



Firefighters' Strategies for Processing Spatial Information During Emergency Rescue Searches

Julia Cope^{1,6}, Marco Arias^{2,6}, DeAndre' Williams^{3,6},
Cristina Bahm^{4,6}✉, and Vusumuzi Ngwazini^{5,6}

¹ University of Pittsburgh, Pittsburgh, USA

² California State Polytechnic University, Pomona, USA

³ Indiana University, Bloomington, USA

⁴ La Roche College, Pittsburgh, USA

cristina.bahm@laroche.edu

⁵ Oakwood University, Huntsville, USA

⁶ iSchool Inclusion Institute, Pittsburgh, USA

Abstract. Firefighters face a unique wayfinding situation when they are in emergency situations. This study aims to examine the strategies that firefighters use when in an emergency situation to provide insights for future research. In this study, we interview 12 firefighters from three regions of the US to understand the navigation strategies they use during rescue missions.

After analyzing the results using grounded theory as a basis, we found that firefighters use various navigational strategies that serve one of four purposes, (1) to build a path, (2) to improve vision, (3) to create a cognitive map, and (4) to make directional decisions. From here, we hope to link these unique navigational purposes to actual tools that can help firefighters save lives.

Keywords: Spatial cognition · Firefighters · Human factors

1 Introduction

Indoor navigation is complicated by factors such as repetitive structure, stacked floor plans, and a lack of recognizable landmarks [4, 6, 8]. These difficulties are further complicated for firefighters during rescue searches due to the conditions under which they must navigate. Conditions such as low visibility due to dark smoke and limited movement due to heavy gear and hot gases means firefighters often crouch or crawl on the ground while searching. In many cases, firefighters do not know where survivors will be or what to expect inside the building. Additionally, the structure of the house may change due to collapses or spreading fire, potentially making past routes unnavigable.

In this paper we define navigational strategies as behavioral patterns between the subject, the environment, and any tools that decrease the cognitive load of navigation. The navigation strategies that firefighters use must help them to overcome the unique challenges they face while trying to navigate indoor spaces. The design of user-centered wayfinding tools must be informed by the interactions between the user's

internal representation of space and the environment itself [3, 9]. It follows that to create personalized navigation aids for firefighters, we must first understand the current navigation strategies and tools in use by firefighters during emergency rescue searches.

This work is a continuation of the work started in [9] which pointed out the need for cognitively salient wayfinding aids for firefighters specifically. In this study, we interview 12 firefighters from three regions in the USA, in California, Pennsylvania, and Maryland, to investigate the navigational strategies they use during rescue searches. After analyzing the results using grounded theory as a basis, we found that firefighters use various navigational strategies that serve one of four purposes, (1) to build a path, (2) to improve vision, (3) to create a cognitive map, and (4) to make directional decisions. From here, we hope to link these unique navigational purposes to actual tools that can help firefighters save lives.

2 Literature Review

The broad purpose of a navigational strategy is to help the user interact with the environment in a “consistent and unambiguous way,” Freksa [3]. One reason it is difficult to navigate in a complex indoor environment according to [5] is that staircases, or floor to floor transition points, are often not depicted well on wayfinding aids. Battles and Fu [1] examined a variety of wayfinding strategies that are adopted by travelers using a schematic map of a multi level building.

[2] showed how the role of background knowledge is used to evaluate indoor landmarks. This coupled with the fact that firefighters face a particular set of difficulties that call for cognitively salient wayfinding aids [9] means that it is important that we take into account what firefighters actually do in the field when they are on rescue missions and design our tools around that.

3 Methodology

This research intends to lay the groundwork for understanding the strategies and tools that firefighters currently use so that advanced technologies can be applied to specifically fit the needs of firefighters in the field. To begin examining this, we performed semi-structured interviews with 12 firefighters, asking them to verbally explain how they navigate indoor environments during rescue searches. Table 1 displays information about each participant.

After gathering basic demographic information, we asked participants about how they were trained to navigate as a firefighter and what they believed were the most effective strategies for indoor searches. We also asked firefighters what problems they encounter during indoor navigation and any potential solutions they could imagine. All interviews were recorded and later transcribed. Transcriptions were then analyzed using a thematic analysis methodology based in grounded theory. We analyzed the verbalizations of all firefighters and grouped their navigational strategies into four categories according to the purpose of the strategy.

Table 1. Demographic information for participants

Participant	Number of years active as a firefighter	Last active location
1	25	Pittsburgh, PA
2	19	Pittsburgh, PA
3	3	Lake Elsinore, CA
4	33	Kensington, MD
5	3.5	San Diego, CA
6	20	Pittsburgh, PA
7	12	Pittsburgh, PA
8	10	Kensington, MD
9	10	Wheaton, MD
10	15	Wheaton, MD
11	26	Wheaton, MD
12	16	Los Angeles, CA

4 Results and Discussion

As shown below in Fig. 1, firefighters reported using a variety of different strategies to navigate indoor spaces. Using grounded theory, we analyzed the verbalizations of all firefighters and grouped their strategies into four categories according to the purpose of the strategy in helping the firefighter achieve their goals of searching the building and exiting safely.

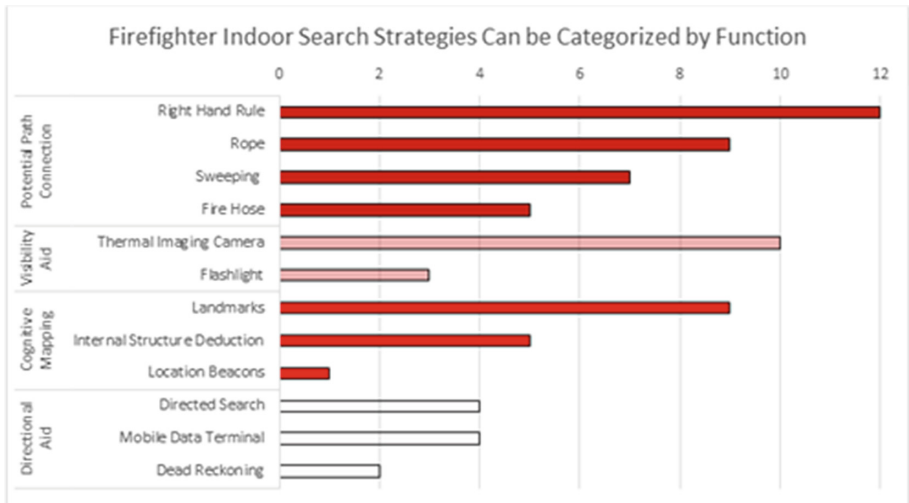


Fig. 1. Figure showing firefighters' indoor search strategies

Although from different parts of the country and with different years of service, there were clear similarities in the way that firefighters processed and used spatial information in an environment to find their way around. We were able to group these into four groups:

- Potential Path Connection Strategies as Navigational Aids
- Visibility Aids as Navigational Aids
- Cognitive Mapping Strategies as Navigational Aids
- Directional Aids as Navigational Aids

4.1 Potential Path Connection Strategies as Navigational Aids

The location and number of survivors in the building is often unknown, so firefighters must perform an extensive search of the building. This proves difficult due to low visibility and potentially changing structure of the indoor space. Firefighters use specific search patterns, which we have named potential path connection strategies, to perform an extensive search while remaining oriented and connected to a path to an exit.

An example of a potential path connection strategy is the right-hand rule, where firefighters feel their way around a room by keeping their right side along the wall to search the entire perimeter of a room, before moving on to the next room. The right-hand rule allows firefighters to perform an extensive search of the building while remaining connected to the wall. As seen in Fig. 1, all firefighters reported using the right-hand rule while navigating indoors during emergency situations. Firefighter 2 described, “In a fire we are trained to feel the wall as a left-hand or right-hand search and stick to that because if you need to get out you can turn around and follow that.” Additionally, firefighter 3 mentioned that the right-hand search “allows you to do a full circle inside the house... that way you don’t get lost.” The idea is that when firefighters remain connected to the wall, they remain connected to a path that either brings them all the way through the building or can be traced backwards to an exit. However, this is only a potential path out since structures may collapse and fires may spread, which can prevent previous routes from being taken. Firefighters described the right-hand rule as the baseline strategy used for indoor searches, upon which other tools and strategies built.

Another potential path connection strategy is sweeping, which is when firefighters extend their search off the wall by feeling with their bodies and tools that lengthen their wingspan. Firefighter 7 says he was trained to “function as a two-person team. The first person can be the orientation guy, whose primary job is to follow the wall and search for landmarks such as windows, doors...” The second person will extend the search by sweeping areas further away from the wall. The sweeping firefighter will call out the landmarks that they encounter, such as any furniture. Firefighter 10 explained, “you never go farther than where you can hear your partner, you know, if we go into a fire, I like to be able to see you. If I can no longer see you, [due to low visibility from smoke], I want to be right there... within proximity.” The sweeping partner(s) extend the search into the room while visually or verbally keeping in contact with the orientation partner. Sweeping is one of the most commonly mentioned strategies used during rescue missions and is used in conjunction with right-hand rule.

Additionally, for large area searches, firefighters extend their search by using rope. Firefighter 6 described using “a piece of rope or a piece of webbing...[to] give an anchor point if the visibility is bad.” A rope can be tied off at a fixed point or held by another firefighter to allow a firefighter to extend the search farther into a large area while being anchored to a fixed position. Similarly, to a rescue rope, a fire hose can also be used as a path to an exit: firefighters can follow to hose line back outside.

4.2 Visibility Aids as Navigational Aids

One of firefighters' challenges during rescue searches is limited visibility inside the structure due to heavy smoke. Visibility aids function as navigational aids as they provide the firefighter with more spatial information than they could directly experience from the environment without the tool. Many firefighters report using a handheld thermal imaging camera which allows them to see heat signatures as seen in Fig. 2. Firefighter 3 mentions that “the thermal imaging camera is really effective...if we are inside a structure that has heavy smoke and you can't see through it, that camera allows us to see heat signatures.” Firefighters additionally use flashlights which are typically attached to their jackets. The use the flashlights to see in front of them as well as to be visible to other firefighters and any survivors inside the structure.



Fig. 2. Showing the handheld thermal image scanner

4.3 Cognitive Mapping Strategies as Navigational Aids

Cognitive mapping navigational strategies help subjects create mental representations of space based on external information. Firefighters must process new spatial information quickly as their first exposure to the internal layout of a building is usually during the rescue search. An example of a cognitive mapping strategy is internal

structure deduction, when an individual predicts the internal structure of an indoor space based on present features that are similar to those in previous experiences. Firefighter 4 states that, “houses are configured in such a way so that you look at a type of house and you can tell the basic layout before you even go through the front door. Cape Cod [houses] usually have a central stairwell, more modern houses have the stairwells usually to one side...in older houses, it’s usually in the back.” Firefighters use internal structure deduction as a mental shortcut to predict spatial information. Firefighters use the strategy to create a cognitive map to remain oriented and to make spatial decisions in their search. Also, Firefighters remember specific landmarks, notably doors and windows, as points of reference in case they must turn around and find the nearest exit. Their use of landmarks primarily seems to be an aid to recalling a short route to an escape more so than an aid to deciding which direction to go next.

4.4 Directional Aids as Navigational Aids

Directional aids help individuals decide which specific direction to go. Firefighters typically do not know the layout of the building or where survivors will be inside the building, so they are unable to find or follow specific directions to a useful location. For this reason, directional aids are some of the least commonly used search strategies by firefighters. Firefighters may follow a directed search, which is when they go directly to a room in a building if there is known to be a survivor there. Firefighter 7 described that “if somebody says, ‘My kid’s in there,’ and they point to a window... we’re going to use a ladder to get to that particular window... That method as far as targeted [or directed] search is actually very effective.” Firefighters will use verbal directions if they lead directly to a known location of a survivor. However, this information is not often available, and thus extensive search strategies such as the right-hand rule are more commonly implemented.

Fewer than half of the firefighters interviewed mentioned using the mobile data terminal suggesting that it is not used as a source of information as commonly as strategies such as the right-hand rule or the thermal imaging camera. That is not to say that the firefighters we interviewed do not have access to mobile data terminals, rather it implies that this is not thought of as a “go-to” strategy for indoor searches.

5 Conclusion and Future Work

The purpose of a navigational aid is to provide a tool to interact with the environment in a “consistent and unambiguous way,” Frankenstein [2]. Firefighters have unique goals and challenges while navigating indoors during high stake situations. In this research, we examine the specific strategies that firefighters currently use to understand how they process the spatial information around them. We found that firefighters around the country use similar rules that allow them to either (1) build a path (2) improve their vision (3) use cognitive strategies and (4) use directional aids. Future work should focus on incorporating the results of this study directly into the design of wayfinding aids for firefighters.

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