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Reducing the impact of cognitive bias in decision making: Practical actions for forensic science practitioners

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ABSTRACT

Previously published methods for reducing the impact of cognitive bias in forensic decision making have focused primarily on actions at the laboratory or organizational levels. This paper presents generalized and specific actions that forensic science practitioners can take to reduce the impact of cognitive bias in their work. Practical examples illustrating ways that practitioners can implement many of the specific actions are also provided, along with some suggestions for handling court testimony about cognitive bias. The actions presented in this paper provide a means through which individual practitioners can take ownership for minimizing cognitive bias in their work. Such actions can provide supporting evidence to stakeholders that forensic practitioners acknowledge the existence of cognitive bias and its potential influence on their work, and they can also stimulate implementation of methods that focus on solutions at the laboratory and organizational levels.

1. Introduction

Forensic cognitive bias is "the class of effects through which an individual's preexisting beliefs, expectations, motives, and situational context influence the collection, perception, and interpretation of evidence during the course of a criminal case" [1]. Despite containing the word "bias," it is important to emphasize that cognitive bias is not intentionally discriminatory, as in the everyday usage of the term "bias" associated with racism, antisemitism, sexism, etc. Likewise, it is important to note that the term "cognitive bias" does not itself mean or imply errors due to carelessness, misconduct, or incompetence. Cognitive bias refers to influences that typically operate on an individual's thought processes outside of their conscious awareness, making them both challenging to recognize and difficult to control. Thus, even highly skilled, ethical individuals are not immune from cognitive bias.

Since the 2009 NAS report [2], many studies across forensic domains (including DNA, fingerprinting, forensic pathology, and toxicology) have demonstrated that situations exist in which cognitive bias can impact the decision making of forensic science practitioners,[1] especially in cases involving complex, difficult, or high stress situations (for a review, see Kukucka & Dror [4]).

Several ways to minimize cognitive bias in forensic decision-making have been suggested, including various techniques for information management. Case managers, who screen case related information to determine its analytical relevance prior to its dissemination, can be utilized to control the flow of unnecessary and potentially biasing information to forensic science practitioners [5]. Linear Sequential Unmasking (LSU) [**6**], which focuses on minimization of cognitive bias in the forensic disciplines related to pattern recognition, emphasizes controlling the sequence of flow of task relevant information to practitioners. Thus, LSU provides a mechanism through which practitioners receive the information they need to perform their analyses, but at a time that minimizes its biasing influence, and in a manner that emphasizes transparency regarding what information was received and when. Linear Sequential Unmasking-Expanded (LSU-E) [7] broadens LSU to make it more generally applicable to all forensic disciplines while also reducing "noise" from additional human factors. When considering what information to provide and when, the strength of LSU-E comes from its use of three evaluation parameters: biasing power (i.e., the information's perceived strength of influence on the outcome of an analysis), objectivity (i.e., the information's perceived extent of variability of meaning to different individuals), and relevance (i.e., the information's

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[1] For the purposes of this work, forensic science practitioner is defined as "an individual who (1) applies scientific or technical practices to the recognition, collection, analysis, or interpretation of evidence for criminal and civil law or regulatory issues; and (2) issues test results, provides reports, or provides interpretations, conclusions, or opinions through testimony with respect to such evidence" [3].

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perceived relevance to the analysis) [7]. LSU-E associated worksheets have been developed [8] to facilitate the practical use of LSU-E within the forensic laboratory setting.

Additional ways to minimize cognitive bias in forensic decision-making that have been suggested include implementing blind verifications, and administering evidence "line ups" during comparative analyses [5]. Blind verifications allow those performing them the independence of mind necessary to form their own opinions and draw their own conclusions without being influenced by the original work. Studies (for reviews, see Cooper & Meterko [9] and Kukucka & Dror [4]) have shown that providing "line-ups" consisting of several known-innocent samples along with the suspect sample, helps to reduce bias originating from inherent assumptions that can occur when only a single sample is provided during comparisons.

However, most of these bias countering approaches require formal adoption by laboratory or organizational level management and implementation within laboratory protocols. Establishing and implementing such protocols can be a slow process, as considerable resources may be required [10], and because common fallacies about the impact of cognitive bias on forensic science [5] may need to be overcome. In this paper we address a specific question: what practical actions can individual practitioners take to minimize bias in their work, even in the absence of supportive laboratory protocols? We focus on translating methods of minimizing cognitive bias into actionable steps that forensic science practitioners can take while conducting all aspects of their casework.

2. General suggestions for practitioners

In general, forensic science practitioners can help minimize the impact of cognitive bias in their own work by:

A. Acknowledging that cognitive bias is fundamental to human cognition and rejecting the fallacies about cognitive bias. It is especially important to recognize that cognitive bias impacts decision making on a subconscious level, that it cannot be controlled through conscious effort or "willpower" alone, and that experts are not immune from it [5].
B. Utilizing validated, standardized methods and procedures, and implementing all applicable quality assurance and quality control measures.
C. Considering and evaluating the possibility of alternative or opposite interpretations at each stage of their analyses.
D. Providing transparency by clearly and concisely documenting and disclosing all aspects of their work, including the bases for their analytical decisions, factors that they are aware were influential in their decision-making processes, the limitations of their analytical methods and opinions, and a detailed, chronological account of all their communications involving information about the case.
E. Advocating for organizational level involvement in combating cognitive bias by bringing related concerns to laboratory management's attention, and by assisting laboratory management with risk assessments aimed at recognizing potentially biasing situations and identifying means to manage them [11].
F. Taking specific actions that will help minimize the impact of cognitive bias on an individual practitioner level, regardless of the status of engagement of the laboratory system or organization (details below and summarized in Table 1).

3. Specific suggestions for practitioners

According to Dror [5], there are eight sources of cognitive bias in expert decision making, and these all apply to the decisions made by forensic science practitioners. Dror groups these eight sources of cognitive bias into three categories. Sources in category A arise from factors related to the specific case that can influence how practitioners perceive, analyze, and interpret the evidence and data. Sources in category B arise from factors related to the specific practitioners doing the work, including their training and experience, their personalities, and their working environment. Sources in category C arise from human nature and the cognitive function of the human brain. These eight sources of cognitive bias often do not function as singular or independent variables, but rather as a combination of two or more sources that together form a complex interdependence among the categories. Hence, most practical solutions will inevitably address multiple sources of cognitive bias.

The subsections below provide the following: first, a brief overview of each of the eight sources of bias identified by Dror [5], second, forensic examples from casework, and third, suggested practical actions that forensic science practitioners can take to reduce the impact of these sources of bias on their daily casework.

Table 1
Summary of implementable actions for forensic science practitioners.

Source of Bias[a]	Practitioner-Implementable Actions
Data	• Educate submitters about the benefit of masking or isolation of only the features of interest. • Request that submitters avoid including potentially influencing context.
Reference Materials	• Evaluate and analyze the evidence (the unknown) before the reference material (the known). • Clearly document the order of operations performed. • If not already in SOP, specify and document criteria for evaluation and comparison outcomes prior to analysis. • Request multiple reference materials (knowns) be provided as a "line-up" for comparisons.
Task Irrelevant Contextual Information	• Avoid reading submission documentation, communication logs, and investigative details to the extent possible. • If exposed to task irrelevant information, document what was learned and when. • Communicate with submitter regarding need to avoid cognitive contamination.
Task Relevant Contextual Information	• Document what was learned, when it was learned, and what impact it may have had on the analysis. • Work toward distinction of task relevant vs. task irrelevant information for each individual forensic discipline.
Base Rate	• Consider and evaluate the possibility of alternative or opposite outcomes at various stages of analysis. • Reorder notes to support pseudo-blinding.
Organizational Factors	• Examine laboratory protocols (and common practices that may be unwritten but are accepted as "just the way it is") for sources of undue influence and stress that could impact cognitive processes and independence of mind; implement new or revised policies as needed.
Education and Training	• Review education and training for inconsistencies with best practices for minimization of the impact of cognitive bias. • Request ongoing training about cognitive bias.
Personal Factors	• Implement contemporaneous documentation of justification for analytical decisions within work notes.
Human & Cognitive Factors, and the Brain	• Recognize symptoms of stress, mental fatigue, and vicarious trauma. • Practice self-care through maintenance of mental and physical well-being.

[a] The sources of bias listed in this column are from Dror [5].

3.1. Category A, source 1: data

3.1.1 The "data" is essentially what forensic science practitioners would recognize as the actual evidence, itself. The item of evidence in and of itself can be a source of cognitive influence when information gleaned from the act of examining it reveals potentially biasing context.

3.1.2 As a specific example, consider a pair of underwear that is being examined as evidence associated with a sexual assault. The size and style of the underwear, observed while it is being screened for serology or trace evidence, can reveal personal information about the wearer (e.g., whether they are a child or an adult, their sense of style or degree of modesty, etc., as well as any injuries sustained), that can impact the practitioner. As another example, consider the written content of threatening or hate-filled letters when examining them for the presence of latent prints or as part of a handwriting comparison. Such written content can provide information that may unduly influence the practitioner.

3.1.3 In most instances, forensic science practitioners must see the evidence in order to examine and analyze it. However, the more they learn about cognitive influence and other human factors on their work, the better they will be at recognizing situations where they must be extra vigilant in ensuring that their exposure to biasing information is minimized or mitigated, so their forensic decisions are based solely on the data itself; nothing more, nothing less.

To help minimize the impact of cognitive influence due to information obtained from the evidence items themselves, forensic science practitioners can take action to educate evidence submitters about the importance of masking and isolating only the features of interest on items of evidence whenever possible. For example, consider the submission of digital images retrieved from a cell phone that depict the profile view of a suspect spraying graffiti on a public monument. If the analytical request is to compare the graffiti symbols to those from previous similar incidents, there is no need for the practitioner to view the portion of the image containing the suspect, which may reveal the individual's race and other personal characteristics. For the examination of symbols, such information is not necessary and is potentially biasing. In this instance, masking (or cropping out) the image so it only contains the portions of the questioned symbol will minimize undue exposure to biasing information that would otherwise be observed about the suspect. Forensic science practitioners can also request that evidence submitters avoid adding potentially biasing context by checking to ensure pocket contents have been removed from clothing items prior to submission, submitting only relevant portion(s) of an item, and taking care with package labeling.

3.2. Category A, source 2: reference materials

3.2.1 The "reference materials" may be more readily recognized by forensic science practitioners as "comparison samples" (or "known" samples). Knowledge of the comparison sample can influence how practitioners perceive and interpret the unknown samples; hence working backwards, looking for the known in the unknown. According to Dror [5,12], "… the human practitioner is driven by a "target" they expect (or want) rather than by the actual data."

3.2.2 As a general example, consider the popular "Where's Waldo?" puzzles, in which the Waldo character (a bespectacled cartoon man clad in red and white striped shirt and hat) is drawn somewhere within a complex and colorful scene involving many individual images as purposeful visual distraction. When engaged in such a puzzle and asked to find Waldo, it is only natural to skim the image while targeting one or more of Waldo's more individualizing characteristics, and almost completely disregarding other individual images that might be present. When practitioners are exposed to comparison samples prior to the examination and documentation of questioned samples, they can become driven by the "target" rather than by the actual evidence.

A forensic example would be a latent fingerprint examination in which the suspect's ten-print card is the "target" that drives the perception of minutia in the latent fingerprint, or similarly, when interpreting a mixed DNA profile, determinations of allele drop out are driven by the existence (or lack thereof) of alleles in the suspect's DNA profile.

3.2.3 To help minimize the negative impact of cognitive influence due to reference materials, forensic science practitioners should avoid potential targeting effects by evaluating, analyzing, and documenting the questioned samples first before observing comparison samples (see LSU-E [7]). Furthermore, in their documentation they need to clearly indicate at what point in the analytical scheme the comparison samples were first observed. Additionally, if not already contained within their standard operating procedures, practitioners should specify and clearly document the criteria they will use for evaluation and comparison outcomes prior to performing their analyses; doing so demonstrates that the basis for analysis did not change upon viewing the comparison sample. Especially in the event of high stakes casework and/or casework involving complex or difficult comparison decisions, practitioners can request multiple comparison samples be provided as a "line-up" in order to further reduce the potential for targeting effects [5].

3.3. Category A, source 3: contextual information

3.3.1 Forensic science practitioners will recognize contextual information as all the "investigative and background information" about a case. Depending on the type of analysis being performed, such contextual information can be either relevant or irrelevant to the process of determining and interpreting facts from the evidence. Task irrelevant information refers to contextual information that is not necessary to perform the type of analysis in question.

3.3.2 Some examples of task irrelevant contextual information include race or religion of the suspects involved in the case, their criminal history, information that they confessed, whether the police believe the suspect is guilty, eyewitness identifications, and the findings and opinions of other forensic analyses and lines of investigation. Many research studies across various fields of expertise [13,14]—not just forensic science—have shown that task irrelevant information is problematic because it can lead to cognitive bias that, if unmitigated, can affect the analytical decisions upon which conclusions are based.

Exposure to task irrelevant information is particularly troublesome because once seen, heard, or read, this potentially biasing information cannot be unseen, unheard, or unread (see the bias fallacy of "the illusion of control" [5]). Furthermore, because it impacts cognitive processes on a subconscious level, its influence cannot be countered using conscious effort alone [5].

3.3.3 The most effective way to minimize the negative impact of task irrelevant information on forensic analyses is to never be exposed to it in the first place. To minimize their exposure to such information, forensic science practitioners should avoid reading investigative details and commentary in submission documents, communications logs, and investigative reports whenever possible. Additionally, they should actively avoid discussions of task irrelevant case details with evidence submitters, investigators, and other lab personnel. When engaged in conversation with these individuals regarding a case, practitioners should communicate the need to avoid cognitive contamination by starting conversations with a preface such as the following: "Before we begin our discussion of this case, please know that in order for me to do my best work, I am asking you not to tell me information such as the name, gender, race, ethnicity, or past criminal record of the suspects. Please also do not tell me about any confessions, eyewitness or video accounts, or other opinions about the evidence I will be examining."

Task relevant information refers to contextual information that is necessary to establish or interpret the facts of the evidence for a given type of analysis. As an example, information that an article of clothing was found in the desert several months after a crime was committed is task relevant in a fibers comparison, as this information could explain

faded coloring of the fibers. While task relevant information is important in forensic work, it must be provided at the appropriate stage during analysis in order to minimize the potential for it to impart undue cognitive influence [6].

Information management tools such as case mangers [15] and LSU-based techniques [6–8] can be implemented to guard against exposure to task irrelevant information and to facilitate the dissemination of task relevant information to the practitioner at the appropriate time and sequence during analysis. However, because these tools generally require management-level intervention and operational changes, full implementation of these tools by individual practitioners is not simple. Nevertheless, many elements of LSU-based techniques can be implemented by forensic science practitioners even if they have not yet been formally adopted across the laboratory's procedures.

Forensic science practitioners should be transparent regarding what contextual information they receive and when [16]. In their work notes and other laboratory records, practitioners should fully document what contextual information was learned, when it was learned (i.e., at what stage in the analysis scheme), whether it is considered task relevant or task irrelevant and why, and what impact it may have had on the analysis. As an example, in a case involving the analysis of a beverage to determine if it contains an adulterant, the submission documentation states that the beverage sample was recovered from a "coffee cup belonging to victim Jane Doe, Caucasian female, age 37." Because the practitioner's laboratory does not redact such information from the submission documentation, the practitioner sees it when confirming the case number, item number, and barcode information for the evidence received for analysis. Therefore, the practitioner should clearly document it as follows:

> "The evidence submission form was viewed during initial receipt of custody and inventory. It contains the following task irrelevant information: "victim Jane Doe, Caucasian female, age 37." The evidence submission form also states that the evidence was recovered from a "coffee cup," so the original beverage in question may have been coffee (with possible inclusion of the usual coffee additives: creamers, sweeteners, artificial flavorings, etc.). This information is considered task relevant because knowing about the potential nature of the original beverage can assist in determining what types of components are reasonably expected to be present, and what types might be considered adulterants. The standard analytical scheme for questioned adulterated beverages will be applied. The information about the potential nature of the original beverage will be considered after identification of the components of the sample, but prior to determination of individual components as potential adulterants."

While the example above involves unsolicited exposure to task irrelevant contextual information prior to the start of analysis, forensic science practitioners will sometimes encounter occasions in which they need to seek out task relevant information to complete or refine their work. When information management tools are not in place, practitioners again should fully document the details of the information retrieval in their work notes. In this instance, practitioners should record their analytical findings and opinions developed prior to requesting the task relevant information, as well as their reason(s) for requesting it. For example, as part of the analysis of a liquid submitted as a general chemical unknown with contextual information that it had originated from a bottle labeled as drinking water, the practitioner determined that the liquid contained bleach and documented her findings and opinions in her notes. Then, to ensure that all probative questions of interest to the submitter were answered, the practitioner requested additional information about the investigation. In response to her request, the practitioner was told that the liquid was originally drinking water, was reported to have smelled like "chemicals," and was thought to have been adulterated. The practitioner documented her request for information, why it was requested, and the resulting new information in her notes. Equally importantly, the practitioner's documentation also included a statement that the requested information did not change her original findings and opinions, but that her choice of final report wording would change to reflect her laboratory's approved report wording for adulterated beverages as a specific subset of general unknown analysis. This type of documentation provides transparency through full disclosure of what information was sought and why, what information was actually received, and what impact it had on the practitioner's work.

Such awareness and consideration of the impact of potentially biasing information can empower forensic science practitioners to approach laboratory management if they believe that their analysis may have been compromised by an inadvertent exposure. The resulting discussion with management could lead to the biasing information being redacted from the case documentation, and then the case being reassigned to another practitioner who has not been compromised.

An important step in controlling the flow of contextual information to minimize the potential for cognitive bias is providing training to all individuals who communicate with forensic science practitioners during the full course of a case. Forensic science practitioners should recommend and actively participate in training investigators and evidence submitters about potentially biasing information, the importance of withholding it unless it is specifically requested, and the associated risk of perpetuating and compounding bias as such information spreads among individuals with various roles in the case investigation [5,17].

3.4. Category B, source 4: base rate

3.4.1 Base rate refers to the naturally occurring frequency of a phenomenon in a population [18]. In forensics, base rates can originate from discipline-wide generalizations or from a practitioner's own casework experience. Expectations derived from known or perceived base rates can give rise to biasing effects that may influence the work of forensic science practitioners [5,19], including their decisions regarding sampling, data collection, method selection, testing strategy, comparison criteria, judgement, and interpretation. Thus, while experience can improve certain aspects of forensic work, studies have demonstrated that it can sometimes create bias and lead to the wrong decision [20–23].

3.4.2 As an example of how base rate expectations can influence forensic science practitioners, consider a fire debris analyst whose casework experience demonstrates a strong, positive correlation between samples submitted as "hits" from a particular scent detection canine and the analyst's own determination that the sample contains gasoline. While interpreting a complex and challenging data set arising from a sample submitted as a "hit" from this canine, the analyst struggles to decide regarding the presence or absence of gasoline. Ultimately, the analyst concludes that the sample contains gasoline. However, during technical review, feedback from multiple reviewers unfamiliar with the canine's prior "hit"-to-gasoline frequency results in multiple independent conclusions that the sample does not contain gasoline. Further discussion reveals that the analyst "gave the canine the benefit of the doubt," thus uncovering a decision influenced by base rate expectations.

Another example of how base rate expectations can influence forensic science practitioners involves the circumstances under which they perform verifications for their colleagues. For instance, forensic labs that only verify identifications, and have a very high rate of confirmations during verification, can create *a priori* expectations that every verification will be an identification, and that every identification should be verified as correct. Additionally, the perception that a particular analyst (e.g., the individual with the most seniority, or the unit's technical lead or trainer) never errs can lead to an *a priori* expectation that all of her identifications should be verified as correct.

3.4.3. One way to minimize the impact of base rate expectations on verifications is to implement blinding [24], whereby the verifying practitioner does not know the identity of, nor opinions rendered by, the analyzing practitioner prior to drawing his or her own opinions independently. Forensic science practitioners at laboratories that have not

yet implemented blinding can purposely reorder their work notes to support pseudo-blinding. For example, consider the work notes of a practitioner who routinely starts her electronic notes package for seized drugs analysis with narrative explaining the instrumental tests performed along with her interpretation of the data from each instrumental test, followed by a summary of her opinions, and then her data presentation in which comparison/known samples are presented first and the questioned samples appear last. To support pseudo-blinding with respect to her rendered opinion, this practitioner simply needs to reorder her notes so that only intake, inventory, and testing methods narrative appear first, followed by the data presentation with the questioned samples placed before the comparison/known samples, and ending with the narrative explaining her interpretations and opinions. Such ordering provides effective pseudo-blinding that allows others (e.g., individuals performing verifications, technical reviewers, or attorneys) an opportunity to interpret the data and form an independent opinion prior to being exposed to the opinion of the analyzing practitioner.

Another way that forensic science practitioners can guard against the interference of base rate bias is to use a differential diagnosis type approach [5,25] to consider and evaluate the possibility of alternative or opposite outcomes at various stages of their analyses. Asking themselves, "… what else could this be or mean?" or "… but what if it's not what I am currently thinking?" may help practitioners in their thought processes by focusing them on the facts of the evidence at hand, and checking the impact of their potential susceptibility to base rate expectations. Such questions also assist the practitioner in articulating justifications for their decisions, which should also be recorded in their notes.

3.5. Category B, source 5: organizational factors

3.5.1 Organizational factors and work culture can create pressures that result in a variety of biases, such as an allegiance effect and "my side" bias [26]. The adversarial side that retains the expert can influence an implicit allegiance and "my side" bias that can affect the expert's interpretation decisions. This is different from explicit partiality, where one side is openly and intentionally favored over another; that's an ethics problem. Dror states "… science is muddled with managerial authority and other organizational pressures" [5].

3.5.2 Several examples of such bias can be observed in relation to court testimony. First, forensic science practitioners are routinely encouraged to prepare in advance for the presentation of evidence with the attorney who intends to call them as a witness (most often the prosecutor), but equal encouragement and opportunity to meet with the opposing side is rare. Meeting with the calling side and not providing equal time to the opposition is a form of "my side" bias. Another example comes in the form of voluntarily supplying information that is beneficial to the calling side, but of which the calling attorney would not have otherwise been aware. For example, consider a trial involving DNA where there is some similarity of the traits of the evidence profile and the traits of the person of interest, but not enough to report an opinion. Prior to trial, the practitioner alerts the calling attorney to prepare a DNA profile chart for use in court because it will support the calling attorney's argument. The calling attorney could then present the DNA profile chart to the jury and question the practitioner about all the points of similarity or dissimilarity, thereby suggesting an opinion that has not been reported. Symptoms of "my side" bias can also present more subtly in testimony. For example, consider an instance where the calling attorney has misrepresented the evidence in court in a way that misstates its accuracy, certainty, perceived strength, or limitations. A practitioner impacted by "my side" bias might be less inclined to correct or clarify the attorney's misrepresentation during testimony.

3.5.3 While complete removal of laboratory systems from the oversight of law enforcement agencies and prosecutor's offices is ideal, there are many challenges to such change; overcoming these challenges takes time and requires resources that are often scarce.

In the interim as organizational oversight changes are occurring, awareness of the allegiance effect, acknowledgement of the pressures of working within the adversarial system, and commitment to being equally accessible to both sides are good first steps in combating the influences of organizational factors that can lead to cognitive bias. Additionally, forensic science practitioners can work together with management to examine laboratory protocols (and common practices that may be unwritten but are accepted as "just the way it is") for sources of undue influence that could impact their cognitive processes and independence of mind, and then implement or revise policies as needed. For example, a laboratory policy on error mitigation that is written using language with an accusatory tone places undue additional pressures on those involved and can foster a blame placing organizational culture [27]. Careful examination of such laboratory policy, undertaken as a collaborative effort between practitioners and management, can result in neutralized wording that not only reduces undue pressures, but also encourages change in organizational culture.

3.6. Category B, source 6: education and training

3.6.1 The education and training of forensic science practitioners plays a significant role in how they go about their work, how they approach cases, what methods they choose, how they interpret the evidence and data they generate from it, how they make decisions and form their expert opinions, and how they communicate with the trier of fact. However, the education and training of most forensic science practitioners is currently lacking not only in basic foundational information related to human factors in general, including sources of cognitive bias, but also in information about how to minimize the impacts of such factors.

3.6.2 In the most egregious of instances, some education and training of the past has perpetuated practices that amplify the impact of one or more sources of cognitive bias. For example, a trainee who is taught to examine comparison/known samples prior to questioned samples in order to "know what to look for and get done faster," may become a practitioner who utilizes reference material in a way that creates bias.

3.6.3 Forensic science practitioners should seek proper basic foundational training in human factors and bias. Then they should commit to regularly scheduled "refresher" training that includes a review of the sources of cognitive bias and presents relevant updated information on how to minimize them. Forensic science practitioners should also review their past discipline-specific education and task-specific training for inconsistencies with currently established best practices for minimization of the impact of cognitive bias on their work, and then take appropriate corrective action to address any identified inconsistencies. Depending on the degree and anticipated impact of the inconsistency, suitable corrective action could range from an informal, personal commitment to change, to a formal request for additional or updated training, as needed.

3.7. Category C, source 7: personal factors

3.7.1 Shaped by their own unique experiences and perspectives, every person's ideology influences how they think both in their personal lives and in the workplace. For example, a practitioner who is the survivor of an assault that occurred in an alley at night may have certain beliefs that could impact their objectivity when analyzing similar cases.

3.7.2 Personal factors that affect decision making encompass concepts like motivation, personal ideology, individual beliefs, tolerance for risk, the need for cognitive closure, and tolerance for ambiguity. Such personal factors tend to be more influential in analyses involving relatively ambiguous subjective interpretations or comparisons, and less influential in analyses involving more objective interpretations based on quantification and instrumental data. However, while increased implementation of standardized methods, technology, and automation into the workflow can help minimize the impacts of cognitive bias from

personal factors, it does not eliminate them [24].

3.7.3 An important way to help reduce the impact of cognitive bias from personal factors—and one that can be immediately adopted by forensic science practitioners—is to implement detailed and contemporaneous documentation of justifications for their analytical decisions within their work notes. That is, at each point within their analytical scheme that they make a key decision that impacts the direction of their next step, or the final outcome, practitioners should document their reason(s) for making the decision. This practice provides transparency through a written, chronological record of factors that practitioners are aware were influential in their decision-making process [16], and that form the basis of their final analytical result. A further benefit of the mere act of formulating and articulating justifications for their analytical decisions is that it requires practitioners to pause and reflect on their reasoning, which provides an opportunity to maximize the chance that decisions are based solely on the facts of the evidence at hand and not on any personal factors.

As an example of properly documenting the basis for a decision, consider a practitioner examining an evidence item consisting of fragments of post-blast material for the presence of explosive residues using a standardized analytical scheme [28]. As part of the initial visual examination, the practitioner notes that the post-blast material is packaged in a container that is not vapor-tight, and that there are racial slurs written on some of the fragments. Following the standardized analytical scheme, the practitioner makes the analytical decision not to perform a vapor analysis based on the evidence packaging, and he documents this decision in his notes as follows: "Vapor analysis to test for the possible presence of some organic explosives was not performed due to packaging that is not vapor-tight." Such documentation explicitly states the underlying reason for the analytical decision, thereby clearly demonstrating that the decision is based on facts associated with the evidence and not on any personal factors arising from observation of the racial slurs.

3.8. Category C, source 8: human and cognitive factors and the human brain

3.8.1 Cognitive processes, psychology, and other brain related functions form the underlying foundation of how humans interact with and utilize information to make analytical decisions. Cognitive processes are all the mental functions involved in the acquisition, storage, interpretation, manipulation, transformation, and use of knowledge [29]. Thus, cognitive processes encompass such activities as attention, perception, learning, and problem solving [29]. Furthermore, cognitive processes influence and form our perception of the world.

3.8.2 The amount of information that the human brain must process each day is staggering. Heuristics are cognitive shortcuts that are used to quickly and efficiently process information and make decisions. Such mental short cuts are based on subconscious assumptions, categorizations, and other rapid information processing methods that may not accurately reflect all facets of the reality of a situation, and therefore can be a source of cognitive bias [30].

An example of a type of heuristic that can affect forensic science practitioners is anchoring bias, in which the first piece of information received or discovered about an individual item of evidence, or about a case in general, becomes the most influential information in subsequent choices or decisions, regardless of its actual relative value [31]. An important example of information that could impart anchoring bias in forensic science is prior knowledge that a person of interest has made a confession [32]. Such information can influence practitioners at each step of their analyses, and the impact of its influence is maximized when analytical decisions are complex or challenging.

Confirmation bias is one of the most widely discussed forms of cognitive bias in forensic science. Confirmation bias refers to the subconscious tendency to selectively seek and interpret information in a manner that reinforces a preferred viewpoint [33]. In forensic analyses, confirmation bias can arise from exposure to task irrelevant information (e.g., confessions, eyewitness reports, results from other analyses, etc.), from the use of single suspect items instead of evidence line-ups when making comparisons, and from verifications that do not utilize blinding. The most famous example of confirmation bias in forensic science was uncovered in the Brandon Mayfield case related to the Madrid train bombings. In this case, Mayfield was erroneously identified by FBI practitioners as the source of a latent fingerprint lifted from a bag containing detonating devices associated with the incident [34]. A report of the investigation subsequently conducted by the Office of the Inspector General concluded that confirmation bias—arising from exposure to task irrelevant information, use of single suspect item comparisons, and knowledge of other examiners' findings during verifications—was a contributing factor to the erroneous identification [34].

3.8.3 Cognitive processes can also be influenced by stress and vicarious trauma, both of which can be caused by exposure to the contextual information of a case. One example of when a forensic science practitioner might be experiencing symptoms of stress and vicarious trauma is having nightmares about a particular case. Recognizing when a case has had an emotional impact is a good first step toward mitigating the influence of human and personal factors on downstream analysis. If a practitioner feels some emotional reaction to case facts that they have been exposed to, they should consider approaching management to discuss next steps. Perhaps the case can be further sanitized and transferred to a coworker if the practitioner feels as though they have been compromised.

Stress and working many hours overtime can impact the quality of decision making and can result in error. Forensic science practitioners need to be aware of the signs and symptoms of decision fatigue, vicarious trauma, and burnout related to the serious nature of forensic casework. They should take steps to practice self-care and develop healthy coping mechanisms when symptoms of burnout are detected. Practitioners may be able to control their physical working environments by undertaking complex and decision heavy tasks in designated quiet areas of the laboratory or by implementing closed-door office hours to prevent interruption during interpretation or review of complex cases.

Forensic science practitioners should also implement healthy boundaries related to the number of hours they work on a regular basis, ensuring they are getting the appropriate amounts of sleep each night and are maintaining an appropriate work-life balance. They should have colleagues whom they can lean on in times of stress, and who understand the types of stressors the work may impose both mentally and physically. Practitioners should take advantage of any mental health resources provided by the laboratory or seek them out independently, if necessary. Forensic science practitioners can also commit to maintenance of their mental and physical health by ensuring they utilize their sick and vacation time to its fullest extent when the need for mental or physical rest arises.

4. Limitations of practitioner-level actions

The actions suggested above are intended to provide forensic science practitioners with a means to begin incorporating bias mitigating solutions into their daily casework while their laboratory's protocols are being developed. While anecdotal evidence supports the utility of these practitioner-level actions in the absence of related laboratory protocols, no formalized research has been conducted to demonstrate or quantify their potential impact. Additionally, there are some important limitations of practitioner-level actions to consider.

Because cognitive bias happens at a subconscious level, practitioners, like all humans, are often unaware of what information is biasing, how it may influence their decisions, and if they are actually overcoming their own biases. The differential diagnosis approach and transparent documentation can help, but since human tendency is to rationalize decisions, some documented justifications for a

practitioner's decisions can seem reasonable despite having been influenced by cognitive bias. Furthermore, without standardized laboratory procedures for bias mitigation, individualized approaches can lead to variability and inconsistency of implementation, which could result in additional complications for the case, the practitioner, the laboratory, or the organization. Thus, formalized protocols that support laboratory or organizational level bias mitigation procedures, observation, and feedback mechanisms are needed.

Taking into consideration these limitations, forensic science practitioners are encouraged to educate themselves about cognitive bias and its influence on expert decision-making, to implement the suggested practitioner-level solutions to the extent that is reasonable for their individual situations, and to advocate for, and assist with, the development of bias mitigating laboratory protocols.

5. Suggestions for handling court testimony about cognitive bias

How can forensic science practitioners handle questions about cognitive bias during court testimony? Assuming they have implemented the suggestions above, they should:

1. Acknowledge that cognitive bias is fundamental to human cognition, that it happens in forensics as well as other expert domains, and that it cannot be combated using conscious effort alone.
2. State that they utilized validated, standardized methods and procedures, and implemented all applicable quality assurance and quality control measures specifically to address cognitive bias.
3. Explain how they took specific actions that will help minimize the negative impact of cognitive bias on their own work; for example:
   They used LSU and also actively avoided interactions with other personnel that could lead to exposure of task irrelevant contextual information.
   They disclosed all contextual information to which they were exposed, when they were exposed to it, and how it impacted their analysis, by recording this information in their work notes or the laboratory's communications log.
   They identified key decisions made during their analytical process, articulated a justification for their choices during these decisions, and recorded all of this in their notes.
   They disclosed known limitations and other factors potentially affecting the weight/significance of their findings and opinions in their laboratory report.
   To the extent allowed by applicable law and laboratory procedure, they were available to both adversarial sides for pre-trial conferencing. During pre-trial conferences with both sides, they provided their CV and work notes, and they discussed any case specific concerns or issues that may have arisen during their analysis, or in the process of forming their opinions, whether or not they were specifically asked about them.

The following mock transcript excerpt provides an example of how such testimony might proceed:

Attorney: Are you familiar with cognitive bias?

Practitioner: Yes.

Attorney: What is cognitive bias?

Practitioner: Cognitive bias is about how our life experiences, along with new information to which we are exposed, might influence the decisions we make. Cognitive bias is a consequence of processes that occur within the brain at a subconscious level and cannot be controlled through conscious effort or "willpower" alone.

Attorney: Are you susceptible to cognitive bias?

Practitioner: Yes. All humans are susceptible to cognitive bias.

Attorney: What do you do to minimize cognitive bias in your work?

Practitioner: As a forensic scientist, there are many things I can do to help minimize the effects of cognitive bias on my work. First, I acknowledge that I am susceptible to cognitive bias, and that I cannot control cognitive bias by conscious effort alone. I have made a personal commitment to learning all I can about cognitive bias and methods for minimizing it. In general, I actively avoid communications that could provide information that is not strictly necessary to perform proper scientific testing and evaluation of the evidence; I adhere to standardized laboratory procedures and scientific methods; and I implement all applicable quality assurance protocols. For each case, I record contemporaneous, detailed notes about all of my communications, including statements regarding whether the information is task relevant or task irrelevant, and my perception of its impact on my work. My work notes for each case provide transparency by detailing all my observations, the analytical decisions that I make, and the basis or justification for each of these decisions. My written report discloses any limitations of my analyses and opinions that are specific to situations encountered during the case, and it includes a statement notifying the reader that my detailed notes are available upon request. Furthermore, during the weeks leading up to a trial, I make myself available to meet with both the prosecution and the defense attorneys for pre-trail conferencing. During these meetings, I voluntarily disclose and discuss any issues that may have arisen during my work in the case, including any concerns about the influence of cognitive bias. All of these things, together, form my best, good-faith effort to minimize cognitive bias throughout every stage of my work.

6. Concluding thoughts

While the suggestions for forensic science practitioners presented in this paper may not solve the entire problem, they provide a means through which individual practitioners can take immediate action to minimize cognitive contamination, which can in turn:

1. Stimulate implementation of previously published methods that address cognitive bias at the laboratory or organizational level,
2. Encourage training initiatives between the laboratory and stakeholders regarding what information is task relevant, as well as when, how, and to whom it should be communicated, and
3. Provide supporting evidence to stakeholders (especially when giving testimony in court) that forensic science practitioners:
   (a) acknowledge the existence of cognitive bias and have an understanding of what it entails,
   (b) recognize that cognitive bias is a result of innate cognitive processes and therefore can (and will) happen to them,
   (c) accept that conscious effort alone cannot protect them from the negative impacts of cognitive bias, and
   (d) demonstrate methods they have individually implemented to reduce the chances of cognitive contamination in their work product.

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