

Neural Basis Analysis of Firefighters' Wayfinding Performance via Functional Near-Infrared Spectroscopy

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Abstract: Disorientation has been identified as one of the leading causes of firefighter injuries and fatalities. In search and rescue tasks, firefighters have to build up a general understanding of an unfamiliar space with limited time and limited information at hand. These two factors together lead to firefighters' insufficient development of spatial knowledge that could induce firefighters' disorientation. Therefore, there is a pressing need to better understand how and why different types of spatial information, including landmark, route, and survey information, affect the development of firefighters' spatial memory of unfamiliar environments. This study examined functional brain connectivity associated with different forms of spatial information that regulate firefighters' wayfinding performance. We conducted a virtual reality (VR) experiment to investigate the brain-based connectivity changes during wayfinding tasks. To achieve the research goal, we recruited 40 firefighters from the Bryan Fire Department in College Station, Texas. The Firefighters were requested to find three missing victims in a VR office maze, given different wayfinding information, including landmarks, routes, and maps. Functional near-infrared spectroscopy (fNIRS) was used to analyze firefighters' cerebral hemodynamic responses associated with neural activation and connectivity patterns. The results showed that the firefighters had better task performance when they used route or survey spatial information than when they used other information. Survey information (maps) led to higher neural activation and less-desired neural connectivity patterns than did landmark and route information. Although maps provided complete spatial information about the building layouts in the experiment, they also burdened firefighters' cognitive processes and required additional effort in memory retention and path planning. Thus, survey information did not result in better performance as suggested by previous studies. The findings are expected to help fire departments design better training protocols and inspire the design of cognition-driven personalized wayfinding systems for firefighters. DOI: 10.1061/(ASCE)CP.1943-5487.0001031. © 2022 American Society of Civil Engineers.

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Introduction

Firefighting has been identified as a fairly dangerous career, challenged by intensive physical activities and difficult decision-making in hazardous and dynamic environments (Bryant and Harvey 1996; Nydegger et al. 2011). FEMA reported that there were 58,250 firefighter injuries and 64 deaths in the line of duty in 2018 (FEMA) 2018). Among all the causes of firefighters' injuries and fatalities, disorientation was a leading cause, pertaining to 42% of the reported incidents (FEMA 2018). According to the landmark, route, survey (LRS) model (Siegel and White 1975), human beings develop spatial understanding of any new space based on three types of spatial information: landmarks, routes, and survey. In a normal situation, there is a systematic process for a person to utilize all three forms of spatial information to develop spatial knowledge of an unfamiliar building environment. In contrast, firefighters always have limited resources at hand and limited time to develop spatial knowledge of unfamiliar building environments compared with a normal situation. Morganti et al. (2007) identified time pressure and limited spatial information to be the root causes of firefighters' disorientation during search and rescue tasks. There is a need to better understand how different forms of spatial information affect the development of firefighters' spatial memory of unfamiliar environments. It also is important to investigate the fundamental cognitive and neural mechanisms through which different types of spatial information contribute to firefighters' wayfinding performance, because these are fundamental processes that may help pre-



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