Decision Making under Stress in Emergency Response: Challenges and Opportunities

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BACKGROUND

Firefighting is an inherently dangerous occupation, with over 100 fatalities and 85,000 injuries in the United States annually; this fatality rate is three times that of most other occupations (RAND, 2004). Fatalities in younger firefighters are usually the result of traumatic injuries, while cardiovascular disease underlies most fatalities in older firefighters. For all firefighters, trauma is the leading cause of injuries. Firefighting *per se* is the most injurious activity, since responding to and fighting fires comprises only 10 to 20% of a firefighter’s on-duty time yet accounts for over half of all traumatic injuries. While the circumstances surrounding these injuries are sometimes beyond human control, many fatalities “are the result of a chain of events, which, if detected early, has the potential to be broken and prevent many, or even most, fatalities” (FEMA, FA-220, 2002). One factor in this chain of events is almost certainly poor decision-making, epitomized by the 2007 Charleston fire of a commercial showroom, in which nine firefighters died as a result of a series of poor decisions (see www.cdc.gov/niosh/fire/reports/face200718.html for report). Enhancing decision-making skills in firefighters, especially in the stressful environment of the fireground, is critical to breaking this chain. However, a review of the literature on decision making under stress present conflicting models and ambiguity.

This document reviews literature on decision making under stress. The review mainly addresses three parameters that are document to effect judgment and decision making: experience, time pressure, and difficult tradeoffs. The document also proposes virtual reality as a venue with high potential for establishing a breakthrough in research in this area.

JUDGMENT AND DECISION MAKING MODELS

Classic theories of choice stress decision making as a rational choice process. The classic model for making decisions among sets of alternatives that vary on several dimensions is Multiattribute Utility Theory (MAUT). MAUT proposed that a decision maker identify a set of alternatives and a set of decision dimensions, assign a weight to each of the dimensions, calculate the utility of each alternative on each dimension, and select the alternative with the highest overall utility.

Numerous studies have found that MAUT and other classical decision theories are not good descriptions of how decisions are actually made (e.g., Kahneman & Tversky, 1979). Rather, a distinction must be made between *normative* and *descriptive* theories: that is, how decisions ideally should be made given unlimited resources, versus how decisions actually *are* made (Dillon, 1998). Although extensive research has been done into descriptive theories of choice, much of this research has been done using abstract decisions that bear little resemblance to the naturalistic decisions actually encountered by decision makers. However, a sacrifice of realism has often been necessary to gain the experimental control needed to test psychological theories.

Experience: The most-cited descriptive model of choice for high-stress time-critical decisions, such as those made by fireground and military commands, is the RPD Model. RPD was introduced by Klein (1989) as a descriptive model of decision making in naturalistic settings. Klein (1999) presents the model as follows:
The Recognition-Primed Decision (RPD) model fuses two processes: the way decision maker sizes up the situation to recognize which course of action makes sense, and the way they evaluate that course of action by imaging it.

The RPD model proposes that experienced decision makers employ a singular evaluation strategy. In singular evaluation, the decision maker considers only a single possibility and then acts on it, rather than comparing two or more alternatives as proposed by traditional decision theories. In the RPD model, the decision maker first examines the situation for identifying cues and immediately thinks of a possible action. The action is evaluated by running a mental simulation. The decision maker modifies the action based on the results of the simulation, and then implements the action if the results seem acceptable.

Because their first impulse is usually an appropriate response to the situation, Klein (1999) suggests that experienced decision makers do not bother searching for and evaluating other alternatives. If the situation changes, a new course of action will present itself and the process will be repeated. By not comparing alternatives, Klein proposes that experienced decision makers save valuable time in time-critical situations while still arriving at acceptable solutions. He argues that explicitly comparing alternatives is done primarily in situations that cannot be assigned to a prototype, either because the situation is sufficiently novel or because the decision maker is inexperienced. Klein suggests that these decisions are often inferior to those made by experienced decision makers using a singular evaluation strategy.

Other theories that have considered the effects of experience on decision making include “decision making by analogy” (Khong, 1992), “dynamic vs. static decision making” (Mintz et. al, 1997), and polihurestic theory (Mintz & Geva, 1997), which postulates a two-stage decision strategy. At the first stage, a critical dimension is identified and a noncompensatory decision mechanism is employed to eliminate alternatives that are unacceptable using a simplified heuristic-based process. The remaining set of alternatives is then analyzed to minimize risk and maximize award (Mintz & Geva, 1997). Mintz (2004) tested the effect of familiarity of the decision task on polihurestic theory using high-ranking military officers. The results demonstrated that when familiar with the decision task, decision makers are more prone to employ an alternative-based information acquisition strategy: that is, to consider all aspects of each alternative in turn. However, the results also strongly support the conclusion that a noncompensatory mechanism, EBA, was also used early in the decision task to reduce the range of alternatives. In EBA, a decision-maker considers one or more critical dimensions, in turn, across all alternatives, rather than considering all dimensions of each alternative, in turn, as in an alternative-based strategy. Alternatives that fall below minimal thresholds on critical dimensions are eliminated. Evidence for use of a mixed choice strategy such as EBA has been found by many other decision researchers: e.g., Payne and Braunstein (1978), Bettman and Park (1980), and Levin’s group in their works on phase narrowing (Heller, Levine, & Goransson, 2002; Levine, & Jasper, 1995; Levine, Jasper, & Forbes, 1998; Levine, Prosansky, Heller, & Brunick, 2001).

These results seem to contradict the RPD model, which proposes that experienced decision makers rarely consider multiple alternatives, even to eliminate them quickly. However, it is important to note that Klein recognized that proof is needed as to whether decision makers actually do compare alternatives subconsciously (Klein, 1998, p. 297).
Time Pressure: The effects of time pressure on choice and process have been addressed in a variety of studies (Betsch, Fiedler, & Brinkman, 1998; Diederich, 2003; Dror, Busemeyer, & Basola, 1999; Payne, Betteman, & Luce, 1996). Ben Zur and Breznitz (1981) suggested three optional response modes when making decisions under time pressure: (1) accelerate information processing (see also Maule, Hockey, & Bdzola, 2000); (2) process a subset of the most important information (filtration—Miller, 1960); and (3) shift the processing strategies. Maule and Hockey (1993) divided these response modes into two distinguishable stages: micro-strategy changes (acceleration and selectivity) and macro-strategy changes (attribute-based, rather than alternative-based, strategies).

Payne, Johnson, and Bettman (1988) conducted computer simulations to examine the relative accuracy of heuristics under time pressure across various task environments. The results indicated that under high time pressure, the use of strategies that review some information about all alternatives leads to improved accuracy. One such strategy is EBA. Another is the lexicographic strategy, in which all alternatives are considered based only on the most critical dimension. The alternative best on this dimension is the one chosen. If two or more alternatives are tied on the most critical dimension, then the process is repeated on the next-most critical dimension, and so on until a choice is made. Payne, Johnson, and Bettman (1990) found that both EBA and the lexicographic strategy perform well under conditions of moderate time pressure with a large number of alternatives and dimensions, or under severe time pressure with a moderate number of alternatives/dimensions. However, EBA proved to be the most robust rule when the task environment becomes very difficult, involving both high time pressure and large decision set. Based on these and similar experiments, Payne, Johnson, and Bettman (1993, pp. 165-166) concluded that decision makers implement a hierarchical approach to time constraints that includes acceleration of processing, increased selectivity, and, finally, a shift in strategies from compensatory to noncompensatory, supporting Ben Zur (1981) and Maule, Hockey, and Bdzola (2000).

Other studies on time pressure also suggest an advantage for noncompensatory strategies. Rieskamp and Hoffrage (2008) demonstrated that under low time pressure, a strategy that integrates all information available predicted the inference well, whereas under high time pressure, lexicographic heuristics best predicted inferences. Rieskamp and Hoffrage’s (2008) work strengthened the results of Payne and Bettman (1996), who examined decision making under situations where opportunity-cost time pressure exists. Their results indicated that the lexicographic choice rule is a very attractive strategy in these situations.

Huber and Kunz (2007) tested the effect of time pressure on both information search and the search for Risk Diffusing Operators (that is, the search for further lines of action) in quasi-realistic scenarios. Their results are consistent with previous work: the search for information on negative consequences increases with time pressure, while the search for information on probabilities decreases. Zakay (1993) introduced a model suggesting that under time constraints, the decision maker automatically allocates resources to monitor time, and by doing so reduces the mental resources available to elevate decision making quality. His findings are supported by earlier work by Zakay and Wooler (1984), demonstrating that, while training improves decision quality in general, it does not result in improvement under time pressure. The majority of work on decision making under time pressure indicates that risk aversion
increases with time pressure (e.g., Maule, Hockey, & Bdzola, 2000). However, the results by Huber and Kunz (2007) do not necessarily support these findings.

The effects of time pressure under more realistic decisions have been less well studied. Ahituv, Igbaria, and Sella (1998) examined the effects of completeness of information and time pressure on the decision making performance of field commanders in the Israeli Air Force. The results showed that complete information, in general, improved performance; however, under time pressure, complete information did not yield performance improvement. Klein’s (1998) RPD model maintains that decisions under severe time pressure (less than 1 minute) are habitual or intuitively non-analytic, generally using the singular evaluation strategy discussed above. It is important to stress that his work is based on interview protocols conducted with firefighters after the decision making process occurred. The present proposal instead will use a VR environment to study decisions made under time pressure as the decisions are being made.

**High Tradeoff Values:** The firefighting force is occasionally engaged in decision tasks with extremely difficult tradeoffs: decision dilemmas where there are no safe alternatives. A firefighting incident commander may select an alternative line of action that increases risk to his subordinates in order to reduce risk to potential victims. Should he select a safer alternative for his subordinates, he may increase victims’ risk. Shepard (1964) suggested that, when facing a decision task where alternatives have both advantages and disadvantages, the immediate sub-goal becomes reducing the emotional discomfort associated with the state of conflict induced by the decision problem. Hogarth (1987) likewise proposed that decision makers will tend to avoid strategies, such as MAUT, that require explicitly making the difficult tradeoff.

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As the review above indicates, a consensus on decision making under stress is yet to be reached. Kowalski-Trakofler and colleagues from the National Institute of Occupational Safety and Health presented addressed judgment and decision making under stress in emergency management. In their review they wrote (2003):

*During an emergency situation, critical judgments are frequently made under conditions of acute temporary or prolonged stress. Emergency decision makers are required to process massive amounts of information, which is sometimes incomplete or faulty, usually under severe time constraints... The relationship of stress to judgment and decision making is an aspect of human behavior that remains inadequately explored. The literature in this area is extremely complex and not conclusive... This paper has suggested that a better understanding of the interplay between stress and an individual's judgment and decision making activities would yield a better understanding of how people reach the choices they make in emergencies. As far as studies of judgment and decision making are concerned, the limited literature in this area suggests a strong need for increased attention to the topic.*

**Stress Effects in Firefighters**

Firefighters experience both physical and psychological stressors as part of this occupation; both types of stressors may contribute to their increased levels of morbidity and mortality. The physical stresses of this occupation are well known, including heat, cold, and
extreme physical exertion (Sothmann et al., 1992a; Bruce-Low et al., 2007; von Heimburg et al., 2006). Firefighting also provides considerable exposure to psychological stressors (Beaton et al., 1998; Bryan & Guthrie, 2005). Exposure to the physical and psychological stressors of firefighting in a real-world or in a firefighting drill situation disturbs homeostasis, resulting in the activation of the hypothalamic-pituitary-adrenal (HPA) axis and the sympathetic nervous system (SNS), which restore homeostasis (Granger et al., 2007; Roy, 2004; Smith et al., 2005).

Blascovich and Tomaka (1996) presented a framework that differentiates challenge-stress from threat-stress states. Challenge stress is a state in which an individual feels he or she has the appropriate resources to deal with the situation, whereas in a threat-stress state he or she perceives a lack of necessary resources (see also Frankenhaeuser, 1986; Henry, 1980). Mendez et al. (2007) showed that these two stress states have different cardiovascular signatures. Challenge-related stress results in an increased cardiac output and a reduction in the total peripheral resistance, to allow increased blood volume to the periphery and increased rate of blood flow to the brain and muscles. In contrast, a threat state presents a cardiovascular profile with reduced efficiency and increased vasculature resistance. Kassam et al. (2009) assigned participants to social feedback conditions designed to engender challenge and threat states, and showed that participants in the challenge group adjusted cognitively better than did those in the threat group, with this effect mediated by cardiovascular reactivity. Their work demonstrates the importance of considering profiles of cardiovascular reactivity when examining the influence of stress, emotion, and motivation on decision-making. We will do so in the proposed research by assessing the cardiovascular responses of firefighters as they are exposed to decision-making scenarios varying in both time pressure and tradeoff values.

**USE OF VR TO ESTABLISH ACCURATE HUMAN RESPONSE**

VR typically refers to projection surfaces (back- or front-projected) where stereo graphics are used with three-dimensional viewing and with input devices such as shutter glasses and data gloves. For the proposed study, VR will be defined as three-dimensional computer-generated graphics that are displayed large enough to encompass all of the user’s visual field and controls allowing users to interact with the system, thereby creating a virtual world that users are likely to experience as if they are inside it. Several key elements are necessary for this simulation to be successful (Dohse, 2007): (1) immersion, (2) presence, and (3) situation awareness.

**Immersion** is defined as a quantifiable description of the technology (Slater et al., 1996). Immersion is increased in two ways: (1) by isolating a user from the real environment and (2) by creating realistic sensory inputs. Thus, a system that has a small field of view, low screen resolution, poor sound quality, and an obtrusive style of control has a much lower level of immersion than a system with a large field of view, high-quality visual and auditory output, and more natural modes of interaction. The Virtual Reality Application (VRAC) at Iowa State University is a home for a six-sided computer automatic virtual environment (CAVE™). This system, termed the C6, creates an exceptional degree of immersion with its field of view and resolution. The C6 is a six-sided immersive system in which a participant is fully enclosed with 10’ x 10’ screens. Each screen projects representations with a resolution of 4,000x4,000 pixels, which is over twice the resolution of high-definition television. The C6 is the highest-resolution VR system in the world, more than double that of any other similar system.
Presence is a subjective feeling of being inside a virtual environment. A high level of presence means that users feel as though they are part of the virtual world. In this study, the simulation will be in immersive stereo, where each user will wear active shutter glasses. This, combined with the resolution and field of view from the C6, will provide a high level of visual realism. The shutter glasses will be attached to the helmet of the participants, to not distract from their tasks while in the simulation. The use of active stereo is important to control the perception of a participant’s position and body in the virtual environment. In addition, custom graphics programs, called shaders, are used to render photorealistic objects and scenes in real-time to further increase a participant’s presence.

Situation awareness (SA) is “the perception of the elements in the environment within a volume of time and space, the comprehension of their meaning and the projection of their status in the near future” (Endsley, 1988). Situation awareness has three levels: the first level is perceiving different elements of the environment, the second level is understanding what the different elements are and what they mean, and the third level is interpreting the near-future state of those elements. Proper SA is critical to a participant’s interaction with a simulation (Ma & Kaber, 2007). If SA is compromised, then data collected in response to the simulation may be inaccurate.

Virtual reality as an agent of behavioral change

An excellent source of research to build from is the use of VR simulations in exposure therapy (ET). ET is used to treat patients suffering from psychological disorders ranging from mild anxiety to a more debilitating condition such as post-traumatic stress disorder.

VR has been used to conduct exposure therapy for a number of anxiety disorders, including claustrophobia (Botella, Banos, Perpina, Villa, Alcaniz, & Rey, 1998), acrophobia (Emmelkamp, Krijn, Hulsbosch, deVries, Schuemie, & van der Mast, 2002), and fear of flying (Maltby, Kirsch, Mayers, & Allen, 2002). In these studies, Virtual Reality Exposure Therapy (VRET) (i.e., the use of VR to create environments that provoke anxiety) was used to present realistic trauma-inducing cues to patients, with increasing levels over time. Three randomized controlled trials have been reported involving patients with severe height phobia (acrophobia). Emmelkamp and colleagues (Emmelkamp, Bruynzeel, Drost, & van der Mast, 2001) found VRET to be as effective as in-vivo exposure on a number of self-report measures. In a later study, Emmelkamp and colleagues (2002) found VRET and in-vivo exposure to be equally effective on all measures, including a behavioral approach test, and were maintained at a 6-month follow-up. The third study compared two different types of VRET, which differed in their degree of presence (Krijn et al., 2004b). In one condition, a computer-automated VR system was used with active shutter glasses. In the second condition a head-mounted display (HMD), a lower-cost technology with a smaller field of view, was used. In the study, presence was higher in the computer-automated VR system, providing evidence that a VR simulation such as the computer-automated VR system can evoke anxiety and stress.

As with VR in general, effective VRET requires patients to feel present in the virtual environment; thus, the virtual environment needs to be able to elicit psychological arousal, and the virtual environment needs to resemble the natural environment (Krijn, Emmelkamp, Olafsson, & Biemond, 2004a). While the participants in these studies are different from emergency responders, both groups are under stress and anxiety.
Based on preliminary results from experiments conducted by the authors, and echoed in a review by Lee (2005), VR can be fully immersive and can evoke behavior change in firefighters. For example, civilian firefighters (Bliss & Tidwill, 1997) learned to navigate a rescue route in an unfamiliar one-floor building using head-mounted VR displays to “see” the route and a three-button mouse to control movement. Twenty min later, they entered the actual building wearing vision-limiting goggles to rescue a mock baby. Time to effect the rescue was markedly better than the non-trained group (115 secs vs. 177 secs) and comparable to that using the traditional, and much more familiar, method of reading blueprints. Using a head-mounted VR display and a joystick, naval firefighters learned how to navigate multiple levels of a ship and practice fire extinguishing techniques with a VR fire (Tate, Sibert and King, 1997). When tested on the actual ship with a real fire, and compared to traditional navigational training, the VR-trained group was quicker getting to the fire (6:55 vs. 8:39 minutes) and faster extinguishing it (9:26 vs. 11:43 minutes).

**Preliminary Studies**

Fourteen career firefighters underwent the 15 minute VRE scenario described above; the scenario included pre-backdraft (static, low time pressure) and pre-flashover (dynamic, high time pressure) situations. Heart rate (ECG), blood pressure (beat-by-beat, Finapres), and heart rate variability measures were assessed. Robust increases in heart rate (peak 53 ± 11 bpm above resting, mean ± SEM), systolic blood pressure (22 ± 4 mmHg), and a marker of sympathetic arousal (20 ± 3 fold increase in LF/HF ratio) were seen during the 15 minutes. Moreover, there were differences in the heart rate and blood pressure responses between the pre-backdraft and pre-flashover situations (p=0.060 and p=0.037, respectively). Effect sizes were moderate for heart rate and systolic blood pressure [.55, .32, respectively, Cohen’s d (Cohen, 1988)] but absent (.00) for sympathetic arousal; thus, different stressors resulted in different cardiovascular responses despite similar levels of sympathetic arousal. However, the more dangerous pre-flashover situation elicited markedly more sympathetic arousal (effect size=1.15) and blood pressure increases (effect size=.92) in the experienced firefighters (20+ yrs, n=6) than the less experienced firefighters (<2 yrs, n=8). Debriefings indicated that the former perceived the pre-flashover situation as a much greater threat. These findings provide strong evidence that the VRE used here is effective at evoking high levels of immersion, situational awareness and presence. Thus, we are confident that the VRE scenarios will be as effective as the logical alternative, “real” fireground training exercises, but without the physical danger and physical demands associated with fire training outside. From a research perspective, the VRE is superior, since the stressful situations are totally reproducible and identical for every subject.

**Analysis of individual differences in stress response, judgment, and decision making**

Figures 1 and 2 present the physiological responses (i.e., heart rate, blood pressure, and heart rate variability [LF/HF ratio]) of two career fire department chiefs who participated in the preliminary assessment. Both chiefs have 20+ years experience in very active fire departments. Based on their responses to the demographic and experience questionnaire, they have similar professional profiles. However, their responses to stressors and their decision making portraits are on the two disparate edges of the response spectra.
Upon entering the C6, the firefighters went through two training scenarios (denoted as “Maze” and “Car” in the figures below). Then the firefighters went through the static and low time pressure ‘Pre-Backdraft’ scenario (denoted as “outdoor” in the figures) and the dynamic, high time pressure ‘Pre-flashover’ scenario (denoted as “indoor” in the figures).

As Figure 1 reveals, the first chief was a high reactor to the stress in the scenarios. At the end of the “indoor” scenario (where smoke becomes very dense and accumulates rapidly), this chief’s physiological response has a cardiovascular profile that is typical to a threat-related stress. i.e., he perceives that he does not have the mental horsepower to deal with the situation, resulting in a sharp increase in blood pressure and decline in heart rate (essentially he is “shutting down”) (Kassam, et al., 2009). An analysis of his decision making profile (Figure 3, below) demonstrates the devastating effects of the stress on his judgment and decision making capacity.

A review of Figure 2 shows that the second fire chief is a low reactor. His blood pressure, heart rate, and heart rate variability hardly fluctuated along his journey. As described below, his decision was an appropriate one (Figure 4).

To illustrate the effect of the stressors on the judgment and decision making of the high and low reactors, portions of their pre-backdraft decision making portraits are presented in Figures 3 and 4. As Figure 3 reveals, the high reactor fire chief utilized a non-compensatory decision making strategy, exhaustingly reviewing all the information available along the decision dimensions (reviewing some of the information more than once) demonstrating a ‘confrontation avoidance’ behavior (Payne et al. 1993, P. 30). Moreover, this exhaustive review of information along the dimensions indicates a struggle to decide on a decision making strategy. Finally, the chief selected “Attack through the main door” as a line of action, which will result in devastating consequences (likely a massive explosion). Attacking through the main doors in backdraft fire scenarios has claimed the lives of many firefighters. In contrast, the decision making portrait of the low reacting chief suggests a decision strategy that is consistent with the singular evaluation of RPD (Klein, 1993). After reviewing the cues, the chief identifies the scenario as a pre-backdraft, reviews one information bin, and selects “Horizontally ventilate through a window” which is an appropriate line of action for backdraft.
List of sample video clips from pilot work in virtual reality

It is important to emphasize that these clips are recordings of the experiment as it appears on a computer monitor, and not from within the actual virtual reality (VR) environment. The video clips present only 1 perspective (the front view) of the 6 views provided by the 6-sided VR chamber and these clips are not in 3-D. Even if the firefighter turns around in the VR environment, the views presented here remain the front view. The red dot seen in the video clips is where the firefighter is looking, based on his head movement. The “window” or “heads up display” seen is the decision matrix presented to the firefighter as part of VirtuTrace. VirtuTrace is the software developed by the researchers. VirtuTrace alters the VRE in real-time to create a fully immersive environment for the subject. It includes a sophisticated real-time decision capturing algorithm that also uses process tracing to trace decision-making processes in VR and analyze these processes. For the firefighter, VirtuTrace facilitates radio communication with his superiors, peers, and subordinates during an emergency response. When requested by the firefighter, VirtuTrace will project a matrix into the VRE as a floating “window.”

Pre-backdraft scenario (speakers on):
http://www.vrac.iastate.edu/~godbyk/virtutrace/pre-backdraft.html

Here, a Captain from a fire department in Iowa performs a visual inspection of the front and back of the house (i.e., commonly called a “360”), returns to the front of the house, turns around and calls up the decision matrix. He reviews several pieces of information from the matrix before making his decision.

Pre-flashover scenario (speakers on):
http://www.vrac.iastate.edu/~godbyk/virtutrace/pre-flashover.html

Here, the firefighter quickly recognizes the situation and does not even enter the interior. He calls up the decision matrix and rapidly makes a decision.

While the review above support VR as an agent of behavioral change, while anecdotal, our pilot work has already led to changes in firefighter behavior. For example, the pre-backdraft clip referenced here is a short excerpt of this Captain’s participation in a pre-backdraft scenario. Toward the end of this experience, as the captain is acquiring information through the radio communication, he continues to monitor the house for further developments. This is standard practice for a firefighter and indicates a high level of immersion in the VR environment.
environment. As researchers, we know the Captain is continuing to monitor the house because the red dot seen in the video clip is where the Captain is looking.

We present this clip for a reason: the Captain and his troops participated in our preliminary assessment. In the evening following the assessment, the Captain and his troops were dispatched to a burning residence. According to the fire department’s Deputy Chief, the Captain’s tactic was unusual: shortly after deploying his troops, he called all the troops back for reorganization and re-assessment, and then decided to change his approach to the fire scene. This had never been done in the history of this fire department—stopping a fire attack in the middle of the approach.

The research team subsequently interviewed the Captain, and his reflection indicated that the exposure to the pre-backdraft scene in the virtual reality environment altered his judgment and decision making at the fireground. Likewise, a few of the less experienced firefighters on this crew told the research team that the “training was great” (i.e., participating in the VRE simulations) since they had an idea of what to expect.

**SUMMARY**

Naturalistic decision making (NDM) is a school of thought that desires to study decision making in the natural environment of the decision maker and to minimize/eliminate the uncertainties and biases that laboratory studies introduce. A virtual reality (VR) environment allows mimicking of a natural setting while preserving the qualities offered by controlled laboratory environments. The authors documented the ability of virtual reality environments to establish appropriate physiopsychological reactions and serve as an agent of behavioral change, a combination of qualities that is unique due to its potential for producing intellectual merit as well as establishing impact.

Researchers at Iowa State University developed software, VirtuTrace, that is utilizing human-computer interactions via VR technology in conjunction with decision tracing technology for emergency response simulations. VirtuTrace represents a breakthrough in NDM studies and will lead to a significant leap in studying decision making for emergency response.

**REFERENCES**


