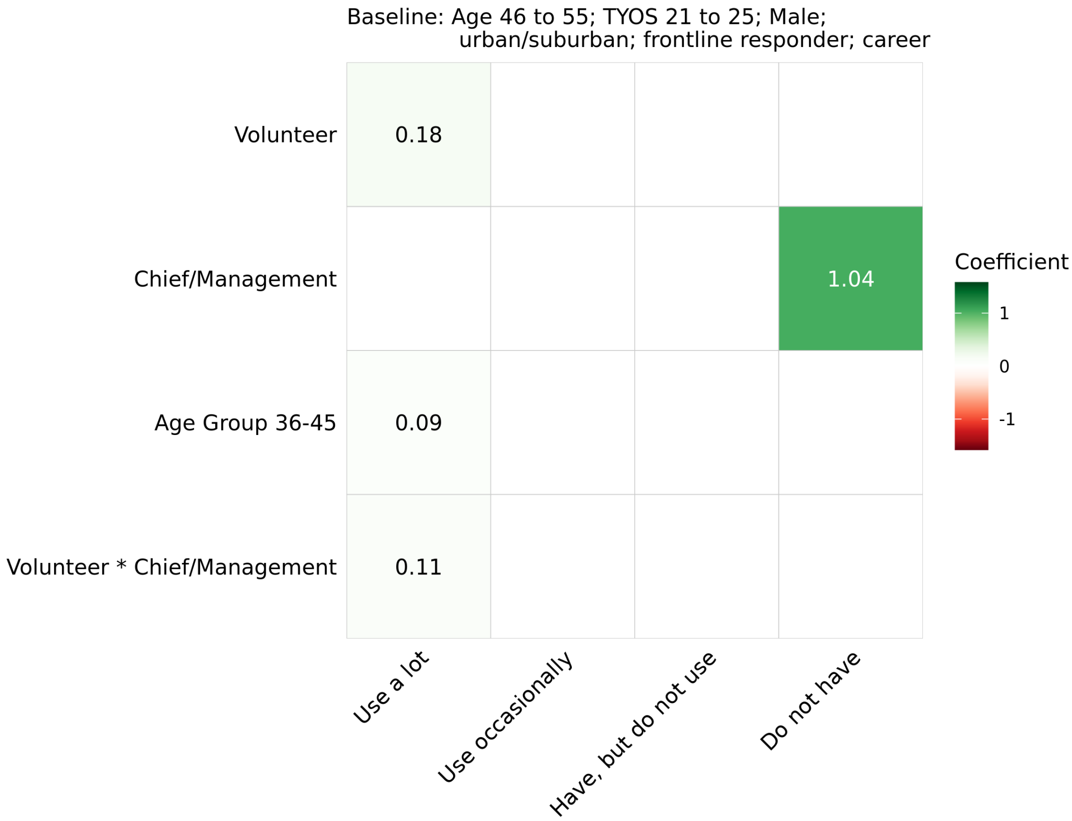

Fig. B.4.2.1 FF Device Usage Frequency: Personal Smartphone

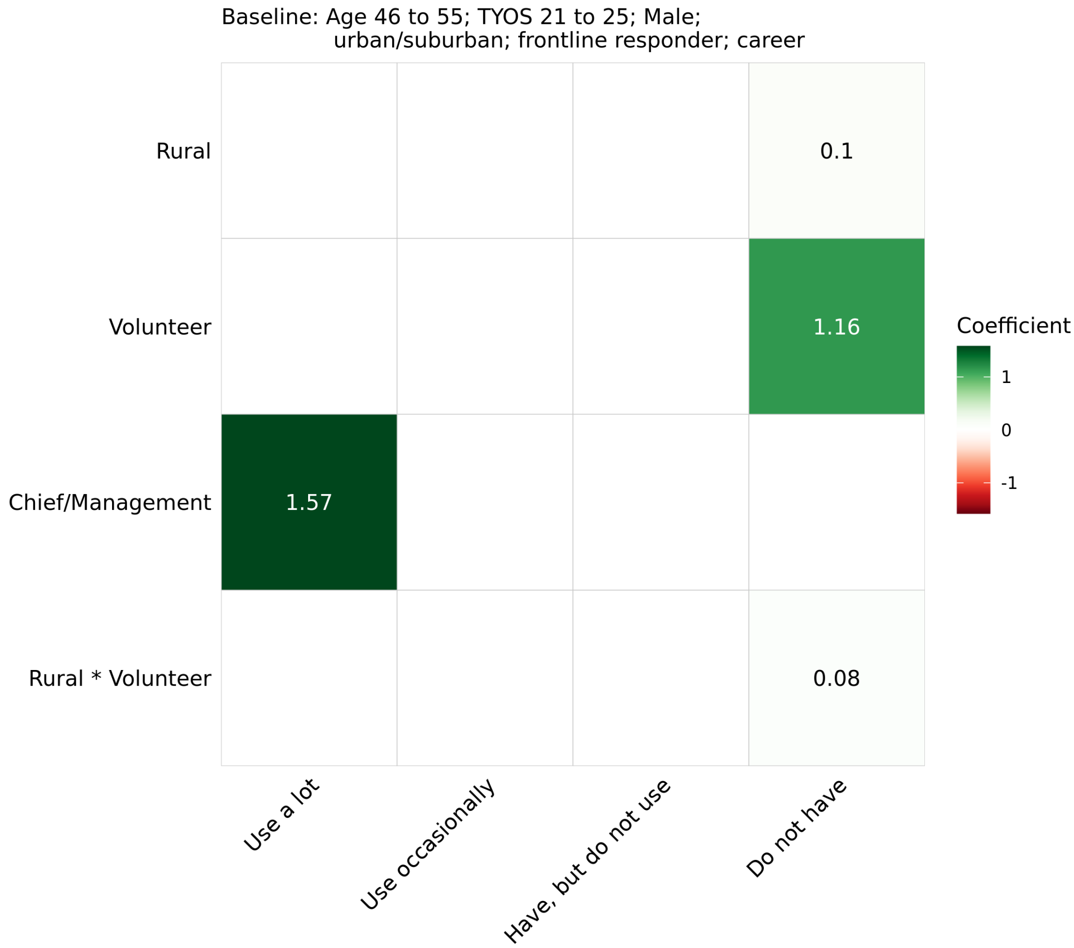

Fig. B.4.2.2 FF Device Usage Frequency: Work-issued Smartphone

Fig. B.4.2.3 FF Device Usage Frequency: Desktop Computer

Fig. B.4.2.4 FF Device Usage Frequency: Flip Phone

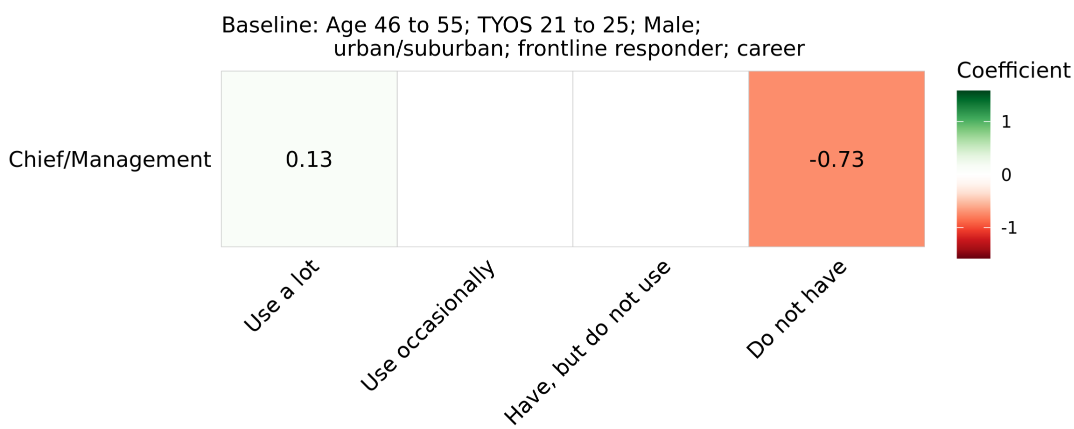

Fig. B.4.2.5 FF Device Usage Frequency: Laptop

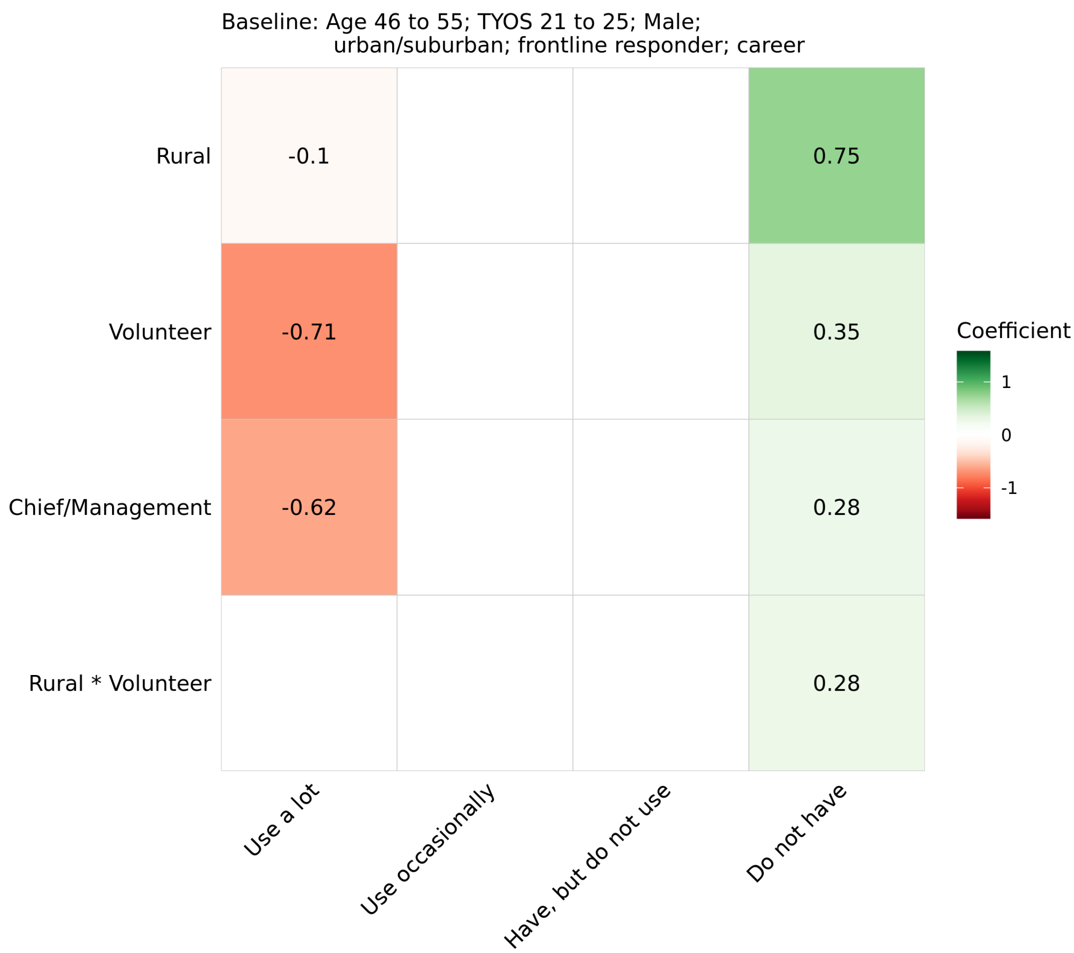

Fig. B.4.2.6 FF Device Usage Frequency: MDT/MDC

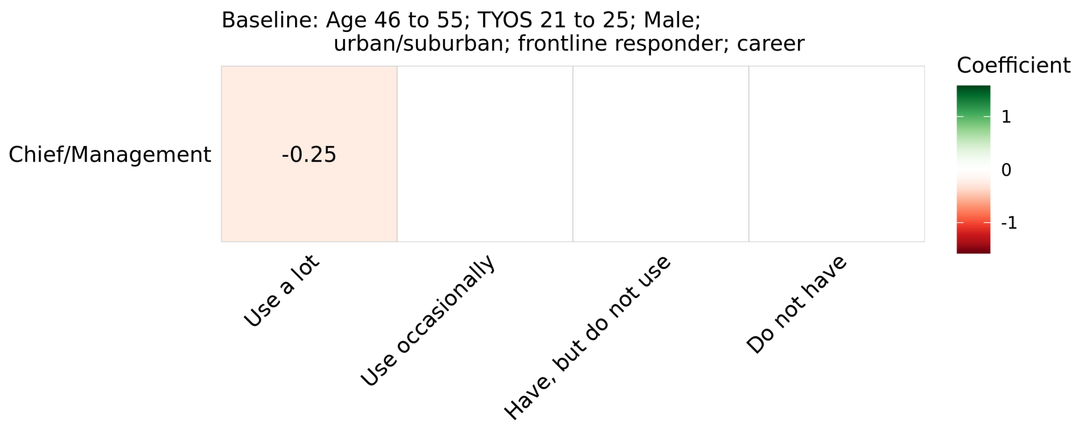

Fig. B.4.2.7 FF Device Usage Frequency: Corded Microphone

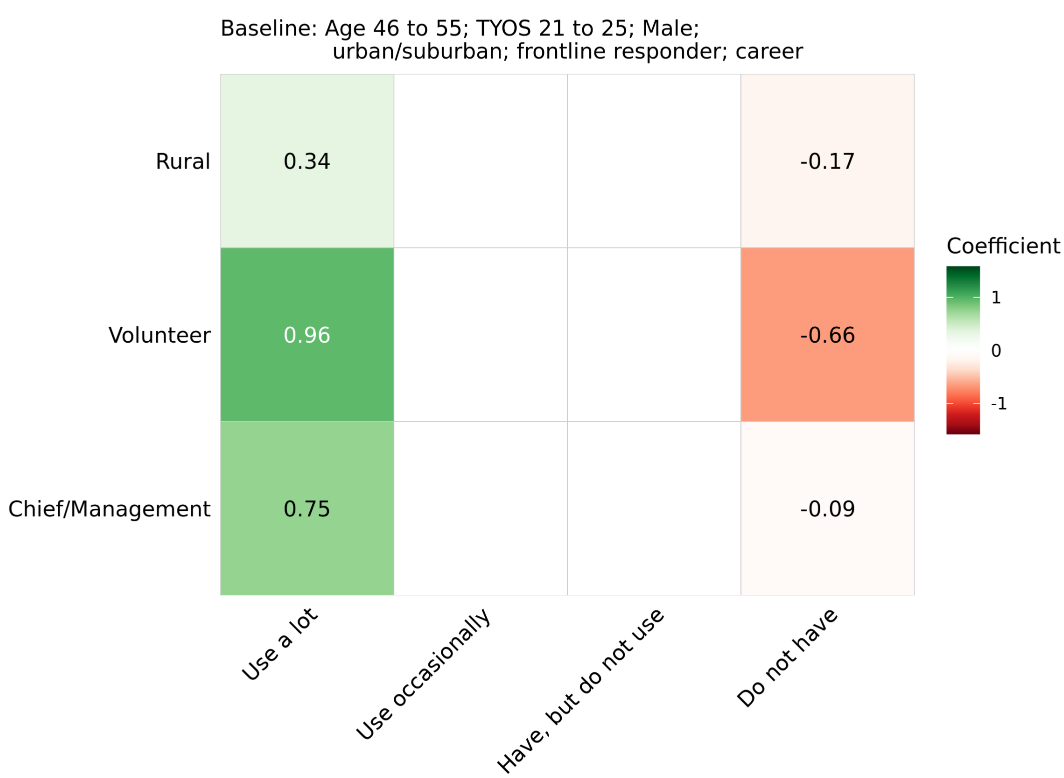

Fig. B.4.2.8 FF Device Usage Frequency: Pager

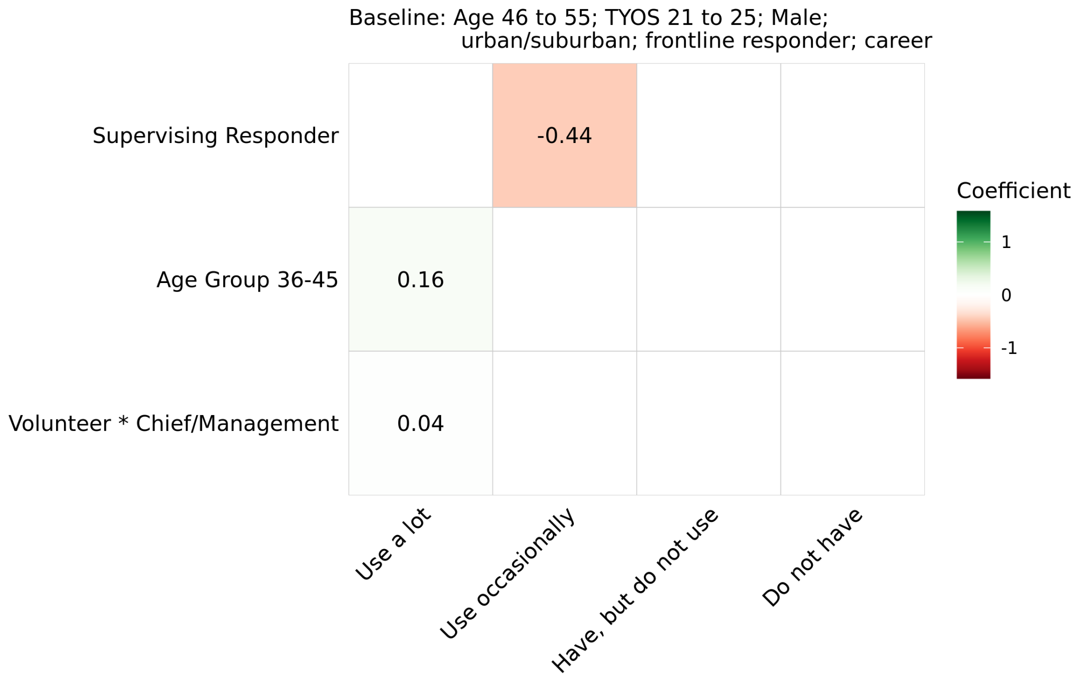

Fig. B.4.2.9 FF Device Usage Frequency: Portable Radio

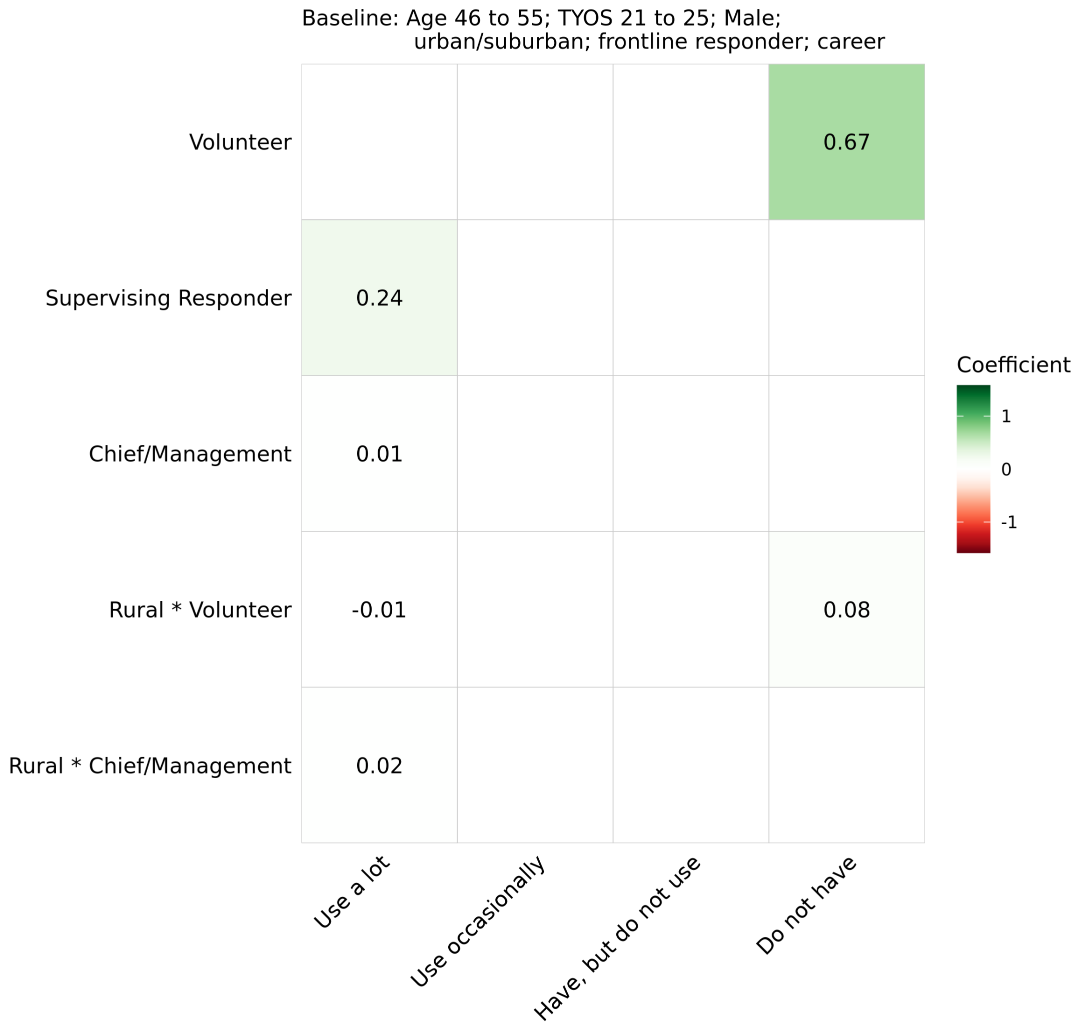

Fig. B.4.2.10 FF Device Usage Frequency: In-vehicle Radio

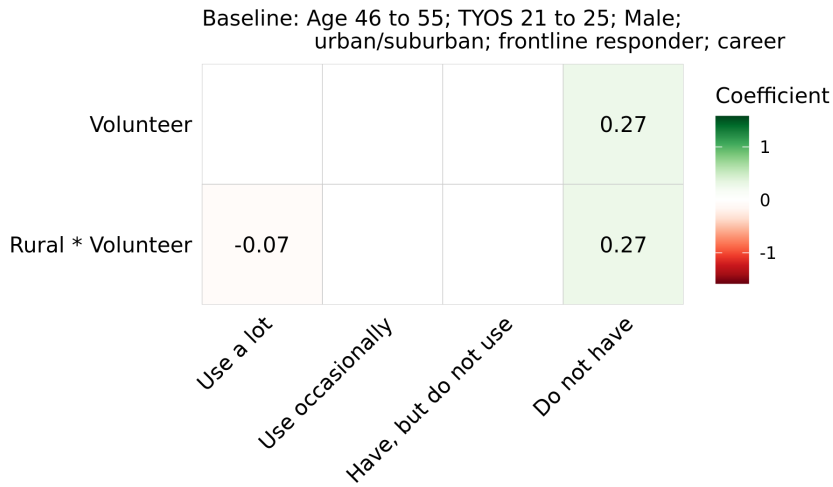

Fig. B.4.2.11 FF Device Usage Frequency: Tablet

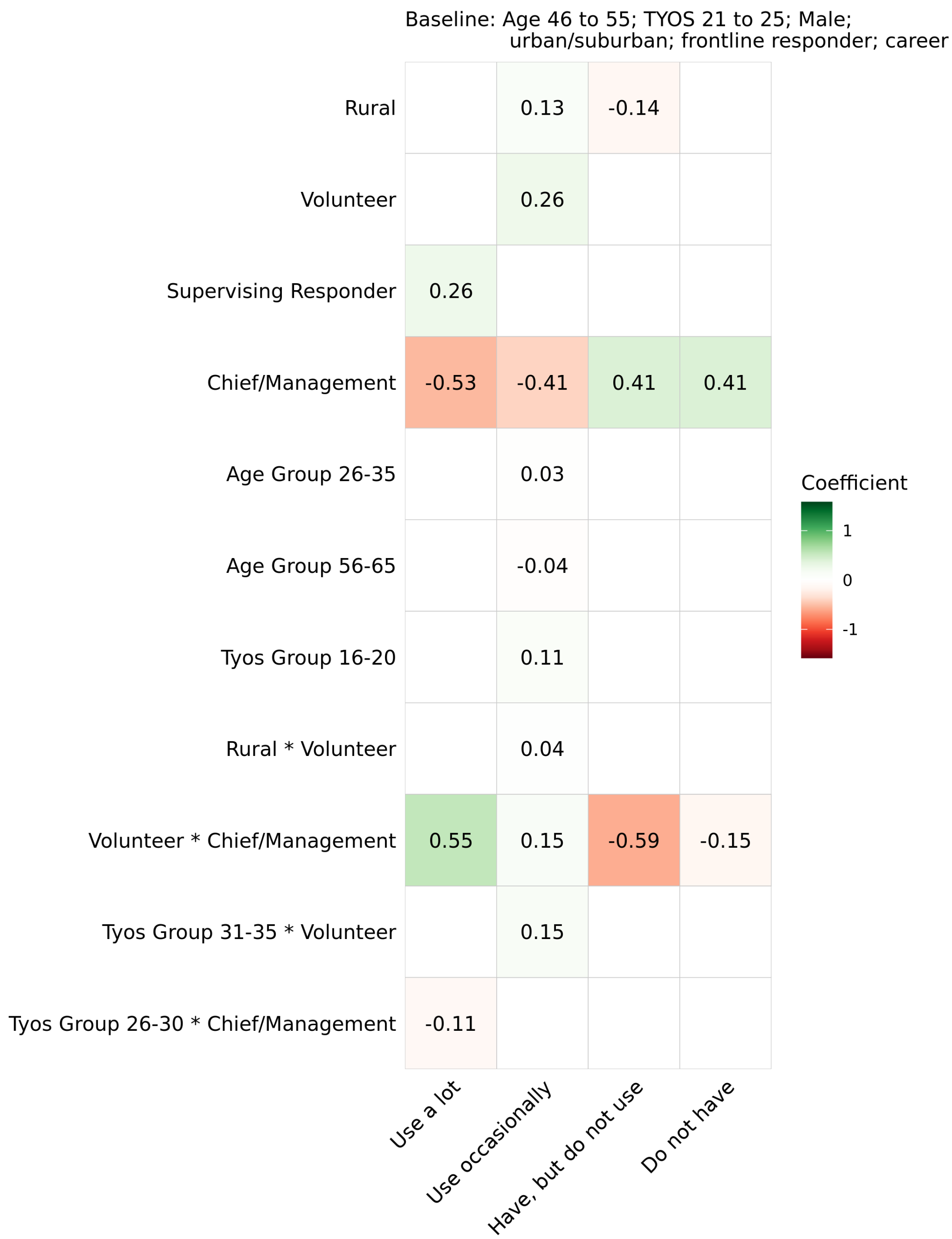

Fig. B.4.2.12 FF Device Usage Frequency: TIC

B.4.3. Problems with Technology

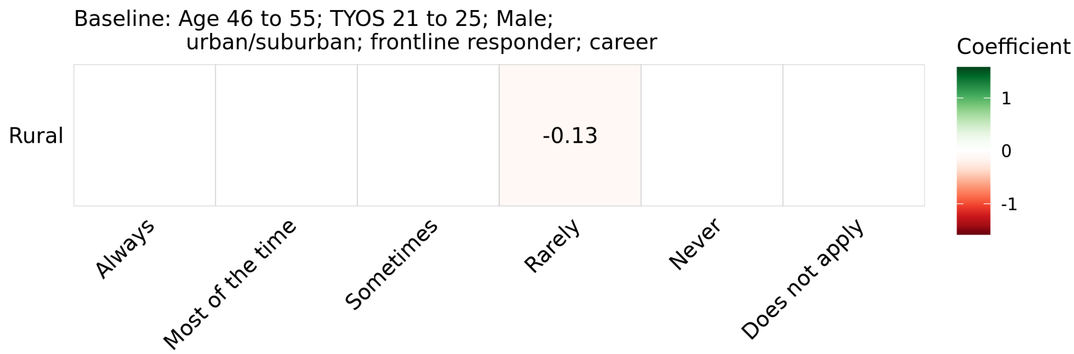

Fig. B.4.3.1 FF Problems with Smartphone: Coverage

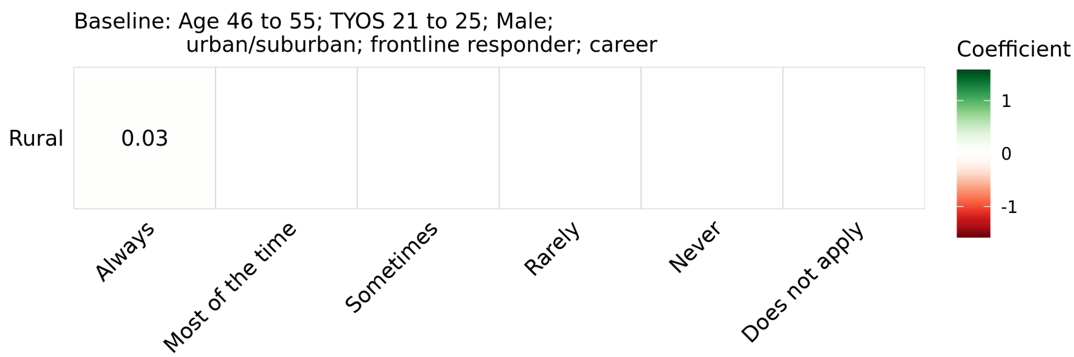

Fig. B.4.3.2 FF Problems with Smartphone: Price

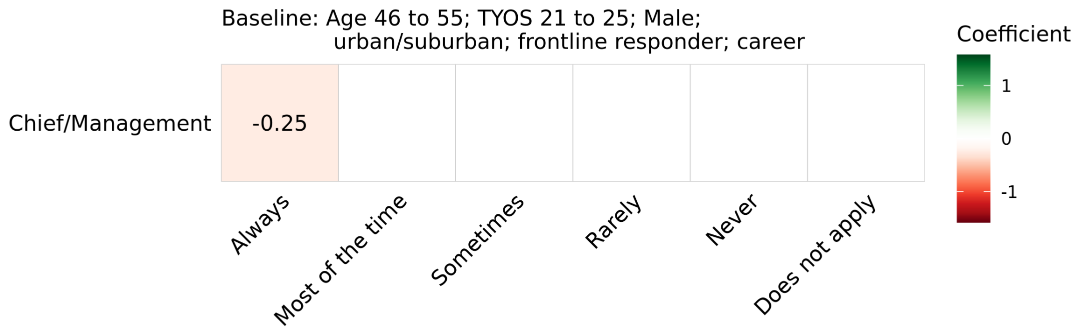

Fig. B.4.3.3 FF Problems with Smartphone: Subsidy

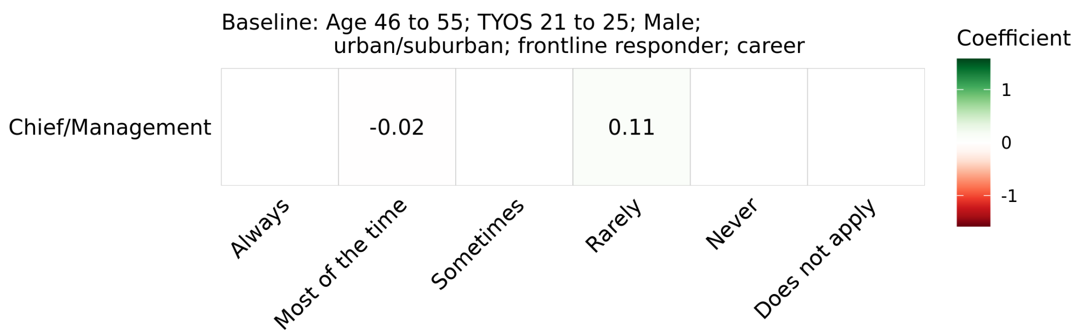

Fig. B.4.3.4 FF Problems with Desktop Computer: Old

Fig. B.4.3.5 FF Problems with Desktop Computer: Price

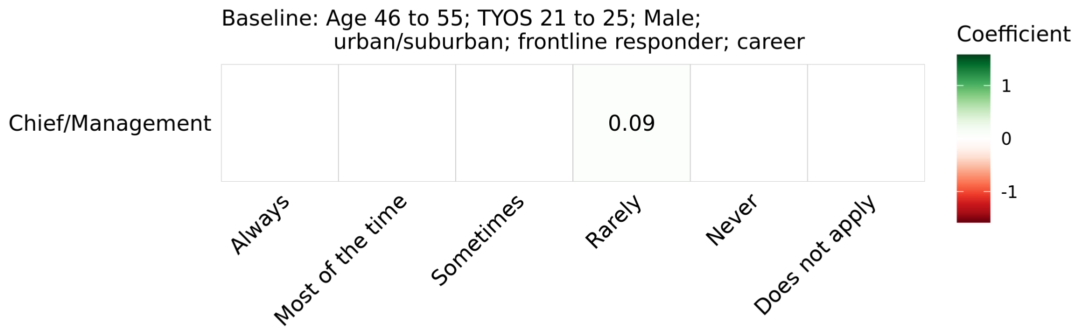

Fig. B.4.3.6 FF Problems with Desktop Computer: Software Update

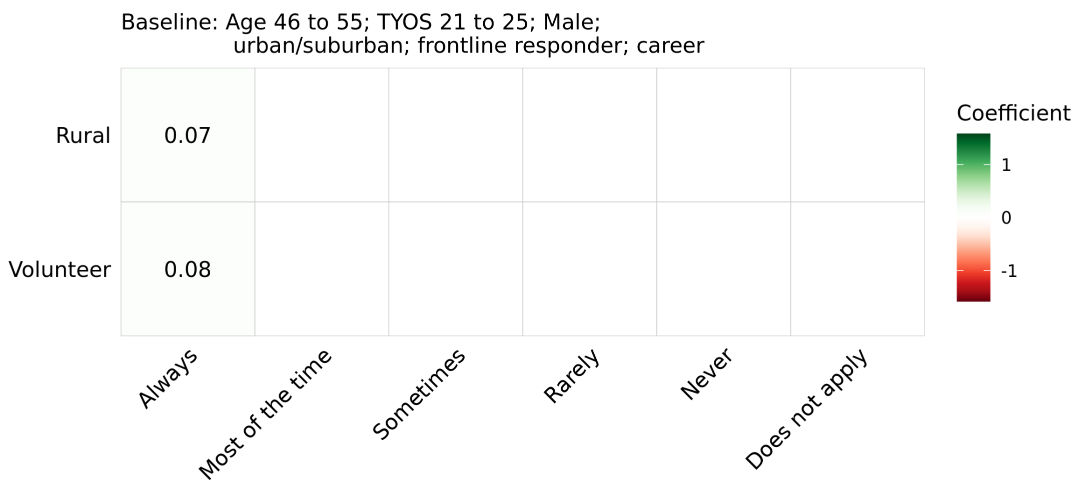

Fig. B.4.3.7 FF Problems with Laptop: Price

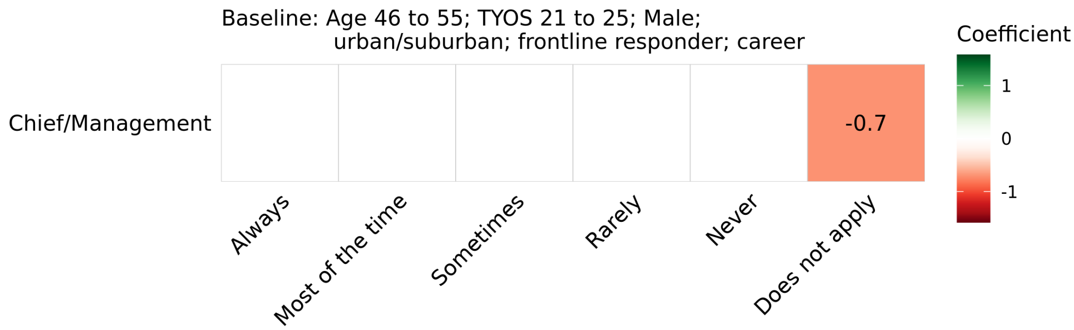

Fig. B.4.3.8 FF Problems with MDT/MDC: Price

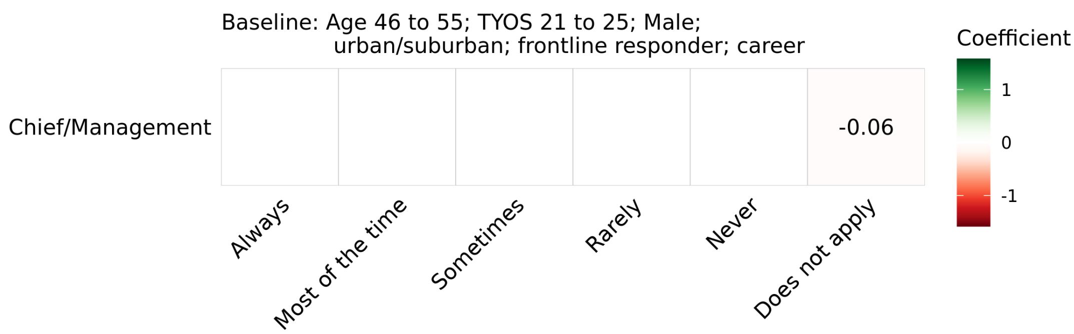

Fig. B.4.3.9 FF Problems with MDT/MDC: While Driving

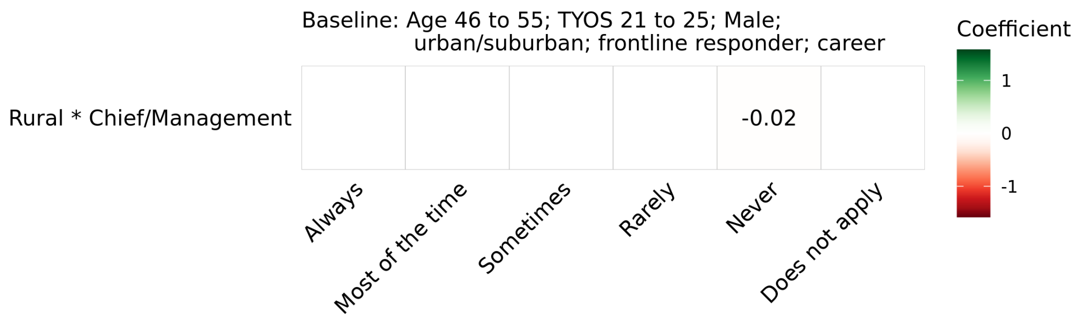

Fig. B.4.3.10 FF Problems with Microphone: Button Size

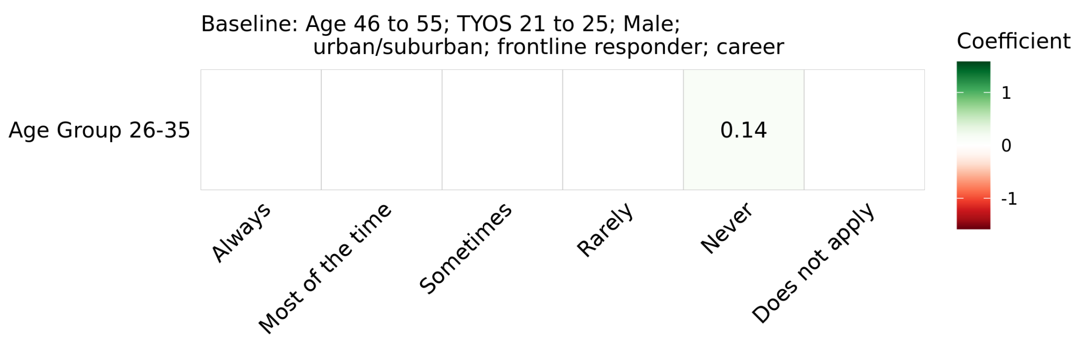

Fig. B.4.3.11 FF Problems with Microphone: Old

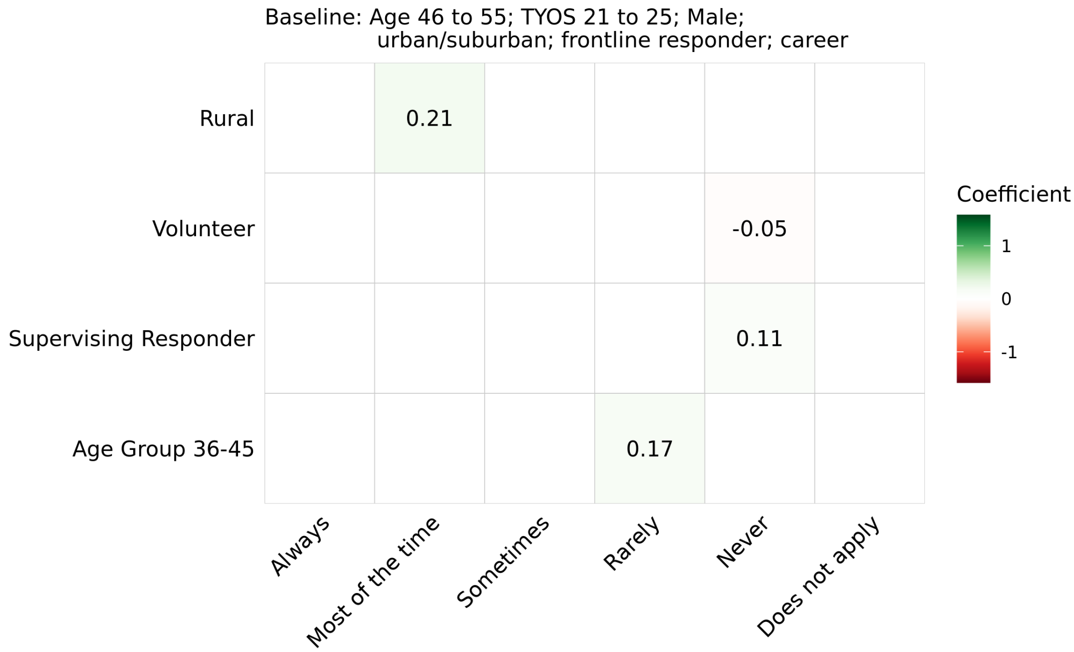

Fig. B.4.3.12 FF Problems with Microphone: Placement

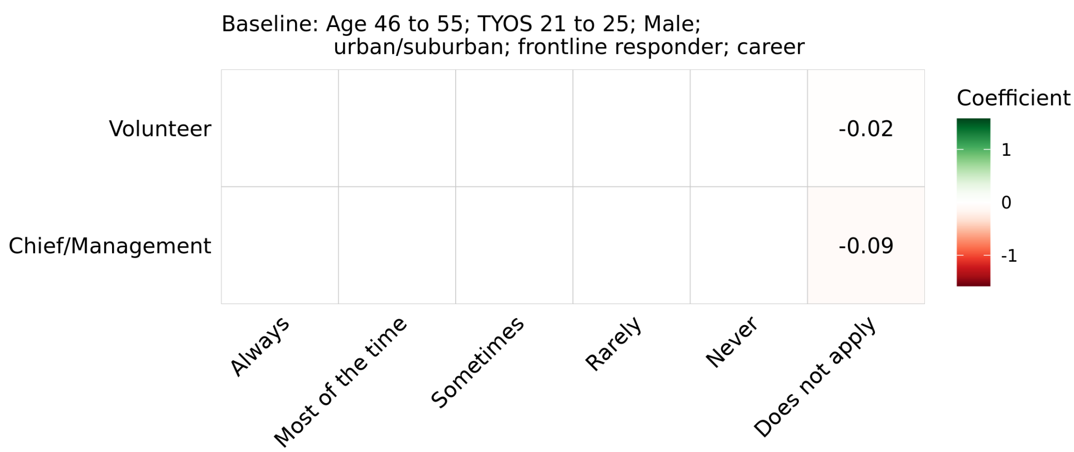

Fig. B.4.3.13 FF Problems with Microphone: Price

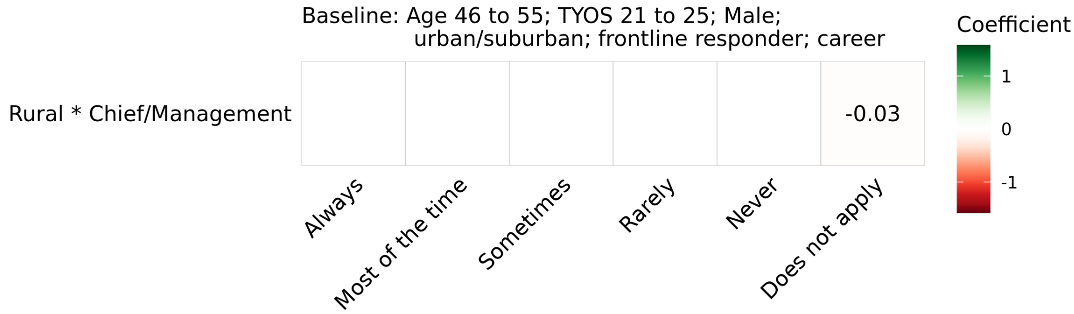

Fig. B.4.3.14 FF Problems with Pager: Price

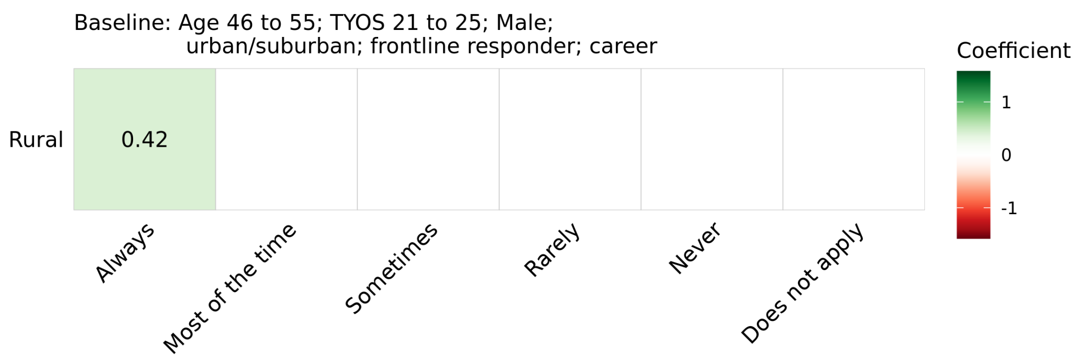

Fig. B.4.3.15 FF Problems with Radio: Coverage

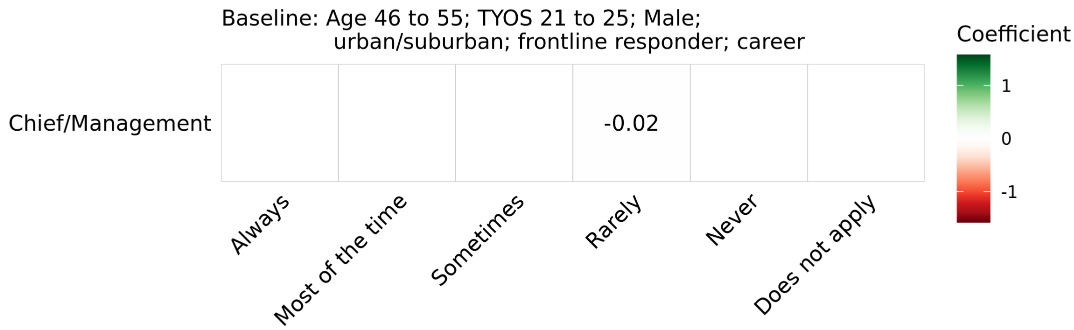

Fig. B.4.3.16 FF Problems with Radio: Interoperability

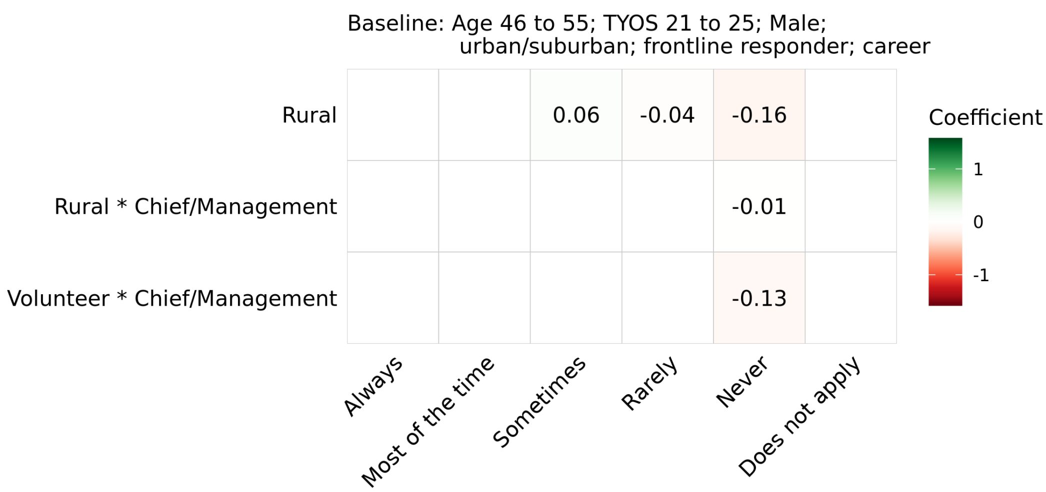

Fig. B.4.3.17 FF Problems with Radio: Old

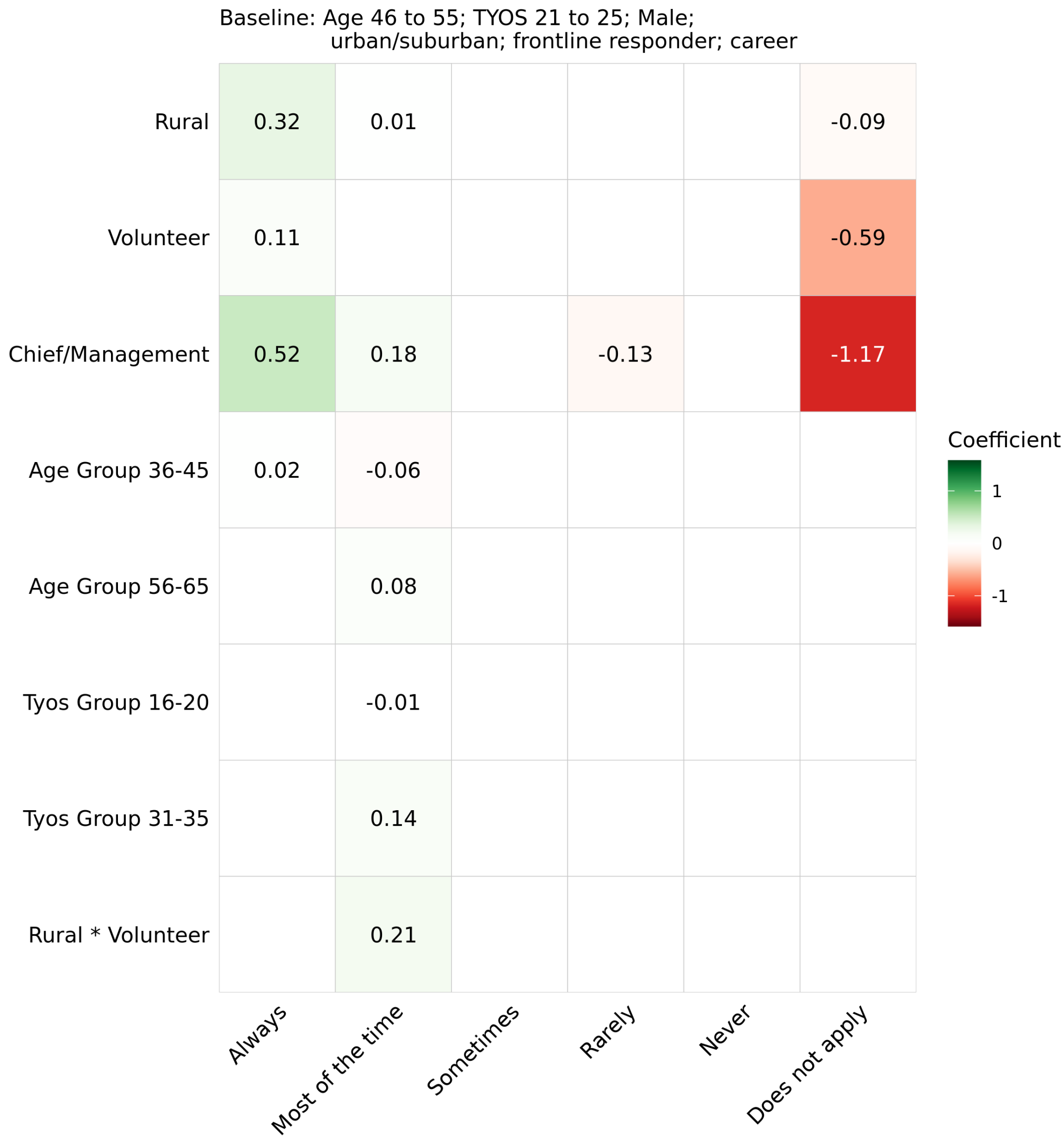

Fig. B.4.3.18 FF Problems with Radio: Price

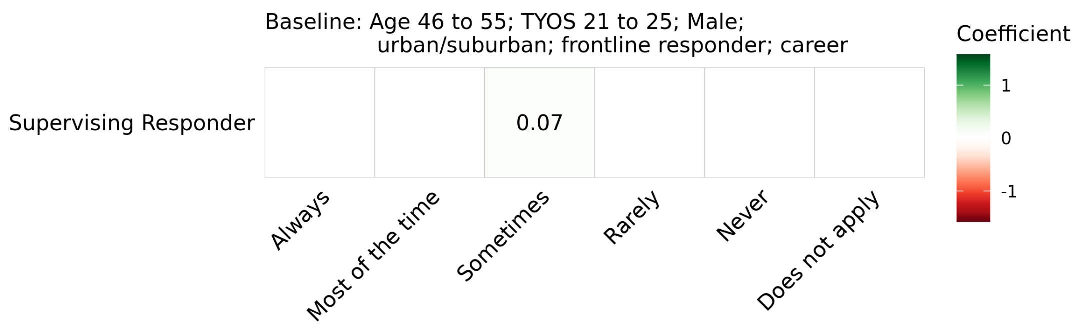

Fig. B.4.3.19 FF Problems with TIC: Battery

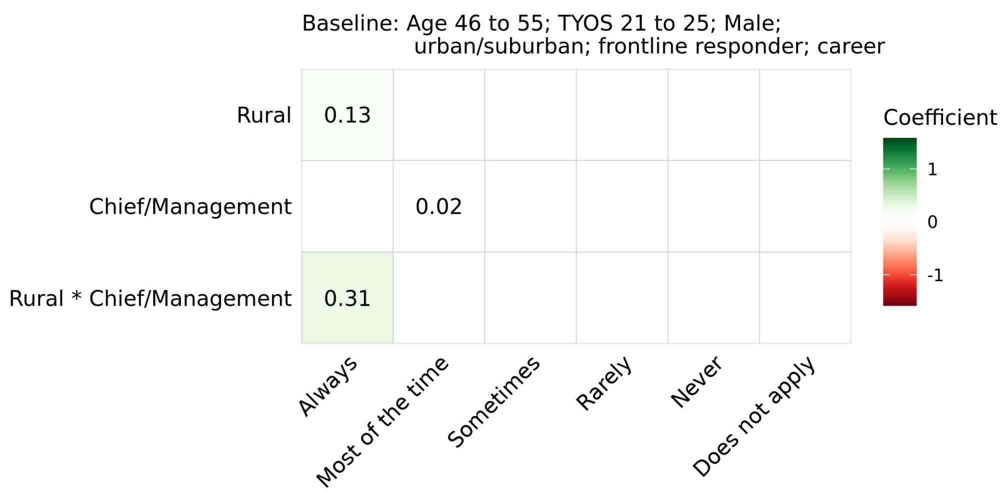

Fig. B.4.3.20 FF Problems with TIC: Price

B.4.4. Application/Software Frequency

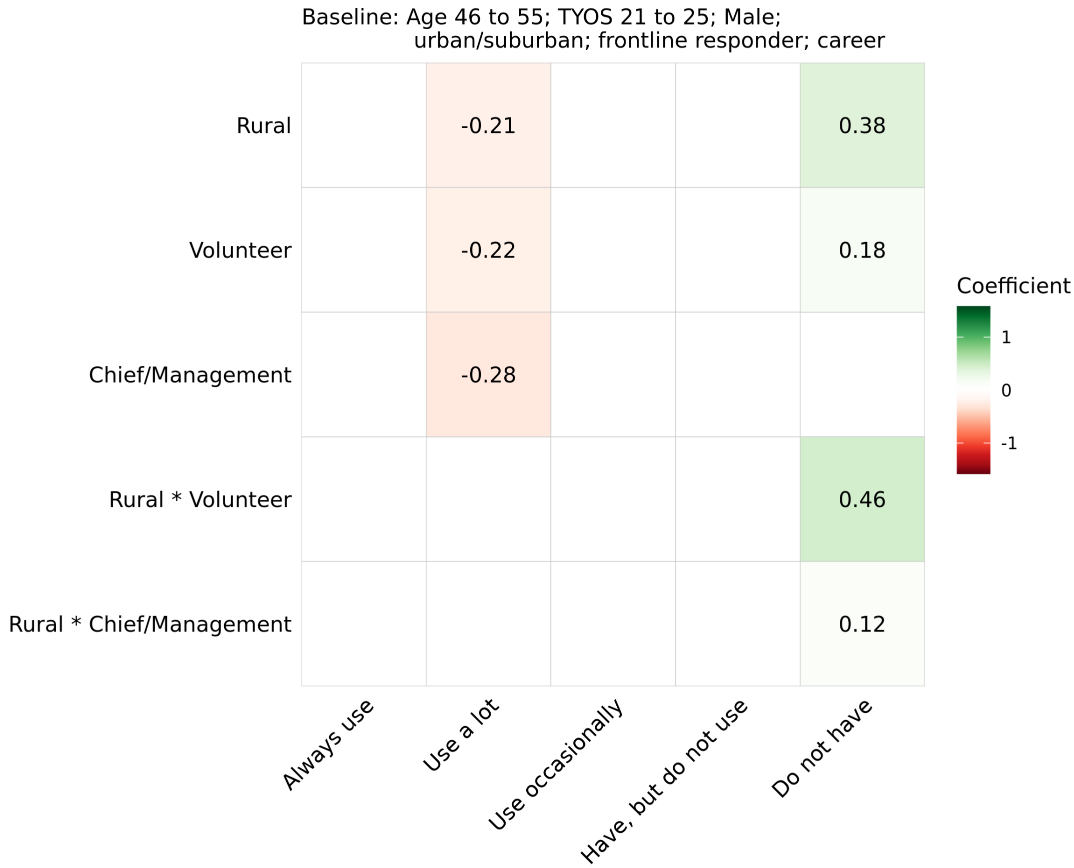

Fig. B.4.4.1 FF Apps/Software Usage Frequency: CAD

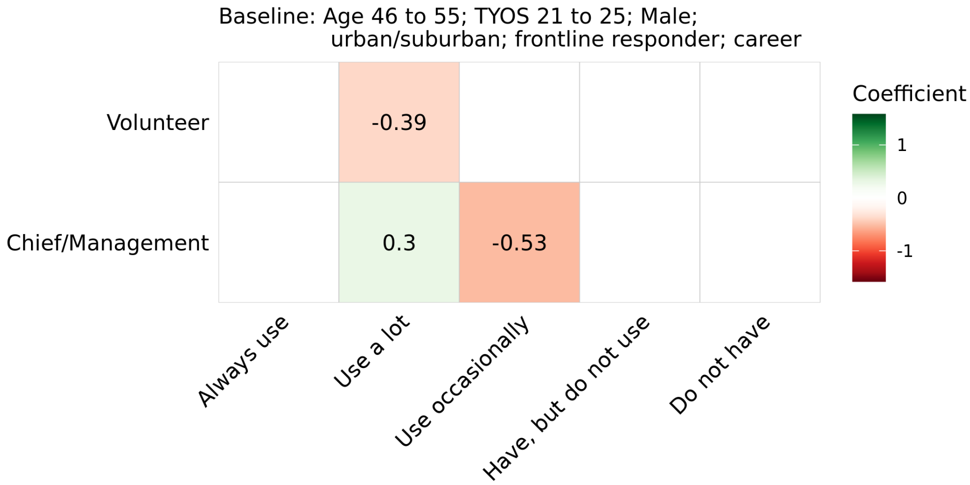

Fig. B.4.4.2 FF Apps/Software Usage Frequency: Email

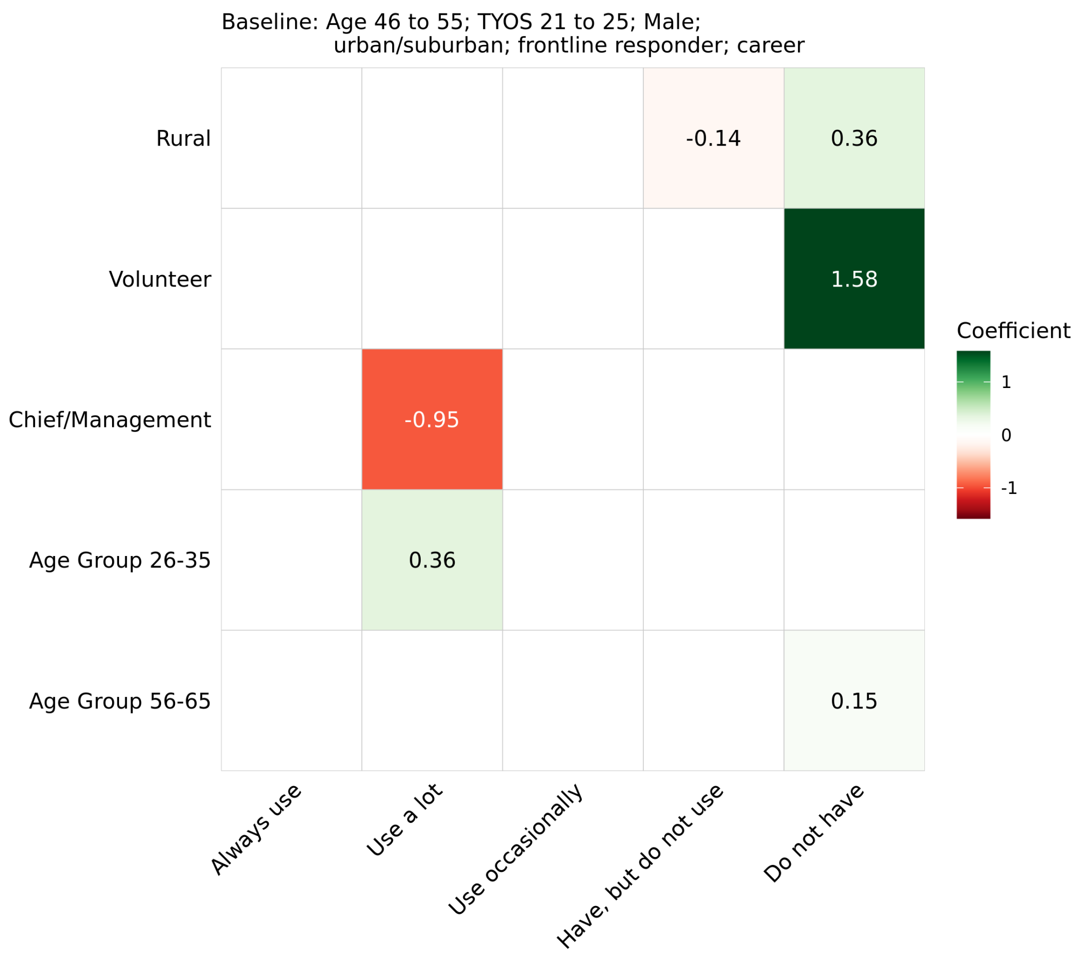

Fig. B.4.4.3 FF Apps/Software Usage Frequency: EPCR

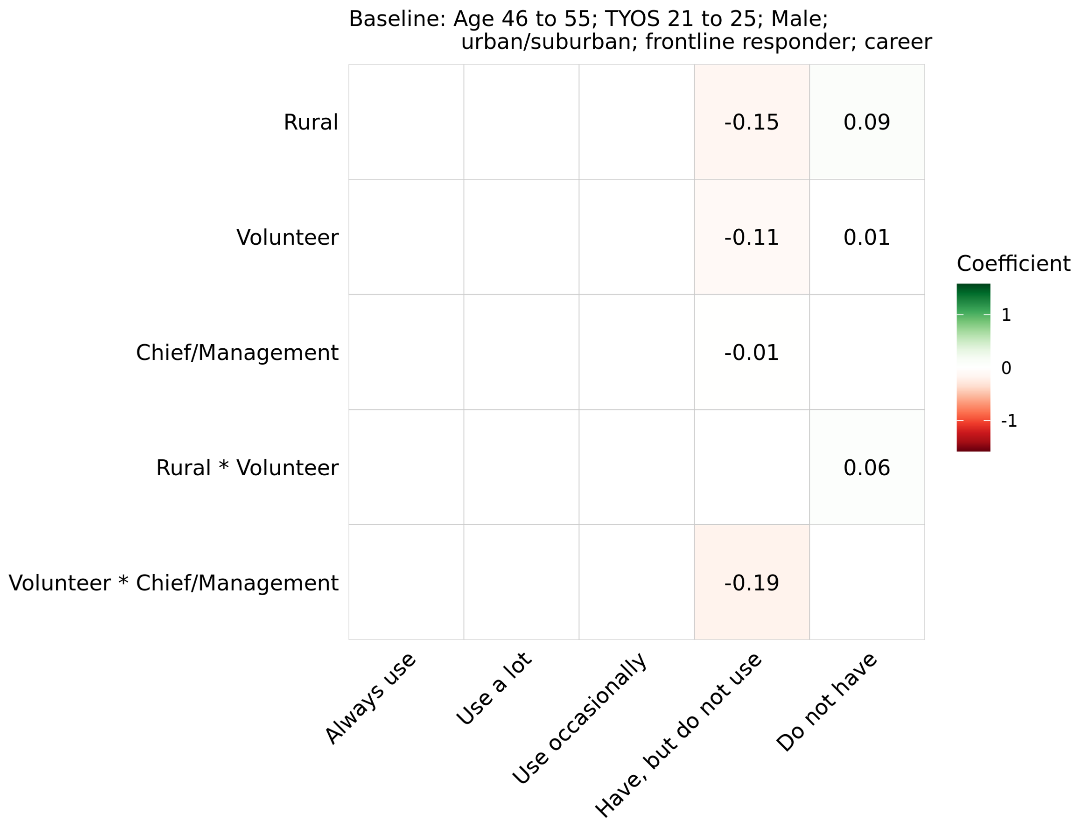

Fig. B.4.4.4 FF Apps/Software Usage Frequency: ERG

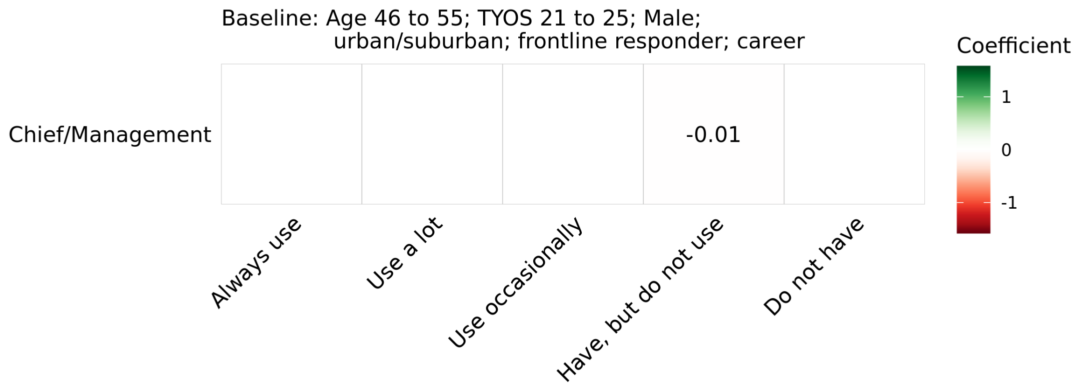

Fig. B.4.4.5 FF Apps/Software Usage Frequency: Hazmat SOPs

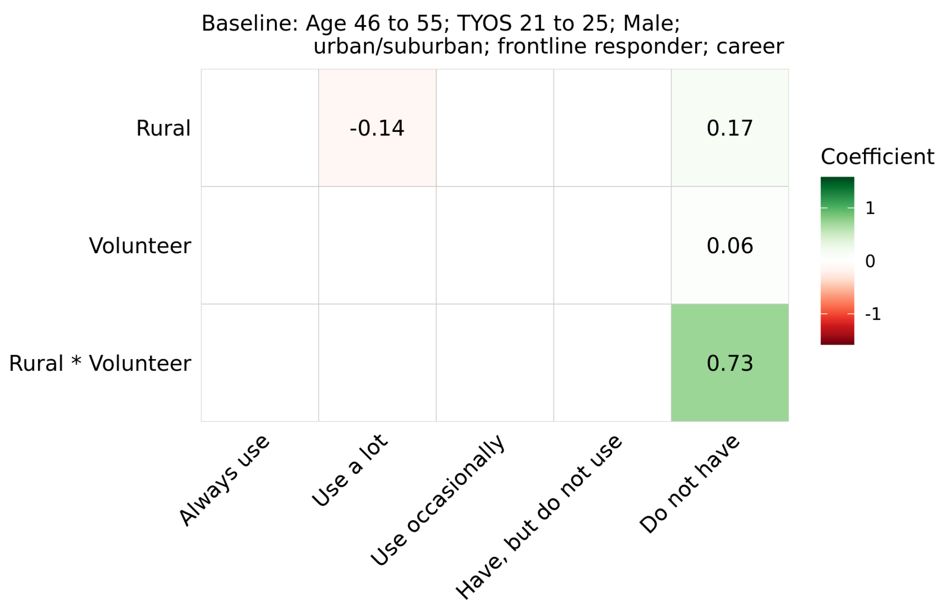

Fig. B.4.4.6 FF Apps/Software Usage Frequency: Hydrant Location

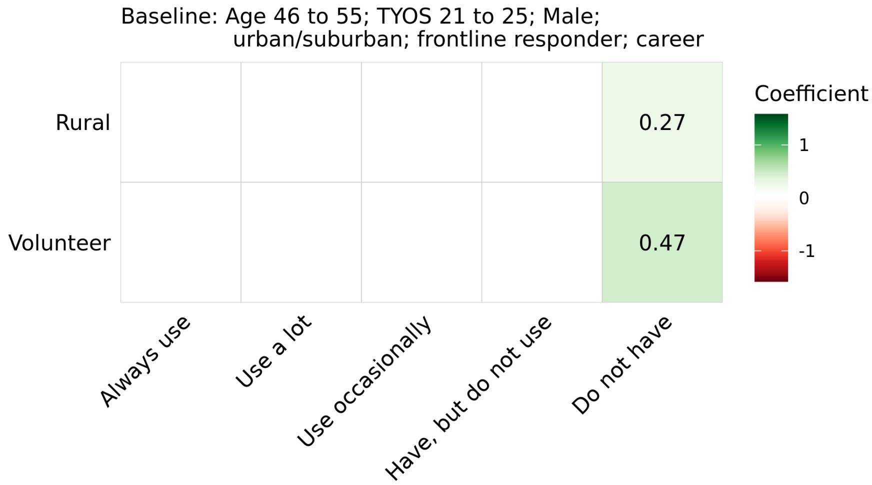

Fig. B.4.4.7 FF Apps/Software Usage Frequency: Language Translation

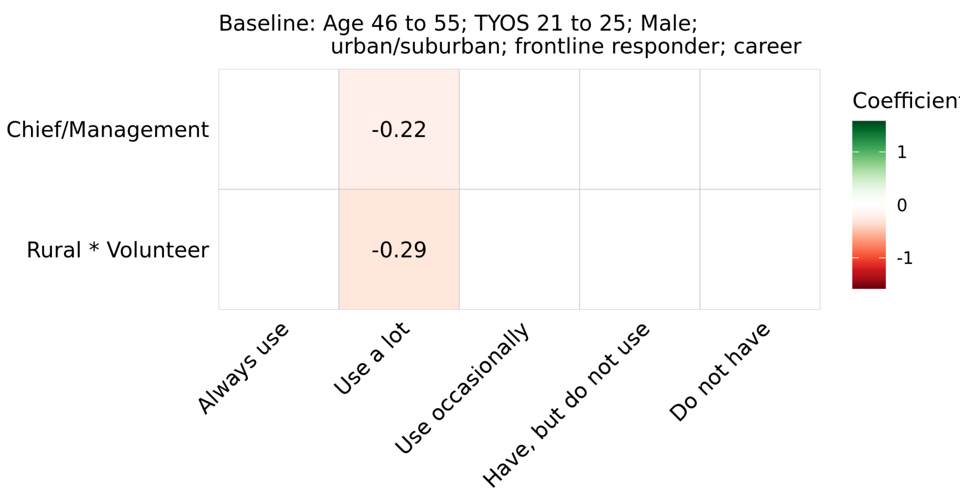

Fig. B.4.4.8 FF Apps/Software Usage Frequency: Mapping/Navigation

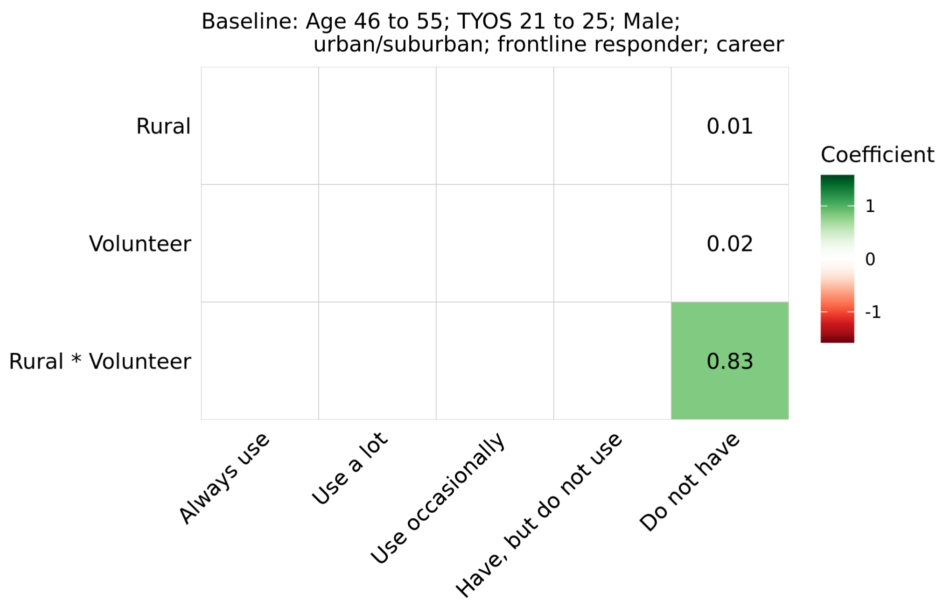

Fig. B.4.4.9 FF Apps/Software Usage Frequency: Pre-plan

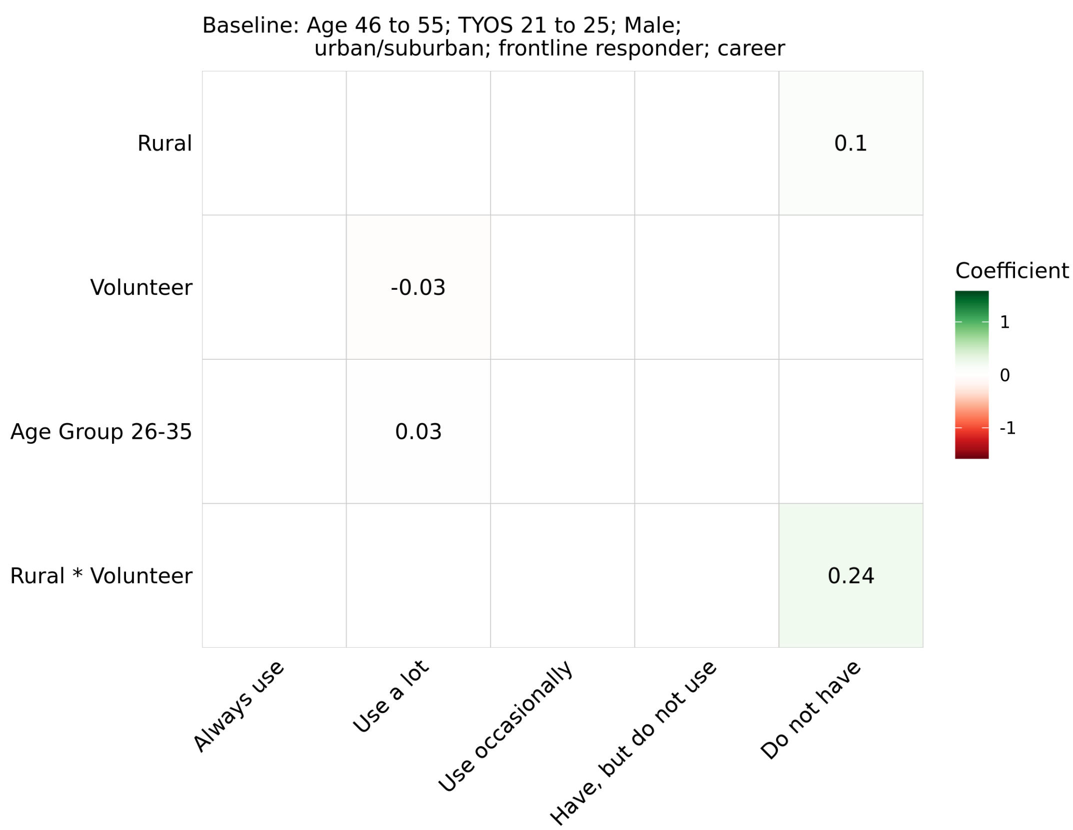

Fig. B.4.4.10 FF Apps/Software Usage Frequency: Report Writing

Fig. B.4.4.11 FF Apps/Software Usage Frequency: RMS

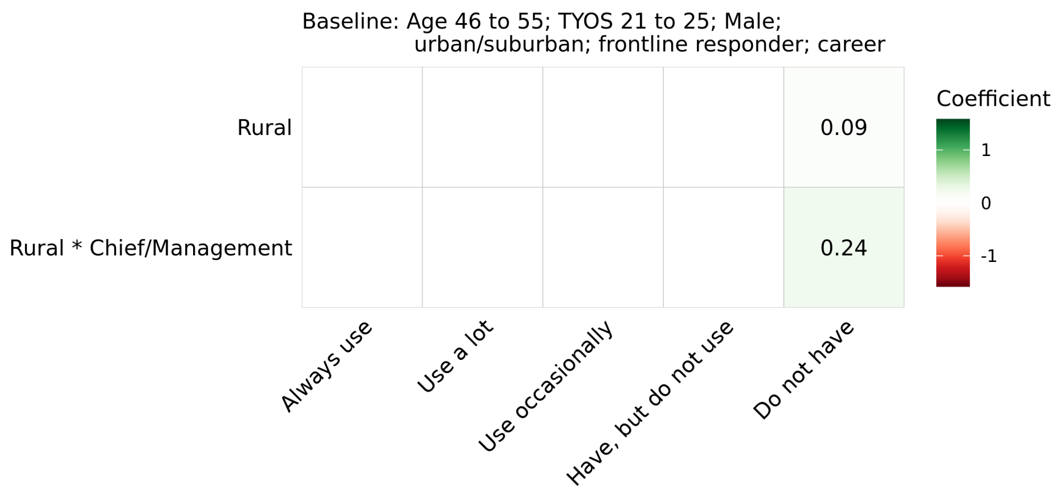

Fig. B.4.4.12 FF Apps/Software Usage Frequency: Traffic

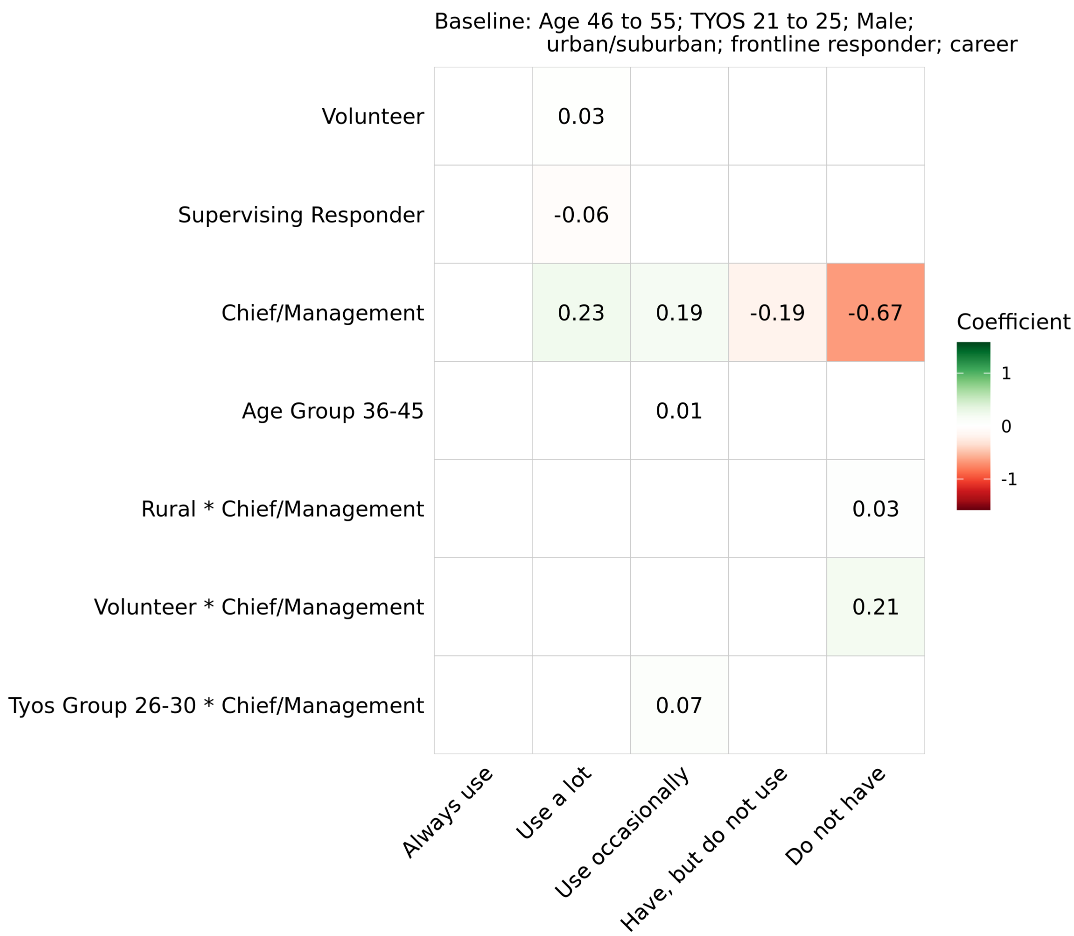

Fig. B.4.4.13 FF Apps/Software Usage Frequency: Weather

B.4.5. Futuristic Technology

Fig. B.4.5.1 FF Perceived Usefulness of Futuristic Technology: Auto. Vehicle Loc.

Fig. B.4.5.2 FF Perceived Usefulness of Futuristic Technology: Drones

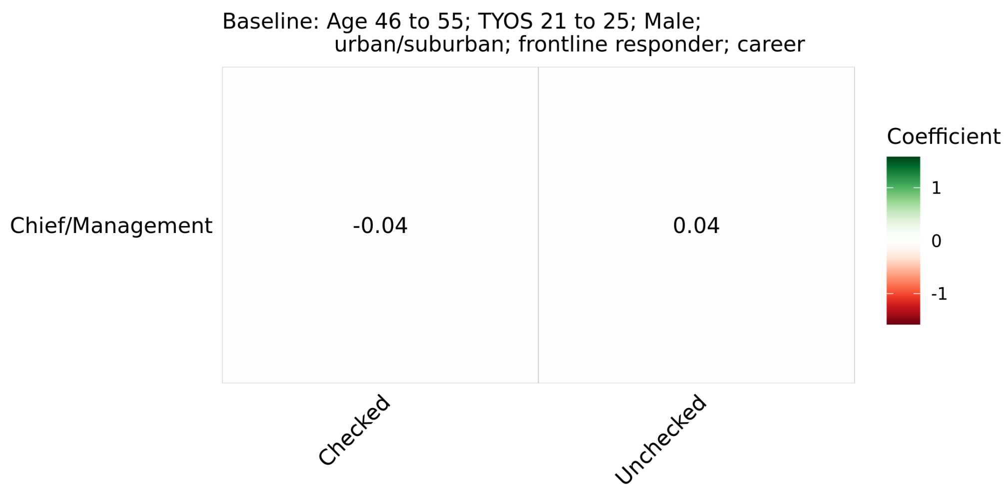

Fig. B.4.5.3 FF Perceived Usefulness of Futuristic Technology: HUD

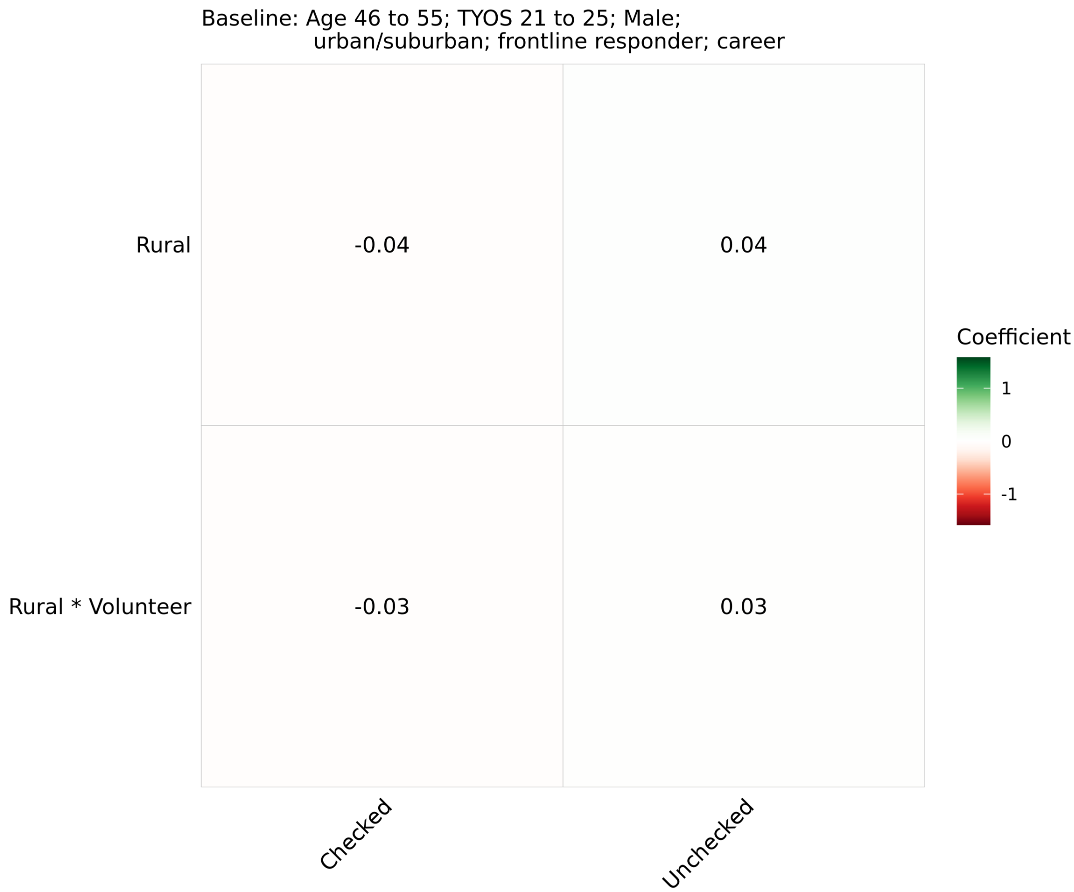

Fig. B.4.5.4 FF Perceived Usefulness of Futuristic Technology: Indoor Mapping

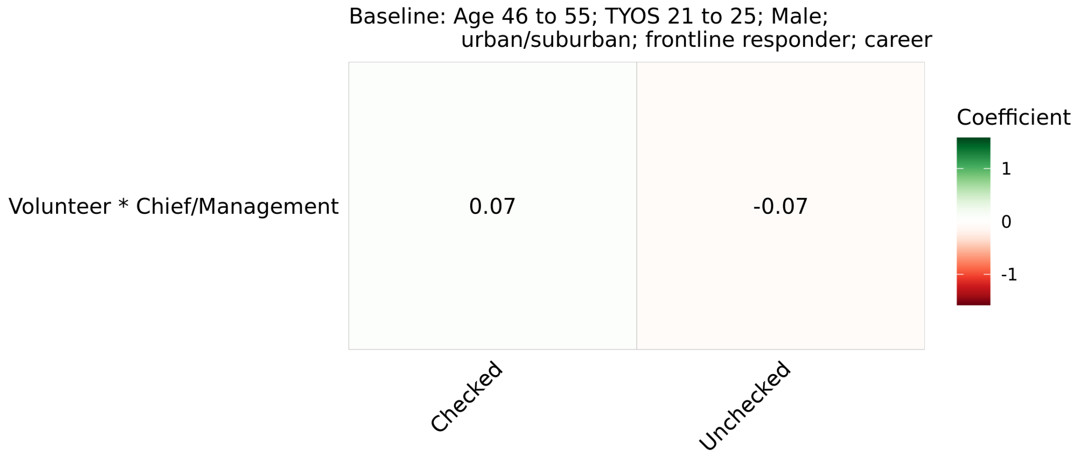

Fig. B.4.5.5 FF Perceived Usefulness of Futuristic Technology: Laptop

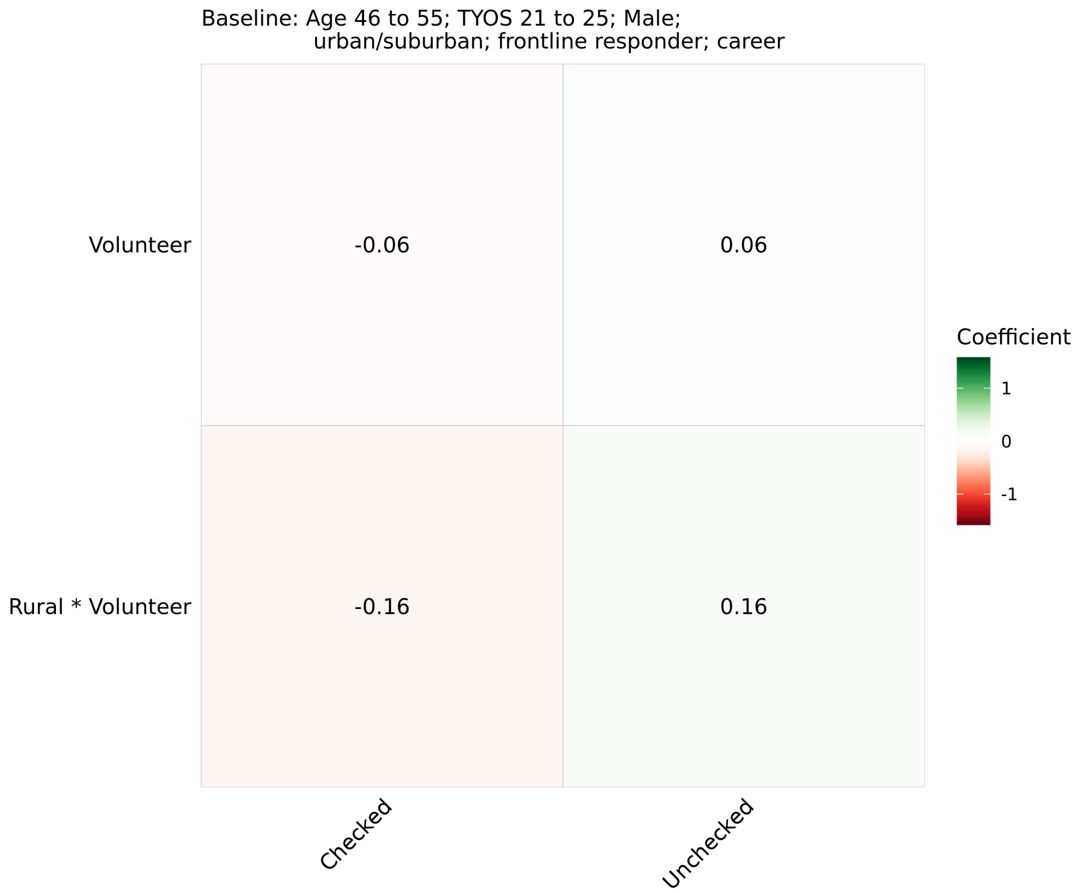

Fig. B.4.5.6 FF Perceived Usefulness of Futuristic Technology: One Login

Fig. B.4.5.7 FF Perceived Usefulness of Futuristic Technology: MDT/MDC

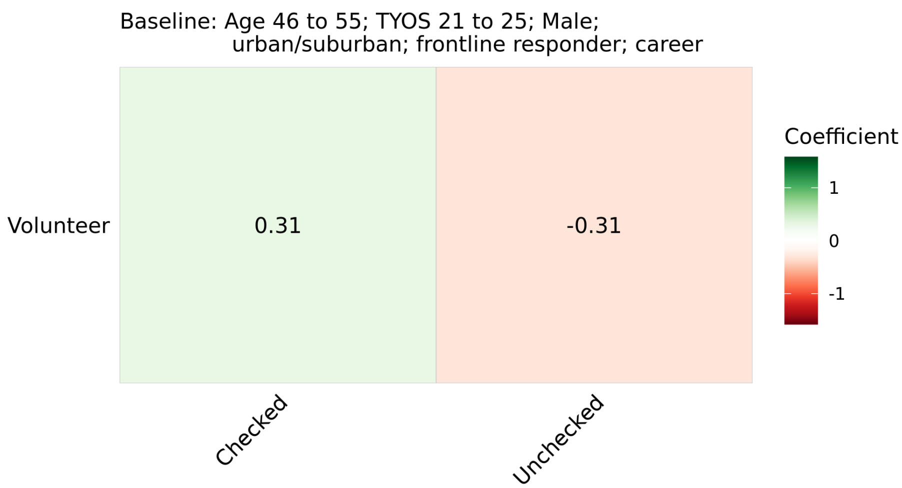

Fig. B.4.5.8 FF Perceived Usefulness of Futuristic Technology: Pager

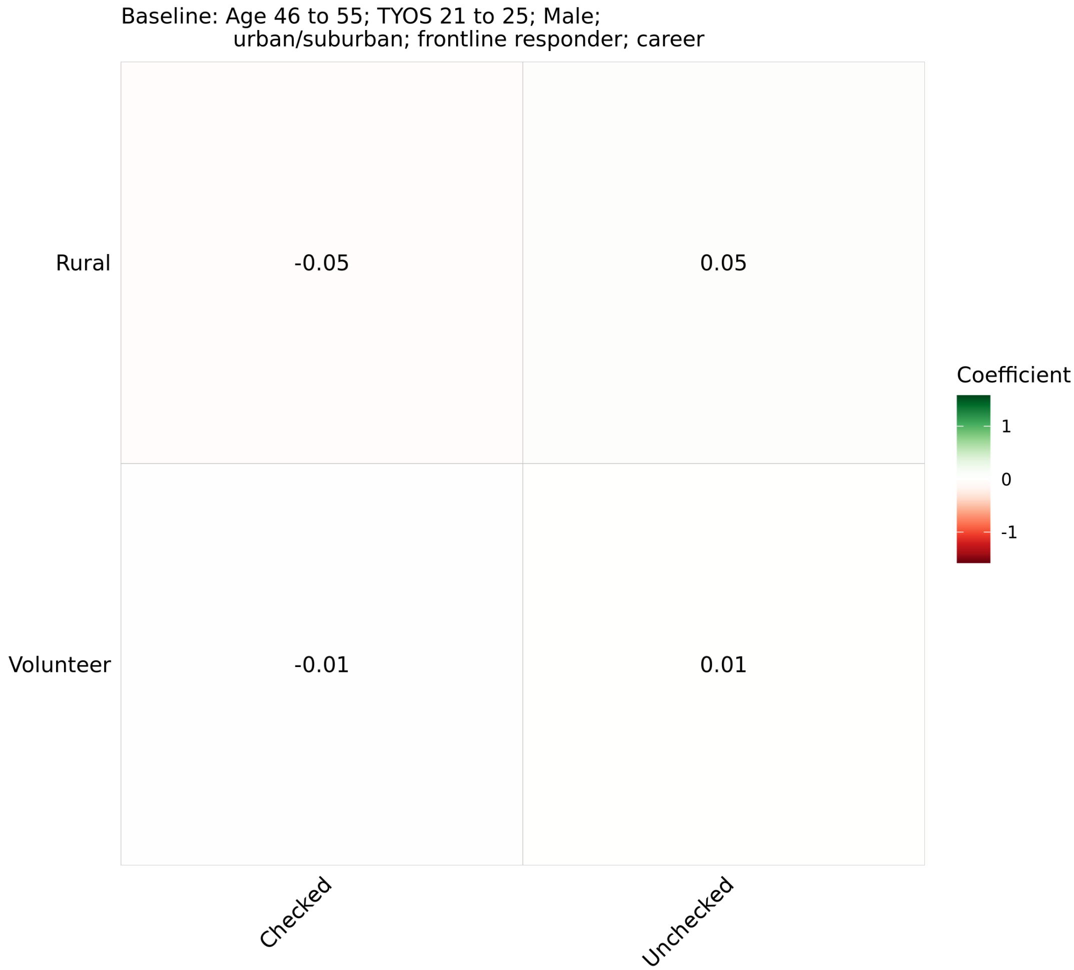

Fig. B.4.5.9 FF Perceived Usefulness of Futuristic Technology: Smart Buildings

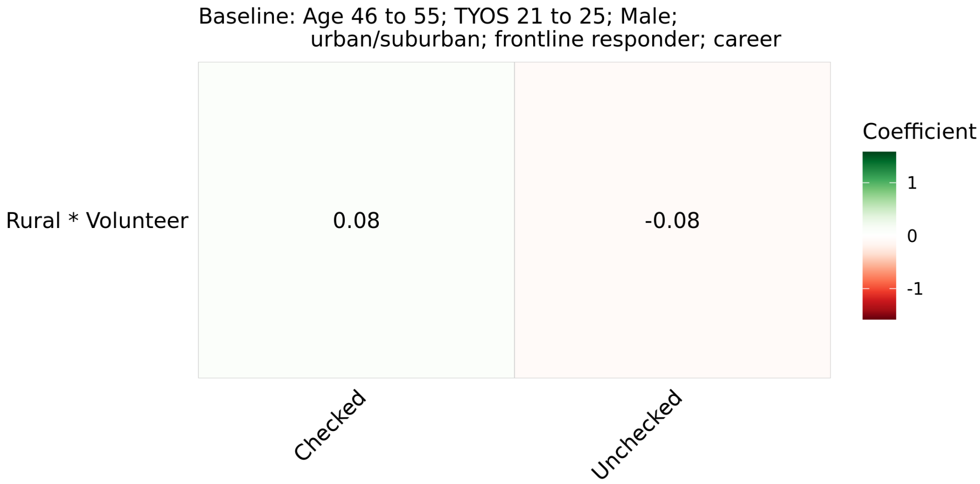

Fig. B.4.5.10 FF Perceived Usefulness of Futuristic Technology: TIC

Fig. B.4.5.11 FF Perceived Usefulness of Futuristic Technology: Real Time Video

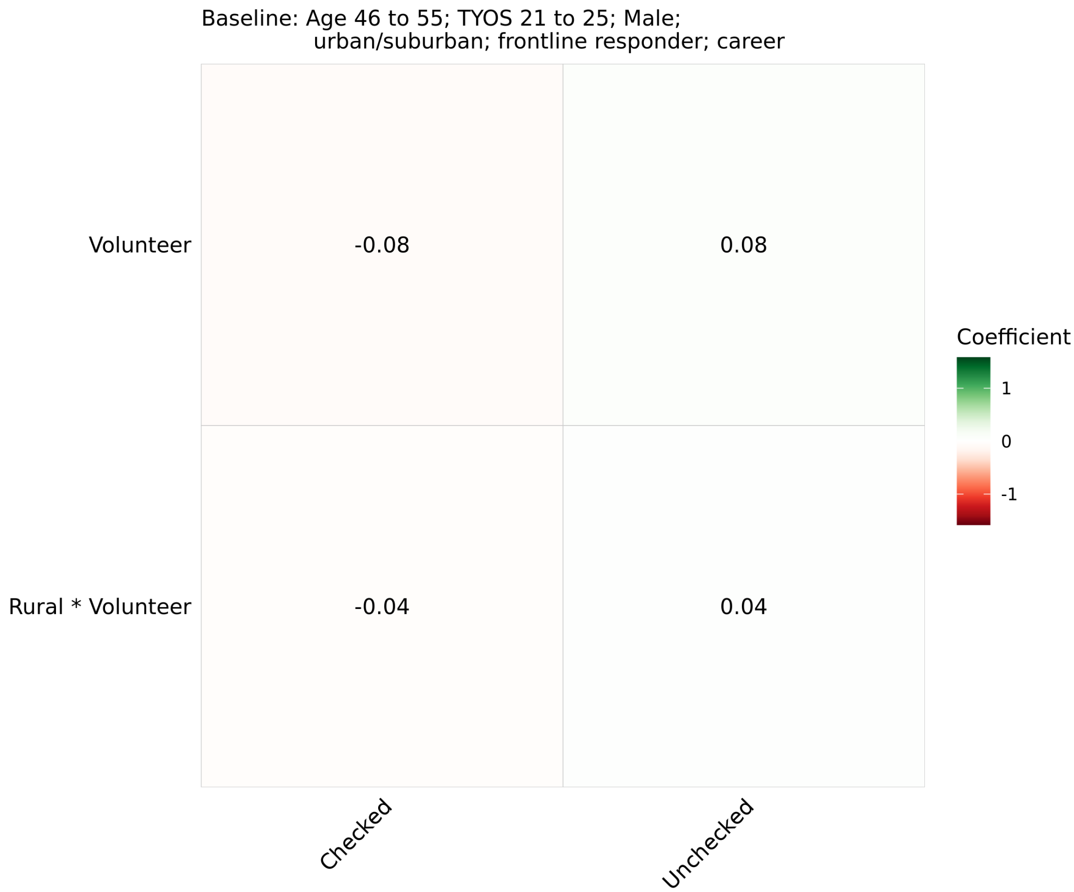

Fig. B.4.5.12 FF Perceived Usefulness of Futuristic Technology: First Responder Vitals

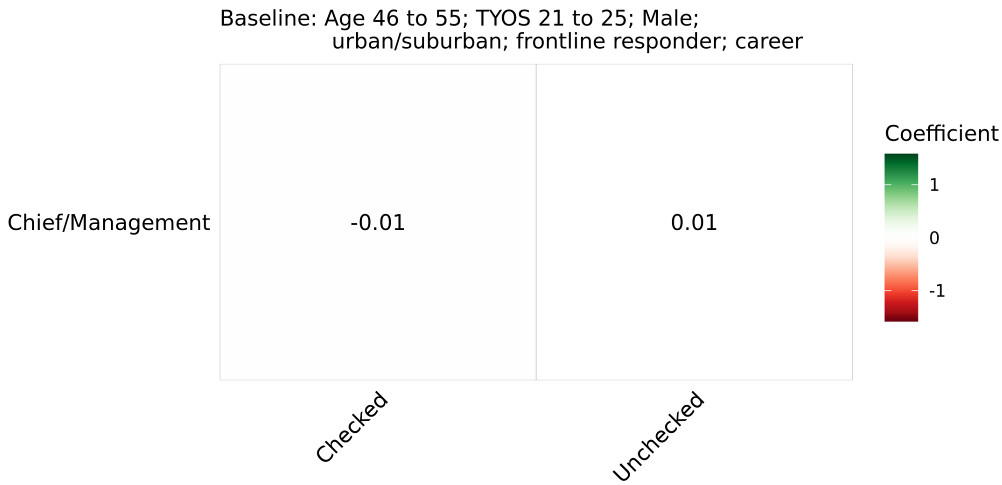

Fig. B.4.5.13 FF Perceived Usefulness of Futuristic Technology: Patient Vitals

Fig. B.4.5.14 FF Perceived Usefulness of Futuristic Technology: Voice Controls

B.5. LE

List of tables and figures

B.5.1. Subgroup Demographics

Table B.5.1.1 LE Demographics

Subgroup		%	n
Area	Rural	32	586
	Urban/Suburban	62	1139
	(missing data)	6	101
Role	Frontline Responder	19	350
	Supervising Responder	30	542
	Chief/Management	46	833
	(missing data)	5	101
Age	18-25	2	27
	26-35	9	161
	36-45	21	389
	46-55	41	757
	56-65	18	330
	Over 65	2	42
	(missing data)	7	120
Years of Service	Less than 1	0	5
	1-5	4	74
	6-10	6	107
	11-15	8	145
	16-20	16	284
	21-25	18	335
	26-30	17	317
	31-35	14	253
	36-40	7	126

	41-45	3	61
	46-50	1	12
	More than 50	0	5
	(missing data)	6	102
Sex	Female	8	147
	Male	86	1564
	(missing data)	6	115

B.5.2. Device Frequency

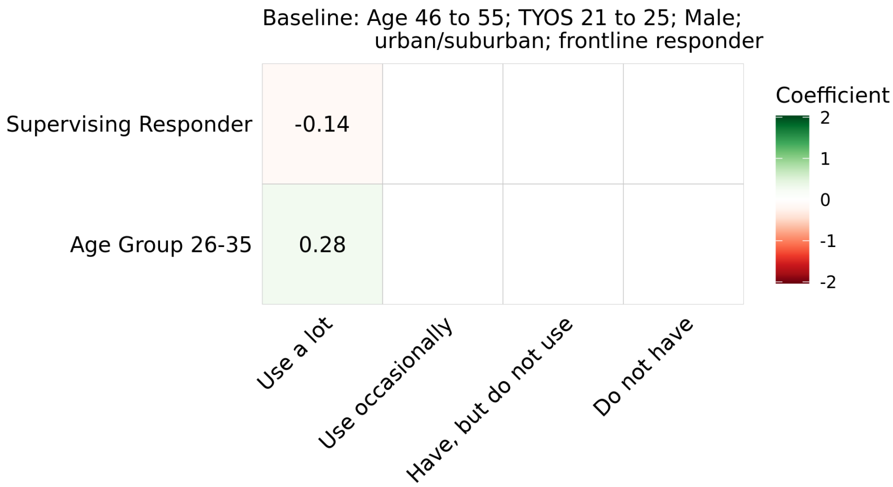

Fig. B.5.2.1 LE Device Usage Frequency: Body Camera

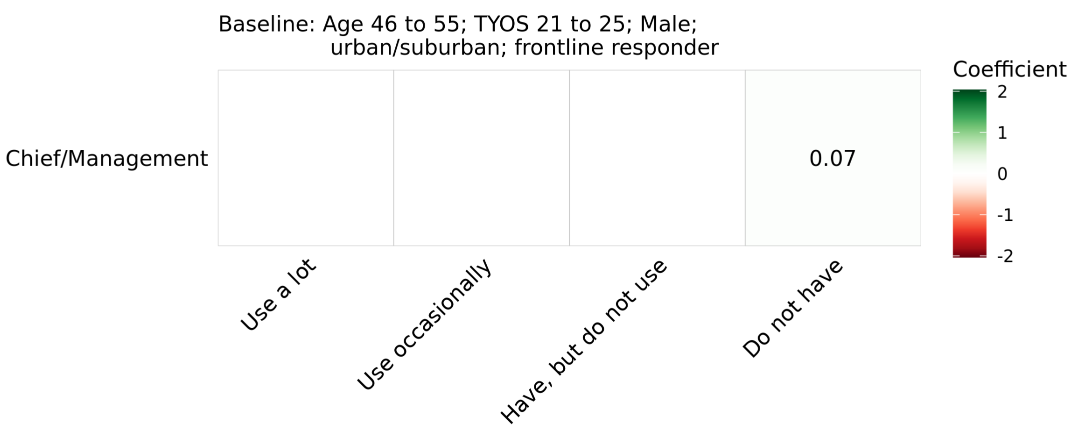

Fig. B.5.2.2 LE Device Usage Frequency: Personal Smartphone

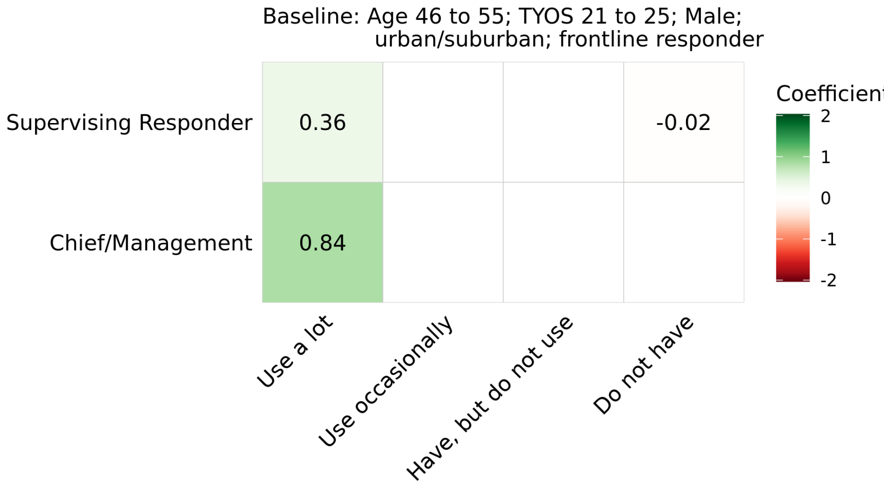

Fig. B.5.2.3 LE Device Usage Frequency: Work-issued Smartphone

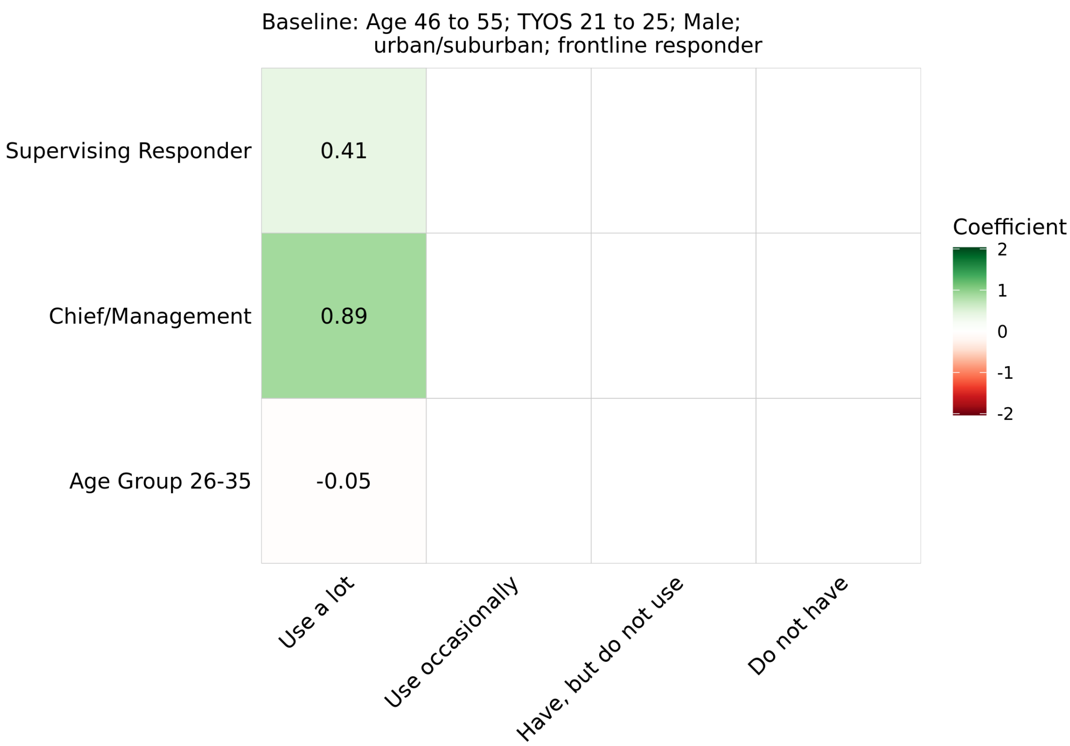

Fig. B.5.2.4 LE Device Usage Frequency: Desktop Computer

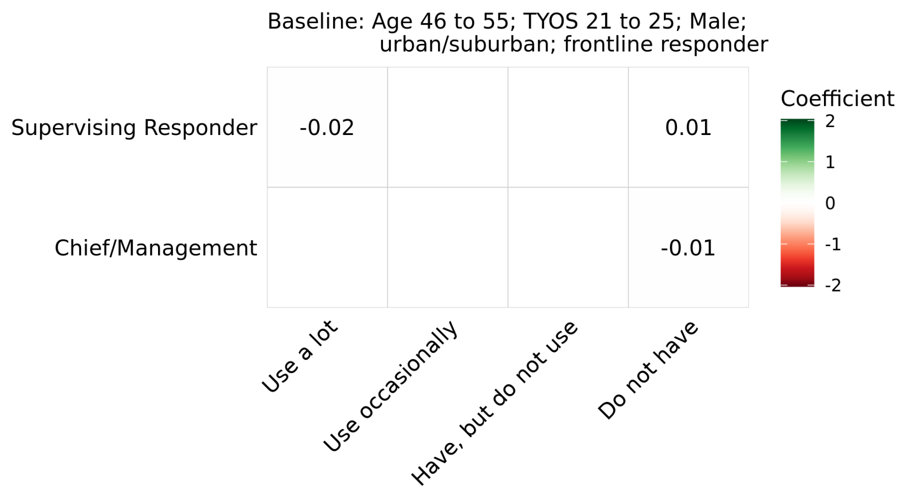

Fig. B.5.2.5 LE Device Usage Frequency: Dash Camera

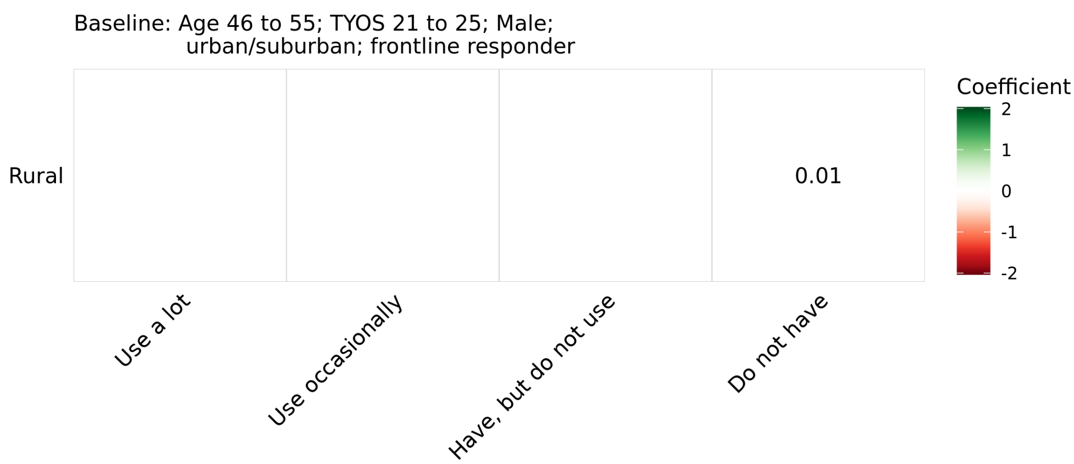

Fig. B.5.2.6 LE Device Usage Frequency: Fingerprint Scanner

Fig. B.5.2.7 LE Device Usage Frequency: Laptop

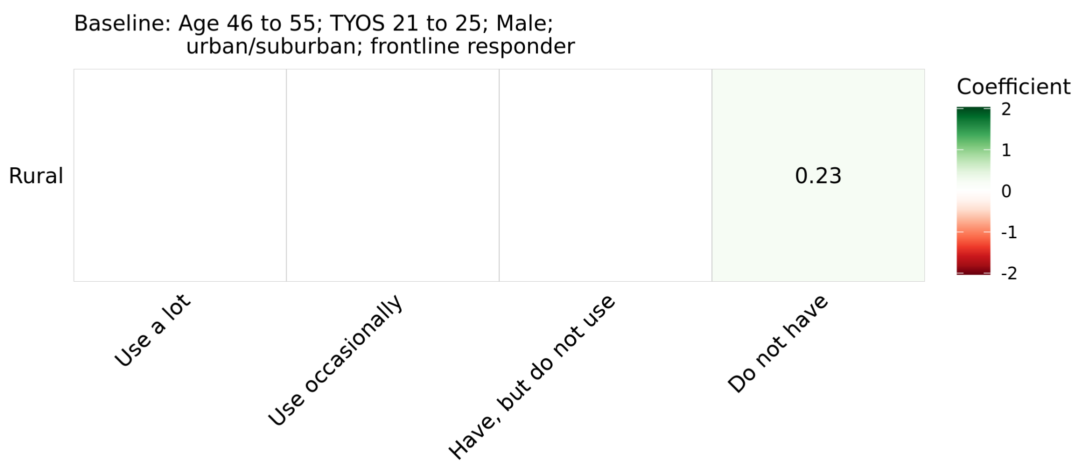

Fig. B.5.2.8 LE Device Usage Frequency: LPR

Fig. B.5.2.9 LE Device Usage Frequency: MDT/MDC

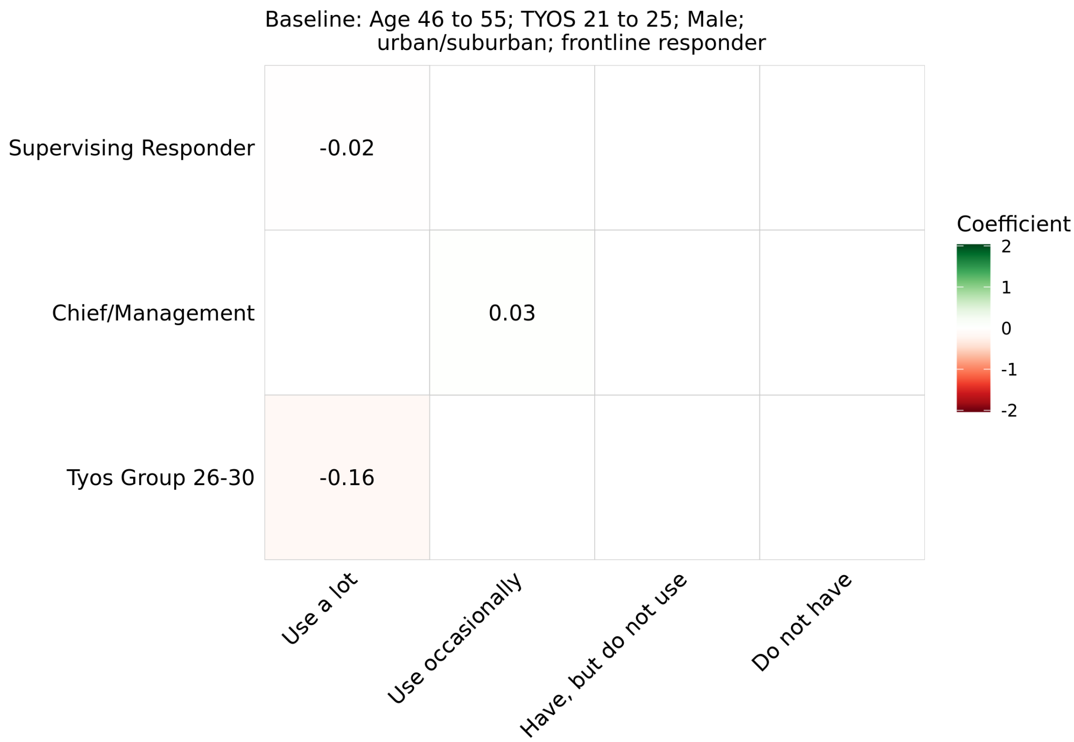

Fig. B.5.2.10 LE Device Usage Frequency: Corded Microphone

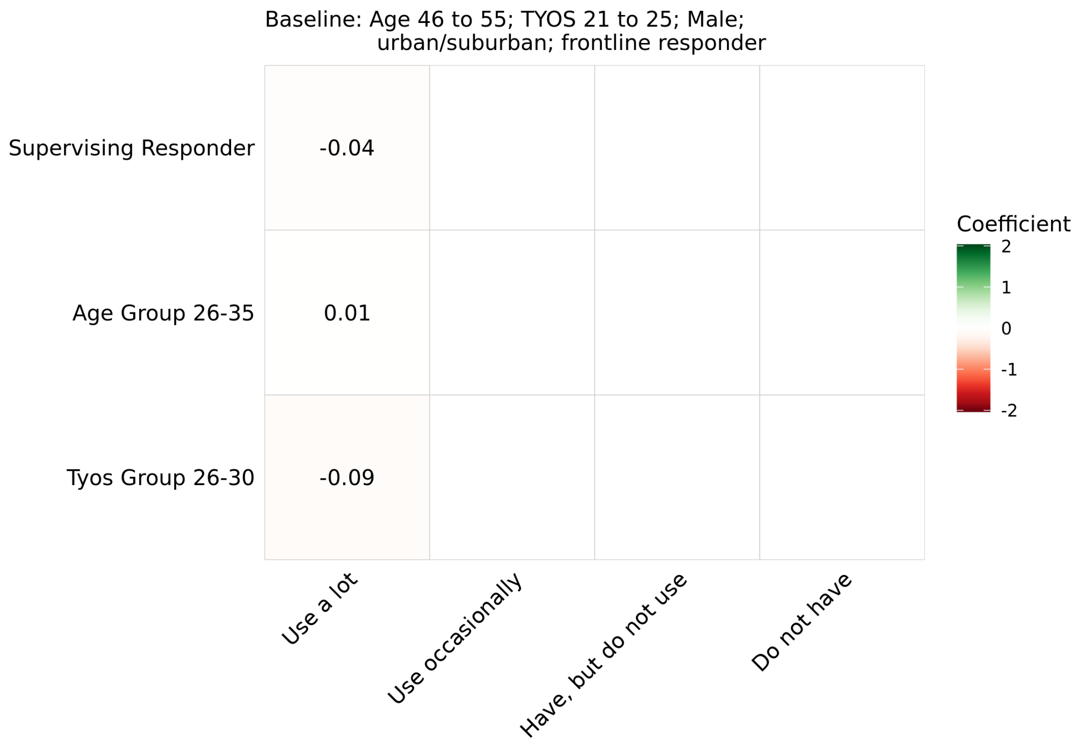

Fig. B.5.2.11 LE Device Usage Frequency: Portable Radio

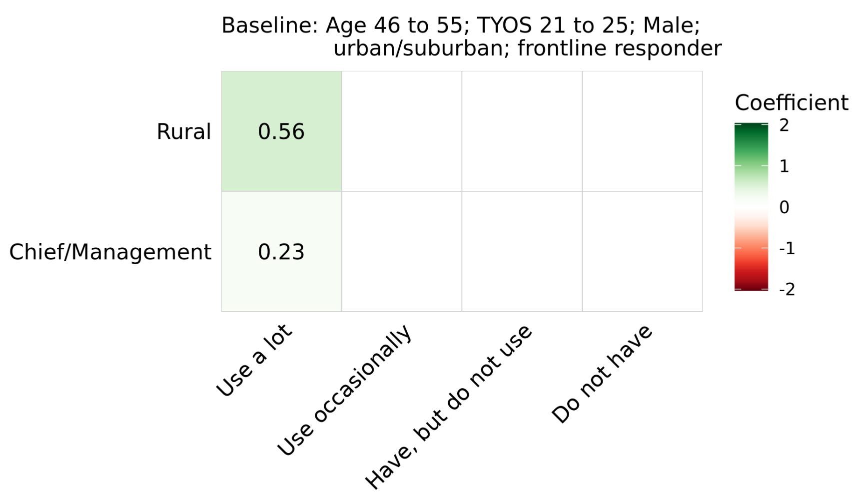

Fig. B.5.2.12 LE Device Usage Frequency: In-vehicle Radio

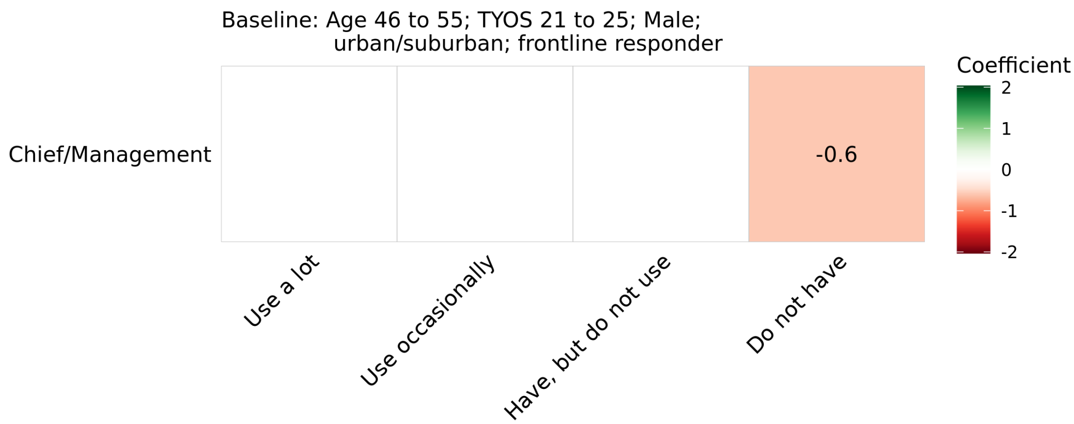

Fig. B.5.2.13 LE Device Usage Frequency: Tablet

B.5.3. Problems with Technology

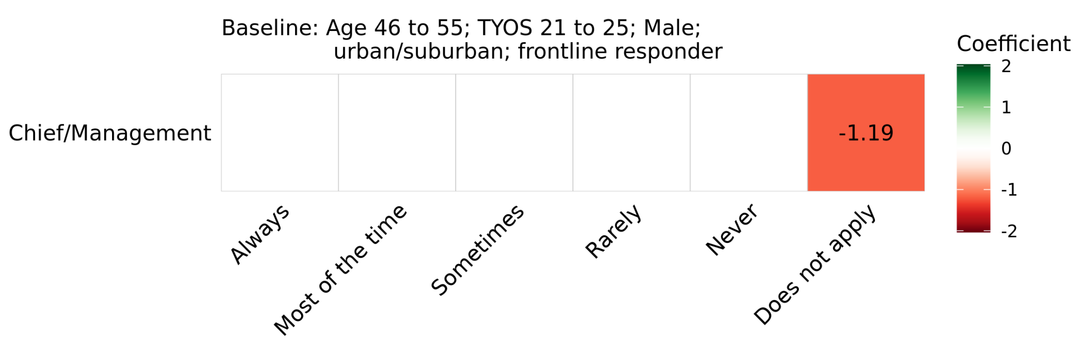

Fig. B.5.3.1 LE Problems with Body Camera: Price

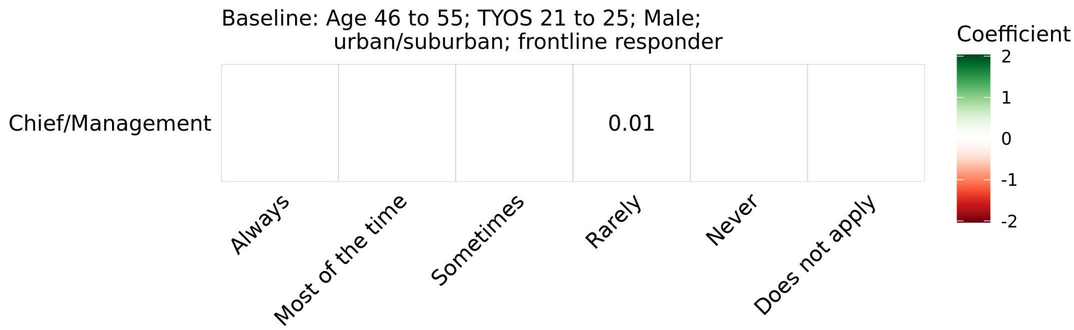

Fig. B.5.3.2 LE Problems with Smartphone: Dropped Call

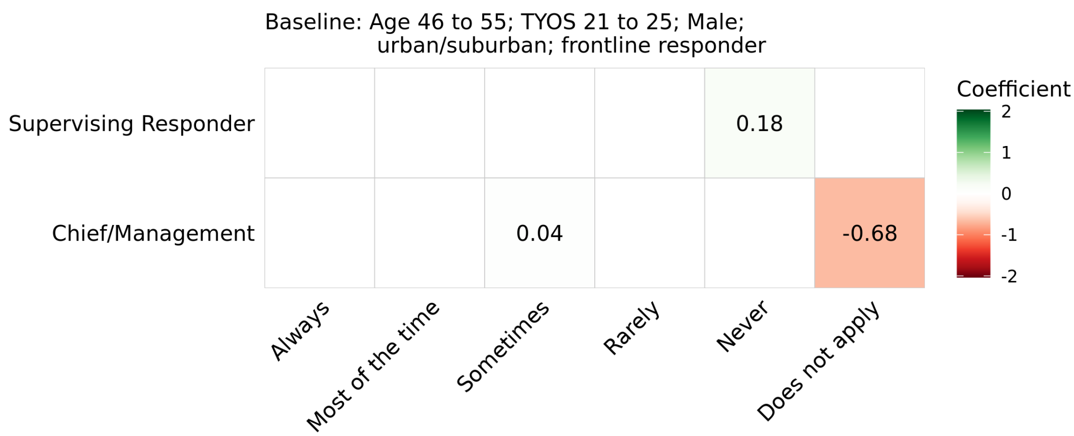

Fig. B.5.3.3 LE Problems with Smartphone: Price

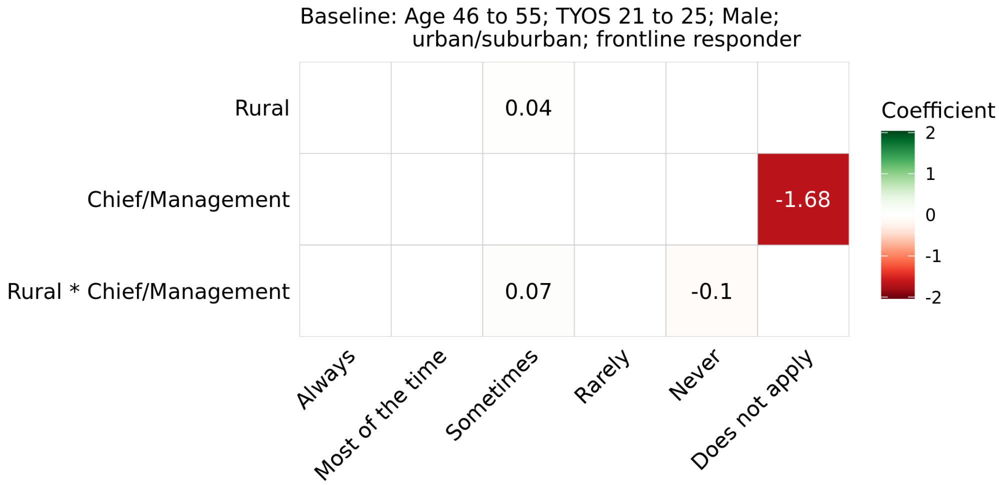

Fig. B.5.3.4 LE Problems with Desktop Computer: Price

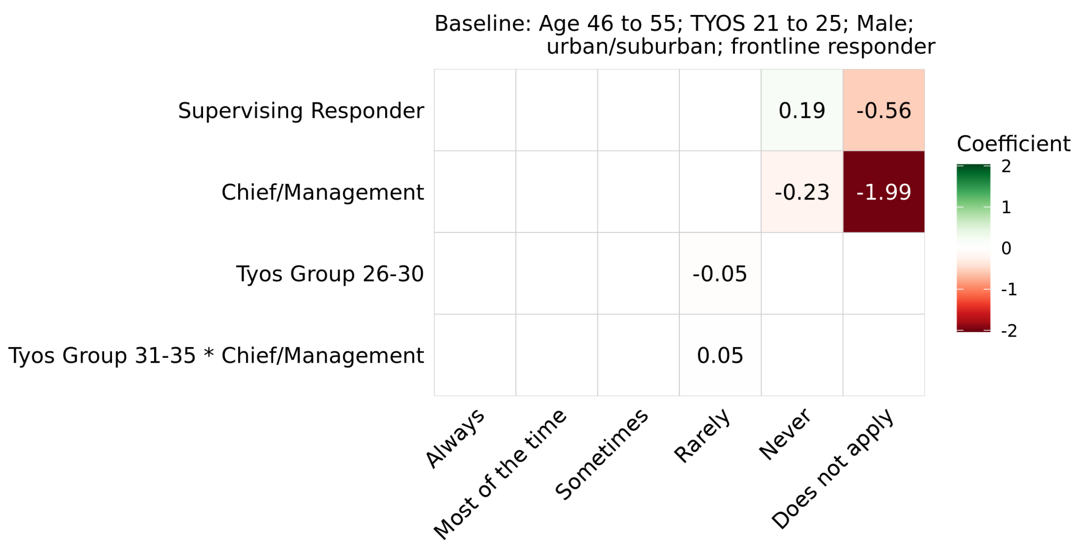

Fig. B.5.3.5 LE Problems with Laptop: Price

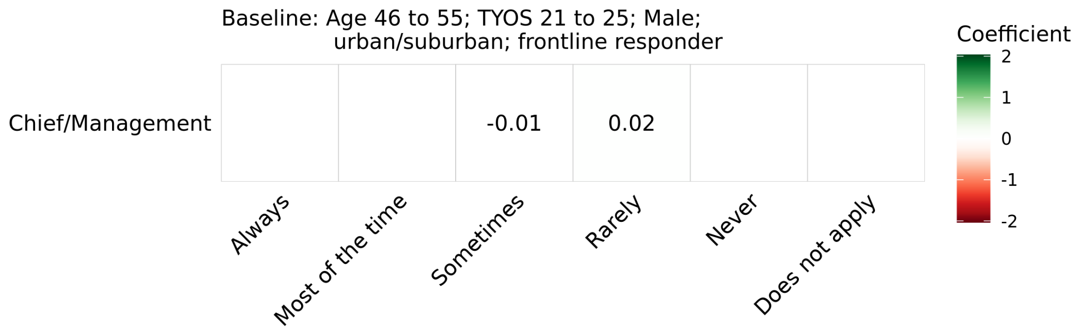

Fig. B.5.3.6 LE Problems with MDT/MDC: CAD

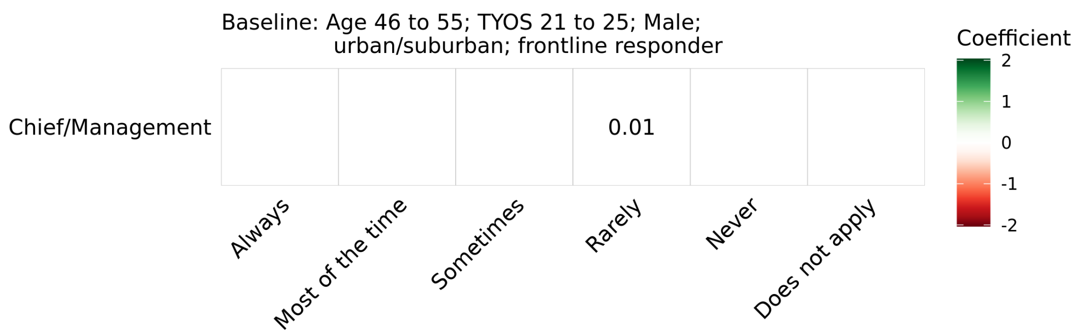

Fig. B.5.3.7 LE Problems with MDT/MDC: Mapping and Navigation

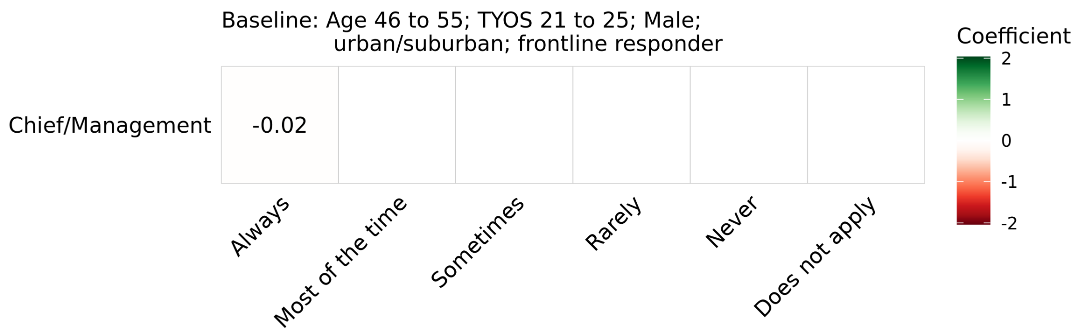

Fig. B.5.3.8 LE Problems with MDT/MDC: Old

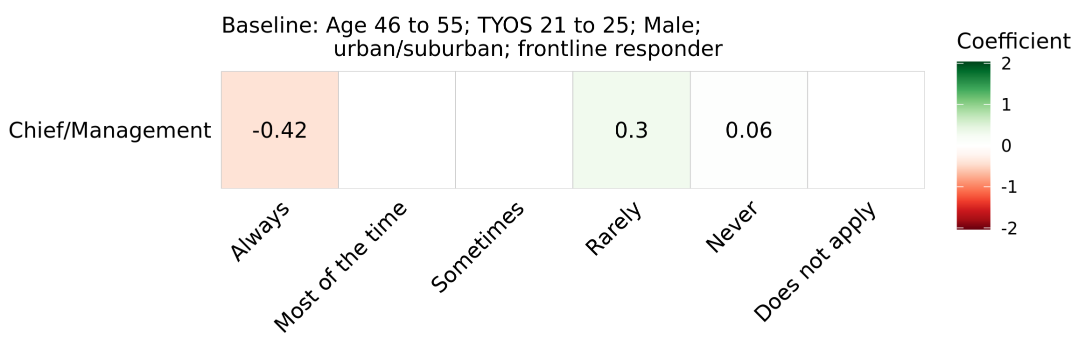

Fig. B.5.3.9 LE Problems with MDT/MDC: Portable

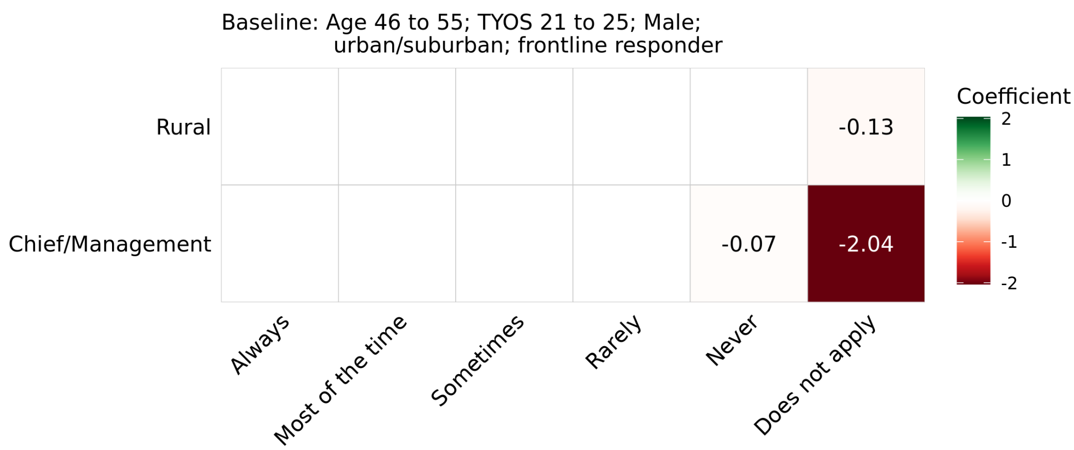

Fig. B.5.3.10 LE Problems with MDT/MDC: Price

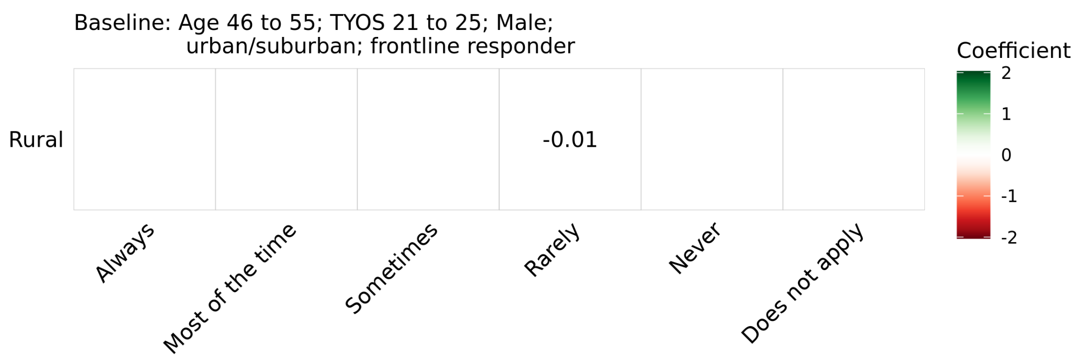

Fig. B.5.3.11 LE Problems with Radio: Coverage

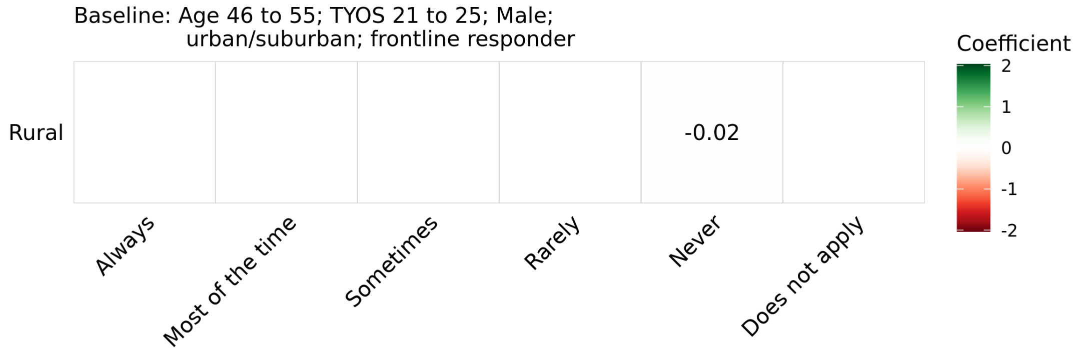

Fig. B.5.3.12 LE Problems with Radio: Interoperability

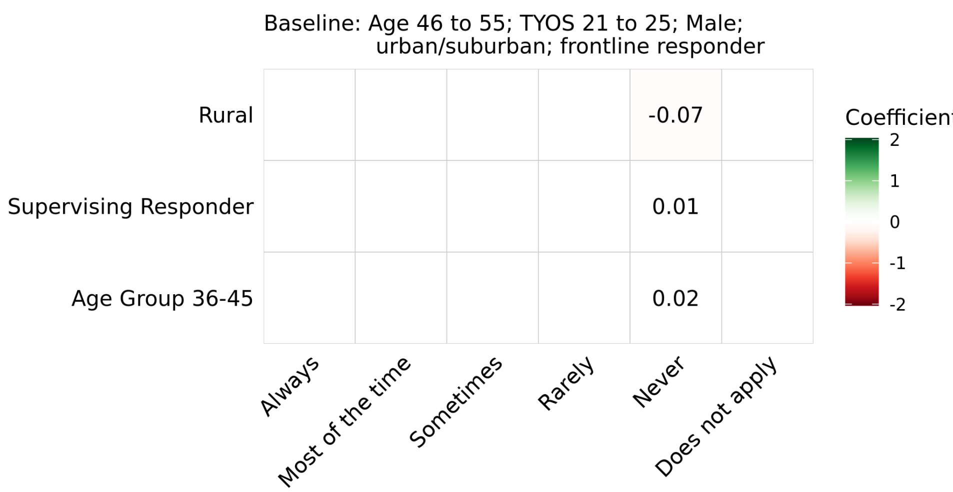

Fig. B.5.3.13 LE Problems with Radio: Old

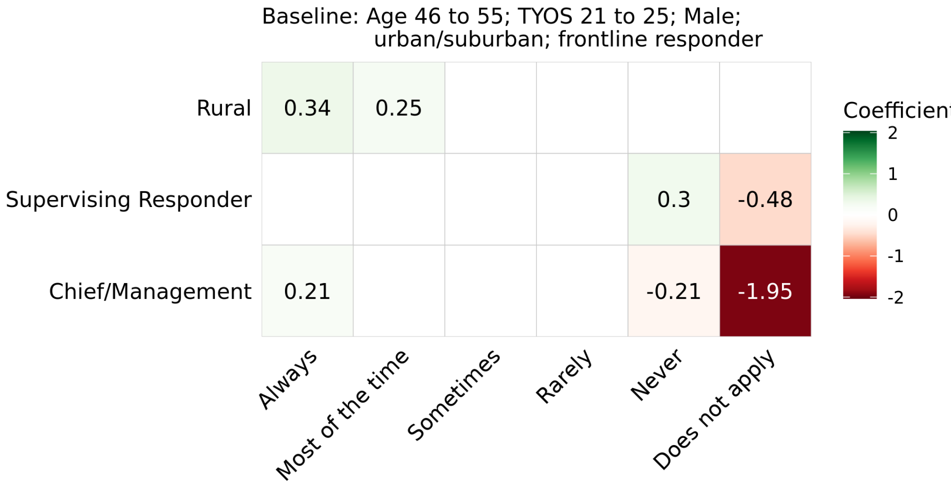

Fig. B.5.3.14 LE Problems with Radio: Price

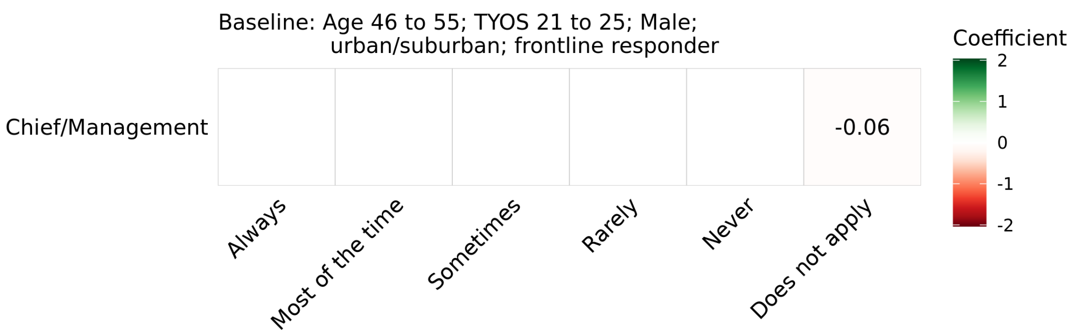

Fig. B.5.3.15 LE Problems with Tablet: Price

B.5.4. Application/Software Frequency

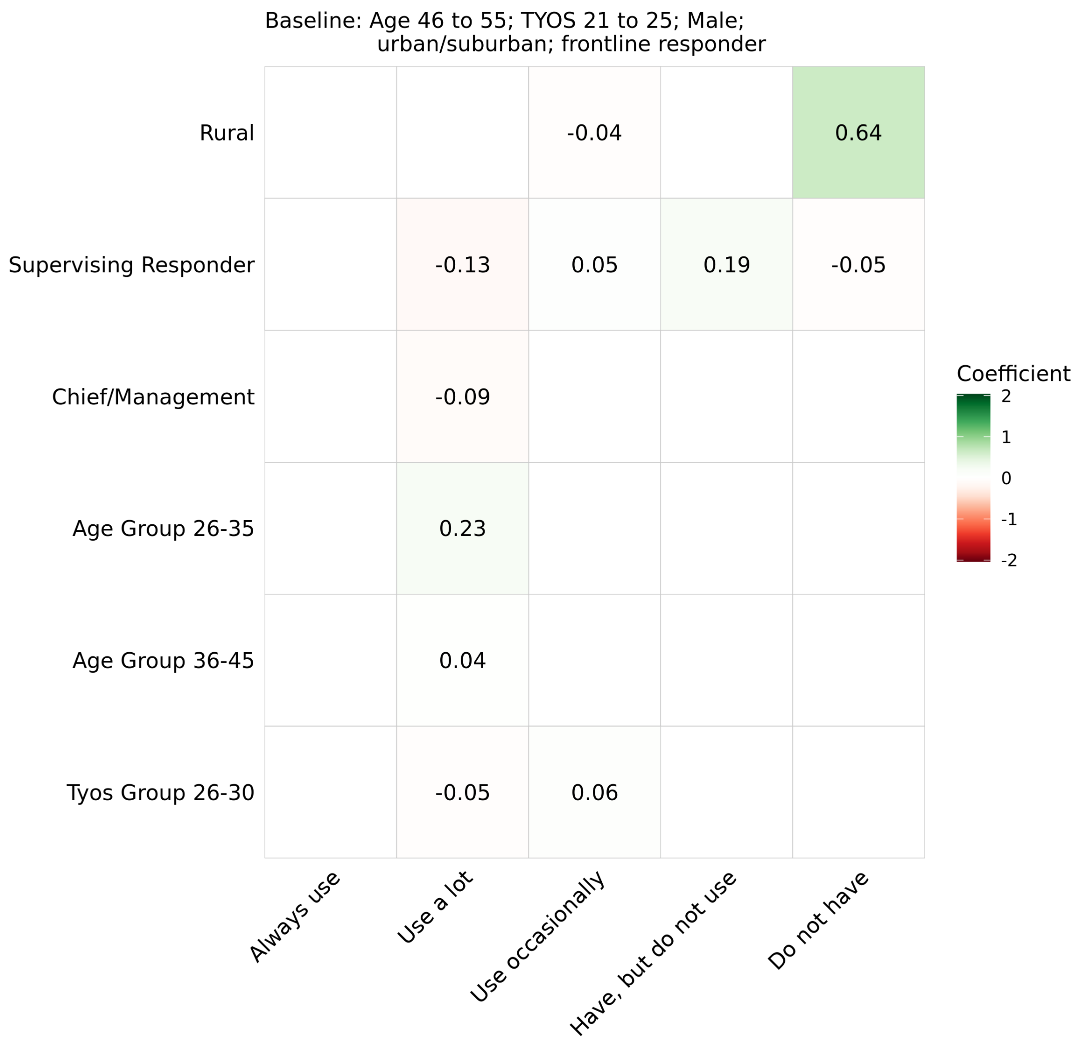

Fig. B.5.4.1 LE Apps/Software Usage Frequency: CAD

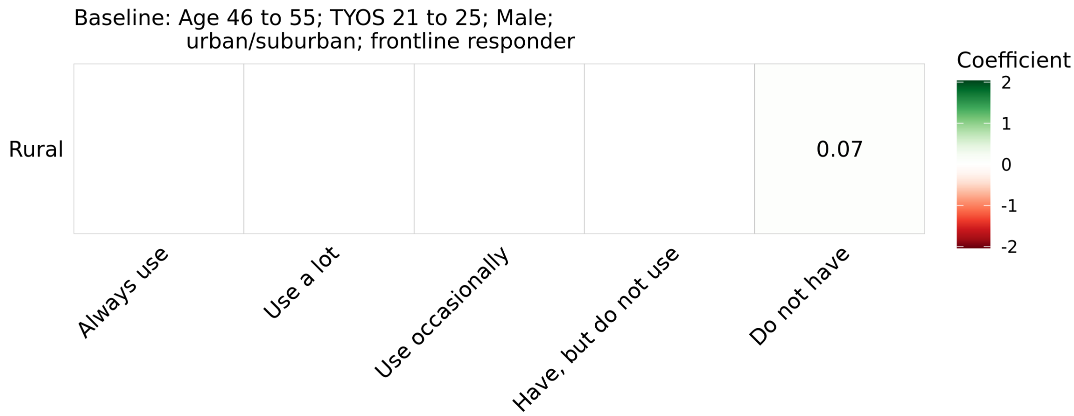

Fig. B.5.4.2 LE Apps/Software Usage Frequency: FR Vehicle Tracking

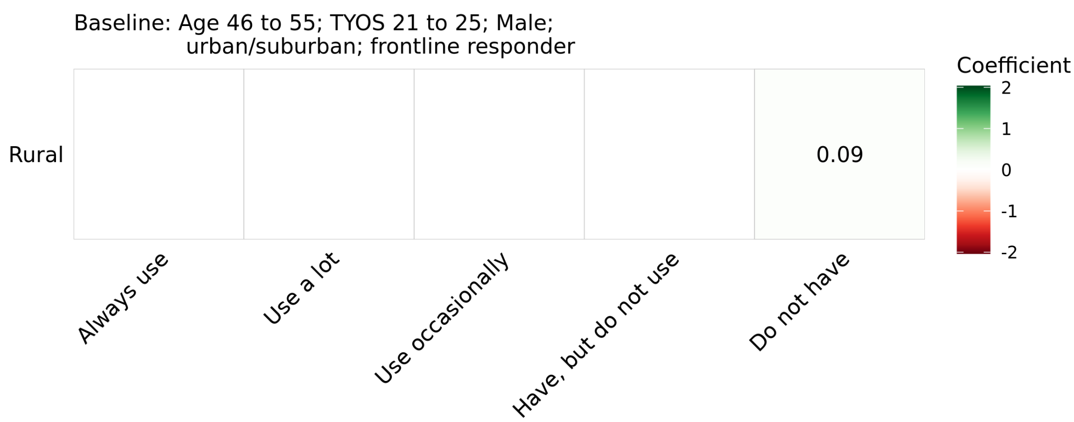

Fig. B.5.4.3 LE Apps/Software Usage Frequency: Language Translation

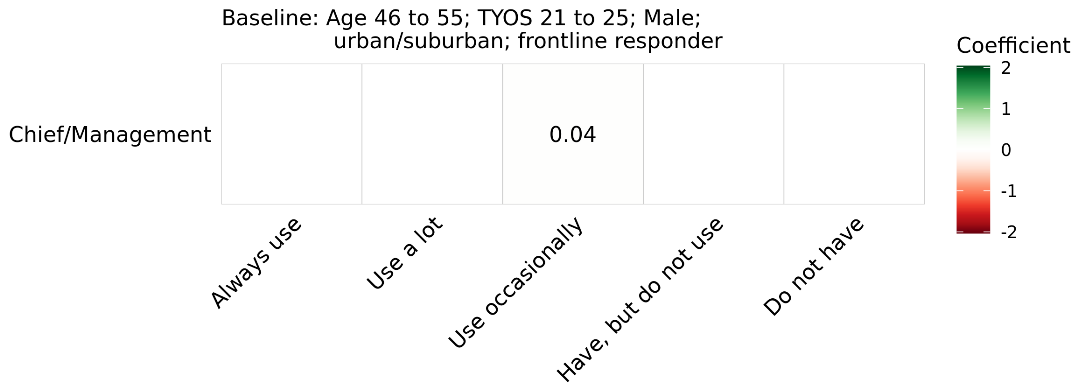

Fig. B.5.4.4 LE Apps/Software Usage Frequency: Mapping/Navigation

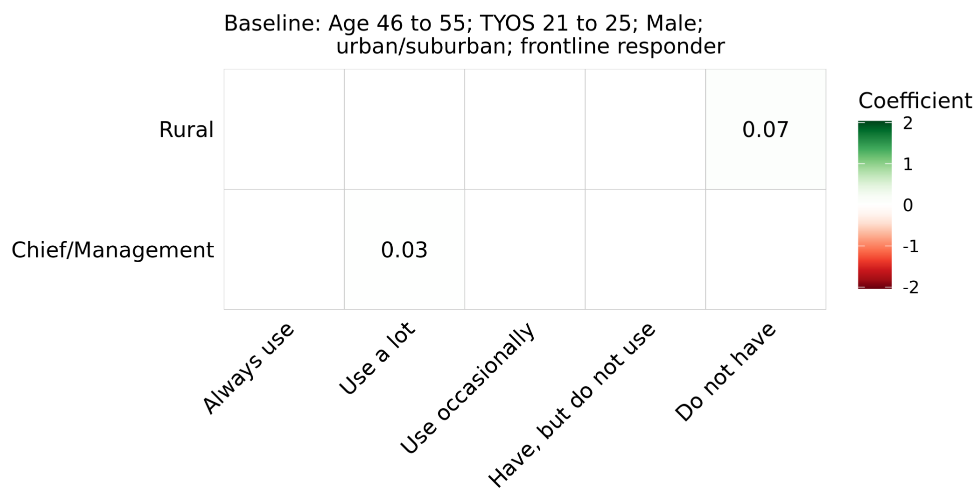

Fig. B.5.4.5 LE Apps/Software Usage Frequency: Electronic Policies/Laws

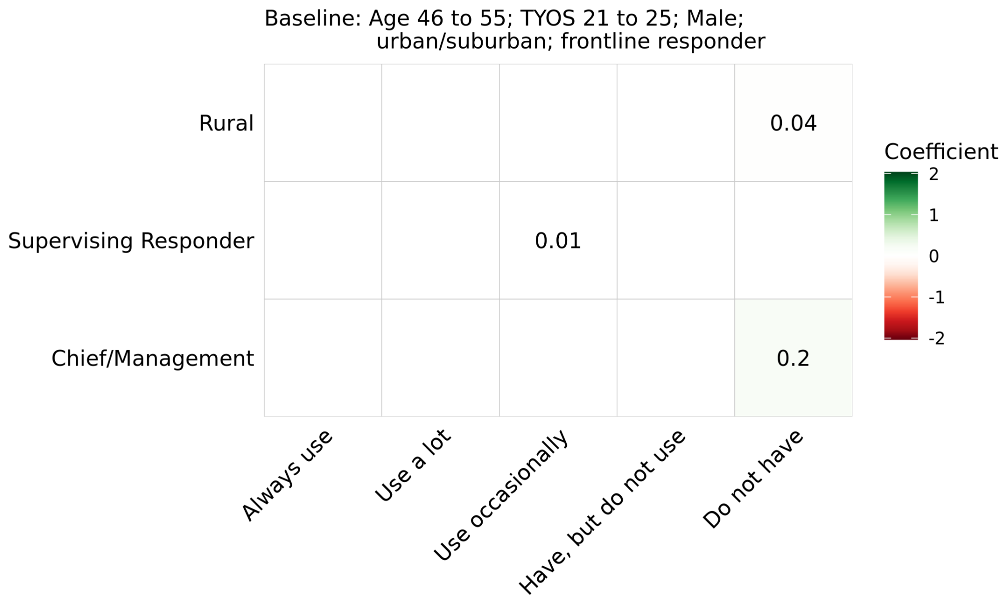

Fig. B.5.4.6 LE Apps/Software Usage Frequency: Report Writing

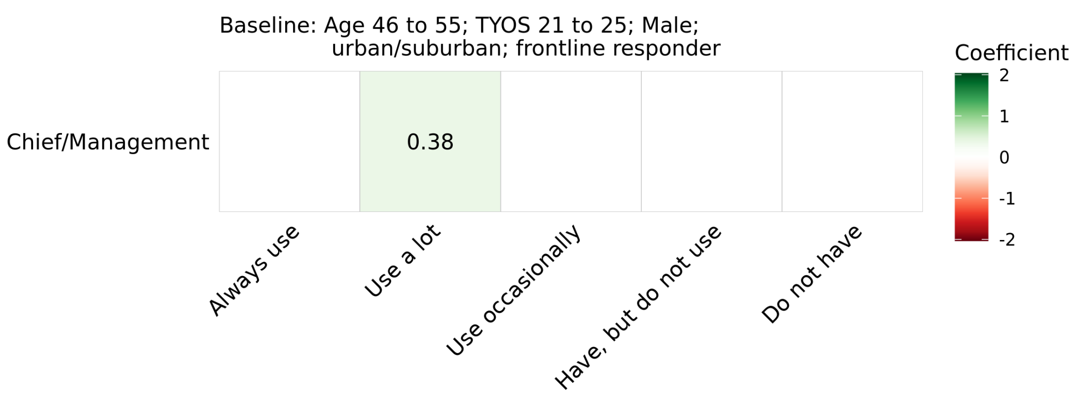

Fig. B.5.4.7 LE Apps/Software Usage Frequency: RMS

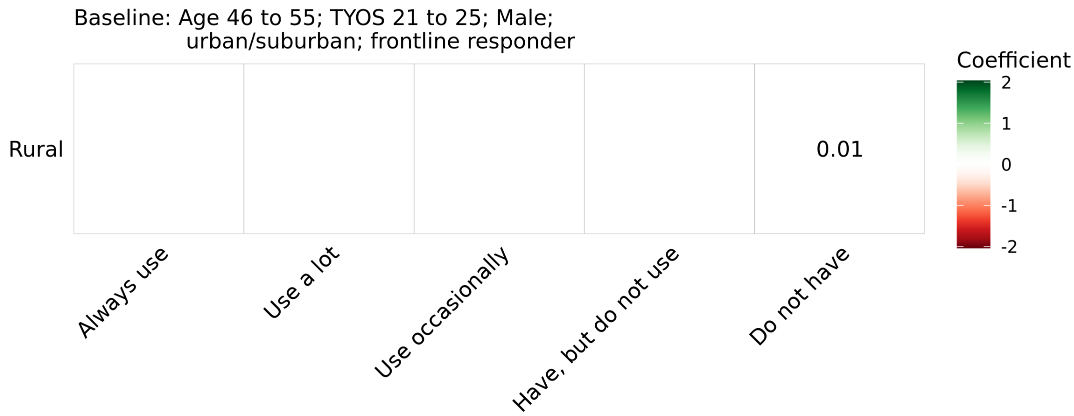

Fig. B.5.4.8 LE Apps/Software Usage Frequency: Traffic

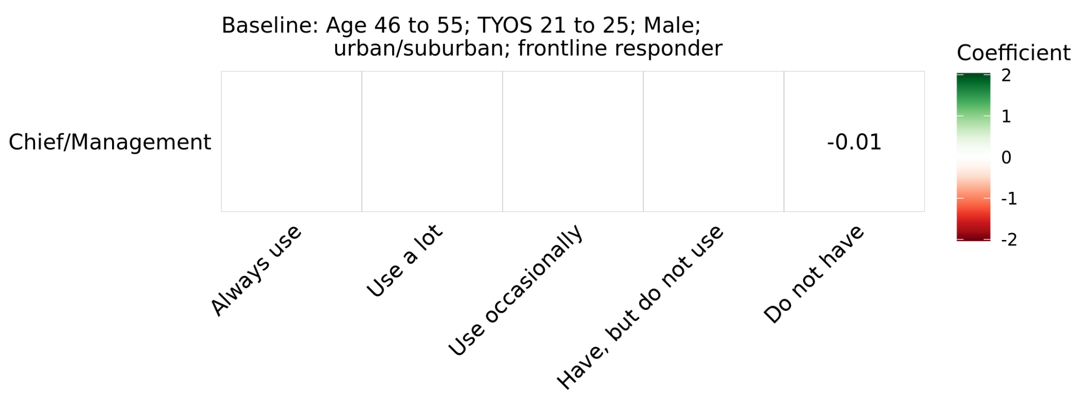

Fig. B.5.4.9 LE Apps/Software Usage Frequency: Weather

B.5.5. Futuristic Technology

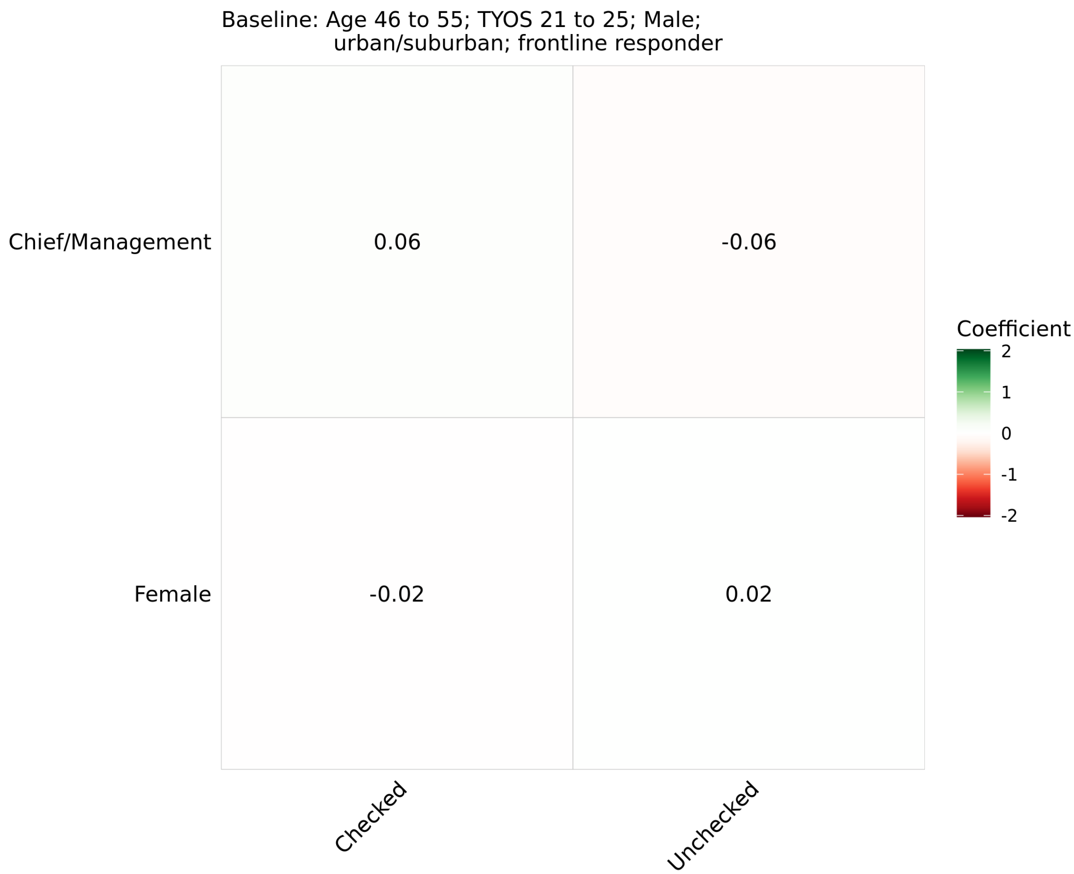

Fig. B.5.5.1 LE Perceived Usefulness of Futuristic Technology: Body Camera

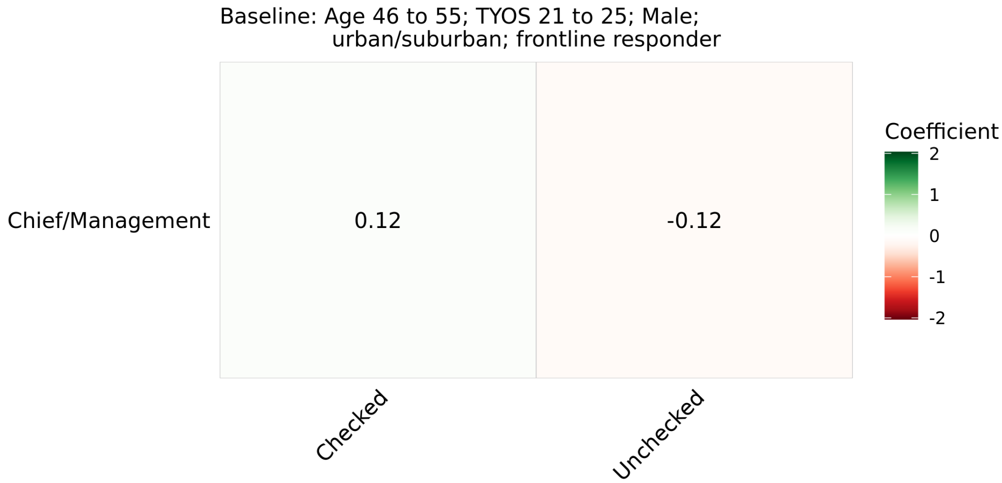

Fig. B.5.5.2 LE Perceived Usefulness of Futuristic Technology: Dash Camera

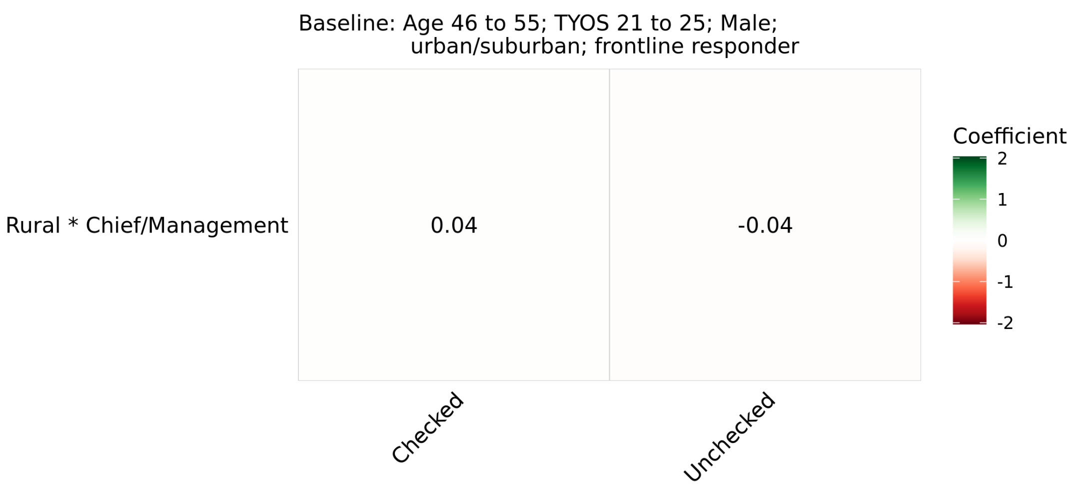

Fig. B.5.5.3 LE Perceived Usefulness of Futuristic Technology: Fingerprint Scanner

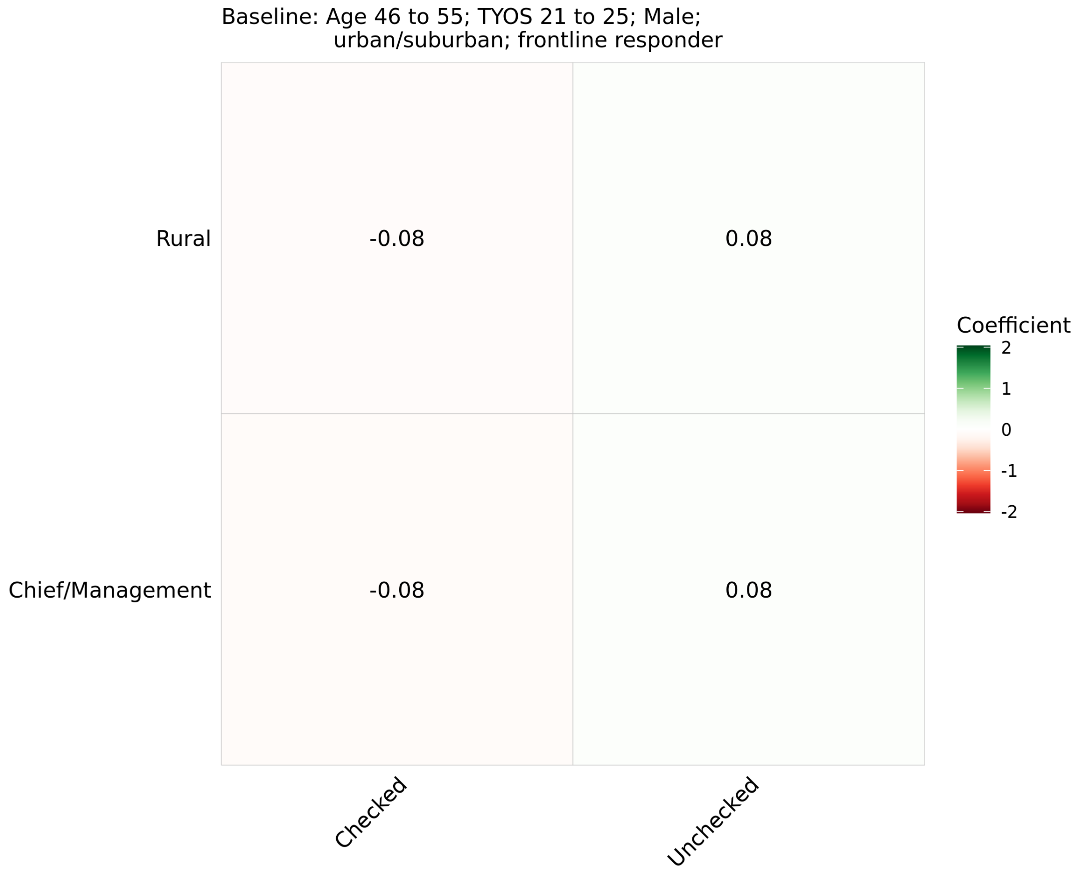

Fig. B.5.5.4 LE Perceived Usefulness of Futuristic Technology: Facial Recognition

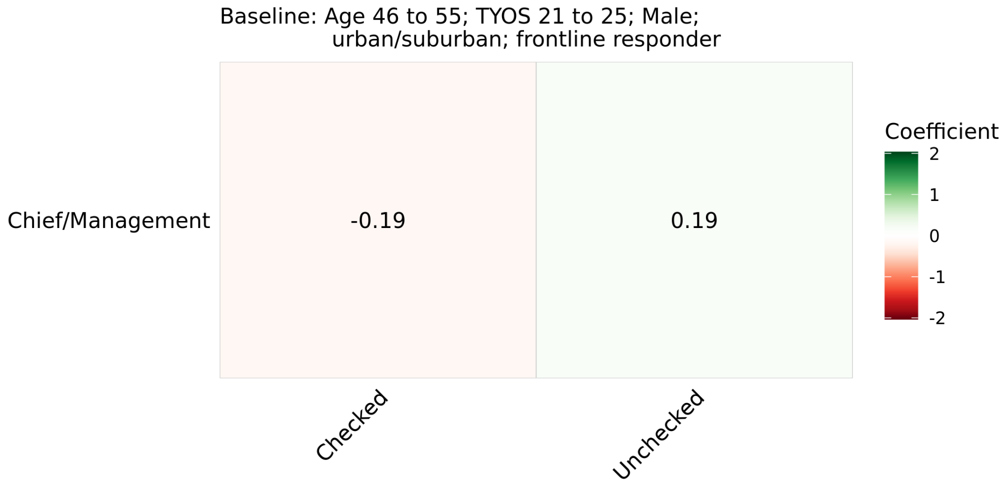

Fig. B.5.5.5 LE Perceived Usefulness of Futuristic Technology: Flip Phone

Fig. B.5.5.6 LE Perceived Usefulness of Futuristic Technology: One Login

Fig. B.5.5.7 LE Perceived Usefulness of Futuristic Technology: LPR

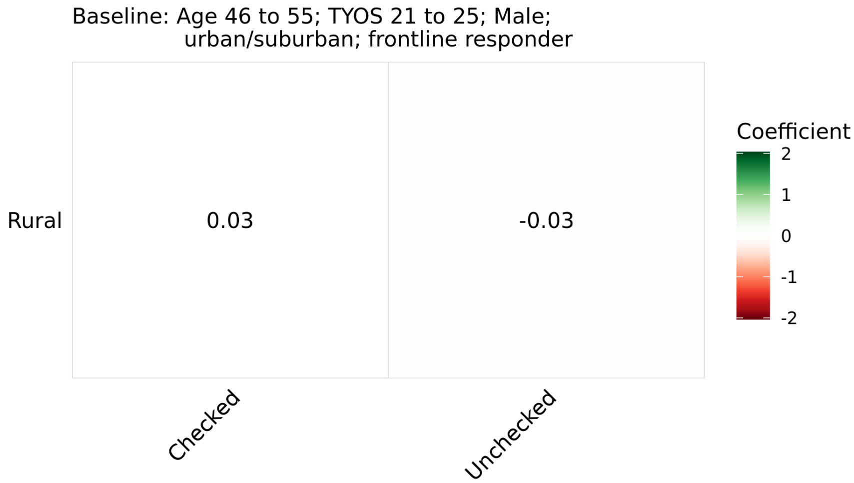

Fig. B.5.5.8 LE Perceived Usefulness of Futuristic Technology: MDT/MDC

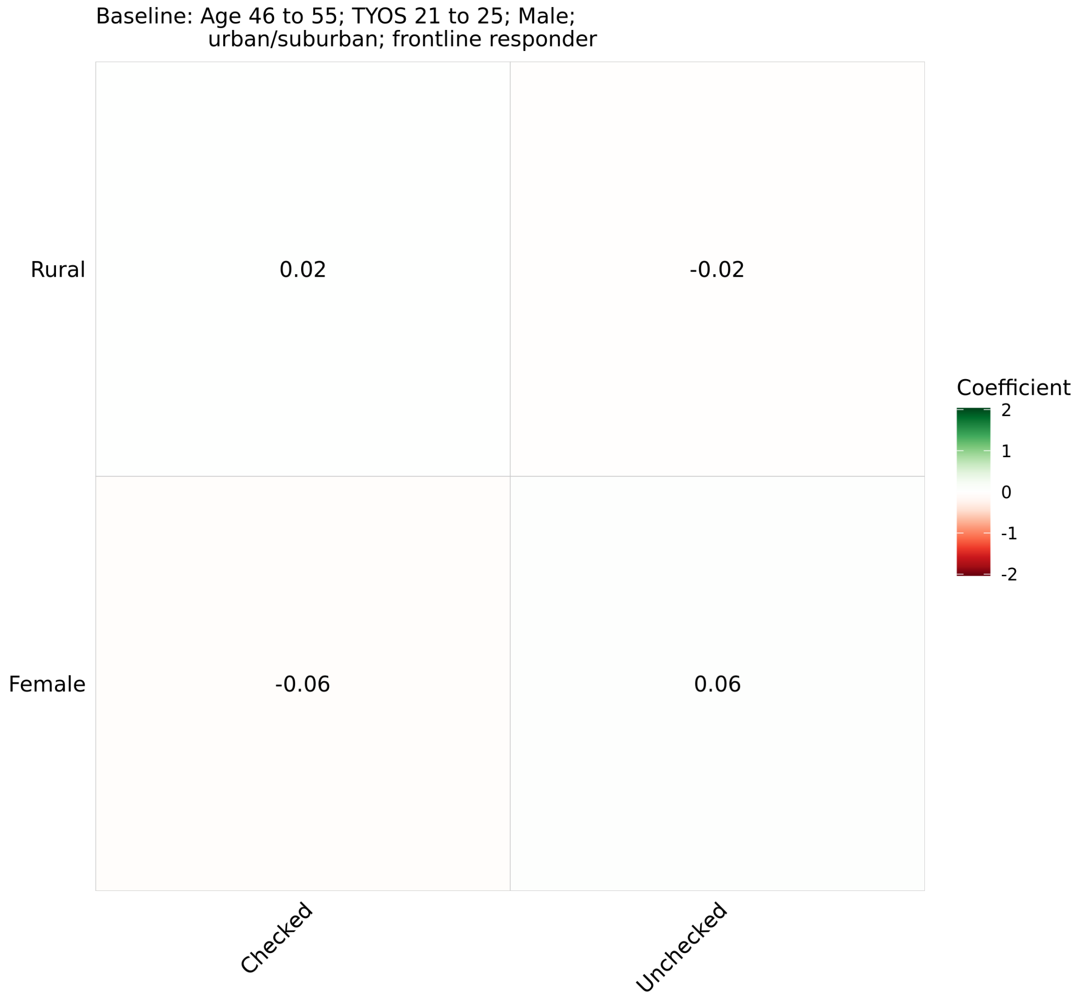

Fig. B.5.5.9 LE Perceived Usefulness of Futuristic Technology: Thermal Imaging

B.5.6. Virtual Reality

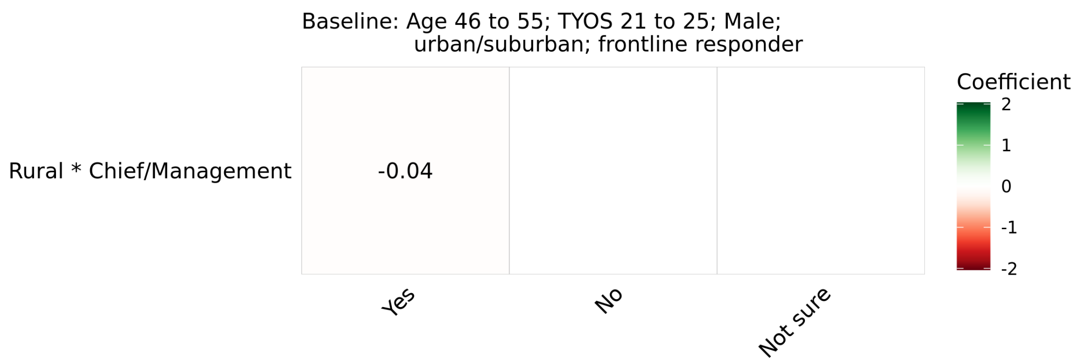

Fig. B.5.6.1 LE VR Training Useful

Appendix C. Glossary

AED	Automatic External Defibrillator
AVL	Automatic Vehicle Location
CAD	Computer-Aided Dispatch
COMMS	Communication Center & 9-1-1 Services
EMS	Emergency Medical Services
EPCR	Electronic Patient Care Reporting
ERG	Emergency Response Guide
FEMA	Federal Emergency Management Agency
FF	Fire Service, Fire Fighting
FR	First Responder
LE	Law Enforcement
LTE	Long-term Evolution
LPR	License Plate Reader
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
RMS	Records Management System
TIC	Thermal Imaging Camera
UI/UX	User Interface/User Experience
VR	Virtual Reality