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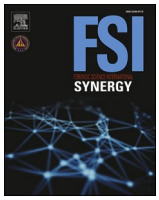

Unpacking workplace stress and forensic expert decision-making: From theory to practice

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ABSTRACT

Workplace stress can affect forensic experts' job satisfaction and performance, which holds financial and other implications for forensic service providers. Therefore, it is important to understand and manage workplace stress, but that is not simple or straightforward. This paper explores stress as a human factor that influences forensic expert decision-making. First, we identify and highlight three factors that mitigate decisions under stress conditions: nature of decision, individual differences, and context of decision. Second, we situate workplace stress in forensic science within the *Challenge-Hindrance Stressor Framework*. We argue that stressors in forensic science workplaces can have a positive or a negative impact, depending on the type, level, and context of stress. Developing an understanding of the stressors, their sources, and their possible impact can help forensic service providers and researchers to implement context-specific interventions to manage stress at work and optimize expert performance.

1. Introduction

Forensic science experts can provide critical information to police, courts, and other parties in the legal system. When so doing, experts must make crucial decisions, such as how to collect and examine the evidence, prioritize exhibits for further analysis, and communicate their findings to fact-finders [1–4]. Decisions made earlier in the forensic process (e.g., at the crime scene) can affect subsequent decisions [2,5–7]. Moreover, different cognitive and human factors influence the reliability of experts' decisions [8]. One such factor is stress [9,10].

Take for example the misidentification of Brandon Mayfield as the perpetrator of the 2004 Madrid train bombings [11–13]. In that case, multiple FBI experts, as well as an expert hired by the defence, all erroneously matched Mayfield's fingerprint to a fingermark recovered from the scene of the bombings. Later, an independent investigation by the Office of the Inspector General (OIG) identified stress and other cognitive factors as having contributed to the erroneous identification [12]—including the high-profile nature of the case, time pressure, and a strong need for closure [14]—all creating fertile ground for a misidentification [11]. Indeed, the OIG stated that the FBI's standard operating procedures at the time encouraged fingerprint experts to make conclusive rather than inconclusive decisions in high-profile cases, even if an inconclusive conclusion was more appropriate:

> "The OIG did find, however, that the FBI Laboratory's stated criteria, for reporting an 'inconclusive' result from a latent fingerprint examination could result in implicit pressure on the examiner to make an identification in a difficult comparison in a case involving a particularly heinous crime, and the OIG recommends that the FBI take several specific steps to reduce any such pressure in the future." ([12], p. 11).

It should be noted that the crime scene fingermark in this case was degraded and highly similar to that of Mayfield, which made the comparison very difficult and therefore more vulnerable to unconscious bias and misidentification (i.e., the 'bias danger zone; see [15]). Even so, this example illustrates how various stressors—like time pressure, difficult decisions, cognitive overload, fatigue, hypervigilance, external scrutiny and other factors—can negatively impact forensic experts. Therefore it is crucial to address these human factors issues [16–20].

Furthermore, workplace stressors can increase financial and

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personnel burdens on forensic service providers, many of which are already underfunded and/or understaffed [21,22]. Research has shown that stress at work can reduce job satisfaction, lower engagement, and increase absenteeism and intentions to resign [23,24]. For example, some law-enforcement agencies have reported attrition rates around 50% over a three-year period, which was attributed to staff being exposed to critical accidents/crime scenes, with about 20% of officers reporting long-term psychological stress [25]. Workplace stress may likewise lead forensic experts, who are valuable employees with specialized skills and in whom much time has been invested, to look for other jobs and eventually leave forensic science. This pattern, which has been described as "train/strain/lose" ([26], p. 211), can be an organizational burden on forensic service providers insofar as it creates a constant need to recruit and train new experts, plus an associated burden on existing experts to provide that training. Frequent turnover in forensic science laboratories can also limit laboratories' ability to handle existing piles of casework or case backlogs [9,27] and may affect the quality of expert performance, such as unconsciously cutting corners to finish cases on time [28].

Despite the potentially detrimental impact of occupational stress in forensic science, there has been surprisingly little research or consideration of how stress may impact forensic expert decision-making [9,29]. Of course, stress can create strain (e.g., anxiety and burnout [30]) that affects experts' *wellbeing* [31–33], but this paper focuses on how stress can also affect experts' *performance* in terms of their engagement in forensic tasks and the quality of their decision-making (see also [9]).[1] Recent research has begun to examine the relationship between stress and forensic expert decisions [9,10,28,29]. However, much remains unknown in terms of understanding and managing forensic workplace stress, and this process is likely to be neither simple nor straightforward.

At a conceptual level, understanding workplace stress and its impact on decision-making is complex. First, there is still no universally-accepted definition of stress or workplace stress [34,35]. One commonly-used definition of stress comes from Lazarus and Folkman's [36] theory of stress and coping, which defines stress as one's perception that the demands of their environment are greater than their ability to cope with those demands [35]. If we adopt this perspective, workplace stress refers to employees' responses to work-related demands that exceed their available resources and coping abilities [25,37]. However, these definitions seem to conceptualize stress— at least implicitly—as universally negative, while some degree of stress may actually enhance performance (e.g., too little stress can lead to feeling bored or undervalued [17]). Clearly it is important to understand what workplace stress is, how to measure it, how it affects performance, and whether there is an optimal level of stress, before considering approaches and policies to manage stress in ways that enhance forensic expert performance.

In this paper, we aim to unpack some of the complex effects of stress on forensic expert decision-making by drawing upon literature from related domains, such as cognitive psychology, medicine, policing, and management. First, we review how forensic experts process information and make casework decisions, including how cognitive and human factors, such as stress, can impact experts' decision-making processes. Then, we identify three factors (decision nature, individual factors, and decision context) that are likely to affect how experts make inferences and conclusions under stressful conditions, with examples from different yet allied disciplines. Next, we consider how different types, levels, and contexts of stress may moderate these effects. Throughout the paper, we offer practical recommendations as well as suggestions for future research. Ultimately, we hope that this paper provides a basis for researchers and practitioners to continue advancing our understanding of how occupational stress impacts forensic expert performance, including ways to pre-empt and manage its negative impacts.

2. A cognitive perspective

2.1. How stress influences forensic expert decision-making

Stress can influence forensic expert decisions, such as when giving a testimony at court or when completing high profile cases in shorter times (e.g., [19]), and it is valuable to consider how that may happen. Forensic experts examine visual information (e.g., bloodstains, fingerprints, toolmarks, and other patterns; [38,39]) by a process called *bottom-up processing* [40,41]. This involves a detailed, analytical assessment of the available data or information, piecing together information to form an understanding of what is being perceived. When perceiving data and information in this way, people cannot process or attend to all of the information available to them all at once; instead, we process the features bit by bit until we feel we have enough information to reach some threshold for making a decision [42]. For instance, when an expert compares a latent fingermark and a reference fingerprint, they cannot process the entire fingerprint all at once; instead, they examine the features within those prints until they feel that they have detected enough similarities (or dissimilarities) to warrant a decision [42]. Therefore, a forensic expert may not necessarily examine all of the information contained within a trace before reaching a conclusion. This phenomenon is not unique to forensic experts and has been shown to occur across many domains (see Decision Field Theory; [43,44]).

After we absorb information via bottom-up processing, that information travels from the sensory organs (e.g., eyes) to the brain and cognitive system where we interpret it via a complementary process called *top-down processing* [11,45]. During this process, different people (or even the same person at different times) may evaluate and interpret the same information in different ways (e.g., notice different features and/or reach different conclusions about the same evidence [46]) depending on their knowledge, experience, expectations, motivations [11]—and indeed, stress level [10]. Generally speaking, our reliance on top-down processing is adaptive. Because the brain does not have unlimited capacity to process information, top-down mechanisms serve as cognitive "shortcuts" to help us process large amounts of information more efficiently. For instance, when faced with a great deal of information at once, we use *selective attention* to process only the sensory information that is deemed most relevant based on our prior experiences, while ignoring other information that we expect to be less relevant [47,48]. In essence, then, the process of becoming an expert in any domain (including forensic science) entails acquiring more knowledge, training, and experience [49] so as to gradually develop finely-tuned top-down mechanisms [50] that improve performance beyond that of novices [51]. That is to say, experts develop heuristics (mental shortcuts, such as selective attention) that enable them to process information in a more automatic and efficient way and thus complete tasks more quickly and easily [52].

However, the same top-down mechanisms that allow experts to process information very efficiently can also create vulnerabilities that increase the risk of misinterpretation—and in some cases, error [51]. One such vulnerability is *cognitive bias*, which refers to "the class of effects through which an individual's pre-existing beliefs, expectations, motives, and situational context influence the collection, perception, or interpretation of evidence, or their resulting judgments, decisions, or confidence" ([53], p.5; see also [11]). For example, if a forensic expert begins an analysis with an expectation of what the result will be, they may experience "tunnel vision" [53], such that they search for information that fits their expectation and ignore or disregard information that refutes their expectation, which can lead to a misinterpretation [54]. Thus, top-down mechanisms are useful to make efficient decisions, but they can also contribute towards systematic errors [11] due to human factors issues, including stress.

[1] We use decision-making and performance interchangeably in this paper, but they are not the same: performance is a broader term that encompasses expert decision-making, and other performance measures.

To manage stress in the workplace, we must first understand how and why stress can influence forensic experts' decisions, so as to eventually increase awareness about potential stressors and their negative effects. Relatedly, being aware of the limitations of human decision-making can reduce the potential for a "bias blind spot" (wherein people recognise bias as a problem for others but not for themselves; [55,56]), which presents a barrier to organizational change. In other words, greater awareness of bias in the forensic community stands to increase willingness to engage with workplace measures designed to mitigate bias and the negative impacts of stress. It is critical to emphasise that the aforementioned biases in how humans process information are natural, unintentional, and subconscious, and discussion of cognitive bias should not be confused with incompetence, carelessness, or intentional dishonesty ([38]; see also [8], for a more comprehensive account of factors, including stress, that can unconsciously affect expert decision-making).

We hope that an enhanced understanding of bias and stress in forensic settings will also encourage researchers to carry out more empirical research on these phenomena and how to counteract them. While some sources of cognitive bias in forensic science are now relatively well understood, others—including sources of stress—remain more elusive. Take, for example, cognitive choice overload, wherein decision-makers who are faced with too many options may end up making a suboptimal decision, or no decision at all [57,58]. This phenomenon may prove applicable to forensic experts who are presented with myriad information and options with respect to a given forensic trace (e.g., case materials, discussions with supervisors, calls from investigators) and may thus be unable to process every single aspect in depth. Some researchers have started exploring other related factors, such as fatigue (e.g., making decisions in the afternoon vs. in the morning [16]), but there remain many unanswered questions in this area as well, such as comparing forensic decisions made after a poor quality of sleep, or shift work *vs.* workday decisions, to name a few.

2.2. Three factors affecting decisions under stress

As explained in section 2.1, the impact of stress on performance is complex. In this section, we consider what happens at a cognitive level when forensic experts make decisions under stress. At the core of this process is the decision-maker—the forensic expert who performs forensic casework and analysis—whose decisions made under stress conditions may be influenced by three factors: nature of the decision, individual differences, and context of the decision ([59]; see Fig. 1).

Nature of the decision pertains to the nature of the forensic decision itself. Examples may include the complexity of the task or evidence in question (e.g., examining mixtures of DNA from multiple contributors), ambiguity of the decision (e.g., having incomplete or degraded bullets for comparison), and the number of informative features therein (e.g., the type and number of minutiae that are discernible in a latent fingermark). All of these examples illustrate parameters that are related to the decision problem space itself. Forensic experts have limited cognitive resources to examine every possible feature or alternative [47]—but despite these limitations, they must nonetheless form a categorical opinion about the evidence if there is enough information (e.g., "identification" or "exclusion"), or they may not be able reach such an opinion (e.g., "inconclusive").

This raises at least two aspects where the nature of forensic decision-making can be a source of stress by itself. First, the "sufficiency threshold" in many disciplines is poorly defined. For example, there is a lack of clarity on what "sufficient agreement" or "sufficient disagreement" mean when it comes to pattern-comparison tasks, like firearms or toolmarks (e.g., see [60] on the lack of objective criteria on decision thresholds). Not knowing how much is enough to report an identification, or enough to report an exclusion, might be fairly stressful, given that there could be negative consequences on both casework outcome and the expert if they make the wrong decision. Second, making a decision at all, as opposed to just reporting observations, might be by itself a source of stress. For example, anecdotal evidence suggests that some agencies moved to observations over decisions when reporting probabilistic genotyping in DNA, and these observations often take the form of a likelihood ratio. Of course, the type of reporting varies across disciplines, but at least it is useful to highlight that, from a cognitive perspective, making a final decision might be more stressful than merely making observations.

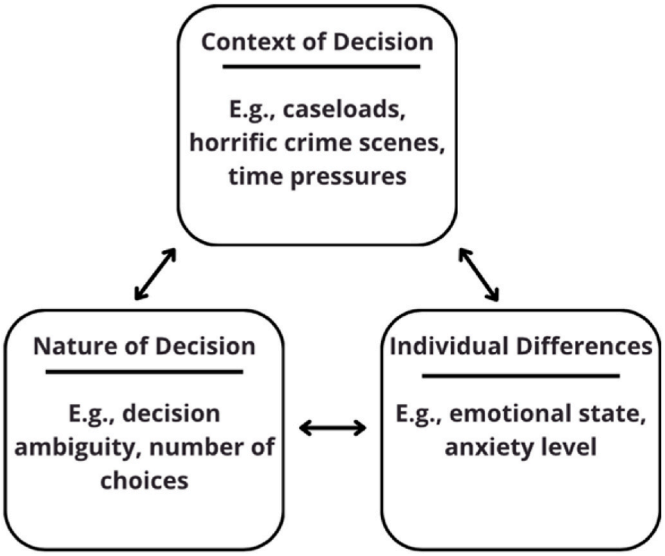

Fig. 1. Three factors that affect forensic expert decision-making. These include the nature of decision (e.g., task complexity), individual differences (i.e., examiners' inherent characteristics), and context of decision (i.e., elements of the environment in which the examiner works). These factors also interact with each other in ways that can amplify the effects of stress.

Individual differences include any personal or inherent characteristics of the decision-maker themselves that may play a role in their stress response (see Model of Stress at Work [61]), such as one's state or trait level of anxiety, tolerance of ambiguity, emotional state, or confidence level [59,62,63]. In one study, for example, researchers found that the introduction of stressors (i.e., time pressure and negative feedback) affected stress feelings of individuals with low and moderate trait anxiety, but not individuals with high trait anxiety [64]. Although the nature of decision and individual factors are distinct, they also interact with one another [59]. For instance, with respect to complex and time-pressured decisions [19], such as collecting traces from ambiguous crime scenes [65,66], the very same stressors may have a more pronounced impact on forensic examiners who tend to be more averse to ambiguity (i.e., those who dislike events of unknown probabilities [67]) as opposed to examiners with greater tolerance for ambiguity.

The decision context pertains to the environment in which forensic experts work and make decisions. These may include forensic-specific stressors (e.g., being exposed to horrific case details) as well as stressors that are not specific to forensic science (e.g., lack of career advancement). Time pressure, whether from investigators and/or supervisors, is another common external cause of stress among forensic experts [9,19,20]. Notably, these external factors could also interact with both the decision's nature and individual factors [59]. For instance, time-pressure (a decision context) could make the same task more cognitively demanding (a decision nature [68]), and even more so for examiners who are less tolerant of ambiguity (an individual factor).

In turn, this combination of factors (decisional, internal, and external) could affect examiners' available cognitive resources and their decision thresholds in forensic pattern-matching tasks (e.g., comparing cartridge cases, handwriting samples, etc) or forensic recognition tasks (e.g., recognizing bloodstain patterns, examining/triaging items from

crime scenes, etc.). As Thompson [60] recently explained, even seemingly minor shifts in examiners' decision thresholds can have a significant impact on their performance:

> "small shifts in forensic examiners' decision thresholds can dramatically affect their error rates and the probative value of their evidence, which can in turn affect the accuracy of the legal system. For example, small reductions in the threshold for identification, which might plausibly arise from an examiner's exposure to task- irrelevant information [which may include workplace stressors], can dramatically increase the risk of convicting an innocent person." ([60], p.1).

Each of these three factors offers a potential intervention point to assist and enhance forensic expert decisions. The first point of intervention may focus on the decision's nature: For instance, forensic labs might *triage* traces that are relatively difficult to assess (like unclear handwriting or an incomplete shoe mark) for more intensive analysis (e.g., additional and/or blind verification) in a way that other less ambiguous traces are not [15,69]. A second point of intervention may focus on the experts' state of mind: For example, training could incorporate realistic simulations that force experts to navigate ambiguous and challenging court testimony. This sort of practice with handling ambiguity builds tacit forms of knowledge that are learned by doing [49] and may increase confidence and resilience (especially among experts with lower pre-existing tolerance for ambiguity). Recruitment and selection procedures might also consider and prioritize candidates who are naturally better situated to cope with stress. A third intervention point may focus on the environment in which decisions are made: For example, forensic labs may benefit from measures that promote well-being and combat fatigue in the workplace, such as flexible schedules and employee wellness programs that focus on protecting employees' physical and mental health [16,20]. The examples offered here are not exhaustive; they are meant to illustrate the possible interventions (targeting three different points) that forensic service providers may consider, depending on their specific context and resources available.

3. Type, level, and context of stress

3.1. Type of stress and forensic decision-making

Research suggests that some types of stressors can enhance decision-making in the workplace, while other types can degrade it. To explain, we draw upon the *Challenge-Hindrance Stressor Framework* (CHSF [70]), a widely accepted and empirically-supported framework [33,71], which has been applied to professionals in law enforcement and healthcare [72,82]. In addition, CHSF combines several work-related stress theories, such as the transactional theory of stress and coping [36] and the conservation of resources theory [73]. While it is acknowledged that other stress frameworks exist (e.g., Transdisciplinary Model of Stress [35]) and that CHSF is not without limitations (e.g., in addressing cross-cultural implications [71]), we chose CHSF as it focuses on stress in the workplace context, as opposed to non-work related stressors (e.g., personal stress). Fig. 2 presents a streamlined version of the CHSF, simplified into four parts for illustration purposes, namely: Part (I) work-related demands-appraisals, Part (II) moderating factors, Part (III) mechanisms, and Part (IV) outcomes (see Ref. [33], for full diagram).

CHSF Part (I) acknowledges that we must consider how people react to and appraise work-related demands in order to understand the effect of stress [70]. Work-related demands that are perceived to contribute to personal development and/or achievement (such as reasonable time pressures and valued responsibilities) are considered positive or "challenge" stressors. Conversely, work-related demands that are perceived to interfere with professional development (e.g., role conflict, role ambiguity, office politics) are considered negative or "hindrance" stressors [33,71]. This distinction is critical; not all stressors are negative, and there are potential benefits of challenge stressors. Unfortunately, some forensic science literature has perpetuated a uniformly negative view of stress. For example, the terms "stress-mitigation" or "stress-minimization strategies" might inadvertently suggest that workplace stress is always detrimental and must always be reduced (e.g., "management can take steps to mitigate this stress; " [28], p.4; "providing multiple types of interventions to mitigate occupational stress; " [161], p.4). Instead, CHSF Part (I) recognizes that there might be occasions when *increasing* stress in forensic science workplaces may actually enhance rather than hinder expert performance. Relatedly, a recent exploratory study found that increasing fingerprint experts' stress levels may improve their performance on some fingerprint matching tasks, especially when the prints were 'difficult' [74]. For this reason, we use the terms "stress management" or "stress optimization" in this paper to more appropriately capture the dual effects of stress.

CHSF Part (II) explains that people often perceive the same stressors in different ways [36]. Situational factors (e.g., job content, supervisory support) as well as individual-level factors (e.g., tolerance to ambiguity, personality) moderate an individual's appraisal of stress [33], similarly to how both external and internal factors can affect forensic decisions, as discussed in Section 2.2. These moderating factors are critical in the forensic science context. For instance, a long-standing and widespread

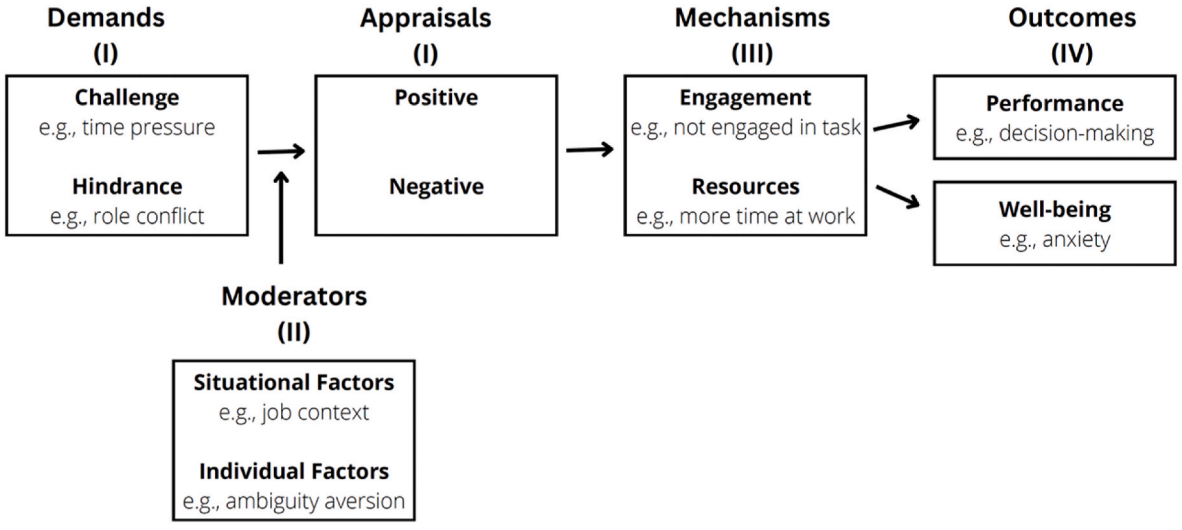

Fig. 2. Simplified diagram of the Challenge-Hindrance Stressor Framework, including four components: Work-related demands-appraisals (I), moderating factors (II), mechanisms (III), and outcomes (IV).

concern in forensic science is stress originating from having too large of a caseload [27,75], yet not all forensic experts—even those within the same laboratory—perceive this as highly stressful [9]. This suggests that there are individual-level differences in how forensic experts evaluate the same stressors, which warrants further investigation. Along these lines, preliminary studies have documented how higher-performing crime scene examiners tend to be relatively stress-resilient [25,76,77]. In one study, for example, high performing crime scene examiners described their own strategies for managing stressors at work (e.g., using "black humour" to cope with unsettling situations, or using outside hobbies to disengage from work-related stress [25]).

Once a person has appraised a stressor, CHSF Part (III) recognizes that several different mechanisms could explain how they respond to that stressor. One possible mechanism follows from the *conservation of resources* theory, which explains that people are motivated to reserve their time and energy for work tasks that matter to them [73,78]. According to this theory, individuals will work for longer hours and invest more energy in facing positive challenge stressors [79], if they feel that this additional work is likely to reap rewards in their environment [80], such as positive feedback from supervisors [81]. However, spending too many resources can have negative consequences. In one study, for example, police officers who faced very high levels of challenge stressors exhibited poorer wellbeing outside of work, such as difficulty 'switching off' during non-work hours and poor sleep quality [82]. Hence, even positive "challenge" stressors can have negative effects when experienced in excess.

Similarly, experts can decide whether (or how deeply) to engage with any given task by considering whether it will be worth the energy that it will require—i.e., whether it will ultimately be rewarding [33]. In forensic science, high profile or serious cases may have additional pressures and require more time and energy [12], but some published research suggests that fingerprint experts are especially motivated to work on high profile cases because they produce stronger feelings of contributing to justice [83]. In contrast, hindrance stressors—such as dealing with unsupportive supervisors [24]—can cause disengagement and deplete resources [71]. Stress management strategies should therefore enable experts to replenish their resources when/if practically possible (e.g., by encouraging time off, flexible schedules, and/or limiting availability to designated working hours [84]), which should benefit experts' wellbeing and performance.

On that note, CHSF Part (IV) identifies two key outcomes of the stress-and-appraisal process, namely *performance* and *well-being* outcomes [33]. In the forensic science context, performance would often include a consideration of the quality of decisions made, levels of engagement in forensic tasks, timely completion of cases, meeting ISO 17025 standards, and other pragmatic outcomes [29,85]. However, effective strategies for optimizing performance may be less clear. For example, to address high casework pressures, some researchers have suggested that forensic science organizations could institute quotas on turn-around times for cases, which may enhance the performance of some experts by creating a "challenge" stressor—but it may lead others to cut corners to meet deadlines (see Ref. [28]). Another related example is the reduction in turnaround times for DNA analysis that were reported after the closure of the Forensic Service Services in the UK, but at the same time there were serious concerns voiced about fewer DNA analysis requests, and the potential for evidence not being collected at crime scenes due to funding constraints [86]. The point here is that simply mandating turnaround times or quotas (i.e., potential challenge stressors) may well have unintended negative consequences.

The second key outcome, well-being, pertains to forensic experts' feelings of fatigue and burnout [30,87], which can affect their subjective happiness, job satisfaction, and sense of purpose [32,88]. Not surprisingly, there is ample evidence that work-related stressors can and do affect forensic experts' well-being [24,89,90]. In turn, an expert's well-being can affect their work performance, and vice versa (e.g. [91]). To illustrate, one study showed that fingerprint experts terminated their search for minutiae more quickly if they were fatigued, suggesting that suboptimal well-being may lead to suboptimal decision-making processes [16].

To summarize, the CHSF framework can help researchers and practitioners to develop and test effective ways to manage stress at work. Prior work has described primary, secondary and tertiary occupational stress management interventions [61,92]. Primary interventions aim to identify and directly address sources of workplace stress, for example by redesigning job tasks or changing work shift hours. Secondary interventions aim to reframe how individuals perceive, react to, and/or cope with stress, such as participating in cognitive behavioral therapies, meditation, or other activities that encourage the development of effective coping mechanisms. Finally, tertiary interventions aim to manage severe and/or chronic impacts of stress, such as posttraumatic stress disorder [93], through measures such as prescription medication or counselling [92,94]. In other disciplines, such as medicine [95], management [94], and policing [96], there is literature to suggest the efficacy of these and similar stress management interventions. However, the effectiveness of these interventions in the forensic sciences remains a promising and important area for future research, as most existing suggestions to manage stress and optimize decision-making are based on subjective outcome measures (e.g., professional opinions, past experiences, etc) rather than objective measures of job performance and/or satisfaction [10,28,97].

3.2. Level of stress and forensic decision-making

In addition to the *type* of stress (i.e., positive/challenge vs. negative/hindrance), one must also consider how the *level* of stress may affect performance. Stress level can be considered to be a function of the number of exposures, frequency, severity, duration, or some combination of these (see, e.g. [98]), and the level of stress that an individual experiences has been shown to affect decision-making [99], and in turn, performance.

The Yerkes-Dodson law is a classic psychological model that posits an inverted U-shaped relationship between stress level and performance [100], such that stress at work could enhance or hinder expert decision-making, depending on its current level [100–102]. According to this law, performance tends to be poor under very low levels of stress, and as the stress level increases, so too does performance, until it reaches some moderate/optimal level of stress, which has been called the "eustress stage" [103]. At the eustress stage, performance is optimized because this moderate level of stress is motivating but not debilitating. For example, individuals under eustress are most likely to meet work-related deadlines [10,104]. In forensic science settings, this theory suggests the value of 'nudging' or otherwise incentivizing Thaler & Sunstein [105], experts who are under-motivated or even bored at work, and consistent with this possibility, Almazrouei et al. [74] provided experimental evidence that moderate stress might cause improvement in forensic experts' decision-making. However, if an individual's stress level increases beyond the eustress stage, performance starts to decline [100,104], which can result in poorer work performance and lower productivity [17]. Having said this, it is worth noting that Yerkes-Dodson Law has its limitations when it comes to understanding workplace stress (e.g., the original research was done on mice, not humans, and the label on the x-axis was arousal, not stress (e.g., see [106]).

Working memory—i.e., the cognitive system that allows people to temporarily maintain and process a limited amount of information (e.g., remembering a person's phone number for enough time needed to dial it)—is thought to be a key mechanism through which stress levels affect cognitive functioning and performance (see Ref. [107], for a review). In one study, for example, police officers who had just completed a 10-day work cycle exhibited significantly lower scores on a working memory test compared to baseline measures, i.e., the first day of the two-week work cycle [108]. Working memory plays a critical role in cognitive

functions that facilitate performance, such as attention [107–109], although the effect of stress on attention is not always straightforward [107]. On the one hand, some research has found that stress narrows attention (i.e., causes *tunnel vision*), leading decision makers to streamline their information processing in ways that focus more on central information and miss or ignore peripheral information that may be important nonetheless [59,101]. However, other research has found the opposite—that stress increases susceptibility to distraction by broadening one's attention span and focusing too much on peripheral/nonessential information [110]. Given these conflicting data, it may be the case that the effect of stress on attention depends on various contextual or individual factors, such as those described in Section 2.2.

However, given that stress level can be operationalised in various ways (e.g., intensity, duration), it is important to note that *acute* stress (i.e., intense short-term stress) and *chronic* stress (i.e., longer-term in its nature) could impact decision-making in different ways. With respect to the latter, a recent study suggested that forensic science professionals experience post-traumatic stress disorder (PTSD) at a much higher rate than the general US population [93]. It stands to reason that the common symptoms of PTSD—such as difficulty concentrating, sleep disturbances, intrusive thoughts, memory impairments, and apathy (e.g. [111])—could interfere with decision-making and performance. These effects have been described in the contexts of policing (e.g. [112]) and nursing (e.g. [113]), amongst others. Moreover, the formal diagnostic criteria for PTSD require direct or vicarious exposure to traumatic event(s), which explicitly includes "repeated or extreme exposure to aversive details of traumatic event(s)" [114]. Accordingly, PTSD and its effects on performance may be a particular concern among field-based (rather than laboratory-based) forensic service providers, who tend to report higher levels of exposure to traumatic scenes, evidence, and other case material [93,115]. Research in other domains has suggested effective ways to ameliorate (e.g., various psychotherapies [116]) or even pre-empt (e.g., trauma resilience training [117]) the negative effects of work-related trauma, and others have proposed protective measures for forensic experts specifically (e.g., [10,29,30,81]), but the efficacy of these interventions remains to be tested.

3.3. Context of stress and forensic decision-making

3.3.1. Uncertainty: ambiguity and risk

Finally, the impact of stress may depend on the *context* in which it is experienced. Decision contexts vary in their levels of (un)certainty [67,118]: Sometimes the consequence of a decision is clear (e.g., paying $5 for a sandwich will result in having a sandwich), but other times the consequence is difficult or impossible to predict (e.g., gambling $5 in a casino could result in a win or loss). Many forensic decisions are made under conditions of uncertainty [119] insofar as 'ground truth' (e.g., what actually happened at a scene, whether two fingermarks/cartridges actually belong to the same person/gun) is typically unknown. External sources of stress and uncertainty may therefore interact to affect decision-making. For instance, when working on a high-profile case, time pressure (an external stressor) might force a crime scene investigator to decide to collect some traces but not others, which will limit the scope of the analysis [19].

Individual differences in tolerance for uncertainty may also affect examiners' decisions [163]. Particularly relevant here is a form of uncertainty that behavioral economists call *ambiguity* [120]. In real-life situations where the outcome of an action is uncertain, the probabilities of the different possible outcomes are not typically known (as is the case with tossing a coin or rolling a die) but rather there is some ambiguity around their relative probability. A number studies have documented a trait called *ambiguity aversion* (e.g. [62,63,67]), which also varies across individuals [121]. It therefore stands to reason that some forensic examiners are naturally less comfortable with ambiguity than others.

Differences in ambiguity aversion may lead experts to make different decisions even with similar information and circumstances. That is to say, individual experts may gravitate toward decisions that are more conservative or more risky, especially in situations where they can anticipate the consequence of their decision [67]. For example, deciding that a bullet found at a crime scene 'matches' a reference bullet (i.e., an identification) typically has a foreseeable consequence—i.e., correctly implicating the perpetrator or wrongly implicating another person—though importantly, the 'ground truth' is rarely ever known in such situations, which makes this a relatively risky decision. In contrast, 'inconclusive' decisions may be considered less risky because the outcome of those decisions is less clear [122]. For that reason, differences in examiners' dispositional aversions to ambiguity and risk—which could be amplified under stressful conditions—may predict how often they reach inconclusive decisions. This is a critical point because, again, even very small fluctuations in an examiner's decision threshold can dramatically affect their performance (i.e., decision accuracy [60]).

Human decision-making also involves risk-taking under conditions of stress [123,124]. In the policing domain, for example, a police officer might decide to shoot a person who could be innocent, or might decide *not* to shoot a person who could then harm others [59]. Risk-taking involves a complex equation of assessing different alternative choices and their consequences before making a decision, which has been called the "payoff matrix" ([125]; see also the three cognitive factors in Section 2.2). A similar risk-taking calculus may underlie forensic science decision-making; for example, Dror and Langenburg [42] suggested that fingerprint experts may opt for the less risky "inconclusive" decision because they are not typically subjected to peer review or challenged in courts, whereas identification decisions raise the possibility of disagreement and/or criticism. Examiners' tendency for conclusive rather than inconclusive decisions—and the role of stress therein—is an especially important consideration in light of ongoing debates over the use of inconclusive judgments in error rate calculations (e.g., [122,126]), including the legal ramifications of such judgments and the question of whether should ever be considered "correct" or "incorrect" (e.g., [42,127,128,129].

Even within the same examiner, the same situation may produce different decisions insofar as research suggests that humans utilize two distinct decision-making systems [130]: *System 1*, which is faster and more automatic/intuitive, and *System 2*, which is slower and more effortful/logical ([47,131]; see also [162], who argues that these systems are two ends of a continuum rather than two distinct processes). This dual-system model is helpful in understanding how stress affects human decision-making, including risk-taking [131,132]: For instance, decision-makers are more inclined to use System 1 when resources (e.g., time) are limited because it offers a fast and efficient decision based on familiarity and experience [47], but these decisions may be more idiosyncratic and therefore less consistent or accurate. Instead, decisions should ideally involve both systems because each system grants distinct benefits; in other words, decisions that incorporate both prior experience (System 1) and logical deliberation (System 2) are likely to be the highest-quality decisions [59].

3.3.2. The environmental context

Decision-making does not happen in vacuum, and stress can be dependent on the interaction between an individual and their environment [25,35,36]. Indeed, the role of context has recently been identified as a limitation to the Challenge-Hindrance Stressor Framework [33,71] insofar as the framework does not recognise that the same stressor may be a positive challenge stressor in some contexts, but a hindrance in others [72]. Identifying context-specific sources of stress can therefore result in policies that target specific stressors. For example, digital forensics experts appear to experience stress by virtue of their frequent exposure to distressing imagery in case materials (e.g., depictions of extreme violence, suicide, and child exploitation; [89,133,134]). Accordingly, laboratories might amend their standard operating procedures to limit the frequency and/or duration of examiners' exposure

to especially unsettling materials [97].

In addition to creating psychological distress, exposure to gruesome imagery has the potential to bias and undermine forensic experts' decision-making, as numerous studies have demonstrated (e.g., [135,136]). For that reason, some have cautioned against showing potentially disturbing crime scene images to forensic experts unless those images are directly relevant to their decision-making [135,137]. In some cases, the content of horrible images may be simultaneously distressing, potentially biasing, and potentially relevant to the examiner, which raises the question of whether the benefits of viewing the images outweigh the risks. To balance these concerns, examiners could follow a Linear Sequential Unmasking (LSU) approach (see, [138,139]), wherein they review the information that is most directly relevant to their decision *before* considering other information that may be somewhat relevant, but also potentially biasing (e.g., distressing crime scene photographs). All the while, examiners using LSU should document their decisions, confidence in those decisions, and any changes to their decision for the sake of transparency (see also the *forensic disclosure model*; [140,141]).

It is also relevant to consider the social context in which decisions are made. During casework, forensic experts communicate with and receive feedback from various parties (e.g., judges, lawyers, ISO auditors, regulators, family, victims, etc.; [85,141]). Within the investigative domain, for example, forensic experts may communicate with law enforcement or attorneys to provide timely information on forensic science results [4,142]. Interactions with different parties may generate different types of stressors (e.g., adversarial allegiance with lawyers [143]) that may require context specific solutions. Approaches, such as Systems Thinking [27,144,145] or Social Network Analysis Campana [146] may be helpful in better understanding such interactions. This is because these approaches suggest assessing the individuals (e.g., the forensic expert) in connection within the broader working context in which they operate, rather than in isolation.

It is also helpful to consider how such interactions, and thus stressors, have differential impacts on forensic scientists who are mainly working in the lab (such as, DNA examiners, fingerprint experts), as opposed to those who operate mainly in the field (such as, crime scene examiners) (e.g., see [115]). Field-based practitioners might feel stressed from work shifts and the lack of ability to organize work-life schedules [25]. In contrast, lab-based practitioners typically do not operate in work shifts, but they might have other stressors, like being expected to respond to communicate or engage with work-tasks after the 9am-5pm working hours (e.g., *email urgency bias* [84]). In the next sub-section, we will dig deeper into one important type of environmental interaction: the expert's interaction with technology at work.

3.3.2.1. Human-technology interaction. Forensic experts' work often requires them to interact with both common technologies (e.g., phones, emails, internet) and specialized technologies (e.g., DNA and forensic chemistry instruments, and Laboratory Information Management System (LIMS)). While these technologies can surely improve the efficiency of communication, documentation, and analysis (e.g. [147]), they may also prompt stress in other respects (see, e.g. [97]). In this section, we consider the potential for so-called "technostress" in forensic workplaces, which refers to the negative consequences of human-technology interactions on behavior and health [148].

"Technostress" occurs when overreliance on technology heightens cognitive demands on individuals [149,150], and it can happen in any professional workplace, including forensic science. Notably, researchers have proposed interventions to address technostress in other domains (e.g., see [149]), which may be suitable for adaptation to forensic science contexts. To be exact, researchers have identified at least four risk factors for technostress in the workplace that can be addressed, including *information overflow*, *continuous partial attention*, *availability*, and *useability* [150].

Information overflow refers to the possibility of forensic experts becoming overwhelmed by the sheer amount of information that they must receive and manage on a daily basis—for example, when frequent voicemail and e-mail messages produce a constant stream of work-task interruptions [151]. In forensic science, both the *amount* and *type* of information from technologies may contribute to overload, since (as noted above) forensic experts often experience secondary traumatic stress by virtue of their routine exposure to distressing messages and/or images [115]. To date, the potential impact of such information has been considered more extensively in digital forensics [89,133,152] than in other forensic science disciplines.

Continuous partial attention refers to employees' ill-fated attempts to manage multiple tasks simultaneously in an effort to improve performance—for example, by continuously checking and responding to emails while completing other tasks. However, multi-tasking in this manner tends to hinder focused attention to any given task (i.e., 'partial attention' [153]), such that overall performance suffers. In forensic science, this could manifest as an examiner unconsciously missing key details of a case report if they are trying to simultaneously attend to a second task (e.g., checking e-mails). However, this possibility has not yet been empirically tested in forensic science specifically.

Availability refers to the fact that technology (e.g., smartphones with e-mail access, virtual meeting platforms) has made it much easier for employees to remain in contact with their employers, such that employees are often expected to be virtually available even when they are not physically present and/or outside of traditional working hours [84,150], which has blurred the once-clear boundary between work and non-work times (e.g., [18,84,87]). To cope with this pressure, research has suggested that employees may opt to work longer hours (i.e., be more available) or work faster, but neither strategy was found to be effective, as the former decreased engagement while the latter increased irritation [79].

Finally, *useability* refers to the constant need to ensure that one's technological knowledge is up-to-date by regularly learning new programs or instruments, which creates cognitive load. Relatedly, switching from one technology to another can cause frustration and irritation, especially if the process is slow or lacks integration. There is already some evidence of this among digital forensic examiners [97], who recommended "for agencies to explore whether digital forensic staff [and perhaps, experts in other forensic specialties] have the technology that they need to work effectively, and whether they have the capacity built into their workloads for regular upskilling, as digital crime becomes more sophisticated" ([97], p. 6).

4. The path forward

There is growing interest in the role of workplace stress in forensic science—and for good reason, given the aforementioned links between stress and performance. In this paper, we aimed to unpack the ways in which stress might affect forensic experts' decisions, draw upon literature from other domains to suggest ways to manage stress in forensic contexts, and draw attention to productive avenues for future research. However, it is also important to recognise that every workplace is different, and what is effective for one agency may not be ideal for another, depending on their cultures, contexts, and available resources. Below, we consider what forensic science stakeholders can do *now* to address the detrimental effects of stress, and we look ahead to other interventions that may be possible in the *future*.

4.1. What can be done now?

An important first step is for forensic science agencies to acknowledge that occupational stress can negatively affect experts' decisions and create undesired organizational costs if left unaddressed. To that end, it may be useful to reconceptualize stress not as an inevitable part of the job (e.g. [154]), but rather as a human resources matter that warrants

continuous monitoring. Even before the COVID-19 pandemic prompted greater emphasis on flexibility and employee wellbeing, some private corporations (such as Google) had already begun taking research-based steps to pre-empt the negative impacts of stress in the workplace [155], and those agencies now provide a model for others to follow. Along these same lines, Roux and Weyermann [156] argued that forensic science practitioners and researchers should learn valuable lessons from the COVID-19 pandemic in terms of preparing for challenges and designing effective workplace environments that protect experts' well-being [156].

To that end, some helpful resources for forensic practitioners and supervisors/managers already exist. For instance, the Forensic Technology Center of Excellence [157] has compiled resources to raise awareness about occupational stress in forensic science and how to manage it (e.g., through webinars, podcasts and reports). In addition, the Office for Victims of Crime [158] has issued a Vicarious Trauma Toolkit that includes resources for dealing with traumatic experiences from work-related tasks. In addition, interventions that have proven useful in managing workplace stressors in domains similar to forensic science (e.g., medicine and policing; [92,94,96,112]) may be adapted for use in forensic science. Anecdotally, forensic laboratories that have implemented employee wellness programs—including elements such as healthy nutrition, yoga/fitness classes, social events, and/or flexible schedules—have lauded the benefits of doing so, and we hope that they will publicize their successes in this regard for others to emulate. The authors of this paper are also happy to provide access to any non-open-access journal articles on stress management interventions.

4.2. What can be done in the future?

Once there is widespread acceptance of the issue and motivation to address it, then policies to manage stress and thereby optimize decision-making will naturally follow. Fig. 3 may prove useful to practitioners in considering interventions or policies to implement. Sweeping organizational-level interventions (i.e., "primary" interventions) are likely to be helpful but they may be met with resistance, so it is important to emphasise that even incremental changes can be beneficial. If it proves difficult to minimize work-related stressors (at least at first), then resources might be allocated to "secondary" interventions (e.g., stress management training, mindfulness techniques, peer support, etc) that do not require changes to existing procedures and are meant to help forensic practitioners better cope with stress. For environments that entail more intense and/or persistent stressors, "tertiary" interventions may involve contracts with counselling services to provide ongoing support to address vicarious trauma.

Regardless of the intervention, it is important to consider how stress can affect the *decisions* that forensic experts make—which is the goal of this paper. Although we have focused largely on the negative effects of stress, we reiterate that some degree of stress can be motivating [100,104] and therefore enhance performance for some experts and/or under certain conditions [74]. Hence, forensic science providers should take steps to ensure that experts' work is appropriately challenging and valued, and perhaps incentivize or 'nudge' experts when/if appropriate, so as to promote optimal stress levels [105].

Relationships with managers/supervisors should be supportive so as to moderate the stress felt by forensic experts [24,81]. Indeed, having a supportive supervisor has been identified as a key organizational stress-optimization strategy in the forensic science workplace: Kelty et al. [97] reported that supervisors could buffer stress by being proactive in necessary actions, such as becoming an integral part of the team, being flexible, not micromanaging, being knowledgeable on specific tasks and building mutual trust. It has also been suggested that managers should develop skills and abilities to be *emotionally intelligent* so that they can manage emotions and stress at an individual level with forensic experts (see [81]). In such supportive environments, managers could adapt a human-centred approach rather than a task-centred one.

Enhancing emotional intelligence may enable managers to actively listen and build confidence with forensic experts so as to manage their stress and well-being [81], which may result in enhanced performance on forensic science tasks. Specifically, training forensic managers/supervisors on emotional intelligence (which includes effective communication) may enable them to be in a better position to identify those who are underloaded, or vice versa, those who are highly stressed; thus, such subjective assessments can indicate the experts may not be operating at a "healthy stress" state. Relatedly, organizational policies for making sure that identification of high stress is not weaponized against the employee (e.g., making them a target for not having career progression opportunities) may be necessary so that practitioners can be forthcoming about the stress they feel with their managers/colleagues.

In term of future research, we encourage researchers to further

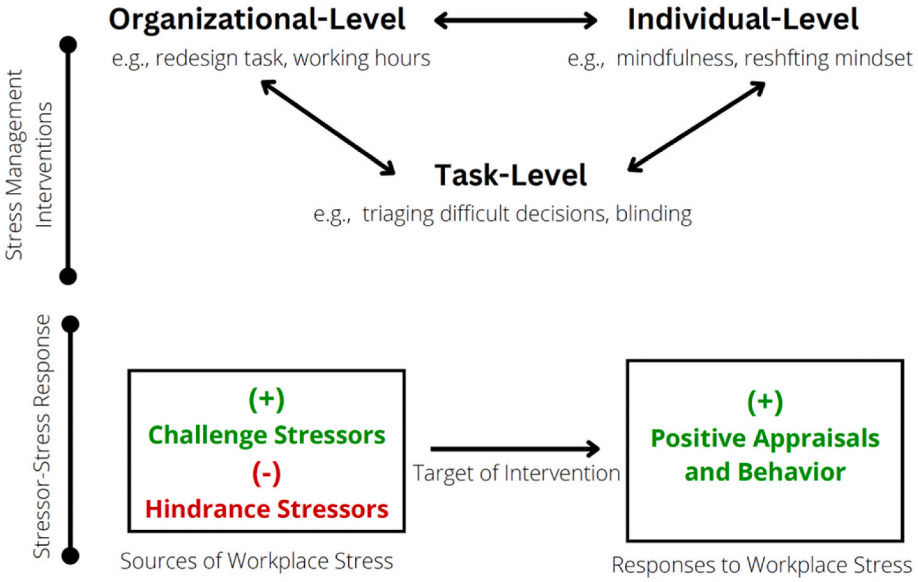

Fig. 3. Overview of potential interventions to manage stress in forensic workplaces. Organizational-level ("primary") interventions target *sources* of stress, including both challenge and hindrance stressors. Individual-level ("secondary") interventions target *reactions* to stress, with the aim of encouraging positive appraisals and developing adaptive behaviours (e.g., coping strategies).

unpack workplace stress in the context of forensic expert decision-making. For example, distinguishing between seemingly direct stress effects (e.g., an investigator is putting pressure on the examiner to get analyses done more quickly than they are comfortable with; e.g., see Part 2 in [9]) and indirect stress (i.e., the expert is not sleeping well because of rumination about job/workload, which may compound their stress because they cannot work as effectively when they are tired; e.g., see research by Cropley and Collis [159] on work-related rumination). Similarly, differentiating inherent workplace stress as opposed to manageable/avoidable stress is useful. There is a certain inherent level of stress associated with an important job that requires expertise (e.g., seeing dead bodies in crime scenes), and stress that is avoidable and damaging/beyond what is helpful to keep people motivated (e.g., having an environment with no tolerance to making innocent mistakes as opposed to a non-putative environment where the system normalizes making mistakes in order to learn from them).

4.3. Conclusion

In some respects, the reality of crime labs may be different from what research is capturing [160], including the role of workplace stress and its influence on decision-making. We understand that resources, working cultures and stress factors vary across forensic science organizations, disciplines, and even individuals within the same organisation, and it is therefore difficult to recommend a one-size-fits-all solution. However, this heterogeneity should not discourage efforts to manage stress, which can be detrimental to the organisation (e.g., in terms of employee retention), the individual (e.g., experts' wellbeing), and the administration of justice more broadly (i.e., the quality of forensic decisions). Even seemingly small investments in managing stress are likely to reap benefits in these respects. We therefore call on researchers to further identify and evaluate specific stressors in forensic science contexts, with an eye toward developing practical and flexible interventions to address them.

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Declaration of competing interest

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