Received: 20 February 2023 | Accepted: 21 February 2023

DOI: 10.1111/poms.13993

POMS

ORIGINAL ARTICLE

The effect of acute stress on humanitarian supplies management

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Handling Editor: Elena Katok

History of the Paper: First Submitted: May 15, 2017; First Reviews: August 25, 2017; First Revision Received: March 22, 2018; Second Reviews: July 11, 2018; Second Revision Received: January 31, 2023; Accepted for Publication: February 21, 2023

Abstract

Humanitarian workers often operate under highly stressful conditions, view emotional scenes, and face high time pressures. This may bias managerial decision-making in humanitarian logistics, but evidence is lacking. We model humanitarian logistics decisions in an adapted newsvendor setting. We experimentally expose participants to time pressure, noise, and emotional pictures. Using physiological and self-reported data, we confirm that these manipulations have different effects on two components of the stress response (negative valence and arousal) and on decision-making quality. Specifically, medium levels of arousal seem to boost decision-making quality, independent of affective valence. However, high time pressure (characterized by high levels of arousal) leads to a collapse in decision-making quality. Our results highlight that some level of stress may be beneficial for decision-making owing to its action-activating properties. However, excessive time pressure sharply overrides and outweighs these benefits. We discuss the generalizability of our results to other emergency situations (e.g., firefighters) and managerial contexts (e.g., crisis responses).

KEYWORDS

acute stress, behavioral operations research, decision biases, humanitarian operations, newsvendor problem

1 | INTRODUCTION

Natural and man-made disasters are projected to become more frequent, driven, for example, by climate change, urbanization, political issues, and pandemics (Banholzer et al., 2014; Besiou & Van Wassenhove, 2020; Coleman, 2006). Besides the necessity to improve disaster preparedness, this trend calls for increased and improved immediate-response and humanitarian development aid, including provision of medical assistance, shelter, and basic daily supplies of water, food, sanitation, and hygiene products. Logistics efforts generally account for 80% of disaster relief and serve as a bridge between preparedness and response (Van Wassenhove, 2006).

Field staff, who are at the forefront of international humanitarian operations, manage and carry out crucial operations on-site to ensure that goods and services arrive where needed (the "last mile" problem). Furthermore, localized management and governance are indispensable for humanitarian programs' sustainability (Bundy, 2009; Kretschmer et al., 2014). However, given their exposed position in the operations chain, field workers face remarkably challenging and stressful working and living conditions. Both cross-sectional and longitudinal studies identify various sources of stress, such as emergency cultures, constant change, work overload, difficulties in managing work–life boundaries, job insecurity, restricted career development opportunities, low salaries, unsafe living conditions, negative health outcomes, and increased risk of experiencing violent trauma and direct attacks (e.g., Cardozo et al., 2012; Jachens, 2018). In a survey of 376 national humanitarian aid workers in Gulu, Northern Uganda, 91% of respondents reported having been exposed to at least one category of traumatic event and 13% to more than 10 categories; 65% reported excessive workloads; 39% reported exposure to excessive heat, cold, or noise; and 23% reported that armed security was necessary. Consequently, 68% of respondents experienced symptoms of depression, 53% exhibited anxiety disorders, and 26% presented with posttraumatic stress disorder (Ager et al., 2012). Similar work in other disaster locations confirms this to be a general issue,

Accepted by Elena Katok, after two revisions.

Maximilian Burkhardt and Felix Jan Nitsch contributed equally to this study.

highlighting a need to pay greater attention to the mental well-being of humanitarian aid workers (e.g., Connorton et al., 2012).

A central theme of these reports and accounts is stress. This is reflected not only in survey responses but also in biological markers (for an overview of the physiology of stress, see Section 2.1; Panter-Brick et al., 2020). Consequently, some humanitarian aid organizations have started to develop guidelines on stress management (e.g., Antares Foundation, 2005; IASC, 2006), proposing the provision of counseling and peer help groups. Yet despite these important and necessary developments, as in other work environments (see, e.g., Moss, 2020), self-care and counseling are unlikely to be sufficient to negate structural stressors affecting humanitarian aid workers, such as work overload and fear of assault. Hence, even in the absence of more severe mental health outcomes, it is safe to assume that humanitarian aid workers operate under high levels of stress.

This has implications for the performance of humanitarian operational processes owing, for example, to increased health-related worker absences. However, even before needing medical leave, stress may affect humanitarian aid workers' decision-making, and hence operations management (Comes, 2016; Roels & Staats, 2021). Related research in decision science confirms that stress may affect risk attitudes, loss aversion, social and moral preferences, and impulsivity (Margittai et al., 2015, 2018; Riis-Vestergaard et al., 2018; Starcke et al., 2012; Starcke & Brand, 2016). Stress also causes a shift from deliberative to intuitive thinking (Margittai et al., 2016), and potentiates decision biases (Yu, 2016). Chronic stress, especially, may affect choice consistency (Nitsch et al., 2021). At a cognitive level, stress has been linked with impaired working memory, problem-solving abilities, and self-control (Beilock & DeCaro, 2007; Maier et al., 2015; Qin et al., 2009). All these factors have the potential to affect operational processes, although direct work in this area remains scarce. Correlational evidence suggests that self-reported stress may affect safety behaviors by container terminal operators (Lu & Kuo, 2016) and high-speed railway drivers (Wei et al., 2016). Another relevant study in this context demonstrates that time pressure and uncertainty (manipulated through experimental vignettes) shift supply chain managers' decision processing, measured by introspective self-reports, toward experience-based and emotional processing (Carter et al., 2017).

In this paper, we shine light on psychological and behavioral aspects of humanitarian development operations and specifically supply management. As alluded to above, sustainable humanitarian programs require supply chains for daily supplies and medical assistance to be built and managed locally (Kretschmer et al., 2014), but field staff are exposed to substantial structural stress. Therefore, it is essential to understand the likely impact of stress on managerial decisions relating to humanitarian supplies.

Field supply-chain managers must stock their supplies based on predictions. Given that demand is uncertain (Kovacs & Spens, 2007) and commodities are perishable (Ferreira et al., 2018), careful trade-offs must be made, as erring in either direction will lead to monetary inefficiency or preventable suffering. Decisions in this setting depend on risk and loss evaluations, which have been shown to be affected by stress (Margittai et al., 2018; Starcke & Brand, 2016). Hence, we hypothesize that inventory management decisions are likely to be affected by the stress faced by humanitarian aid workers (see Section 2). To explore this hypothesis, we experimentally manipulate stress using a validated, modular stress protocol that emulates typical stress in a humanitarian context, with different degrees of time pressure, exposure to emotional images, and noise (Bali & Jaggi, 2015; Reinhardt et al., 2012). Following best practices in biopsychological stress research, we measure individual stress using a combination of psychological and physiological data. We model decision-making in humanitarian inventory management as an adapted newsvendor problem task (see Section 3).

Our experimental manipulation successfully modulates the psychophysiological stress response, indicated by increased subjective and physiological arousal and increased negative affect. As predicted in the cognitive stress literature, in the newsvendor setting, performance benefits from medium stress levels, which relate to increased arousal and are independent of affective valence. However, high time pressure (characterized by high levels of arousal) leads to a collapse in performance in the newsvendor setting. This collapse is explained by exacerbated demand-anchoring bias. Importantly, the negative stress effects fade with prolonged experience of the task and are no longer significant at the end of the session (see Supporting Information Table S1). This suggests that sufficient training and experience on a task (beyond verbal instruction and explanation) may protect decision-makers from negative stress effects on performance (see Section 4). Our results generally align with research on work stress and decision biases (Yu, 2016) and map closely onto previous work on the inverted-U-curved relationship between stress and cognitive performance (Sandi, 2013; Sapolsky, 2015).

Our results imply that humanitarian aid organizations must pay attention to the behavioral biases of on-site supplies managers owing to their high stress exposure, and that humanitarian supplies managers may systematically display increased anchoring bias under high stress conditions.

2 | THEORETICAL FRAMEWORK AND HYPOTHESES

In this section, we review the literature on stress and the newsvendor problem to deduce our hypotheses and motivate our experimental paradigm.

2.1 | The psychology and physiology of stress

People experience stress when facing stimuli that exceed their perceived capability to cope, behaviorally or emotionally (Lazarus, 1966). Such stimuli (or *stressors*) include harsh environmental conditions, negative evaluations by others, viewing emotional images, and time pressures in important tasks. As outlined in Section 1, stressors are ubiquitous in humanitarian work. Stress is characterized as a state of threatened homeostasis in the dynamic equilibrium between psychological demands and resources. Hence, the stress response comprises a repertoire of behavioral and physiological adaptations, usually referred to as the fight-or-flight response, with the goal of resolving the threat and re-establishing homeostasis.

On a psychological level, stress is characterized by negative affect and elevated arousal (Russell, 1980). For example, people report feelings of distress, anxiety, worry, and threat. On a physiological level, stress has been characterized as a time-dynamic "neurosymphony" of the sympathetic–adrenergic–medullary system and the hypothalamic—pituitary–adrenergic (HPA) axis (Hermans et al., 2014; Joëls & Baram, 2009). Psychological arousal maps onto activation of the sympathetic nervous system (Posner et al., 2005); hence, besides self-reports, stress can be measured through peripheral physiological measures, such as skin's conductance reaction or heart rate (Lazarus et al., 1963).

Excessive, and especially chronic, stress exposure is well known to be associated with various negative health outcomes, such as obesity, cardiovascular disease, and depression. However, it is important to note that the normal stress response is adaptive, mobilizing resources toward threat resolution. It is also time-dynamic and multidimensional (Hermans et al., 2014; Joëls & Baram, 2009), so evaluation of stress effects requires nuance. A parsimonious but appealing model conceptualizes the cognitive costs and benefits of stress as an inverted-U function of stress severity: absence of stress is typically experienced as understimulatory, whereas high degrees of stress are experienced as *stressful* (Sapolsky, 2015). In line with this, mild, acute stress, especially when linked with the task at hand, may enhance cognitive performance, and even severe stress may be beneficial for well-rehearsed tasks (Sandi, 2013).

2.2 | Effect of stress on the newsvendor's performance

We model the setting of humanitarian supply chain managers as an adapted newsvendor problem. Briefly, in the newsvendor problem, a supply manager must stock inventory based solely on predicted demand (prior to any actual demand realization), knowing only the stochastic distribution from which the quantity demanded will be drawn. This problem typically allows for an optimal solution. However, real decision-makers often make suboptimal and biased choices (Bolton & Katok, 2008; Schweitzer & Cachon, 2000). Since the main goal in a humanitarian crisis is not profit but alleviation of human suffering (De la Torre et al., 2012), we adjust the classical commercial newsvendor model to fit a cost-based objective function (for details, see Section 3.1).

According to Kahneman and Tversky (1982), the "anchoring and insufficient adjustment" heuristic causes the decision-maker to anchor on a piece of information and insufficiently adjust subsequent decisions away from that anchor. This tendency underpins what is known as the pull-to-center effect and the demand-chasing heuristic, which were first described by Schweitzer and Cachon (2000). The pull-to-center effect is often claimed to be a principal source of suboptimal decisions made in the newsvendor context. It refers to decision-makers' inclination to anchor their perspective on mean demand, which leads not to optimal order quantity but to orders between optimal order quantity and mean demand. This effect has been observed in other newsvendor experiments (e.g., Benzion et al., 2008; Bolton et al., 2012; Bolton & Katok, 2008) and persists in various experimental settings and participant groups. The demand-chasing heuristic refers to decision-makers anchoring on a prior order and then adjusting the next order toward the corresponding prior demand. In their analysis, Schweitzer and Cachon (2000) find only weak support for this heuristic. However, Kremer et al. (2010) report that demand chasing is a significant factor in order decisions, and Moritz et al. (2013) find that this heuristic partly mediates the influence of cognitive reflection on expected profit.

We propose that stress significantly affects these biases—and hence decision quality—in the newsvendor context. Kassam et al. (2009) find that stress may lead to weakened adjustment behavior, and thus to a stronger anchoring effect in the decision context. The extent to which less adjustment occurs depends on the type of stressor. In Kassam et al.'s (2009) study, a negative stressor leads to less adjustment (away from the anchor) than a positive one. They conduct a modified version of the Trier social stress test, in which participants engage in mock job interviews. Inbar and Gilovich (2011) show that decisions made while experiencing uncertainty-driven stress lead to less adjustment from a self-generated anchor. This research suggests that perceived stress may lead to less adjustment in newsvendor decisions, and thus to order decisions being even more strongly affected by the pull-to-center effect and the demand-chasing heuristic. In the former case, reduced adjustment would lead to a stronger pull by the mean demand away from the expected optimal order, thus resulting in lower decision quality. In the latter case, reduced adjustment would lead to increased order adjustment reflecting the previous period's demand realization.

In assessing the effects of stress on anchoring and insufficient adjustment, we must distinguish between different individual stress responses. Stress theory generally predicts an inverted U-shaped relationship between arousal and performance (Duffy, 1957; Sapolsky, 2015; Yerkes & Dodson, 1908). For example, Teichner et al.'s (1963) distraction–arousal theory proposes that stressors affect performance either by distracting the operator, and thereby reducing the attention paid to a primary task, or by increasing stress beyond optimal levels. In view of this general literature, we make the following two hypotheses on decision-making under risk in an operations management context.

Hypothesis (H1) For low levels of stress response, newsvendors are more likely than those in a no-stress condition to repeat prior orders; however, for high levels of stress response, they tend to adjust their orders to demand observed in the previous period.

Hypothesis (H2) For low levels of stress response, average orders are pulled less toward the mean demand than under a no-stress condition; however, this effect is reversed for high levels of stress response.

3 | EXPERIMENTAL DESIGN

This section describes the setup of the experiment designed to test our hypotheses. It explores the effect of stressors on decision biases and decision quality or the extent to which decisions on order quantities are optimal in the (adjusted) newsvendor game described in Section 3.1. In all five of the experimental treatments, participants play the newsvendor game with the calibration described in Section 3.2. Across treatments, we induce additional stress by applying stressors during the game, as explained in Section 3.3. During the experiment, participants' stress levels are measured, as described in Section 3.4, (a) to validate their reactions to the stress induction and (b) to relate their stress responses to their decisions. The experimental process is reviewed in Section 3.5.

3.1 | Newsvendor in humanitarian logistics

The chosen decision scenario is that of humanitarian aid operations. In these kinds of operations, the beneficiaries (affected populations in need of help) rely on support for perishable items such as food, water, and medicine, and nonperishable goods including shelter, blankets, and hygiene products (Lodree, 2011). We focus on a perishable relief item (e.g., food or medicine) that cannot be stockpiled. Since the main goal in a humanitarian crisis is not to profit but to alleviate human suffering (De la Torre et al., 2012), we adjust the classic commercial newsvendor model to fit a cost-based objective function. In humanitarian logistics, the commercial rationale underlying the trade-off between inventory holding cost and service level is offset by the greater benefit of commodities' availability in relation to that cost (Long & Wood, 1995). In other words, having the required relief item available is more valuable than maintaining low inventory levels. Nevertheless, humanitarian organizations have a strong incentive to provide relief items as cost-efficiently as possible. They rely heavily on donations (Besiou et al., 2012), and budget efficiency must constantly be improved owing to increasingly frequent disasters and the need for transparency (Global Humanitarian Assistance, 2018). This also reflects the authors' experience of working closely with humanitarian organizations.

We assume that the newsvendor is a procurement manager of a humanitarian organization responsible for a specific region. This manager orders q units of one specific perishable relief item for one distribution center (DC) in the region at unit cost c. Items are shipped to the DC, where beneficiaries pick them up, or from where they are distributed onwards. Demand D is realized after the order is placed. If demand D exceeds the ordered quantity q, then shipment from another DC is automatically triggered so as to satisfy the unmet demand $(D - q)$ at an additional penalty unit cost p. Shipments between DCs are enabled by the existence of multiple DCs in most regions. Gonçalves and Castañeda (2013) utilize a similar concept in their newsvendor-based experiments for prepositioning decisions, incorporating a reorder cost factor for an "automatic" demand fulfillment. In the event of oversupply, if the order quantity q exceeds demand D, then all excess units $(q - D)$ must either be discarded or reshipped at unit cost d. For random demand D with distribution function F and density function f, the realized cost of ordering q is

$$C(q, D) = c \max(q, D) + p(D - q)^{+} + d(q - D)^{+}$$

and the expected cost is

$$E\left[C(q, D)\right] = \mathrm{c} \int_{0}^{\infty} \max(q, D) f(D)\, dD + \mathrm{p} \int_{q}^{\infty} (D - q)\, \mathrm{f}(\mathrm{D})\, dD + d \int_{0}^{q} (q - D)\, \mathrm{f}(\mathrm{D})\, dD.$$

It is well-known that the optimal order quantity $q^{\star}$ that minimizes the expected cost must satisfy $F\left(q^{\star}\right) = \frac{p+c}{2c+p+d}$.

3.2 | The newsvendor game

Within each treatment, participants play a 50-period newsvendor game, with the same demand and economic parameters across all three treatments. Demand is both discrete (not continuous) and uniformly distributed as $D \sim U(0, 100)$. Parameters are calibrated to an optimal order quantity of 75% of the maximum possible period demand, so $q^{*} = 75$. Since humanitarian operations are not driven by the profit motive, we adjust the newsvendor game by redefining its goal to be cost minimization (as described in Section 3.1).

Subjects in all treatments receive the same up-front information about the game. The goal of the game is to minimize the overall cost. The price to purchase a single widget is one taler. In order to meet demand when there is a supply shortage, additional widgets must be ordered at nine talers each—that is, one taler to purchase, plus a penalty of eight talers per unit. Inventory at the end of each period cannot be stored and must be disposed of, which costs two talers per unit. The optimal strategy of ordering 75 units has an expected total cost of 7500 talers and yields 500 lottery tickets (see Section 3.5).

3.3 | Treatment manipulations

Our experiment consists of five separate treatment conditions (between-subject design). The BASIC treatment is the control treatment, in which the game is performed as just described. For the four manipulation treatments, we apply two different stressors of varying intensities. These stressors frequently arise in real-world decision contexts, such as disaster relief operations and other humanitarian logistics situations.

In the TIME treatment, we apply time pressure by restricting the time allowed for decisions in each period. Participants have only 5 s (vs. no deadline in the control treatment) to make decisions after viewing the order decision screen and are allowed only 3 s to view the feedback screen. In preparing this experiment, we found that these time restrictions produce sufficient stress in participants while still granting enough time to enter an order and grasp the feedback information. If the allotted time expires before an order is placed, 0 units are ordered and the experiment automatically moves to the next period. There are never any time restrictions while the instructions are given, nor while responding to the between-period stress assessment questionnaire and the postexperiment questionnaire. Periods in which the experiment automatically orders 0 units are discarded from the analysis in Section 4.

In the TIME10 treatment, we vary the application of time pressure. Here, the participants are allowed 10 s to make an order decision, and the feedback screen can be seen for a total of 6 s. Similarly to the TIME treatment, the experiment automatically moves to the next period when the time has expired. These time restrictions are designed to induce an intermediate level of stress in the participants. Thus, we seek to assess how variations in time pressure affect the stress response and decision quality. Apart from the changed time restriction, this treatment is the same as the TIME treatment.

In the EMOSENS treatment, stress is induced by a combination of physical and emotional stressors, as in the Mannheimer multicomponent stress test (Reinhardt et al., 2012). For the physical stressor, we use white noise, the volume of which is varied (in decibels from 73 to 93 dBA) every 15 s to preclude habituation. All participants hear the sound via identical on-ear stereo headphones at the same volume. For the emotional stressor, we use affectively unpleasant pictures selected from the International Affective Picture System (Lang et al., 1997). This database comprises more than a thousand pictures with varying stimulation potential with respect to both the extent and valence of arousal. For each picture, both dimensions are rated on a scale from 1 to 9, where 9 corresponds to the most arousal or most positive valence. For example, pictures with positive valence show puppies, beaches, and positive family scenes, whereas pictures with negative valence contain violent and often nauseating scenes. Negative valence depictions include physical violence, severely wounded people and animals, oppressive scenes of anxious people, and dangerous animals in a frightening context (e.g., spiders). We present participants with diashows (slide shows) containing a variety of pictures that vary in valence but always score high on the arousal dimension. During the decision stage, five pictures characterized by both high arousal (>6) and negative valence (<2.5) are shown. After each such block of five pictures, one picture with high arousal (>6) yet positive valence (>6.5) is shown to avoid habituation effects. To maintain stress induction during the feedback stage, we present a different set of pictures with similar arousal and valence ratings. During the instruction phase, we state that participants can influence the severity (valence) of the pictures shown by making better decisions. Although the diashows for all participants participating in the EMOSENS treatment are similar for all periods, and decisions do not affect the pictures shown, we add this statement to the instructions to give participants an additional incentive to make good decisions.

The EMONEUTR treatment is similar to the EMOSENS treatment. Subjects hear the same white noise modulation during the experiment and are presented with diashows during the decision and feedback stages. Because presenting diashows may distract participants from their task, and thus alter decision behavior, we must test for a potential distraction effect of the diashows. For this purpose, we use pictures with neutral content—in other words, a low arousal rating (<3) and a neutral valence rating (>4.5 and <5.5)—to create the diashows for this treatment. The number of pictures in the diashows is unchanged.

3.4 | Measuring stress

As outlined in Section 2.1, stress can be assessed on a psychological (negative affect, high arousal) and a physiological (sympathetic activity, HPA-axis activation) level. As recent research shows that psychological and physiological stress need not be aligned (Dalile et al., 2022), we decided to measure both subjective and physiological indicators of stress. We measure psychological stress by asking participants to self-assess their affective valence and arousal separately, using pictographic response scales (self-assessment manikin [SAM] scales; Bradley & Lang, 1994). These scales each range from 1 to 9, with higher values corresponding with higher arousal and negative affect, respectively.

We measure the physiological stress response as the change in the heart rate (HR). To measure the heart rate, we use 15 Polar H7 Bluetooth sensors. This elaborate measurement process serves not only as a simple manipulation check but also detects differences in decision performance and biases under different levels of stress. Prior to the experiment, the participants are asked to apply the sensors and to sit quietly, with no distractions, for 5 min. This procedure enables us to record an individual baseline (BL) measurement of their heart rate. Because individual participants' resting HR varies significantly, we use the BL to calculate an individual stress score (ISS) as follows: $ISS = (HR_t - BL)/BL$ (adapted from Blascovich et al., 2004; Preston et al., 2007).

To process the raw data generated by these sensors, we use RHRV (a package for R). The HR is calculated from raw

TABLE 1 Experimental process

Stage	Activity	Description
Preparation (5–10 min)	Arrival information Application of HR sensor Baseline measurement	Information about the experimental procedure Distribution and application of HR sensors Five-minute baseline measurement of HR
Briefing (15 min)	Basic instructions Individual exercise Solution discussion Game description	Instructions on decision task and the related cost Test whether participants understand the basic relationships Improve understanding of the underlying problem Additional information about incentives and treatment setups
Game (30–40 min)	Decision-making Postexperiment questionnaire Debriefing	Five training periods, then 50 periods of decision-making Assessment of control variables Payout information and return of sensors

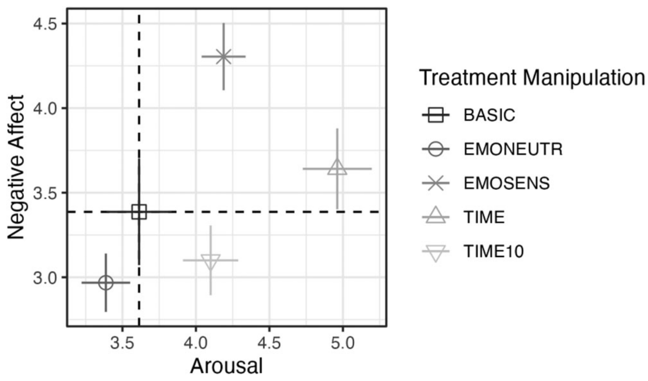

FIGURE 1 Psychological stress response to treatment manipulations. *Note*. Group-level estimates are depicted for arousal (x-axis) and affect (y-axis). Error bars depict the standard error of the mean. Shape and gray tone denote the treatment manipulation. The dashed cross mark denotes levels for the BASIC condition as a reference point. The graph shows that, for example, the EMOSENS condition (x-shape) on average shows a stark increase in negative affect and a medium increase in arousal compared with the BASIC condition (square). The TIME condition (triangle) shows a small increase in negative affect but a stark increase in arousal.

R-R interval data (i.e., the time intervals between subsequent heartbeats). The raw data transmitted from the sensors contains artifacts (faulty measurements), so must then be cleaned prior to analysis. The data-cleaning algorithm is designed to filter any measurement that deviates by more than 20% from its predecessor, and any HR that does not lie between 30 and 220 beats per minute (Thuraisingham, 2006). We then average the HR values over a specific period to ensure comparability.

3.5 | Laboratory protocol

For the main experiment, we recruited 154 participants from WHU—Otto Beisheim School of Management's M.Sc. and B.Sc. programs. Owing to measurement interruptions in the HR sensor, 21 datasets are excluded from the analysis presented in Section 4. Each participant participates in only one session. Communication between participants is strictly forbidden for the duration of the experiment. Participants are randomly assigned to the different treatments. The sessions last about 40 min, depending on the treatment, and each participant receives 5€ for participating. At the end of the experiment, participants receive virtual lottery tickets in amounts reflecting their performance in the experiment: a participant who orders the optimal quantity will receive 500 lottery tickets. After the experiment, lots are drawn for the opportunity to win one of ten 50€ vouchers, which serve as a monetary incentive for participants. The binary lottery we employ is based on a system, described by Katok (2011), that has the advantage of reducing the effect of risk aversion (Roth & Kagel, 1995). The experiment is programmed in z-Tree (Fischbacher, 2007). Table 1 provides an overview of the experiment's three stages.

4 | RESULTS

This section describes the results of our study. Section 4.1 addresses whether our treatment manipulations induced stress as expected. Section 4.2 describes treatment effects on ordering behavior. Section 4.3 identifies explanations for treatment effects on a psychological, physiological, and computational level.

4.1 | Did our treatment manipulations trigger stress?

The subjective stress response was characterized as a two-dimensional construct of affective valence and negative arousal, following the circumplex model of emotion (Russell, 1980), measured by two separate SAM scales. Hence, we tested the effectiveness of our treatment manipulations compared with the BASIC condition on this two-dimensional construct, using pairwise two-dimensional Kolgomorov–Smirnov tests. The results show that all treatment manipulations differed from the BASIC condition (see Table 2 and Figure 1). Breaking the results down by each dimension, we found that compared with the BASIC condition, all but the EMONEUT condition significantly increased arousal, but only the EMOSENS condition significantly increased negative affect (see Table 2). Our measure of the physiological stress response was a relative increase in the heart rate, which is linked most strongly to sympathetic activation and physiological arousal. In line with our results for subjective arousal, we found that compared with the BASIC condition, all but the EMONEUT condition significantly increased arousal (see Table 2 and Figure 2). This confirms that our treatment manipulations were both subjectively and physiologically stressful.

TABLE 2 Group-level, time-averaged results

Dependent Variable	BASIC	EMONEUTR	EMOSENS	TIME	TIME10
Psychological stress (vs. BASIC)		$Z = 2.261$ $p = 0.004$	$Z = 2.8$ $p < 0.001$	$Z = 2.47$ $p = 0.001$	$Z = 1.845$ $p = 0.054$
Arousal (vs. BASIC)		$t(37.824) = -1.167$ $p = 0.417$	$t(40.003) = 2.465$ $p = 0.037$	$t(48.932) = 4.175$ $p < 0.001$	$t(49.654) = 1.675$ $p = 0.054$
Negative affect (vs. BASIC)		$t(46.554) = -0.818$ $p = 0.25$	$t(41.43) = 2.151$ $p = 0.018$	$t(45.203) = 0.644$ $p = 0.523$	$t(42.5) = -0.762$ $p = 0.45$
Individual stress score (vs. BASIC)		$t(52.367) = 1.196$ $p = 0.237$	$t(43.726) = 1.719$ $p = 0.093$	$t(44.889) = 3.93$ $p < 0.001$	$t(51.855) = 2.831$ $p = 0.007$
Average order quantity (vs. optimal quantity)	$t(24) = -4.843$ $p < 0.001$	$t(30) = -5.546$ $p < 0.001$	$t(22) = -1.368$ $p = 0.185$	$t(25) = -7.115$ $p < 0.001$	$t(29) = -1.843$ $p = 0.076$
Average order quantity (vs. BASIC)		$t(53.998) = 0.884$ $p = 0.389$	$t(45.972) = -2.605$ $p = 0.012$	$t(48.037) = 2.288$ $p = 0.027$	$t(48.943) = -2.568$ $p = 0.013$
Pull-to-center bias (vs. optimal)	$t(24) = -5.438$ $p < 0.001$	$t(30) = -7.398$ $p < 0.001$	$t(22) = -3.557$ $p = 0.002$	$t(25) = -7.719$ $p < 0.001$	$t(29) = -3.746$ $p < 0.001$
Pull-to-center bias (vs. BASIC)		$t(53.764) = 1.591$ $p = 0.117$	$t(44.121) = -2.120$ $p = 0.040$	$t(47.729) = 2.464$ $p = 0.017$	$t(46.54) = -2.092$ $p = 0.042$

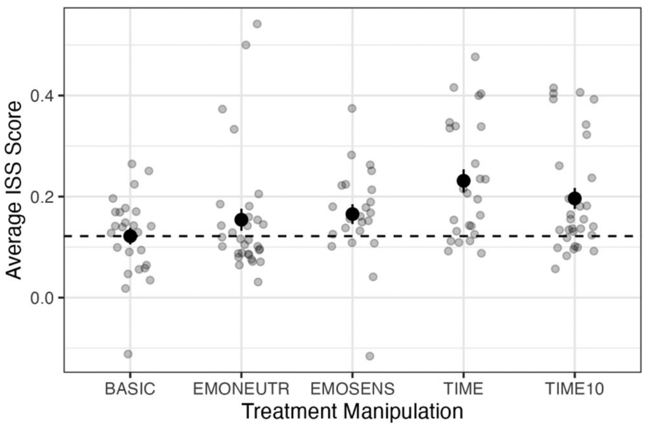

FIGURE 2 Physiological stress response to treatment manipulations. *Note*. Depicted are ISSs (small dots) and group-level estimates (large dots). Error bars depict the standard error of the mean. The dashed line denotes levels for the BASIC condition as a reference point. The graph shows that all treatment manipulations increase the ISS (normalized difference in heart rate from baseline), with the TIME condition showing the starkest increase. This is tentatively in line with subjective arousal ratings (see Figure 1).

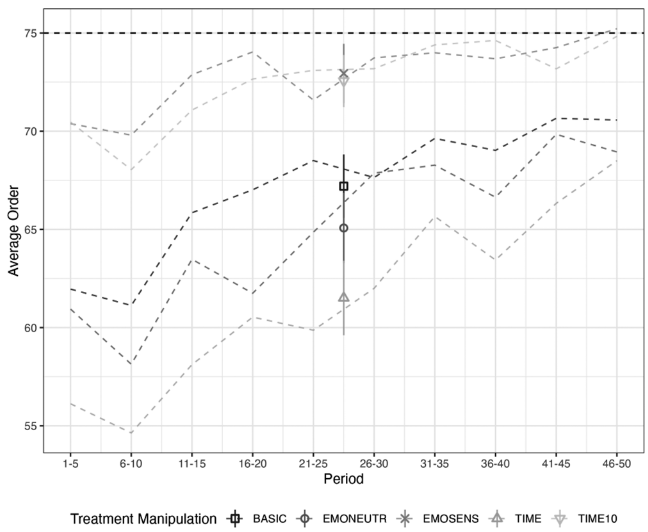

FIGURE 3 Ordering behavior across treatment manipulations and time. *Note*. Depicted are group-level average order quantities over time (dashed lines), and overall group-level estimates (large dots). Error bars depict the standard error of the mean. Shape and gray tone denote the treatment manipulation. The dashed black line denotes the optimal order quantity (75 units). Interestingly, the average order quantity is closer to the optimal value for the EMOSENS (x-shape) and TIME10 (reverse triangle) conditions, whereas participants in the TIME condition (triangle) performed worse than in the BASIC condition (square). Overall, all conditions trend toward the optimal value over time and between-condition differences decrease.

4.2 | Did our treatment manipulations affect ordering behavior?

Overall, the behavioral results show that the average order placed by participants in all conditions apart from the EMOSENS condition was significantly below the optimal value of 75 units (see Table 2 and Figure 3). Participants in the EMOSENS and TIME10 treatments were on average closest to the optimal value, while those in the TIME treatment on average deviated from it the most. In comparison with the BASIC condition, participants in the EMOSENS and TIME10 treatments placed significantly larger average orders, whereas participants in the TIME treatment placed significantly lower average orders. Orders by participants in the EMONEUT condition did not differ significantly from the BASIC condition (see Table 2).

Inspection of the development of order sizes over time reveals that the average order size increased over consecutive periods across all conditions (see Figure 3, dashed lines). To account for this time trend in our data, we repeated our analysis, regressing participant-level demand per period on treatment manipulation, period, an interaction term of both predictors and a subject-level random intercept (marginal $R^2 = 0.130$, conditional $R^2 = 0.468$). This confirmed an overall significant time trend in order behavior ($b = 0.202$, $SE = 0.021$, $p < 0.001$). Furthermore, compared with the BASIC condition, participants on average in all conditions except the EMONEUT condition displayed different time trends (EMONEUT: $b = -2.908$, $SE = 2.411$, $p = 0.230$; EMOSENS: $b = 8.410$, $SE = 2.592$, $p = 0.001$; TIME10: $b = 7.457$, $SE = 2.430$, $p = 0.003$; TIME: $b = -8.017$, $SE = 2.513$, $p = 0.002$).

The regression analysis confirmed and extended our behavioral results. Compared with the BASIC condition, participants in the EMOSENS and TIME10 treatments placed significantly larger average order sizes, whereas participants in the TIME treatment placed significantly lower average order sizes, and orders by participants in the EMONEUT condition did not differ significantly from the BASIC condition (EMONEUT: $b = 0.031$, $SE = 0.028$, $p = 0.272$; EMOSENS: $b = -0.105$, $SE = 0.030$, $p = 0.001$; TIME10: $b = -0.083$, $SE = 0.028$, $p = 0.003$; TIME: $b = 0.092$, $SE = 0.030$, $p = 0.002$).

4.3 | What explains the treatment effects?

Having established that the treatment manipulations affected ordering behavior, we sought explanations for this effect. We attempted to identify first which psychological components of the treatment manipulations affected behavior (Section 4.3.1), and second whether the relationship between individual stress and behavior can indeed be described by the proposed inverted-U shape (Section 4.3.2). Third, we tested whether participants showed a specific pattern of behavioral biases following the treatment manipulations (Section 4.3.3). Lastly, we tested our a priori hypothesis that the pattern of evoked behavioral biases can be predicted as an inverted-U function of the individual stress response (Section 4.3.4).

4.3.1 | Psychological components of treatment manipulation

To further disentangle the effects of our treatment manipulations on ordering behavior, we recoded our complex treatment manipulations into the psychological components present: emotional pictures (only in EMOSENS), noise (EMOSENS and EMONEUT), low time pressure (TIME10), and high time pressure (TIME). We then repeated the regression analysis described in Section 4.2 (accounting for the time trend in the data), substituting the treatment manipulation factor with the recoded predictors of order behavior. Model 1 of Table 3 displays the results of this revised regression analysis. In line with our previous analysis, we again find strong evidence for the presence of a time trend in ordering behavior. We also find that all psychological components of the treatment manipulations apart from noise significantly affect ordering behavior, when taking the main and time-dynamic effects into consideration (all $p < 0.05$).

4.3.2 | Individual stress and ordering behavior

Next, to test whether the relationship between individual stress and ordering behavior is characterized by an inverted-U shape, we included simple and squared terms of ISS and interaction terms with period in our model (Model 2 in Table 3). Our results show that ISS squared significantly predicts ordering behavior beyond the psychological treatment components, but that this relationship decays over time.

4.3.3 | Behavioral biases

The demand-chasing heuristic refers to the decision-maker anchoring on a prior order and then adjusting the next order toward the corresponding prior demand. We quantified individual demand chasing, following Bolton and Katok's (2008) procedure (Lau & Bearden, 2013), as the Pearson correlation of order size in the current period with demand in the previous period. Across treatment manipulations we find positive demand chasing (percentage of significant demand-chasing participants: BASIC 40%, EMONEUTR 51.6%, EMOSENS 56.5%, TIME 30.8%, TIME10 0.367%). However, contradicting H1, we find no significant (time-dependent) differences in demand chasing between treatment manipulations (all $p > 0.20$; see Supporting Information Figure S1 and Tables S2 and S3).

The pull-to-center effect is often claimed to be a principal source of suboptimal decisions in the newsvendor context. This refers to decision-makers' inclination to anchor their perspective on the mean demand, which leads not to optimal order quantity but to orders between optimal order quantity and mean demand. We quantify the pull-to-center effect, following Bostian et al. (2008), as the degree to which participants' order behavior is swayed from the optimal order amount toward the mean demand, parameterized in the following model:

$$q_t = \bar{D} + \alpha \left(q^* - \bar{D}\right) + \epsilon_{t.}$$

The parameter α denotes the degree of rationality, that is, as α approaches 1, q_t approaches $q^* + \epsilon_t$. The extent of the pull-to-center effect for an individual participant is then given by $1 - \alpha$ (henceforth, *Bostian alpha*). We find that participants in all conditions on average showed some degree of pull-to-center bias (see Table 2 and Figure 4). In addition, we find that all treatment manipulations apart from the EMONEUTR condition differed significantly from the BASIC condition, in directions aligned with our model-free analysis (see Table 2). This is in line with H2.

TABLE 3 Regression analysis of ordering behavior

Model: *DV*	M1: *Order*		M2: *Order*		M3: *Bostian Alpha*	
Predictors	Estimates	*p*	Estimates	*p*	Estimates	*p*
(Intercept)	62.048 (1.794)	<0.001	62.986 (1.844)	<0.001	0.581 (0.054)	<0.001
Period	0.202 (0.021)	<0.001	0.166 (0.025)	<0.001	0.059 (0.003)	<0.001
Emotional pictures	11.318 (2.468)	<0.001	11.618 (2.460)	<0.001	0.375 (0.074)	<0.001
Emotional pictures × Period	−0.135 (0.029)	<0.001	−0.141 (0.029)	<0.001	−0.052 (0.004)	<0.001
Noise	−2.908 (2.411)	0.228	−2.943 (2.403)	0.221	−0.144 (0.072)	0.045
Noise × Period	0.031 (0.028)	0.272	0.025 (0.028)	0.371	0.004 (0.004)	0.291
Time pressure						
High	−8.017 (2.513)	0.001	−7.683 (2.519)	0.002	−0.216 (0.075)	0.004
Low	7.457 (2.430)	0.002	7.538 (2.432)	0.002	0.204 (0.072)	0.005
High × Period	0.092 (0.029)	0.002	0.075 (0.030)	0.014	0.010 (0.004)	0.013
Low × Period	−0.083 (0.028)	0.003	−0.089 (0.029)	0.002	−0.038 (0.004)	<0.001
ISS			−13.530 (5.539)	0.015	−0.357 (0.066)	<0.001
ISS^2			26.454 (9.063)	0.004	0.642 (0.105)	<0.001
ISS × Period			0.470 (0.180)	0.009	0.165 (0.024)	<0.001
ISS^2 × Period			−0.803 (0.341)	0.019	−0.272 (0.046)	<0.001
Observations	6,715		6,636		6,664	
Marginal R^2/conditional R^2	0.130/0.468		0.133 / 0.468		0.229/0.827	

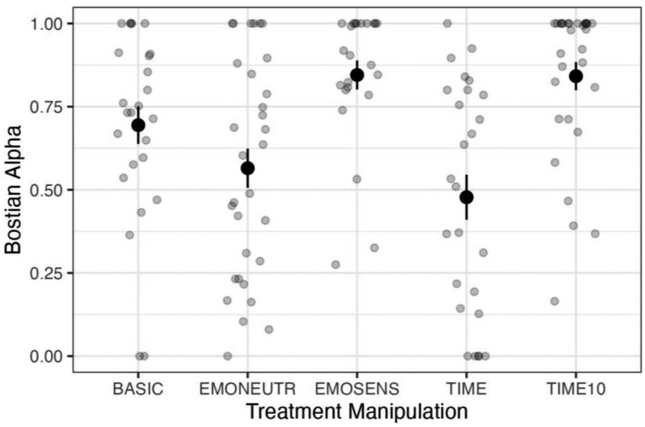

FIGURE 4 Pull-to-center bias across treatment manipulations and time. *Note*. Depicted are individual pull-to-center bias estimates (small dots), and group-level estimates (large dots), operationalized following Bostian et al. (2008). Error bars depict the standard error of the mean. Interestingly, on average participants in the EMOSENS and TIME10 conditions showed reduced pull-to-center bias, whereas those in the TIME condition showed increased bias compared with the BASIC condition.

4.3.4 | Individual stress and behavioral biases

The crucial test of H2 is whether the inverted-U-shaped relationship between individual stress and ordering behavior also holds for our parametric measure of the pull-to-center effect, Bostian alpha. Hence, we repeated the analysis described in Section 4.3.2, substituting the individual Bostian alpha estimate for order behavior as the dependent variable (see Table 3, column 3). In line with our previous analysis, we again find strong evidence for the presence of a time trend in ordering behavior. We also find that all psychological components of the treatment manipulations, including noise, significantly affect ordering behavior, considering main as well as time-dynamic effects. Our results confirm that ISS squared significantly predicts pull-to-center bias beyond the psychological treatment components, but that this relationship decays over time.

5 | DISCUSSION

This paper investigates the influence of an acutely stressful environment on humanitarian operations managers' decision-making. We experimentally manipulate stress using a validated, modular stress protocol that emulates typical stressors in a humanitarian context, with different degrees of time pressure, exposure to emotional images, and noise. We model decision-making in humanitarian inventory management as an adapted newsvendor problem task. Our results provide a necessary first basis for examining the operational consequences, in terms of how biases influence managerial performance in stressful and important situations in which beneficiaries are in need and lives may be at stake.

5.1 | Overview of results

Our treatment manipulation successfully modulates the psychophysiological stress response. Specifically, the different treatment conditions differentially manipulate the two dimensions of psychological stress (negative affective valence and arousal), following the circumplex model of emotion (Russell, 1980). Similarly, the different treatment conditions differentially manipulate physiological stress, operationalized by relative changes in the heart rate (ISS).

On a behavioral level, our results show that limited time pressure and exposure to emotional pictures lead to improved newsvendor performance, operationalized by the closeness of supplies orders to the optimal level. These manipulations are both associated with medium levels of subjective arousal and physiological stress. On the other hand, *high* time pressure, which is associated with high subjective arousal and physiological stress, has a negative impact on performance. Lastly, noise by itself has only a limited effect on stress and performance. This hints at the fact that differences in behavioral outcomes following the treatment manipulations may be explained by differences in the psychophysiological response state. Importantly, this explanation also holds at the level of individual differences. Specifically, the differential impact of the treatment manipulations on behavior may be explained by the physiological stress levels evoked: on the individual level, we observe an inverted-U-shaped relationship between the stress reaction and performance, which is predictive even when controlling for the main effect of treatment manipulation. This means that moderate levels of stress lead to improved newsvendor performance, whereas high levels of stress flip this effect. Our results align with an influential psychological model of stress that conceptualizes the cognitive costs and benefits of stress as an inverted-U function of stress severity in which the absence of stress is typically experienced as understimulatory, whereas high degrees of stress are experienced as *stressful* (Sapolsky, 2015), as well as with empirical work on the impact of stress on decision-making in emergency contexts (Ozel, 2001). Importantly, we show that even relatively simple physiological measures (such as heart rate) may significantly improve predictions of individual operations management performance beyond recognition of psychological context factors.

Using two models of typical behavioral biases in the newsvendor problem, we further confirm that stress-related changes in performance are driven specifically by differences in pull-to-center bias, which refers to decision-makers' inclination to anchor their perspective on mean demand. More precisely, the treatment manipulations and individual stress levels affect a computational parameterization of pull-to-center bias in a qualitatively similar fashion to the absolute order amount levels, but explain a substantially higher level of variance. However, this is not the case for the degree of demand chasing, another typical bias whereby decision-makers anchor on a prior order and then adjust the next order toward the corresponding prior demand. Consequently, we are able not only to explain changes in newsvendor performance under stress on both psychophysiological and computational levels but also to effectively link these two levels of explanation with each other. Our results extend previous studies that establish the presence of biases in newsvendor decision-makers generally (e.g., Schweitzer & Cachon, 2000) and individual differences between them (e.g., Moritz et al., 2013), by showing that the strength of biases may be modulated by contextual factors (see also Kirshner & Moritz, 2023).

Another consistent finding across our analyses is that treatment and stress effects reduce over the course of the experiment and are not significant at the end of the session (see Supporting Information Table S1). The main effect of the experimental period, as well as the interaction terms of treatment effects and ISS with the experimental period, are significant in all regression models. This is the case even though participants received extensive explanations of the task and a small number of practice trials before the experimental session, meaning that they were not entirely naive to the task. A tentative explanation of this drift in performance is that only more extensive experience of the task is effective in mitigating the impact of stress on performance. Inspection of the performance trajectories for each condition (see Figure 3) shows that high-time-pressure conditions indeed benefit most strongly from extended task experience.

5.2 | Implications for the humanitarian context

Previous research unequivocally documents that stress is a major issue in humanitarian fieldwork (e.g., Cardozo et al., 2012; Jachens, 2018; Panter-Brick et al., 2020). This problem has become even more prominent during recent global crises, for example in humanitarian healthcare responses to the COVID-19 pandemic and in recent Ebola outbreaks (Kiggundu, 2022). While healthcare workers are routinely exposed to stress, these levels are exacerbated during unusual events such as a pandemic (Irfan et al., 2020). Indeed, many studies have highlighted the stress exposure and mental burden experienced by humanitarian and healthcare workers during the pandemic (Benfante et al., 2020; D'Ettorre et al., 2021; Orrù et al., 2021; Parvin et al., 2022; Ruiz-Fernández et al., 2020; Wang et al., 2020). A similar picture emerged from the 2014−2016 Ebola outbreak (Lehmann et al., 2015; Paladino et al., 2017). Mental health issues will also foreseeably be a major consequence of the Russian invasion of Ukraine (Bai et al., 2022).

Here, we provide novel evidence that stress significantly affects not only the mental health and well-being of field staff but also the efficiency of humanitarian operations. In quantitative terms, the temporally dynamic impact of the psychological context accounts for 13% of individual variability in ordering behavior (see Table 3, Model 1) or almost 30% if combined with a computational model of behavior and physiological stress data (see Table 3, Model 3). This finding posits a novel argument for addressing the problem of structural stress within organizations.

Second, our research adds nuance to current discourse on the impact of stress in humanitarian contexts. We show that not all stress is bad and that the relationship between stress levels and performance is nonlinear. In our experiment, medium levels of subjective arousal and physiological stress, as evoked by medium time pressure and exposure to emotional pictures, are associated with improved performance, compared with a high time pressure condition characterized by high levels of stress on the one hand, and noise-only and control conditions both characterized by low levels of stress on the other. Although we must be cautious about drawing inferences for the field context, where stress levels may be substantially greater and more variable, our results tentatively suggest that humanitarian organizations should focus on reducing peak stressors (e.g., traumatization, extreme time pressure), but that good performance in demanding environments is generally possible.

Third, our results hint at the possibility that sufficient training and preparation may be another avenue through which to mitigate stress effects, besides stress reduction. Across all treatment conditions of our experiment, participants' performance benefited from more hands-on experience with the task, but this effect was especially pronounced for the high-stress treatment. This was the case even though all participants received extensive instructions and solved a number of practice trials prior to the experimental session. Similar insights have been formulated in other high-stress environments, for example, for wildland firefighters (Useem et al., 2005).

5.3 | Implications for managing stress

A question that naturally arises from our research is how to manage the impact of stress on humanitarian organizations and decision-making. Although mitigating stress effects was not the main concern of this study, some avenues for possible interventions emerge.

First, our research highlights that the extent rather than the mere presence of stress matters. Hence, good stress management should start by assessing stress. This means both identifying structural stressors and measuring individual stress. Straightforward assessments of individual stress might utilize a single- or two-item self-assessment scale such as the one used in this research project (Bradley & Lang, 1994; Folstein & Luria, 1973), and commercial wristbands to continuously monitor heart rates might be feasible for some organizations and application scopes.

Regarding structural stressors, our research suggests that peak levels of stress are especially harmful to decision-making. Therefore, building on the systematic measurement of stressors and stress outlined above, managerial interventions should target structural stressors that evoke the highest levels of stress. On the other hand, minor sources of stress such as moderate time pressure may have negligible or even positive effects on decision-making. Again, inferences from our research must be drawn with caution with respect to the field context here, where stress levels may be substantially greater and more variable.

Lastly, to address the impact of stress on decision-making, our results hint at the possibility that sufficient training and preparation may mitigate stress effects. Immersive and virtual reality simulations might offer an effective and cost-efficient approach (Andreatta et al., 2010; Hsu et al., 2013; Jung, 2022; Sharma et al., 2014). Moreover, our research suggests that field staff and managers operating under high stress conditions may especially benefit from decision support systems (see, e.g., Ortuño et al., 2013; Sahebjamnia et al., 2017). Ideally, the recommendations of decision support systems might be deployed on a just-in-time basis, combined with continuous stress monitoring of decision-makers.

Although our research was motivated by the context of humanitarian operations and designed to deliver formative insights in this context, similar implications can be expected to hold more broadly. For example, seminal work on management of business crises suggests that it is necessary to consider the influence of time pressure, limited information, and stress on decision-making (Smart & Vertinsky, 1977). Future research should investigate how far psychological factors, and especially stress, aggravate supply chain problems during crises such as the COVID-19 pandemic.

5.4 | Limitations

This paper presents data from a randomized controlled study, combining methods from behavioral operations research with psychophysiological measurements to study the influence of stress on decision-making in humanitarian supplies management. We adopted an interdisciplinary approach to its design and analysis. Our results tell a consistent story and have the potential to inform future research and practice, as outlined above. However, our study has a few limitations regarding its interpretation.

First, we report the results of a laboratory study from a sample unrepresentative of field staff in humanitarian organizations, which limits the ecological validity of our experiment. Future research must therefore test whether our results would hold in a more naturalistic setting (e.g., a lab in the field experiment with field staff humanitarian workers). Nevertheless, several factors speak for the generalizability of our findings. First, our results are aligned with theory on stress and cognition more generally (Sapolsky, 2015), which suggests that the effects we observed may be attributable to a general cognitive phenomenon rather than the specific contextual conditions of our experiment. Second, while our results are novel in the context of humanitarian operations research, our conclusions are well-aligned with practical insights from other high-stress environments, such as wildland firefighting (Useem et al., 2005).

We should also highlight that in our experiment we studied the influence of acute stressors on decision-making, that is, of distinct, time-restricted stressful events. Specifically, we investigated how time pressure, emotional pictures, and noise influenced performance during the task. Conceptually different from this type of stress is chronic stress, which arises when stressors are sustained over extended periods, either from a series of multiple stressful events or from structural issues. As outlined in our introduction, humanitarian field workers reportedly experience both types of stress. However, owing to ethical considerations, experimental laboratory studies are not well-suited to studying chronic stress. Here, lab-in-the-field studies might meaningfully complement our approach to study chronic stress.

Another point relating to the generalizability of our results is that our sample included men and women but in a proportion of approximately 2.5 to 1. While additional robustness checks did not indicate that our results were attenuated by gender (all $p > 0.05$), we know from previous work that the stress response may vary by sex (Kudielka & Kirschbaum, 2005). Therefore, future work should replicate our results in a more gender-balanced sample and explicitly address gender and/or sex effects.

Finally, we must address the concern about specificity in explaining our behavioral results through stress. As argued above, we show that order behavior and our computational parameterization of pull-to-center bias are differentially affected by differing conditions of our standardized modular stress protocol (Bali & Jaggi, 2015; Reinhardt et al., 2012). We can explain this differential effect on both group and individual levels through assessed stress levels. Importantly, the relationship between stress and performance is nonlinear, as predicted from the literature (Sapolsky, 2015). However, our results do not speak to the exact *cognitive-psychological* mechanism that drives these results. This means that our experiment cannot distinguish whether stress affects order behavior and pull-to-center bias, for example, through a pathway of attentional effects, reduced working memory capacities, or other cognitive functions that are modulated under stress. Although such insights would be formative for psychological theory, our conclusions for humanitarian operations management are agnostic to these mechanisms.

REFERENCES

Ager, A., Pasha, E., Yu, G., Duke, T., Eriksson, C., & Cardozo, B. L. (2012). Stress, mental health, and burnout in national humanitarian aid workers in Gulu, Northern Uganda. *Journal of Traumatic Stress*, *25*(6), 713–720. https://doi.org/10.1002/jts.21764

Andreatta, P. B., Maslowski, E., Petty, S., Shim, W., Marsh, M., Hall, T., Stern, S., & Frankel, J. (2010). Virtual reality triage training provides a viable solution for disaster-preparedness. *Academic Emergency Medicine*, *17*(8), 870–876. https://doi.org/10.1111/j.1553-2712.2010.00728.x

Antares Foundation. (2005). *Managing stress in humanitarian workers: Guidelines for good practice*. Antares Foundation.

Bai, W., Cai, H., Sha, S., Ng, C. H., Javed, A., Mari, J., Su, Z., Shinfuku, N., & Xiang, Y.-T. (2022). A joint international collaboration to address the inevitable mental health crisis in Ukraine. *Nature Medicine*, *28*(6), 1103–1104. https://doi.org/10.1038/s41591-022-01828-w

Bali, A., & Jaggi, A. S. (2015). Clinical experimental stress studies: Methods and assessment. *Reviews in the Neurosciences*, *26*(5), 555–579. https://doi.org/10.1515/revneuro-2015-0004

Banholzer, S., Kossin, J., & Donner, S. (2014). The impact of climate change on natural disasters. In A. Singh & Z. Zommers (Eds.), *Reducing disaster: Early warning systems for climate change* (pp. 21–49). Springer Netherlands, 21–49.

Beilock, S. L., & DeCaro, M. S. (2007). From poor performance to success under stress: Working memory, strategy selection, and mathematical problem solving under pressure. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *33*(6), 983–998.

Benfante, A., Di Tella, M., Romeo, A., & Castelli, L. (2020). Traumatic stress in healthcare workers during COVID-19 pandemic: A review of the immediate impact. *Frontiers in Psychology*, *11*, 569935. https://doi.org/10.3389/fpsyg.2020.569935

Benzion, U., Cohen, Y., Peled, R., & Shavit, T. (2008). Decision-making and the newsvendor problem: An experimental study. *Journal of the Operational Research Society*, *59*(9), 1281–1287. https://doi.org/10.1057/palgrave.jors.2602470

Besiou, M., Pedraza Martinez, A., & Van Wassenhove, L. N. (2012). *The effect of earmarked funding on fleet management for relief and development* (INSEAD Working Paper No. 2012/10/TOM). INSEAD Social Innovation Centre.

Besiou, M., & Van Wassenhove, L. N. (2020). Humanitarian operations: A world of opportunity for relevant and impactful research. *Manufacturing & Service Operations Management*, *22*(1), 135–145.

Blascovich, J., Seery, M. D., Mugridge, C. A., Norris, R. K., & Weisbuch, M. (2004). Predicting athletic performance from cardiovascular indexes of challenge and threat. *Journal of Experimental Social Psychology*, *40*(5), 683–688. https://doi.org/10.1016/j.jesp.2003.10.007

Bolton, G. E., & Katok, E. (2008). Learning by doing in the newsvendor problem: A laboratory investigation of the role of experience and feedback. *Manufacturing & Service Operations Management*, *10*(3), 519–538.

Bolton, G. E., Ockenfels, A., & Thonemann, U. W. (2012). Managers and students as newsvendors. *Management Science*, *58*(12), 2225–2233. https://doi.org/10.1287/mnsc.1120.1550

Bostian, A. A., Holt, C. A., & Smith, A. M. (2008). Newsvendor "pull-to-center" effect: Adaptive learning in a laboratory experiment. *Manufacturing & Service Operations Management*, *10*(4), 590–608.

Bradley, M. M., & Lang, P. J. (1994). Measuring emotion: The self-assessment manikin and the semantic differential. *Journal of Behavior Therapy and Experimental Psychiatry*, *25*(1), 49–59. https://doi.org/10.1016/0005-7916(94)90063-9

Bundy, D. A. (2009). *Rethinking school feeding: Social safety nets, child development, and the education sector*. The World Bank.

Cardozo, B. L., Crawford, C. G., Eriksson, C., Zhu, J., Sabin, M., Ager, A., Foy, D., Snider, L., Scholte, W., Kaiser, R., Olff, M., Rijnen, B., & Simon, W. (2012). Psychological distress, depression, anxiety, and burnout among international humanitarian aid workers: A longitudinal study. *PLoS ONE*, *7*(9), e44948. https://doi.org/10.1371/journal.pone.0044948

Carter, C. R., Kaufmann, L., & Wagner, C. M. (2017). Reconceptualizing intuition in supply chain management. *Journal of Business Logistics*, *38*(2), 80–95. https://doi.org/10.1111/jbl.12154

Coleman, L. (2006). Frequency of man-made disasters in the 20th century. *Journal of Contingencies and Crisis Management*, *14*(1), 3–11. https://doi.org/10.1111/j.1468-5973.2006.00476.x

Comes, T. (2016). Cognitive biases in humanitarian sensemaking and decision-making lessons from field research. In *Proceedings of the 2016 IEEE International Multi-Disciplinary Conference on Cognitive Methods in Situation Awareness and Decision Support (CogSIMA)* (pp. 56–62). IEEE.

Connorton, E., Perry, M. J., Hemenway, D., & Miller, M. (2012). Humanitarian relief workers and trauma-related mental illness. *Epidemiologic Reviews*, *34*(1), 145–155. https://doi.org/10.1093/epirev/mxr026

D'Ettorre, G., Ceccarelli, G., Santinelli, L., Vassalini, P., Innocenti, G. P., Alessandri, F., Koukopoulos, A. E., Russo, A., D'Ettorre, G., & Tarsitani, L. (2021). Post-traumatic stress symptoms in healthcare workers dealing with the COVID-19 pandemic: A systematic review. *International Journal of Environmental Research and Public Health*, *18*(2), 601.

Dalile, B., Torre, D. L., Verbeke, K., Oudenhove, L. V., & Vervliet, B. (2022). When the mind says one thing, but the HPA axis says another: Lack of coherence between subjective and neuroendocrine stress response trajectories in healthy men. *Psychoneuroendocrinology*, *139*, 105692. https://doi.org/10.1016/j.psyneuen.2022.105692

De la Torre, L. E., Dolinskaya, I. S., & Smilowitz, K. R. (2012). Disaster relief routing: Integrating research and practice. *Socio-Economic Planning Sciences*, *46*(1), 88–97. https://doi.org/10.1016/j.seps.2011.06.001

Duffy, E. (1957). The psychological significance of the concept of "arousal" or "activation". *Psychological Review*, *64*(5), 265–275. https://doi.org/10.1037/h0048837

Ferreira, G. O., Arruda, E. F., & Marujo, L. G. (2018). Inventory management of perishable items in long-term humanitarian operations using Markov decision processes. *International Journal of Disaster Risk Reduction*, *31*, 460–469. https://doi.org/10.1016/j.ijdrr.2018.05.010

Fischbacher, U. (2007). z-Tree: Zurich toolbox for ready-made economic experiments. *Experimental Economics*, *10*(2), 171–178. https://doi.org/10.1007/s10683-006-9159-4

Folstein, M. F., & Luria, R. (1973). Reliability, validity, and clinical application of the visual analogue mood scale. *Psychological Medicine*, *3*(4), 479–486. https://doi.org/10.1017/S0033291700054283

Global Humanitarian Assistance. (2018). *Global humanitarian assistance report 2022*. Development Initiatives.

Gonçalves, P., & Castañeda, J. A. (2013). *Impact of joint decisions and cognitive dissonance on prepositioning (newsvendor) decisions* (MIT Sloan Research Paper No. 5021-13). MIT.

Hermans, E. J., Henckens, M. J., Joëls, M., & Fernández, G. (2014). Dynamic adaptation of large-scale brain networks in response to acute stressors. *Trends in Neurosciences*, *37*(6), 304–314. https://doi.org/10.1016/j.tins.2014.03.006

Hsu, E. B., Li, Y., Bayram, J. D., Levinson, D., Yang, S., & Monahan, C. (2013). State of virtual reality based disaster preparedness and response training. *PLoS Currents*, *24*, ecurrents.dis.1ea2b2e71237d5337fa53982a38b2aff. https://doi.org/10.1371/currents.dis.1ea2b2e71237d5337fa53982a38b2aff

IASC. (2006). *IASC guidelines on mental health and psychosocial support in emergency settings*. Inter-Agency Standing Committee.

Inbar, Y., & Gilovich, T. (2011). Angry (or disgusted), but adjusting? The effect of specific emotions on adjustment from self-generated anchors. *Social Psychological and Personality Science*, *2*(6), 563–569. https://doi.org/10.1177/1948550611401426

Irfan, M., Naeem, F., Afridi, M. I., & Javed, A. (2020). Prevention of occupational stress in health-care workers during COVID-19 pandemic. *Indian Journal of Psychiatry*, *62*(Suppl 3), S495. https://doi.org/10.4103/psychiatry.IndianJPsychiatry_844_20

Jachens, L. (2018). Work-related stress in a humanitarian context: A qualitative investigation. *Disasters*, *42*(4), 619–634. https://doi.org/10.1111/disa.12278

Joëls, M., & Baram, T. Z. (2009). The neuro-symphony of stress. *Nature Reviews Neuroscience*, *10*(6), 459–466. https://doi.org/10.1038/nrn2632

Jung, Y. (2022). Virtual reality simulation for disaster preparedness training in hospitals: Integrated review. *Journal of Medical Internet Research*, *24*(1), e30600. https://doi.org/10.2196/30600

Kahneman, D., & Tversky, A. (1982). The psychology of preferences. *Scientific American*, *246*(1), 160–173. https://doi.org/10.1038/scientificamerican0182-160

Kassam, K. S., Koslov, K., & Mendes, W. B. (2009). Decisions under distress: Stress profiles influence anchoring and adjustment. *Psychological Science*, *20*(11), 1394–1399. https://doi.org/10.1111/j.1467-9280.2009.02455.x

Katok, E. (2011). Using laboratory experiments to build better operations management models. *Foundations and Trends in Technology, Information and Operations Management*, *5*(1), 1–86. https://doi.org/10.1561/0200000022

Kiggundu, T. (2022). Notes from the field: Outbreak of Ebola virus disease caused by Sudan Ebolavirus—Uganda, August–October 2022. *Morbidity and Mortality Weekly Report*, *71*(45), 1457–1459. https://doi.org/10.15585/mmwr.mm7145a5

Kirshner, S. N., & Moritz, B. B. (2023). For the future and from afar: Psychological distance and inventory decision-making. *Production & Operations Management*, *32*(1), 170–188.

Kovacs, G., & Spens, K. M. (2007). Humanitarian logistics in disaster relief operations, *International Journal of Physical Distribution & Logistics Management*, *37*(2), 99–114.

Kremer, M., Minner, S., & Van Wassenhove, L. N. (2010). Do random errors explain newsvendor behavior? *Manufacturing & Service Operations Management*, *12*(4), 673–681.

Kretschmer, A., Spinler, S., & Van Wassenhove, L. N. (2014). A school feeding supply chain framework: Critical factors for sustainable program design. *Production and Operations Management*, *23*(6), 990–1001. https://doi.org/10.1111/poms.12109

Kudielka, B. M., & Kirschbaum, C. (2005). Sex differences in HPA axis responses to stress: A review. *Biological Psychology*, *69*(1), 113–132. https://doi.org/10.1016/j.biopsycho.2004.11.009

Lang, P. J., Bradley, M. M., & Cuthbert, B. N. (1997). *International affective picture system (IAPS), Technical manual and affective ratings*. NIMH Center for the Study of Emotion and Attention.

Lau, N., & Bearden, J. N. (2013). Newsvendor demand chasing revisited. *Management Science*, *59*(5), 1245–1249. https://doi.org/10.1287/mnsc.1120.1617

Lazarus, R. S. (1966). *Psychological stress and the coping process*. McGraw-Hill.

Lazarus, R. S., Speisman, J. C., & Mordkoff, A. M. (1963). The relationship between autonomic indicators of psychological stress: Heart rate and skin conductance. *Psychosomatic Medicine*, *25*(1), 19–30. https://doi.org/10.1097/00006842-196301000-00004

Lehmann, M., Bruenahl, C. A., Löwe, B., Addo, M. M., Schmiedel, S., Lohse, A. W., & Schramm, C. (2015). Ebola and psychological stress of health care professionals. *Emerging Infectious Diseases*, *21*(5), 913–914. https://doi.org/10.3201/eid2105.141988

Lodree, E. J. (2011). Pre-storm emergency supplies inventory planning. *Journal of Humanitarian Logistics and Supply Chain Management*, *1*(1), 50–77. https://doi.org/10.1108/20426741111122411

Long, D. C., & Wood, D. F. (1995). The logistics of famine relief. *Journal of Business Logistics*, *16*(1), 213–229.

Lu, C. - S., & Kuo, S. - Y. (2016). The effect of job stress on self-reported safety behaviour in container terminal operations: The moderating role of emotional intelligence. *Transportation Research Part F: Traffic Psychology and Behaviour*, *37*, 10–26. https://doi.org/10.1016/j.trf.2015.12.008

Maier, S. U., Makwana, A. B., & Hare, T. A. (2015). Acute stress impairs self-control in goal-directed choice by altering multiple functional connections within the brain's decision circuits. *Neuron*, *87*(3), 621–631. https://doi.org/10.1016/j.neuron.2015.07.005

Margittai, Z., Nave, G., Strombach, T., van Wingerden, M., Schwabe, L., & Kalenscher, T. (2016). Exogenous cortisol causes a shift from deliberative to intuitive thinking. *Psychoneuroendocrinology*, *64*, 131–135. https://doi.org/10.1016/j.psyneuen.2015.11.018

Margittai, Z., Nave, G., Van Wingerden, M., Schnitzler, A., Schwabe, L., & Kalenscher, T. (2018). Combined effects of glucocorticoid and noradrenergic activity on loss aversion. *Neuropsychopharmacology*, *43*(2), 334–341. https://doi.org/10.1038/npp.2017.75

Margittai, Z., Strombach, T., Joëls, M., Schwabe, L., & Kalenscher, T. (2015). A friend in need: Time-dependent effects of stress on social discounting in men. *Hormones and Behavior*, *73*, 75–82. https://doi.org/10.1016/j.yhbeh.2015.05.019

Moritz, B. B., Hill, A. V., & Donohue, K. L. (2013). Individual differences in the newsvendor problem: Behavior and cognitive reflection. *Journal of Operations Management*, *31*(1–2), 72–85. https://doi.org/10.1016/j.jom.2012.11.006

Moss, J. (2020). Rethinking burnout: When self-care is not the cure. *American Journal of Health Promotion*, *34*(5), 565–568. https://doi.org/10.1177/0890117120920488b

Nitsch, F. J., Sellitto, M., & Kalenscher, T. (2021). The effects of acute and chronic stress on choice consistency. *Psychoneuroendocrinology*, *131*, 105289. https://doi.org/10.1016/j.psyneuen.2021.105289

Orrù, G., Marzetti, F., Conversano, C., Vagheggini, G., Miccoli, M., Ciacchini, R., Panait, E., & Gemignani, A. (2021). Secondary traumatic stress and burnout in healthcare workers during COVID-19 outbreak. *International Journal of Environmental Research and Public Health*, *18*(1), 337. https://doi.org/10.3390/ijerph18010337

Ortuño, M. T., Cristóbal, P., Ferrer, J. M., Martín-Campo, F. J., Muñoz, S., Tirado, G., & Vitoriano, B. (2013). Decision aid models and systems for humanitarian logistics: A survey. In B. Vitoriano, J. Montero, & D. Ruan (Eds.), *Decision aid models for disaster management and emergencies* (Vol. 7, pp. 17–44). Atlantis Press, pp. 17–44.

Ozel, F. (2001). Time pressure and stress as a factor during emergency egress. *Safety Science*, *38*(2), 95–107. https://doi.org/10.1016/S0925-7535(00)00061-8

Paladino, L., Sharpe, R., Galwankar, S., Sholevar, F., Marchionni, C., Papadimos, T., Paul, E., Hansoti, B., Firstenberg, M., Garg, M., Watson, M., Baxter, R., & Stawicki, S. (2017). Reflections on the Ebola public health emergency of international concern, part 2: The unseen epidemic of posttraumatic stress among health-care personnel and survivors of the 2014–2016 Ebola outbreak. *Journal of Global Infectious Diseases*, *9*(2), 45–50.

Panter-Brick, C., Eggerman, M., Ager, A., Hadfield, K., & Dajani, R. (2020). Measuring the psychosocial, biological, and cognitive signatures of profound stress in humanitarian settings: Impacts, challenges, and strategies in the field. *Conflict and Health*, *14*, 40. https://doi.org/10.1186/s13031-020-00286-w

Parvin, T., Rosenbaum, S., Ozen, S., Ewagata, L., & Ventevogel, P. (2022). Mental health and perceived social support of humanitarian workers in Bangladesh during the COVID-19 pandemic. *Intervention*, *20*(2), 151–160. https://doi.org/10.4103/intv.intv_18_21

Posner, J., Russell, J. A., & Peterson, B. S. (2005). The circumplex model of affect: An integrative approach to affective neuroscience, cognitive development, and psychopathology. *Development and Psychopathology*, *17*(3), 715–734. https://doi.org/10.1017/S0954579405050340

Preston, S. D., Buchanan, T. W., Stansfield, R. B., & Bechara, A. (2007). Effects of anticipatory stress on decision making in a gambling task. *Behavioral Neuroscience*, *121*(2), 257–263. https://doi.org/10.1037/0735-7044.121.2.257

Qin, S., Hermans, E. J., van Marle, H. J. F., Luo, J., & Fernández, G. (2009). Acute psychological stress reduces working memory-related activity in the dorsolateral prefrontal cortex. *Biological Psychiatry*, *66*(1), 25–32. https://doi.org/10.1016/j.biopsych.2009.03.006

Reinhardt, T., Schmahl, C., Wüst, S., & Bohus, M. (2012). Salivary cortisol, heart rate, electrodermal activity and subjective stress responses to the Mannheim Multicomponent Stress Test (MMST). *Psychiatry Research*, *198*(1), 106–111. https://doi.org/10.1016/j.psychres.2011.12.009

Riis-Vestergaard, M. I., van Ast, V., Cornelisse, S., Joëls, M., & Haushofer, J. (2018). The effect of hydrocortisone administration on intertemporal choice. *Psychoneuroendocrinology*, *88*, 173–182. https://doi.org/10.1016/j.psyneuen.2017.10.002

Roels, G., & Staats, B. R. (2021). OM forum—People-centric operations: Achievements and future research directions. *Manufacturing & Service Operations Management*, *23*(4), 745–757.

Roth, A. E., & Kagel, J. H. (1995). *The handbook of experimental economics*. (Vol. 1). Princeton University Press.

Ruiz-Fernández, M. D., Ramos-Pichardo, J. D., Ibáñez-Masero, O., Cabrera-Troya, J., Carmona-Rega, M. I., & Ortega-Galán, Á. M. (2020). Compassion fatigue, burnout, compassion satisfaction and perceived stress in healthcare professionals during the COVID-19 health crisis in Spain. *Journal of Clinical Nursing*, *29*(21–22), 4321–4330. https://doi.org/10.1111/jocn.15469

Russell, J. A. (1980). A circumplex model of affect. *Journal of Personality and Social Psychology*, *39*(6), 1161–1178. https://doi.org/10.1037/h0077714

Sahebjamnia, N., Torabi, S. A., & Mansouri, S. A. (2017). A hybrid decision support system for managing humanitarian relief chains. *Decision Support Systems*, *95*, 12–26. https://doi.org/10.1016/j.dss.2016.11.006

Sandi, C. (2013). Stress and cognition. *WIREs Cognitive Science*, *4*(3), 245–261. https://doi.org/10.1002/wcs.1222

Sapolsky, R. M. (2015). Stress and the brain: Individual variability and the inverted-U. *Nature Neuroscience*, *18*(10), 1344–1346. https://doi.org/10.1038/nn.4109

Schweitzer, M. E., & Cachon, G. P. (2000). Decision bias in the newsvendor problem with a known demand distribution: Experimental evidence. *Management Science*, *46*(3), 404–420. https://doi.org/10.1287/mnsc.46.3.404.12070

Sharma, S., Jerripothula, S., Mackey, S., & Soumare, O. (2014). Immersive virtual reality environment of a subway evacuation on a cloud for disaster preparedness and response training. In *2014 IEEE symposium on computational intelligence for human-like intelligence (CIHLI)* (pp. 1–6). IEEE.

Smart, C., & Vertinsky, I. (1977). Designs for crisis decision units. *Administrative Science Quarterly*, *22*(4), 640–657. https://doi.org/10.2307/2392406

Starcke, K., & Brand, M. (2016). Effects of stress on decisions under uncertainty: A meta-analysis. *Psychological Bulletin*, *142*(9), 909–933. https://doi.org/10.1037/bul0000060

Starcke, K., Ludwig, A. - C., & Brand, M. (2012). Anticipatory stress interferes with utilitarian moral judgment. *Judgment and Decision Making*, *7*(1), 61–68. https://doi.org/10.1017/S1930297500001832

Teichner, W. H., Arees, E., & Reilly, R. (1963). Noise and human performance: A psychophysiological approach. *Ergonomics*, *6*(1), 83–97. https://doi.org/10.1080/00140136308930678

Thuraisingham, R. A. (2006). Preprocessing RR interval time series for heart rate variability analysis and estimates of standard deviation of RR intervals. *Computer Methods and Programs in Biomedicine*, *83*(1), 78–82. https://doi.org/10.1016/j.cmpb.2006.05.002

Useem, M., Cook, J. R., & Sutton, L. (2005). Developing leaders for decision making under stress: Wildland firefighters in the South Canyon fire and its aftermath. *Academy of Management Learning & Education*, *4*(4), 461–485.

Van Wassenhove, L. N. (2006). Humanitarian aid logistics: Supply chain management in high gear. *Journal of the Operational Research Society*, *57*(5), 475–489. https://doi.org/10.1057/palgrave.jors.2602125

Wang, H., Liu, Y., Hu, K., Zhang, M., Du, M., Huang, H., & Yue, X. (2020). Healthcare workers' stress when caring for COVID-19 patients: An altruistic perspective. *Nursing Ethics*, *27*(7), 1490–1500. https://doi.org/10.1177/0969733020934146

Wei, W., Guo, M., Ye, L., Liao, G., & Yang, Z. (2016). Work–family conflict and safety participation of high-speed railway drivers: Job satisfaction as a mediator. *Accident Analysis & Prevention*, *95*, 97–103.

Yerkes, R. M., & Dodson, J. D. (1908). The relation of strength of stimulus to rapidity of habit-formation. *Journal of Comparative Neurology and Psychology*, *18*(5), 459–482. https://doi.org/10.1002/cne.920180503

Yu, R. (2016). Stress potentiates decision biases: A stress induced deliberation-to-intuition (SIDI) model. *Neurobiology of Stress*, *3*, 83–95. https://doi.org/10.1016/j.ynstr.2015.12.006

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How to cite this article: Burkhardt, M., Nitsch, F. J., Spinler, S., & van Wassenhove, L. (2023). The effect of acute stress on humanitarian supplies management. *Production and Operations Management*, *32*, 2546–2559. https://doi.org/10.1111/poms.13993