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A practical tool for information management in forensic decisions: Using Linear Sequential Unmasking-Expanded (LSU-E) in casework

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ABSTRACT

Forensic analysts often receive information from a multitude of sources. Empirical work clearly demonstrates that biasing information can affect analysts' decisions, and that the order in which task-relevant information is received impacts human cognition and decision-making. *Linear Sequential Unmasking* (LSU; Dror et al., 2015) and *LSU-Expanded* (LSU-E; Dror & Kukucka, 2021) are examples of research-based procedural frameworks to guide laboratories' and analysts' consideration and evaluation of case information. These frameworks identify parameters—such as objectivity, relevance, and biasing power—to prioritize and optimally sequence information for forensic analyses. Moreover, the LSU-E framework can be practically incorporated into any forensic discipline to improve decision quality by increasing the repeatability, reproducibility, and transparency of forensic analysts' decisions, as well as reduce bias. Future implementation of LSU and LSU-E in actual forensic casework can be facilitated by concrete guidance. We present here a practical worksheet designed to bridge the gap between research and practice by facilitating the implementation of LSU-E.

1. Introduction

In a well-known forensic misidentification error, senior Federal Bureau of Investigation (FBI) latent print examiners concluded with "100%" certainty that a latent fingerprint found at the scene of the 2003 Madrid train bombing belonged to Brandon Mayfield, a Muslim lawyer from Oregon. The Office of the Inspector General (OIG) concluded in a formal review that confirmation bias played a role in the erroneous identification [1]. This case is a striking example of how cognitive biases can affect even the most experienced and highly trained forensic examiners in a well-established discipline—and underscores the need to combat bias in forensic science.

In this article, we provide practical guidance and tools to encourage forensic laboratories to incorporate effective, standardized protocols into their workflow. Doing so will not only minimize bias, but also improve the repeatability and reproducibility of their results and increase transparency in forensic decision-making. We begin with a brief review of different sources of cognitive biases in forensic decision-making and empirical research demonstrating how these biases affect forensic decisions. Then, we introduce the concept of "information management." Broadly, context or information management frameworks are clear, standardized strategies to guide the collection, administration, and use of data in a way that minimizes bias and improves the quality of complex decisions. Linear Sequential Unmasking (*LSU*, [2]) and LSU-Expanded (*LSU-E*, [3]) are examples of context management frameworks created for forensic scientists and form the basis of our main recommendations in this article. We then introduce a practical worksheet that introduces a way to facilitate and standardize the implementation of LSU-E in forensic practice. We provide training materials and specific examples of how to use this tool.

2. The many faces and manifestations of cognitive bias in forensic science

Cognitive bias refers to how preexisting beliefs, expectations, motives, or situational context can influence how people collect, perceive, or interpret information—such that two competent examiners with different mindsets or working in different contexts may form contradictory opinions about the same evidence [4]. Prior research has identified several potential sources of cognitive bias, including the

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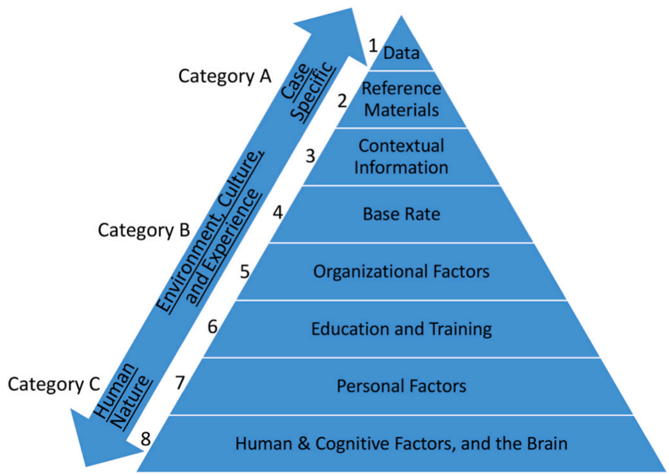

Fig. 1. Eight sources of cognitive bias in forensic science (Dror, 2020 [5]).

procedures used, access to task-irrelevant information, prior experience in unrelated cases, or broader factors associated with motivation, training, laboratory culture, or human decision-making (see Fig. 1, [5]). In other words, bias can emerge from the specifics of a particular case (Levels 1, 2, and 3 in Fig. 1); from a particular examiner, technique, or laboratory (Levels 4, 5, and 6 in Fig. 1); or from innate features of the human brain that transcend the specific case, examiner, or laboratory (Levels 7 and 8 in Fig. 1).

2.1. Examples of cognitive bias in forensic decision-making

The Mayfield case exemplifies several ways in which cognitive biases can result in errors in casework. First, Mayfield became a person of interest after a computer database search determined his fingerprint to be similar to a latent print found at the crime scene. While computer database searches are very useful tools, the similarity rankings and meta-data provided therein can also bias examiners' evaluations of the candidate prints (Level 2 in Fig. 1) [6].

Table 1
Ratings of the biasing potential, subjectivity, and irrelevance of "Case Information" (Fig. 1, Level 3) from empirical studies addressing contextual bias in forensic disciplines.

Contextual information	LSU-E Ratings	Technique, participant sample, and citation	Notes and caveats
Another examiner's (or peer's) decision about the same materials.	Biasing power: 4 Subjectivity: 3 Irrelevance: 5	Novice analysts for fingerprints: Quigley-McBride (2020), shoeprints: Sneyd et al. (2020). Expert analysts for fingerprints: Dror et al. (2006), Langenburg et al. (2009); DNA: Thompson (2009); questioned documents/handwriting: Merlino (2015); ballistics: Mattijssen et al. (2020).	The opinion or reputation of prior examiner might matter for ratings of biasing potential and subjectivity. Thompson (2009) is not a controlled study.
Explicit suggestion about what the conclusion should be/which person left the sample at the crime scene.	Biasing power: 4 Subjectivity: 4 Irrelevance: 5	Trainee analysts for bloodstain patterns: Hugh & Satchell, (2018). Expert analysts for bitemarks: Chiam et al. (2021); CSIs: de Gruijter et al. (2017), Kerstholt & Eikelboom (2007), van den Eeden et al. (2016); ballistics: Kerstholt et al. (2010), shoeprints: Kerstholt et al. (2007), bloodstain patterns: Taylor et al. (2016a, 2016b), forensic pathology (Oliver, 2017), arson (Bieber, 2012).	If the nature of the crime, how the crime was committed, or the type of crime is revealed to analysts, this will increase the biasing power of the contextual information.
The suspect provided a verified alibi.	Biasing power: 4 Subjectivity: 3 Irrelevance: 5	Expert analysts for fingerprints: Dror & Charlton (2006).	The strength and the nature of the alibi will matter for ratings of biasing power and subjectivity.
The suspect confessed to the crime.	Biasing power: 5 Subjectivity: 3 Irrelevance: 5	Novice analysts questioned documents/handwriting: Kukucka & Kassin (2014). Expert analysts of polygraphs: Elaad et al. (1994).	
Information about the type of crime/ photos of the crime scene or relevant to the crime type	Biasing power: 4 Subjectivity: 4 Irrelevance: 4	Novice analysts for fingerprints: Dror et al. (2005), Osborne & Zajac (2016), Quigley-McBride & Wells, (2018), Quigley-McBride (2020). Expert & trainee analysts for forensic anthropology: Nakhaeizadeh et al. (2014). Expert fingerprint analysts: Earwaker et al. (2015), Hall & Player (2008).	The relevance of this type of information will depend on the forensic discipline – very relevant to bloodstain pattern analysts, but not for fingerprint analysts.
Demographic or background information about the victim or suspect (e.g., age, race, occupation, criminal history).	Biasing power: 4 Subjectivity: 4 Irrelevance: 5	Novice analysts for fingerprints: Smalarz et al. (2016); questioned documents/handwriting: Kouwenhoven (2018). Trainee analysts for forensic toxicology: Hamnett & Dror, (2020). Novice & trainee analysts for bitemarks: Osborne et al. (2014). Expert & trainee analysts for forensic anthropology: Nakhaeizadeh et al. (2014). Expert analysts for forensic pathology: Dror et al. (2021); forensic anthropology: Hartley et al. (2021).	
Examiner was exposed to/allowed access to other materials or forensic evidence they were not tasked with analyzing.	Biasing power: 5 Subjectivity: 3 Irrelevance: 5	Novice analysts for fingerprints: Stevenage & Bennett (2017), Quigley-McBride & Wells, (2018), Quigley-McBride (2020). Trainee analysts for forensic anthropology: Nakhaeizadeh et al. (2018). Expert & trainee analysts for bloodstain patterns: Osborne et al. (2016). Expert analysts for bloodstain patterns: Osborne et al. (2016), digital forensics (Sunde & Dror, 2021).	Subjectivity may vary based on the type of evidence or materials the analyst is exposed to, and whether they have access to the report or just the ultimate conclusion.

Notes. More details about each study, the type of information given to analysts in the study and how it was manipulated, the results, and a full list of references can be found on Open Science Framework.[1] These studies all demonstrated the effect of information that falls within the third level of information that can influence analysts, as defined by Dror [5] and Fig. 1.

Second, examiners in the Mayfield case analyzed the reference material (i.e., Mayfield's prints) alongside the latent fingerprint from the crime scene without first evaluating each print in isolation. Research has shown that information from the reference material can bias the analysis of the evidence from an unknown source (Level 2 in Fig. 1, [7]). The OIG [1] concluded in their report that this side-by-side comparison method likely encouraged "backwards" or "circular" reasoning that contributed to the erroneous identification of Mayfield, consistent with the possibility that this type of bias influenced the conclusions in this case.

Third, FBI examiners were privy to task-irrelevant contextual information (Level 3 in Fig. 1)—namely that Mayfield was on the FBI "watch list". There is ample evidence that task-irrelevant information—including racial and other stereotypes—can influence forensic decisions (e.g., Refs. [8,9]; see Table 1). Instead, examiners should base their decisions solely on task-relevant information [10].

Lastly, the verification procedures in the Mayfield case were subject to bias insofar as the verifying examiners knew that the initial examiner had judged the prints as belonging to Mayfield. Studies have now demonstrated that when verifiers are not blind to their colleague's opinion, they are naturally biased to agree with it, such that their opinion does not provide independent corroboration ([11–13]; see Table 1). Instead, verification is most effective when the verifier is kept unaware of the initial examiner's work and conclusion (i.e., "blind" verification; depending on the reason why the verifications were not blind, this information would fall under Level 3 or Level 5 in Fig. 1).

2.2. *Empirical and experimental demonstrations of forensic cognitive bias*

The aforementioned biases are not unique to the FBI laboratory or to forensic work, nor are they an exhaustive list of potential sources of bias. In this section, we briefly review other sources that were not present in the Mayfield case but can nonetheless impact forensic decisions (for a more detailed treatment of sources of bias, see Ref. [5]). Then, we discuss previously proposed methods for mitigating bias in forensic casework, and finally, we introduce our own practical recommendations and tools for doing so.

A large and growing body of research has shown that task-irrelevant contextual information can prompt bias in a variety of forensic domains.

Table 2
Ratings of the biasing potential, subjectivity, and irrelevance of different levels of information available to forensic analysts based on empirical tests of these types of information.

Source of Bias (Fig. 1)	Contextual information	LSU-E Ratings	Technique, participant sample, and citation	Notes and caveats
Level 1 – "Data"	The sample obtained from the crime scene to be evaluated by the forensic analyst.	Biasing power: 1 Subjectivity: 3 Irrelevance: 1		Subjectivity will vary based on the quality of the sample. A poor-quality sample with lots of information loss could be rated 5, but a pristine sample should be rated a 1 or 2. Sometimes the data includes biasing information (e.g., a bitemark indicates the crime was violent)—the biasing power may be higher in these types of cases.
Level 2 – "Reference Materials"	Comparing the crime scene sample to suspect sample is inherently suggestive (bias). Evidence lineups reduce inherent bias in this standard analytic procedure (less bias).	Biasing power: 4 Subjectivity: 4 Irrelevance: 1	Novice fingerprint analysts: Quigley-McBride & Wells (2018), Quigley-McBride (2020). Trainee questioned documents examiners: Miller (1984); hair analysts: Miller (1987). Expert fingerprint analysts: Kukucka et al. (2020).	Biasing power may be reduced if the crime scene sample is analyzed and documented prior to exposure to the reference material. Evidence lineups have a biasing potential of 2 due to changes in response bias (more conservative). The method used is extremely relevant to examiners, but there are many interpretations of the standard procedure (subjectivity).
	Crime scene and suspect sample compared alone (bias) or with a non-matching sample as a reference (less bias).	Biasing power: 4 Subjectivity: 3 Irrelevance: 1	Expert fingerprint analysts: Fraser-Mackenzie et al. (2013).	
	Non-blind procedure (forensic expert knows the answer/location).	Biasing power: 4 Subjectivity: 1 Irrelevance: 1	Expert dog handlers: Lit et al. (2011), DeChant et al. (2020).	Ground truth is unknown, but analysts might form a belief about what ground truth is likely to be after exposure to other case information (+2 subjectivity/irrelevance in the real world).
	Automated Fingerprint Identification System (AFIS) search information, rankings, and output.	Biasing power: 4 Subjectivity: 4 Irrelevance: 3	Expert fingerprint analysts: Dror et al. (2012).	Has not been tested, but these results likely extend to CODIS output and other software used by forensic scientists.
Level 4 – "Base Rates"	Past results from previous 'similar' cases.	Biasing power: 4 Subjectivity: 3 Irrelevance: 3	Novice fingerprint analysts: Growns & Kukucka (2021).	Biasing potential would be lower (1 or 2) for situations where the base rates are less extreme e.g., 60% and 40%.
Levels 5 and 6 - "Organizational Factors" and "Training and Motivation"	Analyst's knowledge about which side (prosecution or defense) hired them to testify.	Biasing power: 4 Subjectivity: 1 Irrelevance: 5	Expert questioned documents/handwriting examiners: Dror et al. (2020).	This is called "adversarial allegiance" in the literature.
	Knowing that the results of your analysis are key to a person's case.	Biasing power: 5 Subjectivity: 1 Irrelevance: 5	Expert DNA mixture analysts: Dror & Hampikian (2011).	
Levels 7 and 8 - "Personal Factors" and "Cognitive Architecture"	Pre-existing beliefs about a suspect's guilt, or personal history.	Biasing power: 4 Subjectivity: 2 Irrelevance: 5	Expert and novice police officers/investigators: Charman et al. (2017).	Police are not usually forensic scientists but do interpret forensic evidence and direct investigations that result in forensic samples. Pre-existing beliefs are fixed (low subjectivity) but are irrelevant.

Notes. More details about each study, the type of information given to analysts in the study and how it was manipulated, the results, and a full list of references can be found on Open Science Framework.[1] These studies all demonstrated the effect of information that falls within the level of information that can influence analysts—labelled in the far-left column—as defined by Dror [5] and Fig. 1.

A systematic overview of this research is presented in Table 1, with a more detailed summary available on the Open Science Framework (OSF[1]; see also [14]). In short, knowledge of task-irrelevant information has been shown to influence judgments of fingerprints, DNA mixtures, bloodstain patterns, skeletal remains, and digital evidence, to name just a few. Table 1 examines studies of task-irrelevant factors pertinent to the particular case the analyst is working on, organized into broader categories based on what suggestive information was presented or manipulated.

With respect to the biases shown in Fig. 1, other studies have found that base rate expectations can impact judgment in the case at hand (Level 4; [9,15]) and professionals tend to show adversarial allegiance by giving opinions that favor whichever side hired their services (Level 5; [16]). These studies are summarized in Table 2, organized according to the levels presented in Fig. 1.

3. The promise of information management frameworks

There are several existing frameworks for how forensic laboratories might implement information management protocols to combat cognitive bias. Perhaps the most prominent example is LSU [2,3], which was designed to manage the impact of biasing information and increase transparency. LSU is an approach to think through and organize forensic analyses based on the information available, how that information should be categorized (again, see Fig. 1), and whether and when it is appropriate for the analyst to access it.

Ideally, LSU would become part of laboratories' pre-set standard operating procedures (SOPs) and implemented *before* the examiner receives and begins to analyze materials. Case information can take on many forms. Even seemingly innocuous communications with the police investigators or lawyers, or basic demographic information about the victim, can contribute to bias effects. It is for this reason that researchers suggest having someone screen information and communications before the analyst receives them. However, individual examiners should also document and evaluate the information available to them.

The LSU framework was initially designed for the pattern-matching forensic disciplines (e.g., comparisons of fingerprints, firearms, handwriting, etc.). However, some forensic practices do not involve visual comparisons (e.g., pathology, crime scene investigation, digital forensics). Furthermore, LSU only deals with minimizing bias—not with improving how decisions are made more generally. Experts often vary in their conclusions, leading to results that are 'noisy' with low reproducibility and repeatability, even in the absence of bias [17]. In one study, for example, when the *same* fingerprint expert examined the *same* set of prints on two different occasions, they reached different conclusions 10% of the time [18]. Similar results have been documented in other forensic domains, including DNA [19,20].

In response to these issues, Dror and Kukucka [3] recently expanded LSU into LSU-Expanded (LSU-E), so that the framework could be applied to any forensic domain and would improve decision making in general, rather than focusing solely on minimizing bias. Under the LSU-E framework, examiners (or SOPs) make *a priori* determinations about what information to consider and in what order. These determinations hinge on three parameters: *biasing power*, *objectivity*, and *relevance*. Biasing power refers to how strongly the information might dispose the analyst toward a particular conclusion. Objectivity refers to the extent to which the information can be interpreted to mean different things depending on the decision makers' particular set of beliefs, feelings, or knowledge—something that has very few meanings is more objective. Relevance refers to the degree to which the information is essential and central to the analytic task. A detailed discussion of these parameters can be found in Dror and Kukucka's [3] paper introducing LSU-E.

As is true of most information management protocols, LSU-E works best if existing protocols or case managers triage information as it comes into the laboratory—i.e., by identifying, organizing, and at times, filtering out task-irrelevant information before it reaches the examiner. However, even task-relevant information varies in its objectivity, relevance, and biasing power. Thus, these protocols also stand to benefit analysts by guiding their thinking about when and how to use the information available as they work through their analyses. Furthermore, the tenets of LSU-E can be used in training new analysts to consider and be aware of information that could inappropriately influence their analyses. Although cognitive biases are difficult to manage, SOPs and forensic examiners can and should consider how various pieces of information might influence their analysis and, in the interest of transparency, there should be clear documentation of which information was used and when, as well as any steps taken to combat potential biasing influences.

3.1. Implementing information management frameworks in practice

To date, LSU and LSU-E have been discussed conceptually, but forensic laboratories have been left to make their own decisions about how to best implement these information management procedures. Information management frameworks, checklists, and worksheets have been used successfully in other disciplines where the consequences of even minor errors can be dire (e.g., medical professionals, pilots, mining industry; [21]). Thus, an advantage of LSU-E is its applicability to a wide range of laboratories or disciplines—including non-forensic disciplines (e.g., workplace safety inspections; [22]). However, LSU-E's flexibility might also be a barrier to implementation if laboratories see it as not sufficiently specific to put into practice. Without clear guidance or concrete tools, laboratories and examiners that employ LSU-type protocols will presumably vary in how they apply the theory of LSU to actual casework, with some approaches being more effective than others [12]. Moreover, a growing number of forensic laboratories now use LSU, but there are relatively few published first-hand accounts of how to actually implement LSU for other laboratories to emulate (e.g., Refs. [23–25]).

For this reason, this article aims to take LSU-E a step further by providing specific guidance and tools for its implementation. In Appendix A, we present a practical worksheet that can be used to implement LSU-E in laboratories and is adaptable to any forensic science discipline. The worksheet is accompanied by an instructions page (also in Appendix A), and a longer explanatory document for training purposes is available in Supplementary Materials and on Open Science Framework (OSF[1]). The worksheet is primarily designed to help develop appropriate SOPs and be used by case managers and intake personnel who are responsible for assessing case information prior to relaying information to analysts. It can also be used as a training exercise or tool.

The worksheet is to be used as follows: First, the user specifies the piece of information in question (e.g., a suspect sample, demographic information, other incriminating or exonerating evidence) and the source of that information (e.g., the crime scene, a conversation with the police investigator, an email from the prosecutor, or a database). Then, the user considers the three LSU-E criteria (i.e., biasing power, objectivity, and relevance), and they rate that piece of information on a 1–5 scale for each criterion. Lower ratings are more desirable in the sense that they are reserved for information that is less biasing, less subjective, and more central to the task—and therefore more reliable and informative. In contrast, higher ratings denote information that is heavily biasing, highly subjective, and less central to the task. As such, this information should be considered later in the analytic process, if at all. The worksheet also provides space for analysts to explain their ratings and make comments. Finally, there is space for the analyst to describe any strategies they used to minimize the adverse impact of this information, such as avoiding it until later in the analytic process or explicitly considering alternative hypotheses.

To practically demonstrate the utility of this worksheet and aid in its

[1] https://osf.io/xm3ru

implementation, we have also provided concrete examples. Tables 1 and 2 catalog empirical studies in which cognitive biases were found to influence judgments of forensic evidence. Table 1 specifically addresses different types of task-irrelevant case information, and Table 2 explores the broader spectrum of information available to analysts, as depicted in Fig. 1. In each case, we have also provided suggested ratings of biasing power, subjectivity, and irrelevance for each type of potentially biasing information, which are informed by the existing research.

For example, consider the studies that have addressed how knowledge of a fellow examiner's opinion can influence one's own opinion (Table 1, first row). Most of these studies were designed such that the participant-examiner knew that a colleague had already made a determination about these materials (either that the materials were from the same or different source). In general, the biasing power of this type of information is high, resulting in a suggested rating of 4 out of 5. The level of subjectivity will depend on the quality and nature of the materials being examined and the nature of the information received about the prior examination (e.g., the verifier's opinion of and/or relationship to the original examiner and whether the verifier received the original evidence or merely the original examiner's notes). Thus, we have suggested a rating of 3 out of 5 for subjectivity, but these ratings may vary between cases. Another examiner's opinion about the same materials is, also, completely irrelevant to the opinion of the verifying analyst—they should give an independent corroboration of the original analyst's conclusion—resulting in a suggested irrelevance rating of 5 out of 5.

Next, the worksheet provides space to explain the ratings assigned to a piece of information and how any potential biasing effects might be mitigated. Sometimes, there will very little required to manage a piece of information appropriately. In contrast, other types of information require reasonably complex management strategies, such as blind verification procedures. Consider, for instance, the illustration of how a full case might be assessed in Appendix B, where we have used the worksheet to evaluate the information available to the FBI fingerprint analysts when they erroneously concluded that the latent fingerprint belonged to Mayfield. For each piece of information, we have provided suggestions for how the biasing effects in the Mayfield case could have been mitigated.

The first item on Appendix B worksheet is the latent fingerprint from the crime scene. This fingerprint is not necessarily a *source* of biasing information in itself, but it may be open to multiple interpretations, such that *other* information may bias analysis of the latent fingerprint if that other information is not managed properly. The solution is to ensure that an independent analysis of the latent fingerprint is completed and documented *prior to* any analysis of any other information in the case (as described in Appendix B example worksheet). Thus, the mitigation plan—i.e., the steps taken to mitigate bias—can be quite simple. The analyst might simply note when a given piece of task-relevant information will be considered as they work the case, or that a given piece of information was redacted or removed from the case file because it was deemed irrelevant and as having very high biasing potential.

The second item in Appendix B worksheet shows a more complex example, based on the fact that the ranking information from the AFIS candidate list can bias fingerprint analysts' conclusions [6].[2] However, the analysts presumably need access to this information to complete a proper analysis, so the solution is relatively complicated. We suggest that another analyst be tasked with submitting the latent fingerprint to an AFIS search and randomizing the order of the candidates before presenting them to the primary analyst. Then, the primary analyst can access the previously-redacted rankings and similarity scores *after* they have completed their initial analysis of the randomly-ordered candidates and, if this new information changes their original decision, they must document and justify that change. Thus, the level of detail will vary by case, type of information, and forensic technique, but the worksheet was designed to accommodate a wide range of forensic domains and decisions.

In some instances, however, there may be no way to adequately mitigate the impact of certain pieces of information. Laboratories that adopt this worksheet may therefore decide to establish "cut-off" values for ratings of biasing power, objectivity, and relevance, such that any information with rating(s) above that value should never be considered. Instead, a case manager or peer can triage that information before it reaches the analyst. That said, establishing universal cut-off scores may prove challenging given the inherent variation among cases and disciplines, and the question of determining appropriate cut-off values is beyond the scope of this article—though we recommend that cut-off scores should be informed by empirical studies, such as those summarized in Tables 1 and 2, whenever possible.

This tool is designed to provide a flexible structure to forensic decision-making that can guide analysts' consideration of the various pieces of information available to them. In our view, the tool is best used to guide examiners in their evaluation of case information, considering the potential influence of that information on their decision-making and how they might minimize that influence as appropriate. Although laboratories have the final say in how this worksheet is implemented and used, we would recommend that a working document be created for each case, and the case intake manager or every analyst who works on that case fill out the worksheet as they complete their analyses. This should be more efficient as it eliminates the need for multiple entries regarding the same information, and these analyses can be incorporated into the official record. This worksheet can also be used as a training exercise.

This system of ratings and the worksheet itself can be used by analysts in any domain of forensic science; in fact, Tables 1 and 2 include studies across 16 different forensic domains. Furthermore, the worksheet permits an evaluation of a wide variety of information—sources of bias from the full hierarchy of information (Fig. 1, [5]) and encourages analysts to regularly engage with research-based solutions to bias. Thus, the worksheet should be adaptable into any laboratory's standard operating procedures or policies in its current form and used after a short training session.

In addition to the benefits in forensic science practice, this worksheet may help jurors to better evaluate the reliability of forensic expert testimony. For example, if the examiner had access to suggestive information, the worksheet can be presented as evidence that adequate mitigation strategies were (or were not) taken to counteract the biasing effect of that information. Indeed, studies have found that jurors can use this type of information appropriately when evaluating forensic evidence: When alerted to an examiner's poor performance on proficiency tests [26] or the possibility that bias tainted the expert's judgment [27], mock jurors appropriately devalued the expert's testimony—and conversely, when informed that the expert followed context management procedures to reduce the risk of bias, mock jurors gave more weight to their testimony [28]. Thus, the worksheet can sensitize jurors in cases where skepticism is warranted, but also bolster the credibility of experts who use appropriate mitigation strategies.

4. Final remarks and conclusions

There are many challenges in implementing research into practice. In forensic science, interdisciplinary work and conceptual solutions are emerging, but actionable practical suggestions are few and far between. The goal of this article and worksheet creation was to provide a tool that examiners can immediately use to think through the potential sources of cognitive bias in their analyses, including practical solutions to these threats. Furthermore, by using LSU-E to optimize the order of information will not only reduce cognitive bias effects, but also reduce 'noise'

[2] This type of biasing information is not isolated to evaluations of fingerprint evidence. DNA analysts use the Combined DNA Index System (CODIS) and, when they do, the candidates are associated with ranking information. Thus, the ranking information is likely to have a similar effect on DNA analysts.

and improve the consistency in results (repeatability and reproducibility between and within examiners) [3,17].

It is important for cognitive bias and forensic decision researchers to take the extra step of ensuring that their research ideas can be put into practice. Forensic analysts and managers of laboratories rarely have access to cognitive and human factors experts, and they may resist or struggle to translate research papers into practice without concrete guidance. This paper aims to contribute to the practical implementation of research. We hope to inspire more efforts among researchers to turn their research-based solutions into implementable tools for forensic analysts, which we believe will contribute substantially to bridging the gap between research and practice.

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Declaration of competing interest

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Supplementary data: Appendix A, Appendix B, and Training Materials

Supplementary data to this article can be found online at https://doi.org/10.1016/j.fsisyn.2022.100216.

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