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Burning Down the Silos: Integrating new perspectives from the social sciences into human behavior in fire research

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Abstract

The traditional social science disciplines can provide many benefits to the field of human behavior in fire (HBiF). First, the social sciences delve further into insights only marginally examined by HBiF researchers, in turn, expanding the depth of HBiF research. In this paper, I present examples of studies from the fields of social psychology and sociology that would expand HBiF research into non-engineering or "unobservable" aspects of behavior during a fire event. Second, the social sciences can provide insight into new areas of research; in turn, expanding the scope of HBiF research. In this section, I introduce pre- and post-fire studies and explore potential research questions that fall outside of the response period of a fire, the phase upon which most focus is currently placed. Third, the social sciences elucidate the value of research methods available to study human behavior. Qualitative research methods are specifically highlighted. These three benefits will allow HBiF researchers to collect a wider range of data, further develop and expand current behavioral knowledge, and increase the impact of this research for both social and engineering applications. Finally, I end with a discussion on possible ways to better integrate the social sciences within human behavior in fire.

Keywords

Human behavior; evacuation; evacuation models; preparedness; recovery; fires

INTRODUCTION

The field of human behavior in fire (HBiF)[a] has deep roots within the field of fire protection engineering[b]. In 2002, John L. Bryan, founder of the fire protection engineering department at the University of Maryland, College Park, published an article outlining the history of human behavior in fire [1]. Some of the earliest work in the field involved the study of pedestrian velocity for the design of New York City's Hudson Terminal Building in 1909 [2], as well as work on the capacity of footways conducted and published by the London Transit Board [3]. The first academic study on human behavior in fire, however, was

[a]The term "human behavior in fire", from the Human Behaviour in Fire Symposium website, refers to the "study of human response when exposed to fire and other similar emergencies in buildings, structures and transportation systems. It includes an understanding of people's awareness, beliefs, attitudes, motivations, decisions, behaviors and coping strategies and the factors that influence them." [http://www.intersciencecomms.co.uk/html/conferences/hb/hb15/hb15.htm]

[b]The term "fire protection engineering" is used throughout; however, it is meant to represent fire safety or protection engineering, in general.

conducted by Bryan himself on the 1956 Arundel Park fire [4]. His rationale for this type of study was the following:

> "…fire protection engineers developed building features to enhance fire safety of the occupants, to control the ignition of fires, and to effectively suppress the fires that did occur…However, it was recognized by some that a difference between a minor fire incident and a major fire incident often involved the human behavior of the personnel immediately prior to the fire incident or during the fire incident."

The 1970s and 80s, labeled by Bryan as "The Productive Years", brought about the redefinition of panic and an appraisal of the term's value [5], the importance of emergency communication [6], individual studies of fires in various types of occupancies (i.e., residential, healthcare, hotels, etc.) [7], a concern for occupants with mobility impairments [8], the observation of evacuation drills from high-rise buildings [9], and the initiation of computer evacuation modeling [10,11,12], among many other efforts. This research prompted an increased demand for fire protection engineers with experience with and understanding of techniques used to incorporate human behavior in engineering calculations. This continuing demand is apparent as options for "in-house" human-behavior-related classes, research, and projects became more prevalent in fire protection engineering or safety departments in universities around the world, including the University of Ulster, University of Maryland, Worcester Polytechnic Institute, Lund University, University of Greenwich, and Victoria University, among many others. Professional societies, such as the Society of Fire Protection Engineers, also produce guidance to help engineers better understand HBiF [13].

The common thread to all of these efforts is their foundation within the fire protection engineering discipline. Some might even go so far as to say that the HBiF field has "silo-ed" itself within the engineering field. The issue here is that HBiF, similar to many other fields involving human performance, addresses a multi-disciplinary problem. HBiF involves the intersection of the built environment (i.e., buildings and infrastructure), the fire environment, and people. This problem requires input from a variety of disciplines outside of engineering. While HBiF has already received significant benefit from non-engineering disciplines, such as environmental and cognitive psychology, human factors and ergonomics, mathematics, architecture, law, chemistry, emergency management and planning, physics, computer science, and toxicology, the field can benefit from expanding even further.

One way to grow the HBiF field is to better integrate the social sciences. The social sciences (i.e., "the study of society and the manner in which people behave and influence the world around us") [14], can provide rich insight to the field of HBiF. Traditionally, the social sciences encompass many different fields of behavioral science, including sociology, social psychology, human geography (i.e., a sense of place), anthropology (i.e., the study of humans–ideas about race, culture, and peoplehood), economics, and political science, to name a few. The introduction of these subjects would provide different perspectives on the way that individuals and groups cope with emergency scenarios.

Better integration of the social sciences would allow HBiF research to expand both in depth and breadth; delving further into current topics, as well as expanding into new (and relevant) research areas. Additionally, a better understanding of social science research methods would ensure the use of appropriate techniques to fully answer HBiF research questions. Insights from the social sciences would allow HBiF researchers to collect a wider range of data, further develop and/or expand the current knowledge of HBiF, and in turn, provide better, more informed guidance, model development and model use (in engineering applications)[c]. Also, expansion and integration of social science concepts and methods would allow the field of HBiF to increase its influence and impact, benefitting not only engineering practice but also social policies and programs that exist to support life safety and the overall well-being of all people affected by fire.

This paper presents three primary benefits of integration with the social sciences. The benefits, namely an expansion of research depth, an expansion of research scope, and a better understanding of social-based research methods, are shown in Figure 1.

This paper begins with a discussion on the seminal work that has already been completed in the field of HBiF–referred to as its current status. Next, trends in this research are identified, acknowledging that most of the research: a) has focused on collecting and analyzing data on the "observable" aspects of HBiF, as opposed to identifying the underlying processes that produce those observations; b) has concentrated on behavior that occurs *during* the fire event (rather than pre-event or post-event behavior); and c) has primarily utilized research techniques that extract quantitative data (leaving behind the more rich, insightful qualitative data that can uncover different aspects of HBiF). I then present examples of research studies (including new theories and methods) from the social sciences that would enable the HBiF field to delve further into the non-engineering or "unobservable" aspects of human behavior in fire, expand its research scope into pre- and post-fire studies, and identify additional research methods (e.g., qualitative techniques) that could help to answer some of the unexamined research questions in the HBiF field (some of which are identified above). Finally, I end the paper with a discussion on how the HBiF field could better integrate insights from the social sciences; e.g., via multi-disciplinary teams and researchers.

HUMAN BEHAVIOR IN FIRE RESEARCH–THE CURRENT STATUS

Researchers in the field of HBiF have provided significant empirical knowledge and understanding into the human response to fires (i.e., a person or group's immediate response to building fires–often evacuation to a place of safety). Boyce [15] recently published a compendium of all papers presented in the human behavior and modelling sessions at Interflam from 1999 through 2013, and the papers presented at the first five Human Behaviour in Fire symposia from 1998 through 2012. The compendium lists over 380 conference publications from 22 different topic areas within the field. This paper focuses upon HBiF conference proceedings because it expands upon a keynote paper and presentation addressing how the Human Behaviour in Fire symposia [16] can benefit from integrating perspectives and insights from the social sciences. This paper is also based on the assumption that the papers presented at HBiF symposia are representative of the research

[c]Model development and model use refer to evacuation models (in the response period) as well as models of human recovery and resilience in the face of fire emergencies.

conducted in the broader HBiF field, especially since no specific research journal exists for HBiF. With that in mind, all of the articles within previous conference proceedings were reviewed to obtain a better understanding of the current status in the field, namely the types of subject areas explored as well as the research methods used.

Current Research Topics in HBiF

The review of the HBiF conference proceedings [15] shows that certain research topics have been more frequently studied than others. A large amount of research has been performed in the area of evacuation dynamics (i.e., the physical movement of people in response to fires)[d]. Research on evacuation dynamics includes the collection and study of movement speeds, density, flows, and, to some extent, merging behavior. This information is extremely important because it provides much needed data for engineers performing life safety analyses, especially those using evacuation models, to calculate the time required for people to move to a safe location. Other publications have reported timing for certain aspects of the building evacuation, such as pre-evacuation delay times and overall evacuation times for the building or for a specific population within the building. More recently, this research has been expanded to include data collection and analysis of the movement characteristics of vulnerable populations, for example, children, older adults, and people with disabilities–including those who require the use of an evacuation aid or device to evacuate the building. Although less frequently studied, movement characteristics of evacuees under the influence of alcohol have also been collected.

There have also been a number of conference publications on the modeling of evacuation movement [15]; specifically, the importance of tracking individuals, their physical movements, and their evacuation timing in the event of a building fire. In addition, several evacuation modeling reviews have been performed–both in publication [17,18] and online [19,20]–analyzing over 60 computer-based evacuation models that are available for use in conducting life safety analyses. Although these models began with a focus on evacuation from buildings, some have been expanded to calculate evacuation timing for rail, air, and maritime transportation systems. These models and their underlying calculation techniques are crucial to the engineering community and performance-based analyses.

Beyond physical-based people movement data and modeling, a significant amount of research has been devoted to certain aspects of human *behavior* in response to fire [15]. These aspects include recording and analyzing the types of evacuation behaviors/actions that are performed during building evacuation; route choice based upon observable characteristics of the building, person, surrounding population, or physical environment; and occupant responses to fire stimuli, including the waking effectiveness of smoke alarms. Data analyzed and reported on human behavior in response to fire have primarily included evacuation-related actions performed by specific building occupants; cues that prompted first-awareness of the fire event and the order of these cues; and the effect of culture, gender, age or other observable characteristics on the performance of actions.

[d]Individual references are not included for each type or category for the purposes of brevity. All publications can be found by searching Boyce [15].

Current Research Methods in HBiF

Similarly, trends can be identified in the types of research methods most frequently used within the HBiF conference proceedings [15]. Within the research papers that focus on data collection of human *behavior* (i.e., excluding studies on people movement, like travel speeds or flow), a large majority of the research studies collect behavioral data[e] via experiments or survey research; primarily using self-administered questionnaires (i.e., paper or electronic).

Experiments similar to those performed by Latane and Darley [21] on social influence allow for the control of a number of variables within an experimental/laboratory setting. In general, researchers can test previously developed hypotheses and identify causal relationships between variables of interest via the use of experimental methods. In experiments, participants are assigned to a control group or experimental group(s), and each group is observed on some dependent variable. Participants may either be aware, partially aware, or unaware of the experiment's purpose. They may have frequent, some, or no interaction with the researchers. Statistical comparisons can then be made between groups, allowing researchers to understand the effect of some variable on the sample population. In the HBiF field, experiments [15] have been performed on alarm recognition, responses during sleep, the impact of exit information, wayfinding and exit choices (including the use of virtual reality simulation [22]), the effect of smoke on behavior, human reaction to stress (during fire), and social influence. Experiments can be performed in which behavior is observed only; however, these HBiF studies were often accompanied by some type of survey or questionnaire. The benefit of the questionnaire is to attempt to understand why certain behaviors were performed (after the experiment), and even to compare a pre-experiment attitude or perspective (captured via survey) with a post-experiment attitude or perspective (also captured via survey).

Even more widely used than experiments is survey research among HBiF studies [15]. Generally, survey research involves asking questions of participants within the study. A variety of instruments can be used, including self-administered questionnaires (paper or electronic), face-to-face interviews, telephone interviews, group interviews (or focus groups), or other methods. In the field of HBiF, researchers have overwhelmingly used self-administered questionnaires (paper or online). These survey research studies have examined cultural differences, firefighter reactions to emergencies, needs or knowledge of people with disabilities, emergency communications (and informational needs), behavior during actual events (collected after an event has occurred), the use of elevators for evacuation, fire safety attitudes and perspectives, and the effectiveness of fire safety-related educational programs. This method is often used when asking people to describe/report their own behavior or experiences during fire evacuations. Survey research using questionnaires has also been used to ask participants to predict what they might do in particular situations (also known as behavioral intention studies); e.g., whether or not they would use an elevator for evacuation in certain situations. It is important to note that researchers using survey research techniques can only study the information that participants are willing or able (via memory) to provide

[e]Here, behavioral data refers to the study of human behavior, i.e., actions performed, and the reasons why those actions are performed during fire events, drills, or experimental studies.

to them; disclosure may be an issue in some circumstances. The survey instrument can range from a very structured, standardized set of questions (often used for quantitative studies) to an unstructured, even conversational set of questions (which can be used in qualitative studies). A large majority of the studies within the field of HBiF from 1998 through 2013 seem to have used structured, standardized sets of questions on the questionnaire (based only upon the numerical data analyzed in the study, since the instrument was rarely provided).

A smaller number of the research articles included in the HBiF conference proceedings engaged in non-questionnaire-based survey research, including face-to-face interviews, telephone interviews or focus groups [15]. While rare, a few studies collected face-to-face interview data with survivors of an actual fire event, with people with mobility impairments, and with members of a community in Arizona who experienced a wildfire event. More frequent, but still minimal, were research studies that obtained and analyzed interview data collected via other means (e.g., through earlier investigations, public documents such as newspapers, photographs, videos, and private documents). Among the conference proceedings, this method, known as unobtrusive measures or secondary data analysis, was used to study human behavior in actual fire events (e.g., the dance party in Gothenburg in 1998, the 2001 World Trade Center Disaster, and the 2003 Rhode Island Nightclub fire) as well as to identify the reasons for fatalities in residential fires.

Trends in HBiF Research Topics and Methods

After a thorough review of the conference proceedings articles [15]–focusing both on research topics and methods–three main trends were observed. One clear trend is the field’s focus on research topics involving the observable aspects of HBiF. Most of the HBiF research is focused on studying the physical aspects of human response; i.e., observation and modeling of evacuation movement. Even research into the behavioral aspects of fire events has primarily focused on the “observable” aspects of the problem; i.e., the data or information that a researcher can readily observe related to HBiF.

With so much emphasis on the observable aspects of human movement and behavior, and the modeling of these, one key aspect that has received less research attention are the underlying or “unobservable” processes of human behavior in fire [16]. Here, I am referring to the motivations, perceptions, and interpretations that drive behaviors. These processes help to further explain the meanings and motivations behind behaviors performed during fire events.

A second trend is that almost all of the research focuses on the actions and movement of people *during* the fire. Evacuation movement and the behavioral responses to fires that are observed in the research listed above take place during and/or slightly after the fire has occurred. A strict focus on the fire event overlooks a great deal of observable and unobservable behavior that can occur both before and after a fire event. An understanding of the pre- and post-fire event can provide the entire story of the impact of fire events on people, thus increasing the ability to improve life safety in fire as well as to improve overall attitudes related to fire safety and decrease negative impacts resulting from fires (such as longer-term physical injuries or mental health effects).

The third trend became evident when reviewing the research methods used by the HBiF studies. Most of the studies that aimed to collect behavioral data used either experimental or survey research methods, with a focus on the use of self-administered questionnaires. As stated earlier, a large majority of these studies seem to have used questionnaires that contained structured, standardized sets of questions. As a result, the researcher was able to enumerate certain aspects of the problem at hand–e.g., reporting that a certain percentage of people used a particular exit, stating that a certain number of people held specific perspectives (provided as response options within the questionnaire), or identifying a link between a certain level of risk perception (independent variable) and a particular action taken (a dependent variable). While this is all important information in understanding HBiF, quantitative data provided by experiments and survey research using questionnaires minimize the researchers' ability to understand the perspectives, motivations, and interpretations that are 'behind' the numbers collected. It is also important for researchers studying certain aspects of HBiF to obtain access to the rich narratives, explanations, and stories of the people whose behaviors they hope to better understand. Identifying both the quantitative trends and the more qualitative reasons behind these trends can provide a clearer and more comprehensive picture of HBiF–before, during, and after the fire event.

The social sciences can provide needed insight on each of the three trends illustrated above. The following three sections of this paper will provide evidence of these insights. The next section will discuss how the social sciences can aid HBiF researchers to further delve into the "unobservable" processes of human behavior during a fire event. The second section provides a discussion on how the social sciences can further expand the scope of HBiF research into the pre- and post-fire event behaviors. Finally, the third section discusses how the social sciences can broaden perspectives of HBiF researchers regarding the range of research methods available. All three of these insights are essential in the quest to provide life safety to building occupants via both engineering and social solutions.

DELVING FURTHER INTO THE "UNOBSERVABLE" ASPECTS OF HUMAN RESPONSE TO FIRES

Over 30 years ago, influential researchers from non-engineering disciplines set the scene for study of the "unobservable" aspects of HBiF; i.e., evacuation processes and decision-making during fire. Researchers in psychology, including Tong and Canter [23] and Sime [24], begun the arduous task of developing conceptual models of human response in fire. Latane and Darley [21], also psychologists, provided the foundation for studying the influence of other people (and their actions) on personal actions in emergency settings. Sociologists, Johnson, Feinberg and Johnston [25], identified that social bonds exist in even the most severe of fire emergencies; i.e., that people put themselves in danger while assisting others. And, finally, Jones and Hewitt [26], also sociologists, focused on the social context and organizational characteristics of the building population within which decisions about group formation, leadership, and evacuation strategy are made.

However, other than the 2001 World Trade Center (WTC) Disaster, for which studies and investigations bridged gaps between engineering and social science disciplines [27,28,29], research into this "unobservable" unknown seems to have gained minimal traction over the years. Only a small proportion of the HBiF conference-related research has focused on the underlying or "unobservable" processes of human behavior in fire [30,31,32,33,34,35]. Without an understanding of this aspect, engineering tools and applications may not be sufficiently inclusive of people, their behavior, and their needs in fires; and as a result they may not produce appropriate and accurate engineering solutions for the relevant fire scenarios. Perspectives from the social sciences allow us to further delve into the "unobservable" processes of human behavior in response to fires–the behaviors and the meanings and motivations behind them before, during and after fire events.

In the following section, I will introduce examples of social science studies[f] that can continue to expand HBiF thinking into the "unobservable" aspects of human behavior in fire. I will focus on the fields of Psychology and Sociology, although there are many other fields within the realm of the social sciences. For each discipline, I provide a definition of the discipline, examples of the subareas within that discipline that are relevant to fires, and then examples of studies that either directly apply or can be related to fire research. All studies provided as examples contain research on the social aspects of fires within buildings; however, studies of fires that occur in a community context, for example, wildland-urban interface fires, may also provide insight here. Overall, the purpose of this section is to show how researchers might delve deeper into the "unobservable" aspects of HBiF by integrating concepts from psychology and sociology.

Examples from Psychology

According to the American Psychological Association (APA) [36], psychology is the "scientific study of mind and behavior". Of the 15 different subfields identified by the APA, environmental and social psychology are highlighted here as relevant to the study of the "unobservable" aspects of HBiF.

Environmental psychology involves the use of science to improve the interactions of people with the world around them. Nilsson [37], a HBiF researcher, provides an example of the use of environmental psychology in his dissertation work. Investigations of previous fire incidents revealed that individuals were more likely to evacuate a building by the most familiar route (i.e., the way in which they entered the structure) [24]. Since unfamiliar exits closer to evacuees were not used as frequently, building evacuation times were lengthened. Nilsson's study aimed to identify the factors that influenced the choice of exit route. Using the Theory of Affordances [38] (i.e., people perceive objects in terms of what they can offer or afford), Nilsson investigated the use of flashing lights at emergency exits via experiments within buildings and road tunnels. Nilsson's study inquired how the exit system was perceived by study participants, and, in turn, how these perceptions influenced exit choice. Findings from this study suggest that the choice of exit can be influenced by changes in the environment, e.g., the use of flashing green lights to signify safety and emergency exit.

[f]Please note that this section is suggestive, and not exhaustive. These highlighted studies are provided only as examples. There are many other studies that could have been highlighted; however, these studies provided examples showing the need for integration.

According to the APA [36], social psychology involves an understanding of how we perceive ourselves in relation to the rest of the world and how this perception affects our choices, behaviors, and beliefs. Kuligowski [39] applied theories in social psychology to the HBiF problem of how humans respond during emergencies after discovering the grossly inaccurate assumptions made by current computer evacuation models. The purpose of this study was to develop a conceptual model of individual decision-making and behavior in the 2001 World Trade Center (WTC) disaster[g]. The hope is that this approach can eventually be used to improve the ways in which current evacuation modeling techniques account for human behavior in fire, after sufficient validation and generalization to other types of fire events.

Kuligowski used a social psychological conceptual model, the Protective Action Decision Model (PADM) [40], as the foundation for understanding individual decision-making and behavior performed during the pre-evacuation period of the 2001 World Trade Center disaster. The PADM, shown in Figure 2, provides an explanation of the meaning-making process in crises to disaster situations. The model, which is based on over 50 years of empirical studies of hazards and disasters [41,42,43,44,45,46] plus theories of judgment and decision-making under uncertainty [47,48,49], provides a framework that describes the information flow and decision-making that influences individual protective actions taken in response to natural and technological disasters. Overall, this framework shows that cues from the physical environment as well as information from the social environment (i.e., emergency messages or warnings), if perceived as indicating the existence of a threat, can interrupt normal activities of the recipient. Depending upon the perceived characteristics of the threat (e.g., assessments of risk to themselves or others), certain types of actions will be performed.

Based upon this model, Kuligowski developed a conceptual model of evacuee decision-making in the 2001 WTC disaster [39]. The WTC conceptual model identified linkages between occupant- and situationally-based factors and the actions performed. Occupant pre-evacuation behavior in the WTC disaster was conceptually modeled by understanding both the disaster environment and the meanings individuals assigned to that environment. Overall, the model shows that WTC survivors consistently developed new social norms and lines of action (see discussion of Emergent Norm Theory in the following section) based upon the meanings that occupants assigned to the situation, including perceptions of risk, familiarity with the building and others in the building, and responsibility for others. These meanings were dependent upon the receipt of environmental cues as well as on pre-existing norms, experiences, training, and social roles. The entire model and its accompanying explanation can be found in several references [39,50,51].

Additional efforts have been made to further develop the WTC conceptual model into engineering calculation techniques [52,53,54], specifically to assign delay timing (a quantitative value) to the process of identifying and assessing risk and making decisions (often considered qualitative in nature), as well as guidance for model developers on how to

[g]This conceptual model was developed by analyzing data collected from the 2001 WTC disaster by the High-rise Evacuation Evaluation Database (HEED) project (http://fseg2.gre.ac.uk/HEED/HEED_intro.html).

incorporate these concepts into current evacuation models [55]. The WTC conceptual model has not yet been generalized to other incidents or validated for use in computer models; however, work has been done to use this model to create a more generalized, comprehensive conceptual model for use by practitioners, model users, and model developers [56].

The Nilsson and Kuligowski studies, founded in psychological theories, help to advance potential solutions to engineering problems. The first problem involved the decision of route choice during evacuation; acknowledging that people are not always aware of their closest exit and they are more likely to choose the route that is most familiar to them. Nilsson's findings allow engineers to enhance the affordability of exits (e.g., via the addition of flashing lights), so that evacuees are more likely to choose the closest routes, thus reducing their evacuation time and likelihood of death and injury. The second problem involved obtaining a better understanding and eventual conceptualization of occupant decision-making during evacuation, in an attempt to improve the ability of current evacuation models to account for human behavior in fire. Kuligowski's findings, once generalized and validated, could be incorporated into current evacuation models, improving the accuracy of evacuation timing results provided to engineers by these models in a performance-based design. Improvement in the accuracy of evacuation timing estimates would ensure that future buildings are designed and built to a sufficient and necessary level of safety.

Examples from Sociology

According to the American Sociological Association [57], sociology is the study of the social lives of people, groups, and societies - "an overarching unification of all studies of humankind, including history, psychology, and economics". Of all the relevant subareas within the field of sociology, social psychology (psychology from the sociological perspective) and environmental sociology are the subareas that would provide the most insight into the "unobservable" aspects of HBiF. Social psychology within sociology (also known as symbolic interactionism or psychological sociology [58]) is the sub-discipline that encompasses such fields as socialization, interpersonal relations and social interaction, attitudes and public opinion, and collective behavior. Environmental sociology explores the various forms of interaction between human society and the environment. Both of these subdisciplines can provide insight on a deeper understanding of a fire environment–the people, their interactions with each other, and their interactions with the fire environment (including the fire and the building).

Two studies of HBiF from sociology, specifically from environmental and social psychological perspectives, are presented here. Both examples are from sociologists at the University of Delaware in the U.S. and provide a perspective on the role of group-level dynamics on fire evacuation behavior. Most studies of human behavior in fire have focused on the behavior of the individual, whereas these studies focus on the group and group behavior.

The first is Aguirre et al.'s study of the 1993 World Trade Center (WTC) bombing [59]. In this study, researchers tested whether the human behavior of survivors of the 1993 WTC bombing were reminiscent of the Emergent Norm Theory (ENT) of Collective Behavior [60,61,62]. ENT posits that in situations where an event occurs that creates a normative crisis (i.e., an event where the institutionalized norms no longer apply), individuals interact collectively to create an emergent, situationally-specific set of norms to guide their future behavior. In other words, people come together to figure out what is going on and what they should do about it. In this study, researchers surveyed survivors of the bombing, supplementing this data with survivor interviews and content analysis of media articles. The dependent variable in this analysis was the number of minutes until the survivors began their evacuation (self-reported). The independent variables tested included the number of people within the group, their social relationships, the threat, and social interactions. Among many findings within this study, Aguirre et al. [59] found that the larger the group (in numbers) OR the stronger the social relationships among group members, the longer the group delayed in initiating evacuation.

The second is a study of collective behavior in the 2003 Rhode Island Station Nightclub fire [63]. Researchers set out to test whether the normative explanation of collective behavior existed in this fire event. This hypothesis posits that people act on the basis of shared social norms, values, and affiliations, and that people assist others, possibly at the detriment of their own lives [60]. In this study, Aguirre et al. provided a unique perspective on the study of fire events by testing the effect of group-level dynamics (e.g., the physical distances among group members at the start of the fire, the number of intimate relationships among them, the extent to which they had visited the nightclub prior to the incident, and the average length of the evacuation route) on deaths and injuries from the fire. After performing a content analysis of documents from the Rhode Island Police Department, the Rhode Island Office of the Attorney General, and the media, results indicated a relationship between group-level factors and counts of injuries and deaths.

Sociology, both its theories and its methods, can provide additional insights on the behavior of the group and its effect on evacuation behavior and timing. These important insights can then be incorporated into evacuation modeling. The two sociological studies presented above show that pre-existing and emergent group and group-level dynamics can have a significant effect on the life safety of occupants during building fires. Currently, most HBiF studies focus on the behavior of the individual, and evacuation models and calculation techniques consider each agent as independent, with very little interaction with the surrounding agents. This contrasts with the sociological studies, which show that decision-making processes and subsequent actions are most likely performed in groups, or at the very least, in relation to other occupants in the building, and that their interactions affect both evacuation timing and fire-related casualties.

Implications for HBiF Research

Although the “unobservable” is not an entirely new concept to the HBiF field, psychological and sociological studies presented in this paper do highlight some important improvements or changes that could be made to HBiF research. First, the studies demonstrate that decision-making processes and group-level dynamics can be studied in order to further understand the “unobservable” aspects of human behavior in fire. They also show that understanding these processes and dynamics (either by the individual or group) can lead to better prediction of protective actions, delay times, and casualties in a fire event.

New and existing research accounting for the "unobservable" aspects of HBiF has implications for many engineering problems. This research can improve the ways that alerts and warning information are created and disseminated before and during a building fire emergency [64]. Further understanding of the types of cues and information (and the methods of disseminating that information) that are more likely to increase receipt, attention, comprehension, and risk perception, and in turn, increase the likelihood of a safer response, will aid message providers in crafting a more effective fire alert and warning system for their building population.

Additionally, research into the "unobservable" can improve the engineering calculations and methods used in life safety analyses. Currently, these calculation methods, including computer evacuation models, forecast little in the way of individual or group behavior without significant user intervention, and typically do not simulate underlying decision-making processes. Instead of simply assigning pre-evacuation time delays to simulated evacuees, as most do now, models could more accurately predict the types of actions performed in specific locations throughout the building and the accompanying time delays for individuals, both alone and within groups, throughout the entire evacuation process. Additionally, models could account for the dynamic nature of individual or group decision-making and behavior during a building fire; i.e., situations where evacuees may change decisions (to evacuate the building, for example) as cues and information change during the event.

Delving into the "unobservable" is not the only way in which the social science can benefit the field of HBiF. The social sciences can also help HBiF research to expand its scope past the study of human behavior during fires (often referred to as the response period). The following section will discuss the timeline of a building fire and the benefits to understanding behavior outside of the response period.

EXPANDING RESEARCH SCOPE TO ACCOUNT FOR PRE- AND POST-FIRE HUMAN BEHAVIOR

Any fire, whether it originates in a building or in the community, has a timeline associated with it. The disaster timeline, shown in Figure 3 [65], can be adapted to any type of disaster, including fire. The first part of Figure 3 (on the left) shows the preparedness period, which is an ongoing time period before a fire occurs. The time period when the fire occurs is often referred to as the response period. The response period is the time from the beginning of the fire incident (i.e., when the fire starts) to the time when the fire ends. This is the phase that includes human response to fire, including protective action (e.g., evacuation) decision-making and response. Most of the research in HBiF concentrates on the response period.

To the right of the response period, labeled as "disaster" in Figure 3, is the recovery period. The recovery period after the fire has occurred is often categorized as short-term (days), intermediate (weeks), and long-term (months to years). The recovery period takes into account the time that it takes for building occupants or community members to fully recover from the fire event, including going back to work, moving back home (if the fire affected their home), recovering from any physical injuries incurred during the fire event, and dealing with and healing from any personal or mental injuries that occurred as a result of the fire (e.g., post-traumatic stress disorder).

The review of the conference proceedings [15] shows that a large amount of research has been performed on human movement and behavior, and the modeling of such behavior, during the response period of a fire. Within the response period of a fire, research has been performed on recognition and response to cues (including alarms), pre-evacuation behavior and timing, wayfinding during the fire event, smoke-people interactions, movement and evacuation dynamics, evacuation strategies (e.g., phased evacuation vs. defend in place and the use of elevators), and the modeling of these behaviors [15].

Although HBiF conference proceedings show that the preparedness period has received less focus [15], research has been performed to study people's attitudes on fire safety [66,67], the benefits of trial evacuations [68], fire educational program development and its effectiveness [69,70], fire safety training tool development [71], and even a study in wildfire preparedness [72].

However, HBiF would benefit from broadening its inquiry into many other aspects of preparedness. The preparedness period is especially important because disaster research has shown that preparedness actions of individuals influence their behavior during the disaster event [73,74,75]. Studies of the preparedness period could be expanded to include inquiry into the types of preparedness activities that are most successful in influencing safe and efficient response behavior. Preparedness actions or behaviors can include training (e.g., practicing with the use of a particular evacuation device, such as an evacuation chair), education (e.g., increasing knowledge about a fire, personal risks associated with a fire, and expectations for a fire event), preparing (e.g., gathering items for an evacuation kit), and planning (e.g., designing a work or home evacuation route) [73]. Taking this one step further, researchers can begin to inquire about the factors that influence preparedness behavior, or the type and amount of preparation that is most successful in reducing deaths/ injuries during fire events. Questions like these are beginning to be asked [76]; however, more work is required to delve deeper into these types of issues.

Similar to the preparedness period, almost none of the research included in the HBiF conference proceedings [15] focuses on the recovery period. During recovery from a fire event, people may have to rebuild their homes, find temporary work, struggle with post-traumatic stress disorder, deal with financial stressors, and care for loved ones, among other stressful scenarios. Out of all the HBiF conference articles [15], only one focused on the recovery period of individuals following a fire event [77]. In this article, McConnell et al. [77] studied the impact that domestic fires had on survivors. By working with the fire brigade, survivors of domestic fires in Northern Ireland (from 2003) were identified and studied to understand the impacts of these fires on physical and mental injuries. Results of this study showed that "domestic fires for survivors do not stop when the fire is out and the smoke has dissipated". In this case, 60 % of the domestic fire survivors were found to experience mild to severe post-traumatic stress after the event; and 40 % were found to display moderate to severe trauma up to 1.5 years after the fire event.

As inquisitive researchers, we could be asking what happens to people during recovery from fire events and why. Long-term physical and mental injuries and stressors from fire events can have negative effects on worker productivity and time spent away from work, employment rates, health care demands and costs, and many other important aspects of society. Researchers in HBiF could continue inquiry into the fire recovery period to understand the factors that influence healthy and successful recovery of people after fire events. This type of study would enable building owners, managers, employers, and emergency personnel to ensure safe, healthy recovery periods of fire survivors and their families after fire events.

The social sciences can help reformulate HBiF's concept of a fire incident timeline. The following section provides two examples of behavioral studies of the pre-event and post-event time periods of a fire, respectively. Both examples are studies of behavior before or after wildland-urban interface (WUI) fire events. The choice of examples from WUI fire studies is deliberate. First, the use of WUI fire studies provides consistency of hazard type. Second, there is a great deal of overlap between human response in building events and human response in community-scale disasters. This was successfully shown in Kuligowski [39], as one example of many.

Examples from Wildland-Urban Interface Fire Studies

There is an entire field of researchers who study the social dimensions of disasters. A sub-group of these researchers study the social aspects of wildfires, and a majority of these studies focuses on the preparedness behavior of community members living in areas of the world exposed to wildfire risk. One of these studies is selected here, since its findings are relevant to researchers in HBiF and the study of building fire events.

In 2015, Dickinson et al. published a study on the preparedness time period of a wildfire event [78]. The purpose of this research was to identify the factors that influenced wildfire risk mitigation behaviors among households that lived in wildland-urban interface (WUI) communities in Colorado, U.S. In this study, wildfire mitigation behaviors included reducing vegetation or fuel around the home or changing structural features of the home in order to reduce the possibilities of fire spread. Dickinson et al. [78] sent web-based or paper surveys to households in two counties in Colorado, from which they received completed surveys from 3500 households (all privately owned properties in the WUI within two Colorado counties). The study's results revealed a positive relationship between fire-specific social interactions and heightened perception of wildfire probability, which in turn was positively linked to vegetative mitigation behavior. These social interactions took place both in formal organized settings, such as community meetings, and in informal contexts, such as conversations between neighbors.

A sub-group of the disaster researchers who study the social aspects of wildfires also study recovery behavior of community members after a wildfire or WUI fire event. However, studies on recovery are in the minority among this research group as well. One recovery study is selected and described here.

Carroll et al. [79] studied the long-term impacts of a large wildfire event in Arizona, U.S. The purpose of this study was to test theories stating that disasters, including wildfires, often have the short-term effect of “bringing people together” while also, under some circumstances, generating social conflict at the local level. Analysis of interviews with community residents as well as key informants (e.g., local government, clergy, social workers, health professionals and the local business community) provided evidence that much of the social cohesion[h] among the community had survived even five years after the event. This study also showed that even though the community continued to support each other, some of the same conflicts that existed prior to the event still remained five years later (e.g., tensions between local groups and outside agencies).

Social science studies of the preparedness and recovery phases of disasters can expand HBiF inquiry past the response phase. The first study (Dickinson et al. [78]) focused on preparedness behavior, identifying that fire-specific social interactions lead to heightened perception of wildfire probability, which in turn, was positively linked to mitigation behavior. Relating this to a building fire event, this study suggests that building-organized meetings and facilitated conversations among building occupants (about preparedness and fire risks) can increase perceptions of risk, and in turn, increase the likelihood of preparedness actions, such as practice and planning. These types of formal or informal social settings can occur at apartment gatherings, neighborhood meetings (e.g., homeowners’ association meetings), office building meetings, and even among a family unit at home. Studies like this can help building managers, owners, and building emergency officials to develop more effective education and training programs for building occupants.

The second study from the social sciences discussed here focused on recovery behavior. The purpose of the second study (Carroll et al. [79]) was to understand how the existing pre-fire social structures, including social cohesion and social conflict, carry over into the recovery period of a wildfire event. Since similar carryover of pre-event social roles into the response phase has been found in building fire events [39,80], it is likely that this phenomenon will be present during the recovery period of a building fire event as well. With this understanding, there might be ways to put mechanisms in place (before a fire event occurs) that would facilitate bringing people together and minimize pulling them apart if a fire event was to occur. Building managers, owners, and building emergency personnel can identify conflicts ahead of a fire event and work to reduce these tensions and strengthen social cohesion, in turn increasing success during the fire recovery period.

McConnell et al. [77] has shown that other aspects of the fire recovery problem can be studied in HBiF, including longer-term physical and mental injuries, such as post-traumatic stress disorder. Although outside of the fire realm, multiple studies have been performed on the mental health of survivors of disasters [81], which could aid HBiF researchers to begin similar types of studies in the context of building fire events.

[h]Social cohesion, also known as social capital, refers to the collective or economic benefits derived from interaction or cooperation among individuals or groups.

Implications for HBiF Research

Overall, expanding HBiF research scope into the preparedness and recovery periods of a building fire has important implications. When studying the response period only, HBiF researchers focus strictly on the life safety of building occupants during fire. By studying pre- and post-fire time periods as well, researchers can begin to broaden their inquiry into whether building occupants are prepared for the next event, and if the next event occurs, will they fully recover? These broader questions extend the impact of HBiF beyond answering the engineering questions (e.g., how safe is this building?) to meeting the broader needs of people in their day-to-day life, including physical and mental health, growth potential, and quality of life. From these new areas of research, HBiF can expand past engineering applications and into improvements to social policies and programs (both at the level of the building and the level of the community). Research that encompasses the entire fire timeline (producing a more complete picture of the overall fire event) can help to improve building-wide fire training and education programs, community fire awareness and preparedness campaigns, pre-fire event planning, post-fire event recovery planning, building or community-wide emergency assistance services, and access to mental health services. Research findings and implementation of these findings can promote a population that is better prepared and more resilient in the face of building fire events.

An added benefit of understanding the entire fire timeline is the ability for HBiF researchers to delve further into the costs of fires–extending this estimate into both the preparedness and recovery periods of a fire event. Calculations of the costs of fire often focus primarily on the immediate impact of the fire (e.g., deaths, injuries, and building damage) as well as the pre-event mitigation efforts that are involved in the protection of building occupants from fires' negative impacts (e.g., fire protection systems, construction, and technology) [82]. However, the longer-term societal costs of fires are often more difficult to estimate and frequently neglected in economic impact studies. Understanding the fire costs–both direct and indirect costs–can help researchers to prioritize their research and focus on the projects that will have the greatest impact from not only an engineering and social perspective, but from an economic standpoint as well.

The previous two sections have outlined the ways in which the social sciences can expand HBiF research depth (into the "unobservable") and research scope (into preparedness and recovery periods) to further understand human behavior in fire and, in turn, improve life safety and well-being of fire survivors. However, expansion of research topics is not the only way that the social sciences can provide insight. The following section provides evidence that the social sciences can expand HBiF research methods, providing the means to ask and answer different types of research questions.

EXPANDING RESEARCH METHODS TO UNCOVER THE MEANINGS BEHIND HUMAN BEHAVIOR IN FIRE

HBiF research can be performed using qualitative methods, quantitative methods, or a mixed-methods approach. Much of the conference-related research [15] on human response to fires has been conducted using quantitative methods; i.e., experiments and survey research techniques. From these numerical data, researchers used quantitative techniques, such as statistical testing or regression modeling, to determine the variables that influenced the perspectives or behaviors being studied. Examples include papers on cultural differences [83], knowledge of refuge areas [84], considerations of usage of elevators (or lifts) for evacuation [85], and evacuation needs from community members following a nuclear accident [86].

There are many benefits to quantitative methods [87]. In experiments, for example, the researcher has the ability to control the scenario, in turn reducing the number of alternative explanations; experiments can be easily replicated, producing higher reliability of results; and experiments can provide relatively ambiguous evidence for causality. Survey research also offers ease of replicability, a reduction in researcher bias, and can be beneficial when asking people about sensitive topics. However, as with any research method, these techniques have weaknesses as well. For experiments, reducing test scenarios to artificial settings may introduce problems with generalizability (or external validity); some questions cannot be addressed in certain more-limited scenarios; and some experiments, especially those that are deceptive in nature, may introduce ethnical issues. Additionally, survey research may limit the extent of the detail, richness, and context of the responses offered by participants; inhibit flexibility of new observations or topics studied during the research; and introduce difficulty in accounting for the complexity of real-world situations and events.

Qualitative research has been represented much less frequently within HBiF conference proceedings [15]. Although this type of research is often faulted by its difficulty with replicability and generalizability, and potential for researcher bias, qualitative research can provide flexibility, internal validity, and rich descriptions and details not as easily obtainable through other methods. A small number of HBiF conference articles involve methods where rich, in-depth qualitative data on human experiences with fire events were collected. Examples include studies of behavior during an actual building fire event [88]; experiences and perspectives of people in tunnels [89], ships [90], and aircraft [91]; and research on planning [92] and recovery processes [93] from wildland-urban interface fires. A similarly small number of research studies were identified that used a mixed-methods approach; i.e., an approach where both quantitative and qualitative data are collected and analyzed. Conference proceedings articles that used mixed-methods approaches studied response during an actual fire event (of which the 2001 WTC Disaster was the focus) [27,28,29], the impact of voice communication messages during a high-rise fire [94], and comparisons of behavior during building fires vs. wildfire events [95].

With so much of the field's focus on the collection of quantitative or numerical data to understand HBiF, the obvious question is why. In the disaster field, which is founded within the social sciences, qualitative research dominated the early work [96]. More recently, the field of disaster research has used both qualitative and quantitative methods to study human response. This finding provides some insight on the current state of research methods within HBiF, which was founded in the field of fire protection or safety engineering. In HBiF, researchers have focused more attention on studying the physical aspects of evacuation (i.e., the movement), as well as gathering and analyzing numerical data both on the physical and behavioral aspects of human response. Both fields and their respective trends prompt the following question: *Are we choosing the appropriate method for HBiF projects or are we choosing the methods with which we feel most comfortable?* The social sciences can shed light on this question and many others that pertain to research methods.

Several factors should be taken into account when selecting the method(s) for a research project. It is not sufficient to choose a method based upon a researcher's comfort level with one approach over the other. In addition, choosing a method because others have used similar methods in a research discipline or topic is also insufficient. Rather, it is important to select a research design that is relevant to the project's research questions [97].

Quantitative research aims to quantify or calculate relationships among variables. Quantitative researchers frequently collect data using statistical sampling techniques and structured research strategies, such as experiments or surveys, to gain information on important concepts in the research. Quantitative researchers then reduce these concepts to numerical variables that represent the quantity, intensity, or frequency of the concept [98]. From these variables, researchers can test, using statistical methods such as regression models, whether the variance in one variable correlates with the variance in another variable and the numerical significance of this relationship [97]. Some of the proponents of quantitative research claim that their work is value-free, or free from researcher bias, if the methods are followed correctly.

Qualitative research, on the other hand, investigates causal relationships among concepts in a different way. Qualitative researchers place emphasis on understanding the *meanings* that people give to their environment and how these meanings influence behavior [97,99]. Instead of focusing on relationships among variables that are measured quantitatively, qualitative research strives to understand the processes by which events and actions take place [100]. This is possible only through a collection of rich, detailed information. Some qualitative researchers [101,102] have stated that qualitative research is better than quantitative research at developing explanations of "local causality," or the events and processes that led to specific outcomes [97]. Also, instead of testing hypotheses based on pre-defined variables, as is done in quantitative research, qualitative research allows for the discovery of phenomena and causal patterns that were not originally anticipated.

Overall, the research questions should drive the type of methods that are used within the research project. The researcher can ask him/herself more about the purpose of the study:

- Is the purpose of this study to find out more about an area on which little is known? If so, then this sounds like more of an exploratory study, which lends itself more to qualitative research methods [87].
- Is the purpose of this study to describe some phenomenon, including identifying the relevant dimensions of this phenomenon? If so, this study sounds more like a descriptive study, which lends itself more to qualitative research methods [97].
- Is the purpose of this study to determine causality or to determine the association between "X" and "Y"? If so, this study sounds more like an explanatory study, which lends itself more to quantitative research methods.

Example from a Qualitative Fire Study

The following example shows the development of a research project [103] that required qualitative research methods [104], based on the research questions outlined in the project:

Project Background—In many countries, individuals with mobility impairments are provided with the freedom and ability to enter and access high-rise buildings on their own; however, they are not provided with the same level of freedom during evacuation. The fire evacuation plan in many buildings requires them to either remain in an area of refuge (a protected space) or to evacuate via an emergency stair travel device or freight elevator with a "buddy". However, recent engineering efforts have designed an elevator system (referred to in the United States as Occupant Evacuation Elevators [OEEs]) to protect passengers, people waiting for elevators, and the equipment from the effects of the fire during the building evacuation process.

For occupants to see OEEs as a viable option for evacuation, they must be seen as safe. In the U.S., for many years, the message to building occupants was to avoid using elevators during fire emergencies. Now that codes and standards bodies have developed requirements for use of OEE systems inside buildings, there is a need for guidance on how the occupants, particularly people with mobility impairments, should use these systems for evacuation in a building emergency.

Project Purpose and Research Questions—Since many social, organizational and human factors-based challenges exist for the use of elevators during evacuations, the National Institute of Standards and Technology (funded by the General Services Administration) recognized that additional research should be performed on how building occupants would respond to the use of elevators during evacuation. Of special interest is the response of people with mobility impairments, who have the most to gain from this option.

With this in mind, the following research questions were developed:

- How do building occupants with mobility impairments currently evacuate multi-story buildings in the United States during fire emergencies?
- What do persons with mobility impairments think about using elevators during fire evacuations? What are their concerns, if any?

Project Methods (data collection and analysis)—From these research questions, it was clear to see that qualitative research methods were required. The research questions, provided above, required a comprehensive understanding of the ways in which people with mobility impairments evacuated buildings in the past. In this project, the researchers were interested in obtaining rich, detailed narratives of people's experiences with elevators and other evacuation devices during previous evacuations (both from training and from actual events). It was also critical to get participants' firsthand perspectives and detailed thoughts about elevator use during evacuation. In other words, it was important to establish an understanding of the *meanings* that people gave to their environment. In this case, the environment consisted of the building in which they worked/lived and the technology offered by the building that could be used for evacuation. In some cases, participants may not have evacuated in an emergency situation or neglected to participate in a drill. Even in these cases, it was important to understand the *meaning* that they applied to the evacuation process and the motivations behind the decision to not participate, if this was a choice.

For this project, in-depth, qualitative interviews were conducted with 51 participants in locations around the United States. All interviews were carried out in person. The format of the interview instrument was semi-structured. A set of brief background questions were followed by open-ended questions that allowed the flexibility to follow the participants' leads during the interviews. More details about the interview instrument can be found here [103]. During the interview, each participant was encouraged to elaborate on their thoughts, resulting in rich and detailed stories that provided the most illuminating insights.

Once the interviews were transcribed, the text was input into a qualitative analysis software. The analysis phase consisted of organizing the information from each interview into a series of themes [105]. To do this, a coding structure was developed [103], and narratives and statements from each interview were then organized based upon this coding structure. Once the coding was complete, researchers performed a systematic exploration of the issues common across participants, while also identifying issues that were only important to a few. Overall, the analysis process allowed for the identification of themes related to the following: evacuation experiences, existing evacuation methods, evacuation plans and training, and perspectives on occupant evacuation elevators.

Reporting of Results—After analysis was complete and themes and findings were identified, researchers wrote up the results. Reporting of research, especially in qualitative research, requires technique and an understanding of qualitative methods. Reporting of results represents the combination of continued analysis and dissemination of results. In this project, Butler et al. continued their analysis as the writing began. The report is organized by the themes identified in data analysis, and contains a series of quotes, taken directly from the participants' interviews, to provide evidence for the themes discussed. The use of quotes in this report, and many other qualitative studies, helps to tell the entire story directly from the perspective of the participants. Quotes in qualitative research provide evidence for the argument in the written study, as well as ensure that the voices of the participants are represented [106]. While the selection and use of quotes can be subjective; it is important to select fragments of quotes that contain elements that have been recognized during analysis, in an attempt to generate the thematic organization for the report. Additionally, sections of quotes chosen for reports are likely to be those that are rich–i.e., containing the key elements in a shortened amount of space.

For example, the following quote was taken directly from Butler et al. [103]. This excerpt is from an interview with a participant explaining prior experiences with evacuation and the risks associated with being lifted from their daily mobility device (i.e., either being carried down the stairs or transferred into an evacuation chair or other device):

> "There's never been a cause for me to evacuate, and I'm glad because had I been evacuated, I would have been injured. If someone tried to lift me, my body is pretty weak, so if you try to put your hand under there, if you didn't know how to lift

> someone like me properly, you'd hurt me. And, generally speaking, that's a big problem…..If you slung me over someone's back, you'd break my back." (Participant BC)

Just from this quote alone, the reader can begin to understand, firsthand, why evacuation planning must include the needs of people with mobility devices and the use of particular evacuation methods may not be appropriate for all people. This quote provides rich, powerful evidence of the danger associated with removing this person from their daily mobility device, and the relief associated with never having to participate in an evacuation drill or exercise in the past. Quotes like this are presented throughout the Butler et al. report [103], providing both evidence of the current problems with evacuation systems and methods that can be used (moving forward) to improve evacuation processes during fire events.

The themes and quotes identified and highlighted throughout this report were then used to create guidance for designers, building managers, and fire emergency personnel on how to improve communication, procedures, and elevator usage during fire emergencies [103]. Additional work and analysis could be performed, in the future, that links the themes in this research to particular individual traits in order to develop more targeted guidance; however, that analysis fell outside of the scope of this project.

Implications for HBiF Research

This example shows the importance and the power of qualitative research. A quantitative-based self-administered survey with response options, for example, would not have been able to fully answer the research questions for this study to the extent necessary to then develop guidance on elevator usage for occupants with mobility impairments. It was necessary to obtain rich, narrative descriptions of the meaning(s) that people assigned to aspects of their environment, which in this case was the building, evacuation methods available in the building, and the people around them during a fire incident.

The social sciences can shed light on all of the aspects of qualitative research design, including the goals of the research (i.e., the purpose), the conceptual framework (i.e., the theories and background of the field, researchers, and participants), the research questions, the research methods, and the validity of the research project/design [97]. Each requires its own consideration and planning before data collection begins. Although this section focuses heavily on the research methods, references are available that can aid researchers throughout the entire qualitative research design process [97, 87,107,108]. Qualitative research design can aid HBiF researchers to delve further into the "unobservable" processes as well as into the preparedness and recovery time periods of a building fire.

The social sciences can also help HBiF researchers to hone their skills in the use of quantitative research methods. The development of surveys, for example, is a very complicated process that is often done and reported on without reference to social science texts. Entire texts have been dedicated to instrument development for quantitative survey research studies [109]. Additionally, texts have been dedicated to the nuances of questionnaire development, including the importance of length, formatting, spacing, question types (open vs. closed), response options for closed questions, ordering of questions, and question wording, among other issues [109,110].

The previous sections have established that the field of human behavior in fire would benefit from integrating concepts from the social sciences. However, integration is not a trivial exercise. There are presumably many different ways in which researchers can begin to integrate social science concepts into HBiF projects. The following section discusses one possible way to better integrate the social sciences into HBiF research; namely, via collaboration with social scientists on relevant research projects and/or research designs.

COLLABORATION AS THE KEY TO EXPANDING HBiF AXES

Collaboration between HBiF researchers and social scientists can exist in many forms. Three example methods for collaboration are presented here: on a project-by-project basis, embedding social scientists within HBiF research organizations and institutions, and developing multi-disciplinary researchers. Each one of these methods is pictured in Figure 4, below, with "H" representing a HBiF researcher and "SS" representing a social scientist.

First, on a project-by-project basis, social scientists could serve as members of fire-related research project teams. Although still outside of the norm, funding opportunities are increasing that require the formation of multi-disciplinary teams. For example, the National Science Foundation, a major funding source for academic research in the United States, has a program entitled Hazard SEES [111]: "*The overarching goal of Hazards SEES is to catalyze well-integrated interdisciplinary research efforts in hazards-related science and engineering in order to reduce the impact of hazards, enhance the safety of society, and contribute to sustainability*." This program specifically seeks research projects that cross the boundaries of geoscience; computer and information science; engineering; mathematics and statistics; and the social, economic, and behavioral sciences. The hope here is that, over time, a larger number of funding agencies will acknowledge the contributions of inter-disciplinary research. In the short-term, however, the HBiF field can take a proactive role in demonstrating its benefits.

Another way to increase collaboration is to embed full-time social scientists within predominantly non-social science organizations and institutions that conduct HBiF research. Currently, there are organizations and academic institutions that have, within their respective departments, social science researchers focused solely on fire-related projects. Examples of institutions where social scientists have been embedded include the University of Greenwich, UK and Victoria University, AU. For organizations and universities that cannot or will not support full-time social scientists, another option might include joint appointments between physical and social science departments or programs. That way, social scientists could be involved in teaching classes and/or performing engineering-based research on at least a part-time basis. Embedding social science researchers within engineering departments allows them to provide daily input on fire-related projects, rather than being called on only for select projects.

Probably the most difficult of the three suggestions would be to establish "in-house" social science capacity within the field of human behavior in fire; e.g., the development of a multi-disciplinary degree in human behavior in fire. Such a degree could require academic credits from a variety of departments including engineering, psychology, sociology, economics, geography, architecture, and many others. This suggestion has its own set of problems. Such a degree would require deeper and more complex changes to the educational system, since the concept of multi-disciplinary study is a relatively new one. Several questions arise; for example, within which academic department(s) would such a multi-disciplinary degree be located? Are organizations and single-discipline departments within academic institutions willing and ready to accept multi-disciplinary graduates? Will multi-disciplinary degrees allow for sufficient depth and breadth of knowledge required to answer research questions in the field?

There are current examples of multi-disciplinary fields that provide significant value to the HBiF field, including human factors psychology and cognitive ergonomics. In general, both fields focus on the design of systems, tools and environments to improve the productivity, safety, and comfort of people. Examples like these can provide a foundation from which to establish a multi-disciplinary field and degree program within HBiF.

These three methods for collaboration, although not the only possibilities, provide three viable options to better incorporate the social sciences into HBiF projects. Hopefully, this article provides the platform to allow researchers to continue this conversation and suggest other viable options not discussed here. Additionally, HBiF researchers who may not be familiar with social science research methods or other literature may choose to delve further into the many references provided in this article. This would be another important step in moving the field closer to the social sciences. Perhaps one day, when the HBiF conference literature is revisited, a larger number of entries will focus on the "unobservable" aspects of HBiF or the preparedness or recovery periods of a building fire, and in doing so, make use of qualitative research methods.

CONCLUSIONS

This paper explored the ways in which integrating concepts from the social sciences could broaden HBiF research perspectives and research methods, and, in doing so, increase impact. Overall, each of the three axes originally shown in Figure 1: depth, scope, and methods, can be expanded via integration with the social sciences. First, we can delve further into the "unobservable" by mining the insights and studies located within the relevant disciplines and subdisciplines within the social sciences. In this paper, subdisciplines within the fields of psychology (i.e., environmental and social) and sociology (i.e., environmental) were explored to expand the types of research questions, methods, and findings necessary to delve further into the "unobservable" aspects of human behavior in fire.

Second, the social sciences provide evidence for the benefits of expanding HBiF research along the fire event timeline. Currently, projects in human behavior in fire have focused primarily on the "disaster" or response phase of a building fire. However, that focus means that we miss out on significant time periods that occur both before and after a fire event;

both of which can have great impact on life safety as well as the overall well-being of a building population. Pre- and post-event studies of wildland urban interface fire events have shown that there is much to be learned from studies that fall outside of the response phase.

Finally, the social sciences provide significant insights on the appropriateness of research methods. References within the social sciences can be mined to make appropriate choices between quantitative and qualitative research methods, or a mixed-methods approach, and the benefits of each. This paper explored the benefits of qualitative research and the ability to delve further into the meanings that people assign to the world around them. Hopefully, more HBiF projects will embrace this technique to expand HBiF research scope and impact on social programs and policies outside of engineering.

The social sciences are filled with theories, research questions, and research methods, just as the ones provided in this paper, that will aid in expanding HBiF knowledge further into the realm of the "unobservable" as well as along the fire timeline continuum. Collaboration and partnership with researchers in relevant social science disciplines can provide added insight on particular projects where their expertise is required. As is shown by Sime's Affiliative Model [24] or Latane and Darley's social influence experiments [21], the field of human behavior in fire benefits each time new theories like these and others (e.g., the theory of affordances [38]) are introduced.

Via better integration, we can begin to burn down the silos between the physical and social sciences. The silos certainly began to smolder with the development of the field of human behavior in fire. We can completely burn down the silos by continuing to expand thinking and perspectives and even HBiF project teams to include the range and depth of knowledge provided by social science perspectives. These perspectives will improve upon current research and outputs, and in turn, provide higher levels of safety for building occupants, improve the efficiency and cost-effectiveness of building design and construction, and provide the means for a higher overall quality of life for the people who live and work in buildings around the world.

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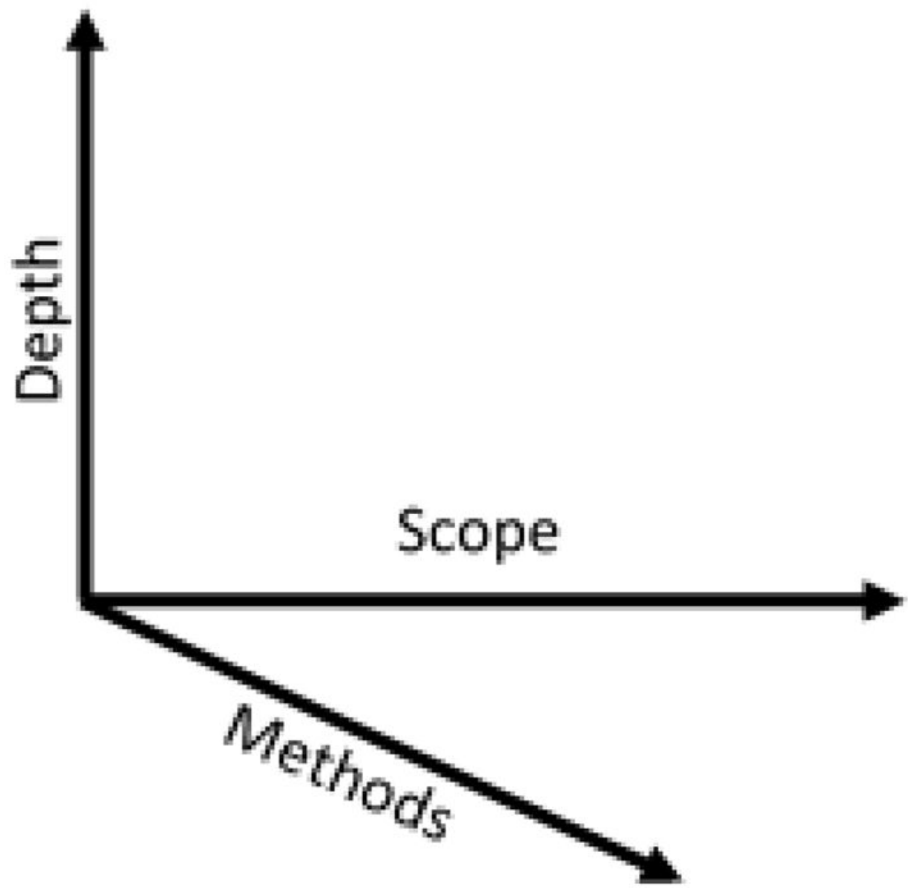

Figure 1.
The three axes of benefits provided by integration with the social sciences

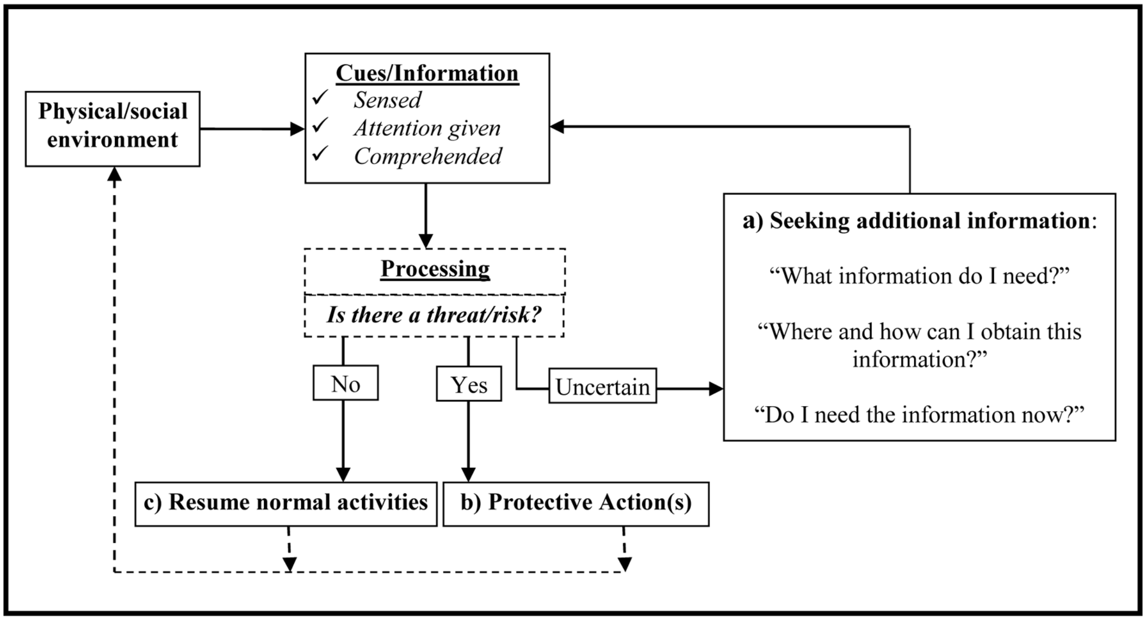

Figure 2.
The Protective Action Decision Model, adapted and redrawn from Lindell and Perry[40]

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Figure 3.
The disaster timeline [65]

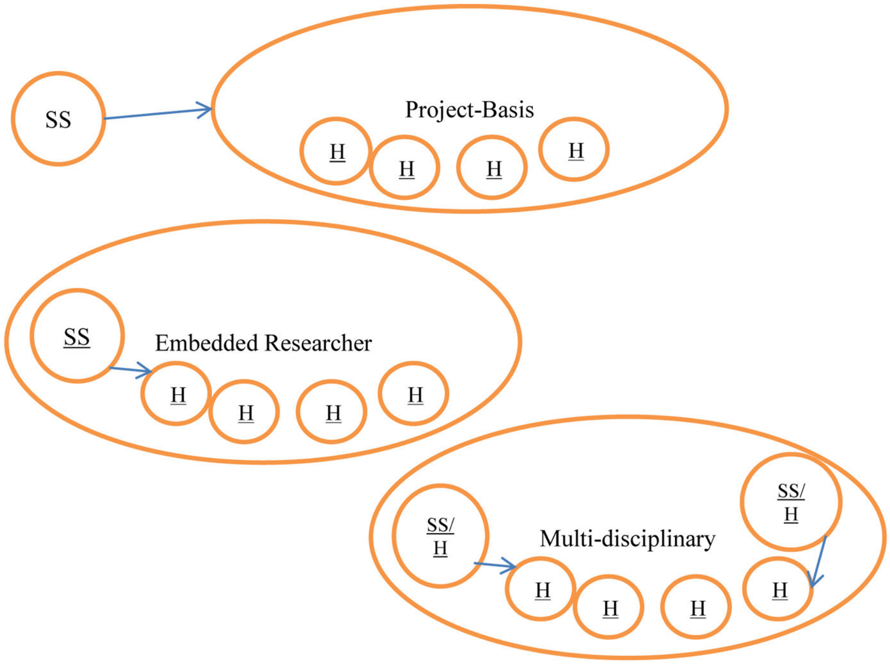

Figure 4.
Methods for collaboration with social scientists