Understanding Naturalistic Decision Making Under Life Threatening Conditions

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ABSTRACT

Motivation – Understand decision making of mission critical personnel (e.g., police, firefighters, warriors, etc.) when life and limb are threatened. **Research approach** – Consilience (Wilson, 1999) was used to synthesize predator-prey dynamics, emotion-primed NDM and intuitive cognition to understand decision making under threat. **Findings** – Advances in ethology, cognitive and neurosciences do provide a means to understand the mechanisms that modulate decision making under threat. **Research limitations/Implications** – The paper presents an ad hoc theoretical model, with partial empirical support, on the predilections and frailties of NDM under threat. Further research is necessary to validate this approach. **Originality/Value** – Current research in NDM has not satisfactorily addressed the cognitive mechanisms driving decision making under threat. This paper attempts to close that gap. **Take away message** – A formal approach to study NDM under life threatening conditions has been proposed. This can be used to inform the design of systems and training programs for mission critical personnel.

Keywords

Naturalistic decision making under threat, predator-prey dynamics, emotion, intuition

INTRODUCTION

> *"I fired and fired and fired and fired and fired. At EVERYTHING.… My nerves were completely shot and I was emotionally drained and I noticed that my hands were still kinda shaking…I was thinking how I was lucky to be alive. I've never experienced anything like the fear I felt today."*

The above account describes U.S. Army Specialist Colby Buzzell's naturalistic decision-action outcome ("I fired and fired and fired…") in the throes of combat (Buzzell, 2008). As seen here, Buzzell's emotions took charge of his decision making process in an almost reflexive and nonconscious way to ensure his bodily integrity and survival. The documentary film maker Ken Burns, who recorded oral histories of WWII veterans, summed up the experiences of soldiers in combat best: "when life is most threatened, when death is possible at any moment, every living moment is vivified" (Burns, 2007).

The issue of "survival" – and the role of emotions in general – in Naturalistic Decision Making (NDM) theory and practice has received little attention. Recently a framework called High Velocity Human Factors [HVHF] (Rahman, 2007a) to study human performance when mission critical domains (MCDs) such as police, firefighting, etc., enter "nonequilibrium states" (volatile, uncertain, complex, ambiguous, high stakes & time-stressed) has been proposed. HVHF's main emphasis is on the emotional modulation of cognition under stress and it has not delved deep into decision making when danger is imminent. However, the HVHF framework has shown that survival is contingent on emotions driving the right cognitive processes, which suggests that survival and affect-driven decision making are inextricably linked.

A BRIEF PRIMER ON EMOTIONS

Before one proceeds to understand decision-making under threat, it is essential to understand the primal circuits in the human neural system, which act as threat detectors and drive decision making in such circumstances.

Aversive emotions (e.g., fear, anger) in particular are a form of an early warning system to an organism and aid in its survival. The neural system is biased towards first warding off danger, the "snake in the grass effect" (Öhman, Flykt & Esteves, 2001; LeDoux, 1996) and then think about it rationally as to what the stimulus (snake or rope?) in the grass really was.

Damasio (1999) proposes that "emotions are useful in themselves, but the process of feeling begins to alert the organism to the problem that emotion has begun to solve. The simple process of feeling begins to give the organism incentive to heed the results of emoting." For example, when an emotion is triggered it is manifested in two phases: In the early phase, it is manifested nonconsciously to mobilize the organism into immediate action. In the latter phase, the emotion enters the conscious phase as a feeling to keep the organism motivated to sustain the action it began to take in the nonconscious phase.

What are Emotions?

The manifestation of emotion mobilizes an organism toward the accomplishment of proximal goals such as avoid pain and seek pleasure in order to fulfill the ultimate goals of survival, sustenance & reproduction, respectively. In fact, Niedenthal and Kitayama (1994) describe emotion as a set of adaptive functions of acting or responding to stimuli that are prewired or "prepared" by biological evolution and yet at the same time, shaped, elaborated, and finely configured by social and cultural learning.

The traditional view in the affective sciences has argued over the last several years that emotion and cognition operate in two distinct (lower and upper cortical centers, respectively) -- low route vs, high route – regions of the brain (Ledoux, 1996). However, based on recent findings from the neurosciences, Duncan & Barrett (2007) have made a compelling argument that the brain makes no distinction between emotion and cognition and that "affect is a form of cognition" in itself. Duncan & Barrett (2007) observe that affect is instantiated by a widely distributed, functional network that includes both subcortical regions (typically called "affective") and anterior frontal regions (traditionally called "cognitive"). They refer to this as the basic circuit for core affect, where "core affect" refers to the psychologically primitive state consisting of hedonic valence (pleasure/displeasure) and arousal. Regardless of the arguments based on neuroanatomical distinctions, cognition and emotion are coming to be viewed as complementary rather than antagonistic processes (Storbeck & Clore, 2007). For a comprehensive treatment of emotion theories, research and methodological issues see Ledoux (1996) and Cacioppo and Gardner (1999).

EMOTIONS DIRECT DECISION MAKING

Emotions are instantiated and expressed as dynamic reflex postures when anticipated action is inhibited or delayed (Löw, Lang, Smith & Bradley, 2008) and can be considered as decision routines learnt at the genetic level through evolutionary processes (Toda, 1980). In other words, an emotion plays an implicit role within the organism to choose one option over the other, or no option at all, in a given situation. The idea being that the eventual decision – and the action – of the decision-maker would result in either an ideal outcome or at least something close to it.

Research in the neurosciences over the last 20 years has unequivocally disproved the Renaissance notion of emotion as giving rise to irrationality (Damasio, 1994), and thus, tainting the normative outcomes desired through pure cognition. Toda (1980), in a pioneering article on emotion and decision making, had argued "…that without desires, loves, and hates there hardly would be utilities." He goes on to observe that the emotion system has the possibility of acting as a purposeful, rational decision system in its own right. Many studies since then [see Pfister & Böhm (2008) and Naqvi, Shive & Bechara (2006) for a review] have validated that emotion plays a positive role in decision making.

Emotion can also be viewed as a two-edged sword as it may bias the decision maker one way or the other resulting in either desirable or undesirable outcomes. For example, an emotion may induce a status quo bias – i.e., stick with a to be or already chosen decision until the end and oppose non-chosen alternatives – in the decision maker (Bagozzi, 1992; Damasio, 1994; Frijda, 1986; Toda, 1980). Furthermore, the type of emotion may bias the human agent to prefer a certain choice alternative over others: e.g., anger may cause the decision maker to chose destructive alternatives whereas fear may result in the decision maker avoiding risky alternatives (Bagozzi, 1992).

Emotions versus Motivations

In this paper we draw a distinction between motivation and emotion as proposed by (Öhman & Wiens, 2002). Öhman & Wiens (2002) acknowledge that emotion and motivation are closely related constructs that sensitize organisms to stimuli but with different ends. That is, motivation is concerned with maintaining the homeostatic [internal] needs of an organism: e.g., when hungry an organism responds to food-related stimuli. Whereas emotion is caused by an external stimulus or event. For example, when an organism experiences fear, it shows an attentional bias to threatening stimuli and escape responses are quickly activated. To be more specific, an emotion is caused by the priming of the sympathetic nervous system, which facilitates a series of mostly automatic and nonconscious responses ranging from stimulus appraisal to action.

DECISION-MAKING UNDER LIFE THREATENING CONDITIONS

Human's decision-making mechanism under threat has been shaped by millions of years of evolution in an environment filled with predators. The encounter with predators (e.g., inadvertently or while hunting) was often sudden, volatile, uncertain and involved high stakes. The orienting and defense response (Graham, 1979), which evolved to counter predators and facilitate our survival, is being put to use in modern times in very different contexts – besides the occasional encounter with the predator in the wild. For example, [survival-based] task dynamics may exist when a soldier, police officer or firefighter is thrust into an adversarial situation where he faces imminent threat to his life, eliciting the [predator-prey] orienting-defense response.

Decision Dynamics: Predator-prey Dyad

When life is under threat, humans and other organisms, choose one or more of the following options in a given order with little conscious thought (Grossman, 1996): Fight, flee, freeze or posture. These behaviors can be thought of operating in the following phases: 1) Orienting response to facilitate focused attention and perception of the threat for detection and analysis. This can be considered as a tactical mechanism to disrupt ongoing activity to process unexpected changes in the world (Öhman & Wiens, 2002) by tuning the body to intake information concerning these changes (Sokolov, 1963). It is indicated by a decelerating heart rate, a.k.a., fear bradycardia (Campbell, Wood, & McBride, 1997; Vila, Fernandez, & Pegalajar 2003); 2) Alarm-reaction, which heightens vigilance accompanied by sympathetic activation of glands and smooth muscles, movement of blood to the gross muscles and cardiac acceleration (Masterson & Crawford, 1982); 3) Aversively-motivated protective actions (fight, flee, or posture) or inaction (freeze), which are hypothesized as the most appropriate course of action for the circumstances are executed by the organism (Lang, Davis & Öhman, 2002). The amygdala and related subcortical centers in the brain, which engender [fear] *emotion* in response to aversive stimuli or events, is the primary driver that manifests the orientation-alarm-action behaviors in response to threats (Ledoux, 1996; Lang et al., 2002). On the psychophysiological landscape of the organism these are manifested as somatic, autonomic reflexes (increased heart rate, releasing of stress hormones, sweating, change in muscle tension, etc.).

The predator-prey model – particularly the reaction of the prey to the threat [predator] – is instructive with regard to the underlying mechanisms that may determine the decision-making routines of humans when life and limb are threatened. (The predator response dynamics are similar to the prey's, but with a positive valence, priming an appetitive-offensive response [Löw, et al.]. This issue is beyond the scope of this paper.)

Decision Making under Threat in a Socio-technical System

This paper's focus is on the decision-making of mission critical personnel, operating in complex socio-technical systems (STS), when they face imminent threat to life and limb. Obviously, in such a system the threat is not from a predator in the traditional sense, but an adversary (e.g., armed fugitive) or an adversarial situation (e.g., trapped in a fire), whose task dynamics are likely to resemble the predator-prey dyad. Furthermore, in the context of a STS, the primal behaviors such as fight, flight, etc., are usually mediated through technology and are contingent on decisions involving human-machine interactions. See Table 1 for sample behaviors.

Type of Human Agent	Nature of Threat	E.g., Sample Behavior
Fire fighter	Lost bearings inside a structure fire.	*Flee:* Issue mayday call; figure out a way to exit the building.
Fighter pilot	Outmaneuvered in aerial combat by adversary.	*Flee:* Pilot performs appropriate air combat maneuvers to avoid the adversary's weapon systems.
SWAT team member	Adversary opens fire.	*Fight:* Take cover; fire back to neutralize adversary and call for help.
Reconnaissance marine	Unexpectedly comes across enemy.	*Freeze:* Stays still and blends (camouflage) with the terrain\vegetation to remain unseen.
Law enforcement officers	Outnumbered by violent rioters.	*Posture:* Exhibit signature and challenge displays (Rahman, 2007b).

Table 1. Threat and sample behaviors of human agents embedded in a socio-technical system

A Model of Emotion-primed NDM

A generic process model showing the early stages of emotion-primed NDM is proposed in Figure 1. It begins with the decision-maker detecting a threat-based decision problem. This, in turn, engenders an appropriate emotion. When this emotion's valence and arousal exceed a certain threshold in kind (aversive valence) and degree (high arousal), it is sensed by the decision-maker's neural system both consciously and nonconsciously (Damasio, 1999). Next, the sensed-emotion modulates the decision scope in one of two-ways: constructive modulation and destructive modulation. In the former case, the engendered emotion plays a constructive role and facilitates the DM to make a decision, which results in a satisfactory outcome. In the latter case, emotion plays a destructive role resulting in an unsatisfactory outcome.

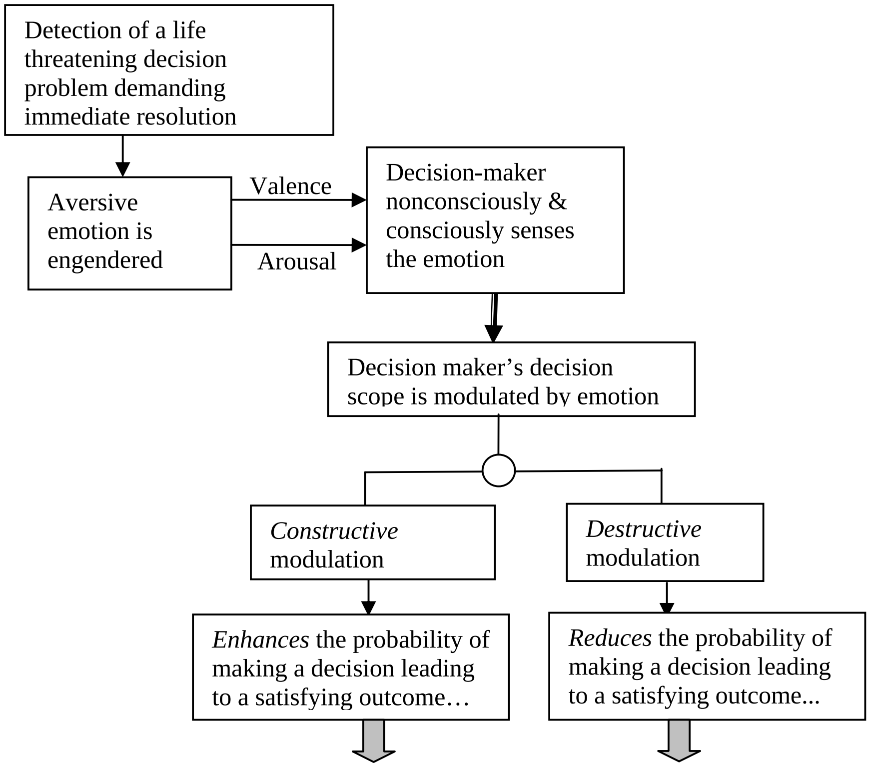

Figure 1. Generic Process Model (early stages) for Emotion-primed NDM

Constructive vs. Destructive Emotional Modulation of the Decision scope

The case that emotions play a constructive role in decision making has been validated in the realm of affective and neurosciences (Damasio, 1999; Bechara & Damasio, 2005, LeDoux, 1996). Furthermore, Barkow, Tooby & Cosmides (1992) have argued that [constructive] emotion is an evolutionarily perfected reaction to danger and not an irrational response. Next we present real life examples that highlight the constructive and destructive routes proposed in the model. Furthermore, we posit that in these cases, the [constructive/destructive] emotions engendered in the decision maker may have modulated his cognition (decision scope) giving rise to either positive or negative outcomes (a.k.a., "hot cognitions"). It is highly unlikely, given the circumstances, that the decision maker would have purely utilized an affect-free ("cold cognitions") for the responses he came up with.

First let us consider two cases of constructive modulation: 1) The ingenuity shown by a smoke jumper (wild land fire fighter) to escape from the Mann Gulch wild land fire (Maclean, 1992), when all was lost. (This smoke jumper survived as he chose to light up the grass in front of him (a.k.a., escape fire), run into its center, and lie down in its ashes – rather than run away from the main fire bearing down upon him. Because the grass around him was already burnt it starved the main fire of fuel and it was forced to go around him. If emotions had played a destructive role, he may have succumbed like thirteen of his crew members who tried in vain to outrun the fire on a steep slope.) 2) The case where a flight instructor (flying as a passenger) took control of the engines of United Airlines Flight 232 (DC-10 aircraft), which experienced a complete loss of flight controls due to massive and multiple hydraulic failures, including the loss of one of its two engines (Kilroy, 2008). (The flight instructor showed extraordinary ingenuity under pressure, when he managed to control the aircraft by adjusting the throttles of the remaining two engines – running one engine faster than the other causing differential thrust – to maneuver and land the plane, which resulted in the survival of 185 off the 296 passengers onboard. It appears that in both these cases the right kind and degree of emotional valence and arousal may have constructively modulated cognition to produce the best possible results.)

Now let us consider two cases of destructive modulation: 1) When plain clothed police officers mistakenly shot an unarmed man in the Bronx following a foot chase (Gladwell, 2005); 2) When the marines of Kilo Company, a unit of the First Marines, third battalion killed 24 civilians in Haditha in response to their convoy being hit by an IED, which instantly killed one of their fellow Marine's (Duffy, McGirk, & Ghosh, 2006).

Rahman (2007a & b) has also reported the roles of constructive and destructive modulation of emotion in the context of applying it to system design and human-machine interaction. He accomplished this by applying Frijda's (1986) five major hypotheses on how emotional arousal can lead to either performance increment or decrement in a human-systems context: response competition, reduction in attentional capacity, hormonal overflow breaking down motor actions, disorganization of thought, and regressive behavior.

As noted in the above cases (constructive and destructive modulation), the scope of the emotionally modulated decision can range from creative problem solving to blind rage. Without emotion playing its role, the human agents in the above scenarios, may not have acted at all for better or worse.

The intriguing question at this point is how could one enhance the constructive aspects of emotional modulation and minimize its destructive aspects through system design, training, etc. As one may note, despite the indoctrination in rules of engagement (i.e., not to kill civilians in the case of the Haditha incident) and training in standard operating procedure (i.e., to get away from a fire that is out of control in the case of the Mann Gulch fire), the human agent(s) chose to violate the norm and intuit their way out of trouble, with catastrophic and successful outcomes, respectively.

The Nexus between Intuition and Emotion

In NDM under stress, research has shown that intuition plays a key role in quickly sizing up the situation (Klein, 1999; Hammond, 2000; Noble, 1993). But what is an intuition? Probably the best definition in the decision-making literature is provided by Kahneman & Tversky (1982): "a judgment is called intuitive if it is reached by an informal and unstructured mode of reasoning without the use of analytic methods or deliberate calculation." Consider again the previously discussed decision dynamics of the predator-prey dyad. The only recourse here is to depend on one's emotionally driven reactions in the interest of time, which in terms of decision making can only be "informal and unstructured mode of reasoning" (intuitive).

There is both indirect and direct evidence that an intuition is a nonconscious and emotionally driven problem solving process (Hammond, Hamm, Grassia & Pearson, 1987; Damasio, 1999). Hammond (2000) in his Cognitive Continuum Theory (CCT) shows that intuition as opposed to analytical cognition has the following properties: low *cognitive control*; rapid *data processing*; low *conscious awareness*; high confidence in *answer*; low confidence in *method*.

One may argue that the constructive use of domain knowledge in the two cases discussed earlier (Mann Gulch Fire & United Flight 232) are not great exemplars of intuitive cognition, because such cognitions are unlikely to occur under stress (particularly under negative emotional arousal). On the contrary, one may raise the counter argument that in the absence of severe stress – e.g., threat to life (negative emotional arousal) – the likelihood of the firefighter and the pilot discovering their ingenious solutions would have been low. It appears that being cognizant of an immediate threat to life may have played a positive role because it resulted in the optimal arousal of the core affective circuit (discussed below) of the firefighter and pilot. Such a psychological state may have enabled them to deploy their tacit knowledge that was abstract and representative of the domain (Reber, 1989) to develop novel responses for resolving a problem never encountered before. On a practical note, the existence of such a cognitive mechanism may be difficult to confirm scientifically given the inherent ethical conflicts in conducting such a study. (e.g., placing a test subject in an experimental situation where loss of life is a viable option; or on the flip side, the validity of the study would be compromised if the experimenter makes the subject believe that the study is just a simulation with no real threats to life.)

One plausible route for intuitive cognition under stress may lie in the core affective circuit (Duncan & Barrett, 2007). It has been pointed that the interactions between the cortical and limbic regions in the core affective circuit – specifically the ventro medial prefrontal cortex, anterior cingulate cortex and amygdala – may play a role for making decisions based on intuitions and feelings rather than on explicit rules (Goel & Dolan, 2003; Shamay-Tsoory, Tomer, Berger, Goldsher & Aharon-Peretz, 2005). Thus one conjectures that the right kind and degree of aversive [emotional] arousal may modulate the cognitive centers of an experienced agent with deep domain knowledge to produce intuitive solutions that are constructive. On the other hand, the suboptimal emotional modulation of cognition may have been one of the significant causes for destructive outcomes. (e.g., Bronx shooting and Haditha Killings). This is because the suboptimal cognitions may have biased the agent to anchor on non-diagnostic cues resulting in confirmation bias due to the improper calibration of the threat, regressive behavior, autovigilance (Larsen, 2004), among other things.

The role of emotion in the context of economic games (with no threat to life) has been widely studied and may apply to life threatening situations in a limited manner. For example, Bechara & Damasio (2005) have shown that emotions play a role in guiding decisions, especially in situations in which the outcome of one's choices, in terms of reward and punishment, are uncertain. They called it the somatic marker hypothesis. Damasio and colleagues showed that the amygdala triggers through the autonomic system different types of bodily states (e.g., changes in skin-conductance response) when decisions lead to either positive or negative outcomes in a given task. That is somatic markers act to simplify the decision as to which behavior to try (Brown & Coles, 2000): i.e., negative somatic markers screen out inappropriate behaviors, and thus, they don't even come across as possible options to consider in the mind of the decision maker; whereas positive somatic markers nonconsciously bring to fore options that lead to behaviors that are likely to result in favorable outcomes. Finally it should be noted that although the somatic marker mechanism is immanent to the human neural system, its expression in terms of specific responses to particular conditions are acquired through learning (Damasio, 1994). Thus it may be possible to devise ingenious training programs (simulations of life threatening conditions) to train mission critical personnel so that their somatic markers (emotive responses) prime them towards making decisions that are likely to result in successful outcomes.

The CCT, core affective circuit, and somatic marker hypothesis describe the possible underpinnings of intuitive cognition, a major component of NDM, particularly under life threatening conditions.

DESIGNING FOR NDM UNDER THREAT

Many domains, such as aviation, military, firefighting, etc., have a firsthand understanding of NDM under threat and have developed protocols, training, rules of engagement, etc., based on their experience. However, due to a paucity of systematic field and lab research on this topic not much has been published by the way of design guidelines for HMIs. Rahman (2007b) developed ad hoc, prescriptive recommendations, called "the laws of High Velocity Human Factors" to address the issues relating to mission critical personnel in nonequilibrium conditions. These seven HVHF laws are briefly summarized below:

1. Law of Relevance; only provide information relevant to the event that can be used to diagnose and resolve the situation.
2. Law of Acceptance; to provide information in a format that can be processed by the human agent given his diminished cognitive capacities due to emotional arousal.
3. Law of Transparence; technology should not become a barrier to information that can be directly perceived in the immediate environment.
4. Law of Clairvoyance; technology, where possible, should assist the human agent to predict the immediate future course of an event.
5. Law of Absoluteness; Critical functions, such as emergency call placement, should have their own dedicated control elements that are accessible and operable in an instance.
6. Law of Intelligence; technology should be smart enough to take over operations when the agent is overloaded with other more important tasks.
7. Law of Reliance; technology should be fail-safe & fool-proof and should accommodate human-interactions errors caused due to high stress.

CONCLUSIONS

The goals of this paper were threefold: 1) highlight the importance and need to understand NDM of mission critical personnel under life threatening conditions; 2) Provide a framework for designers and trainers to account for such issues in the design of systems and training of personnel, respectively. 3) Encourage the research community to systematically study NDM in the field and in the lab by using the model proposed in this paper. Obviously, the overarching goal of any mission critical organization would be the facilitation of successful outcomes for their personnel under imminent threats to life & limb or even when confronted with problems never encountered before. Thus it is important not only to understand routine behaviors under stress but also uncover the underpinnings of the intuitive cognitions shown in real instances as was the case with the firefighter who survived the Mann Gulch fire or the destructive cognitions that led to the Haditha massacre. This paper has just taken a modest, first step towards that.

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