THE PROCESS OF HUMAN BEHAVIOR IN FIRES

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INTRODUCTION

Evacuation models, including engineering hand calculations and computational tools, are used to calculate the time it takes to evacuate a building, which can then be used in an engineering safety analysis. However, there is a lack of available data and theory on occupant behavior for use by evacuation models to estimate evacuation time results and their uncertainty. In lieu of data and theory, evacuation models (and users) make assumptions and simplifications about occupant behavior, which can inappropriately characterize the time it actually takes to evacuate a building. In cases where assumptions lead to evacuation estimates that are either too optimistic or too conservative, buildings and procedures can be designed with either insufficient or unnecessary (and costly) egress routes and fire protection/notification systems. A solution to this problem is to generate theory on human behavior during evacuations from building fires that can be incorporated into evacuation models. Once this theory is robust, validated and incorporated into evacuation models, these tools can begin to *predict* occupant evacuation behavior rather than relying on the user to determine behavior before the simulation begins, as is now the case.

In order to develop predictive theory of human behavior in fires, the factors that influence an occupant to take certain actions must be identified. Examples of actions taken during an evacuation include information seeking, milling, preparing for evacuation, and informing others. This paper briefly outlines the factors that influence an occupant to take actions during his/her evacuation and identifies future areas of research that are needed to develop a predictive behavioral (action-based) model of an evacuation during a building fire.

THEORY OF OCCUPANT BEHAVIOR DURING BUILDING FIRES

Human behavior research has shown that any action performed in a situation is the result of a behavioral or decision-making process,[1] rather than based on random chance or even actions resulting directly from a change in the environment (i.e., a stimulus-response relationship). Research from community evacuations during disasters[2,3,4] and building fire evacuations[5,6,7,8] has shown that before individuals performed an action, they perceived certain cues, interpreted the situation and the risk based on those cues, and then made a decision about what to do (i.e., the action) based on their interpretations. Therefore, each action taken is influenced by this process. Also, there are certain factors that influence each phase of the process; more specifically 1) factors that influence whether the individual perceives the cue (or not), 2) factors that influence what type of interpretation the individual forms about the situation and the risk based on that cue, and 3) factors that influence the decision about an action. This behavioral process is shown in Figure 1.

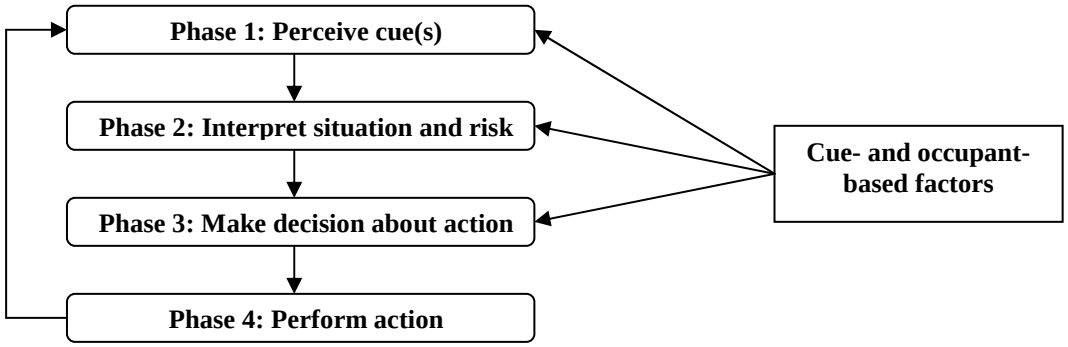

Figure 1: The behavioral process of occupant response in a building fire

In a building fire, the phases and the factors that influence each action are specific to the occupants in the building, the building itself, and the fire event. In the perception phase (Phase 1) of the behavioral process from Figure 1, building occupants can perceive (or receive) external physical and social cues from their environment, including such physical cues as flames, smoke, heat, or debris and such social cues as hearing discussion, seeing others' inaction, or receiving phone calls from outside of the building. Additionally, during this phase, occupants can perceive more complex conditions and states, such as perceived uncertainty, information overload, time pressure, and even their own thoughts or memories from a particular event. In the interpretation phase, *Phase 2*, the occupant attempts to interpret the information provided by the cues perceived during the perception phase.[9,10] During the interpretation phase, occupants interpret or define both the situation (e.g., it is a false alarm or a very serious fire) and the risk to themselves and/or to others. *Phase 3* of the behavioral process, decision-making, involves occupants making decisions on what to do next based on their interpretations of the situations and risks.[11] And, finally, in *Phase 4* of the behavioral process, occupants *may* perform the action that they decided upon in the decision-making phase. For a more complete version of the theory behind each phase in the process, see reference [12].

Occupants will begin a behavioral process when presented with cues or information that interrupts their daily routine. A new behavioral process begins each time an occupant receives new information relating to the event, and a specific action is likely to occur based on whether the information is perceived, the interpretation of the situation and the risk, and the decisions made regarding what to do.

CONCEPTUAL MODEL FOR EVACUATION BEHAVIOR IN BUILDING FIRES

To eventually develop a predictive behavioral model, an understanding of the factors that influence each phase of the behavioral process for building fires is required. Literature from community disasters and building fire evacuations were collected and reviewed to identify these factors. This is a difficult task for several reasons. First, there are both direct and indirect factors that influence each phase of the behavioral process. Direct factors actually influence the main process in each phase, whereas indirect factors can influence the subprocesses that take place within each phase. Second, whereas the perception phase contains a small number of alternatives (i.e., either an individual perceives the cue or not), the interpretation, decision-making and action phases have a large number of options which makes it very difficult to develop linkages between these phases. When presented with building fire cues, for example, occupants have a large number of interpretations that can be made regarding the situation and the risk (Phase 2). Additionally, occupants can perform a large number of actions (Phases 3 and 4). Whereas, if the occupant perceives a cue(s), then he/she will begin to engage in interpretation, few studies[13] were found that effectively linked specific interpretations (Phase 2) with decisions made about specific actions to perform (Phase 3).

This paper begins the development of a predictive behavioral model by identifying the direct factors of influence for Phases 1 and 2 (perception and interpretation). The focus of this paper is to present the factors that influence 1) whether a cue is perceived, 2) whether an occupant interprets the situation as a fire, and 3) whether the occupant interprets a level of risk. In addition, the direction of influence is also included (e.g., whether a factor increases or decreases the likelihood of the phase).

The factors of influence for Phases 1 and 2 have been categorized into two main types: occupant-based factors and cue-based factors.[2] Occupant-based factors include pre-event factors which are those factors possessed by the occupant prior to an event taking place, i.e., education, training, demographic characteristics, etc.; event factors are possessed by the occupant as a function of the event. Cue-based factors, which are inherently event factors, vary by the number of cues, the complexity of the cues (e.g., ambiguous, inconsistent, and too many in number), and the source or type of cue (e.g., smoke condition, other occupants in the building, and people's actions).

Table 1 provides an overview of the influential factors for Phases 1 and 2 of the behavioral process and their direction of influence based on data and theory from human behavior in fires, community-wide disasters, and other types of emergencies. The table should be read in the following way: If

[insert factor here], then the likelihood of 1) perceiving a cue, 2) defining the situation as a fire, or 3) defining the risk to self and/or others [insert direction of influence here – i.e., Increases or Decreases]. An example of this using the factor "Has a perceptual disability (Yes)" is the following: If an occupant has a perceptual disability, then the likelihood of perceiving a cue decreases. At least one reference is provided for each relationship described in Table 1, however, due to space limitations, the full list of references cannot be included. The full list of references for each influential factor can be found in reference [14].

Table 1: An overview of influential factors for Phases 1 and 2 of the behavioral process

Factors	Phase 1	Phase 2: Interpretation	
	Perception	2a: Definition of the Situation as a Fire	2b: Definition of the Risk to Self/Others
Occupant-based pre-event factors			
Has experience with fires (Yes)	Increases	Increases	Increases
Has knowledge of fire/training (Yes)	Increases	Increases	Increases
Habituation with environment (Yes)	Decreases	---*	---
Has knowledge of routes (Yes)	---	---	Decreases
Has frequent experience with "false" alarms (Yes)	---	Decreases	---
Has a feeling of security in building (Yes)	---	Decreases	---
Has a perceptual disability (Yes)	Decreases	---	---
Age (Older adults)	Decreases	---	Increases
Gender (Woman)	Increases	---	Increases
Speaks the same language as others (Yes)	Increases	---	---
Has frequent interaction with family (Yes)	Increases	---	---
Occupant-based event factors			
Has a higher stress/anxiety level	Decreases	---	---
Perceives a time pressure (Yes)	Decreases	Decreases	Increases
Presence of others (especially loved ones) (Yes)	Decreases	---	Increases
Proximity to fire/Visual access (Yes)	Increases	---	---
Sleeping (Yes)	Decreases	---	---
A higher number of behavioral processes (>1)	---	Increases	---
Defines situation as fire (Yes)	---	N/A	Increases
Cue-based factors			
A higher number of cues	Mixed**	Increases	Increases
Consistent cues (Yes)	---	Increases	Increases
Unambiguous cues (Yes)	---	Increases	---
Social cues (others' actions) that are consistent with an understanding of a fire situation (Yes)	---	Increases	Increases
Official source (Yes)	Increases	Increases	---
Familiar source (Yes)	---	Increases	---
A higher dose of toxic gases	---	Decreases	---
Extreme/dense cues (Yes)	Decreases	---	Increases
Visual/audible cues (Yes)	Increases	---	---
Risk information (Yes)	---	Increases	---

*Areas where no research was found is marked by "---"; **Research conflicted on the direction of influence of the factor.

Phase 1: Perception

In Table 1, research shows that both occupant- and cue-based factors influence whether a person perceives a cue. Mileti and Sorensen provide a compilation of all of the factors that influence whether community residents will hear a warning, many of which apply to building fires.[2] The occupant-based pre-event factors that are shown to increase the likelihood of perception are having prior experience with disasters and fires,[15] having some type of knowledge and/or training about fires,[16] being a woman,[17] speaking the same language as the message and others in the building,[18] and having frequent interaction with family.[3,19] On the other hand, the occupant-based pre-event factors that are shown to decrease the likelihood of perception are past experience/habituation with the environment (i.e., spending extended hours in the same environment where the event takes place),[7,20] having a perceptual disability (i.e., a cognitive disability or even loss of any of the senses),[21,22] and being older (i.e., older adults).[3,19,23]

There are also occupant-based event factors that influence perception. These factors that increase the likelihood of perception are being located closer to the event[7,24] and having visual access of the event,[25] whereas those factors that decrease the probability of an occupant perceiving a cue include having higher levels of stress or anxiety,[16,26] perceiving time pressure,[16,26] the presence of others on

the floor or in the area,[20] and being asleep[21] (especially if he/she is very young or very old,[27] intoxicated,[27,28] sleep deprived, or in a deep stage of sleep[29]).

Last, research shows that there are cue-based factors that influence whether a person perceives a cue. The cue-based factors that increase the probability of perception include cues from the fire event that are easy to hear (audible),[22,23] cues that are presented by an official source (e.g., staff, fire warden, etc.),[7,30] and a higher number of cues;[7,30] although if the occupant receives too many cues at the same time,[20] this actually decreases the likelihood of perceiving the cue (i.e., this is the reason a label of "Mixed" is assigned to this category in Table 1). The factor that is shown to decrease the likelihood of perception (i.e., sight) is the presence of thick, dense smoke[31] that prohibits the occupant from seeing the space around him/her (labeled in Table 1 as "Extreme/dense cues").

Phase 2a: Definition of the situation as a fire

Occupants can interpret the situation in many ways; however, the factors that are listed in Table 1 identify those factors that influence whether an occupant interprets a building fire event as a fire event (rather than a false alarm, an evacuation drill, etc.). The occupant-based pre-event factors that increase the likelihood of the occupant defining the situation as a fire are having past experience with fires and having knowledge or training on what to do during fire events.[32] On the other hand, an occupant with frequent false alarm experience[7] or who feels secure/safe in their building[33] is less likely to accurately define the situation as a fire.

Additionally, occupant-based event factors influence whether an occupant defines the situation as a fire. First, research suggests that time pressure negatively affects the development and accuracy of an occupant's definition of the event.[16] Also, research shows that if the occupant is engaging in his/her first behavioral process during the evacuation (resulting in his/her first action), he/she is less likely to define the situation as a fire, and additionally, is more likely to define the situation optimistically. In other words, people's first inclination is to think that nothing bad is happening to them and that they do not need to act.[34]

Table 1 also shows that there are many cue-based factors that influence whether an occupant will interpret the situation as a fire. The occupant's definition of the situation as a fire is more likely when the occupant is presented with a higher number of cues,[4,34] a consistent set of cues (e.g., the smoke, flames, heat, and debris all lead to the same interpretation),[35] and unambiguous cues.[3,20] Other factors that increase the likelihood of the occupant interpreting the situation as a fire include perceiving social cues that are consistent with an understanding of a fire situation (e.g., hearing screams, seeing others prepare, etc.),[7,20] cues from official sources (e.g., the fire department),[7,24] cues from familiar sources (e.g., friends, family, etc.),[35,36] and cues that provide risk information as part of the warning message.[37] On the other hand, if occupants are exposed to certain environmental cues, such as toxic gases from smoke for a certain period of time (e.g., CO, HCN, low O_2), this exposure itself is likely to negatively affect his/her cognitive abilities, including the ability to construct an accurate definition of the situation.[31,38] Prolonged exposure may lead to incapacitation or death.

Phase 2b: Definition of the risk to self/others

The occupant-based pre-event factors that increase the likelihood of an occupant defining risk include having past experiences with fires and/or knowledge/training for fires,[3,19] being older (e.g., older adults),[23] and being a woman.[39] On the other hand, one study shows that having knowledge of the evacuation routes from a building can decrease the likelihood of an occupant interpreting risk.[6] Also, research identifies three occupant-based event factors that increase the likelihood of an occupant defining risk, and those factors are time pressure (or feeling a sense of urgency),[40] the presence of loved ones within the building (e.g. friends, family, etc.),[41] and if the occupant has already defined the situation as a fire,[36] it is more likely that he/she will feel risk to him/herself or to others.

Cue-based factors also influence an occupant's perception of risk. A higher number of cues,[42] a consistent set of cues,[35] the presence of social cues that are consistent with an understanding of a fire situation,[35] and the presence of more extreme cues (e.g., dense smoke)[6,13] increase the likelihood of an occupant defining risk to him/herself or others.

CONCLUSION

Behavior during a building fire evacuation is the result of a behavioral process. Each process begins with new cues and information from the physical and social environment. First, cues need to be perceived, then they are interpreted, and then a decision is made as to what action (including inaction) is undertaken. During an evacuation, individuals repeat this process several times as they engage in a variety of different activities. This paper presents the influential factors for the perception phase and a subset of the interpretation phase of the behavioral process, however, future research, in the form of an in-depth study of real fire events, is needed to identify the factors that influence occupants to decide to take a specific action, and the factors that influence whether that action is ultimately performed. By identifying the factors that have been shown to influence each phase in the behavioral process, researchers can begin to develop a comprehensive, predictive, behavioral model for a building fire evacuation.

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