The use of contextual information in forensic toxicology: an international survey of toxicologists' experiences†

Hilary J. Hamnett[a,1,*] and Rachael Jack[b]

[a]*Forensic Medicine & Science, University of Glasgow, United Kingdom*

[b]*Institute of Neuroscience and Psychology, University of Glasgow, United Kingdom*

†Some of the data in this paper was presented at the 7th United Kingdom and Ireland Association of Forensic Toxicologists' Annual Meeting and Scientific Conference from 31 August to 1 September 2017 in Oxford, UK.

[1] Present address: School of Chemistry, University of Lincoln, Joseph Banks Laboratories, Green Lane, Lincoln, LN6 7DL, UK.

* Corresponding author.

E-mail address: hhamnett@lincoln.ac.uk (H.J. Hamnett).

ABSTRACT

Cognitive bias is a well-documented automatic process that can have serious negative consequences in a variety of settings. For example, cognitive bias within a forensic science setting can lead to examiners' judgements being swayed by details that they have learned while working on the case, and which go beyond the physical evidence being examined. Although cognitive bias has been studied in many forensic disciplines, such as fingerprints, bullet comparison, and document examination, knowledge of cognitive bias within forensic toxicology is lacking. Here, we address this knowledge gap by assessing use of contextual information by an international group of forensic toxicologists attending the 54th conference of The International Association of Forensic Toxicologists (TIAFT) in Brisbane in 2016. In a first study, participants read a set of simple post-mortem toxicology results (two drug concentrations in blood) and then indicated what information they would normally use when interpreting these results in their day-to-day casework. Using a questionnaire, we then surveyed the familiarity of toxicologists with contextual bias and captured any suggested bias-minimizing procedures for use in forensic toxicology laboratories. Thirty-six participants from 23 different countries and with a range of 1–35 years' forensic toxicology reporting experience volunteered. Analysis of their responses showed that the majority of participants used some contextual information in their interpretation of post-mortem toxicology results (range = 3–15 pieces of information, median $\pm$ SD = 11 $\pm$ 3), the most common being the deceased's history of prescription or illicit drug use. More than three-quarters of participants reported being familiar with the concept of contextual bias, although few (n = 9) worked in laboratories that had a formal policy covering it. Over half of participants knew of at least one bias-minimizing procedure specifically for forensic toxicology casework, but only a quarter (overall) reported using bias-minimizing procedures in their laboratories. Our results provide substantial evidence that although practising forensic toxicologists are familiar with contextual bias, many report that they still engage in behaviours that could lead to cognitive bias (*e.g.*, through the use of contextual information, through lack of explicit policies or bias-minimizing procedures). We anticipate that our work will form the basis of further research involving a larger sample of participants and examining other potentially relevant factors such as sex/gender, country and accreditation of laboratories.

Keywords: cognitive bias; forensic toxicology; bias-minimizing procedure; contextual bias

1. Introduction

Despite many technological and scientific advances in forensic science, decision-making remains primarily a subjective, human cognitive process. Consequently, errors and bias are likely to occur with the potential for serious deleterious consequences [1], which can ultimately undermine the value of the scientific evidence that the field of forensic science provides [2]. *Cognitive forensics* is the study of how fundamental cognitive processes, such as constructing, seeking and interpreting information, impact the way forensic science is conducted, and how cognitive knowledge can guide and enhance forensic work [3, 4].

Human perception and interpretation of the world is often influenced by one's expectations and desires [5], for example the more sharply we see an object, the closer we perceive it to be [6]. These 'mental shortcuts' are a fundamental component of human psychology and are often adaptive [7] because they enable the human brain to quickly process a sub-set of task-relevant information from the large amount of complex incoming information, and enable quick decision-making. Factors that influence this sub-selection of information and its interpretation can arise from explicit messages or from subtle cues [5], such as exposure to certain words or images [8]. Although perceptual processes such as tunnel vision, or being influenced by the views of others, occur frequently in everyday life, often with little consequence [9], they can also lead to erroneous judgements [10].

In forensic science disciplines that require humans to make perceptual judgements of similarity, *e.g.*, comparing two trace evidence patterns, such influences can be problematic [9]. This is because forensic experts' judgements can be significantly influenced by external factors, such as contextual information, or internal factors such as emotional state, uncertainty, expectations, and hopes [11, 12], fatigue, urgency, and workload [13]. Therefore, in the forensic context, *cognitive bias* refers to a psychological sway toward one opinion or conclusion versus another based on exposure to case information extraneous to the task at hand [14]. It has several manifestations, including:

- *Contextual bias*—the human tendency to draw conclusions in certain situations based on contextual information. For example, when a forensic scientist is given a great deal of information about the incident that gave rise to the evidence currently being analysed [15];
- *Confirmation bias* or *tunnel vision*—where the analyst gives more weight to information that is consistent with what they already believe [16, 17], and tends to reject, excuse or ignore evidence that could contradict their beliefs [18]. For example, where a forensic scientist checking a colleague's work is made aware of the first result before conducting the test(s) themselves; and
- *Expected frequency bias*, *expectation bias* or *base rate regularities*—where analysts have and apply existing expectations before the actual examination takes place [19]. For example, where the use of an automated fingerprint identification system (AFIS) results in examiners expecting to see positive results near the top of the list of potential 'matches' [10].

All of these cognitive biases can consciously or subconsciously influence the analysis procedures used by forensic scientists as well as the interpretation of their findings [15]. Thus, although extraneous or distracting information cannot change the physical nature of the evidence, it can subtly influence what is examined and the subsequent opinions formed [20].

Given the potential impact of cognitive bias in forensic science, it is imperative that each forensic discipline examines the potential sources and effects of bias, and takes measures to minimise them [21, 22]. Whilst many disciplines such as document examination [4], odontology [14], bullet comparison [16], bloodstain pattern analysis [23], anthropology [21], and fingerprints [24] have already been subject to cognitive scrutiny, there is little research on the potential sources of cognitive bias within forensic toxicology.

1.1. Forensic toxicology

Forensic toxicology involves the detection of drugs and poisons in biological specimens and the application of this knowledge to meet the varied needs of the law [25]. Forensic toxicology cases can include driving under the influence (DUI) of alcohol or drugs, workplace drug testing, drug-facilitated sexual assault (DFSA), suspicious deaths, and sudden, unexpected or unexplained deaths referred to the Coroner. A typical case strategy starts with a set of drug tests on samples of body fluids, such as blood or urine, for a range of drugs or drug 'families' *e.g.*, amphetamines. These are known as *screening tests*. Depending on the results, the screen may be followed by specific *confirmation* and/or *quantification* of presumptively positive drugs. The case strategy can be re-evaluated during testing depending on the results [26], or if additional information on the case is received by the toxicology laboratory. Unlike other forensic disciplines, it is common in forensic toxicology for different scientists to request, carry out and report (and therefore interpret) tests on the same case.

Although toxicology is laboratory-based [22], comparisons of visual data and traces [8], subjective expert decision-making and interpretation of findings still form a substantial part of the process that is followed for a case. For example, during the selection of screening tests to be carried out on the case samples, a toxicologist will often use the case circumstances and the request from the customer (*e.g.,* the pathologist) to decide which drug tests are needed. In many laboratories, a standard set of screening tests is used that covers the most commonly encountered drugs. A small number of additional tests for less commonly encountered drugs (*e.g.,* antipsychotic medications) are then requested on a case-by-case basis. It is at this point that contextual information can be used transparently to develop the case strategy; the case circumstances are relevant to the decisions being made (*task relevant*). However, in some laboratories there is no standard set of screening tests, and the selection of all tests is made on a case-by-case basis. Crucially, these decisions can be affected by expected frequency bias, which occurs when, based on local patterns of drug prevalence, experienced forensic toxicologists become accustomed to drug use occurring at certain rates amongst certain populations (*e.g.*, by location, age, gender, cultural group, *etc.*), and thus expect it to recur at those rates [27]. This can therefore lead to errors in the case strategy because tests are requested based on past experiences or assumptions. For example, some toxicology laboratories use upper age cut-offs for testing for evidence of the use of illicit drugs such as cannabis, which may lead to drug use being missed in some older individuals (despite evidence that drug misuse in this age group is increasing [28]). If the samples in the case are limited in volume, prioritising tests based only on such 'rules-of-thumb' could lead to a case being incorrectly reported as negative.

During screening, techniques such as immunoassay or gas chromatography-mass spectrometry (GC-MS) are used. As part of the latter, a comparison is made between the case sample and a known drug standard and/or mass spectral reference library. At this point, cognitive bias can occur if contextual information on drug use in the case circumstances (*e.g.*, prescriptions, evidence of drug use at the scene, *etc.*), or even test results from other sample types are known by the analyst. In this situation, a poor-quality chromatographic or mass spectral match for a drug could be consciously or subconsciously 'upgraded' to a positive result based on the expectation that the sample should be positive for that drug. Conversely, a similarly poor-quality match might be 'downgraded' [10] to negative if the analyst is not expecting the drug to be present, or its presence 'does not fit the circumstances of the case'. In both situations, the context could give the illusion of a stronger basis for the decision than is warranted by the data [29]. Such scenarios could therefore lead to cases being incorrectly reported, with serious consequences *e.g.*, in a death investigation for any medical professionals involved in the care of the deceased prior to death. The case circumstances at this stage are not relevant to the decisions being made (*i.e.,* that information is *task-irrelevant*), as these are scientific decisions that should be made on the basis of consistently applied scientific criteria (*e.g.,* retention time, mass spectrum similarity, ion ratios, *etc.* [30] – *i.e., task-relevant* information).

The final stage of the case is interpretation, which, in forensic toxicology, depends on the purpose of the analysis and the samples analysed. For example, in DUI cases, 'interpretation' may mean providing an explanation for any driver impairment witnessed or comparing test results to proscribed legal drug or alcohol limits. For workplace drug testing, 'interpretation' usually means reporting the presence or absence of one or more of a list of commonly used drugs at or above a specified concentration [31] (above the specified concentration the case is 'positive', below it is 'negative'). In DFSA cases, interpretation focusses on whether the complainant may have ingested one or more of a very wide range of sedative drugs [31]. In post-mortem forensic toxicology (the focus of this study) 'interpretation' involves discerning what substances, if any, the deceased used prior to their death. A toxicologist also considers whether the concentration of drug present is consistent with therapeutic or normal use, or whether drugs have possibly contributed to the cause of death [32]. As there are many factors that affect post-mortem toxicology interpretation, one set of test results may have several different possible explanations. During interpretation, whilst some background information is task-relevant (see section 4.1 for examples) contextual bias can incline a forensic toxicologist towards only one interpretation of test results. This interpretation is then reported to the customer, without making them aware of the other possible explanations. For example, there is overlap for some drugs between therapeutic and potentially fatal post-mortem concentrations. If a case concentration falls within this overlap range, and the background reports an accusation of deliberate poisoning of the deceased, a toxicologist may be inclined towards a 'fatal' interpretation over a 'therapeutic' interpretation.

As with other forensic disciplines, the methodology used in forensic toxicology can result in ambiguous data and subjectivity in decision-making, and toxicology cases are vulnerable to bias from the point of initial selection of tests to interpretation of the results. Statements such as the recent call for Courts to assess the measures taken by experts to mitigate bias [33], "make it increasingly difficult for forensic agencies and practitioners to simply ignore the potential for extraneous contextual information to have a biasing influence on their opinions." [[23], p. 226].

1.2. Bias-minimizing strategies

Following several high-profile erroneous forensic identifications where cognitive bias was a contributory factor [4], such as the Mayfield [34] and McKie [35] cases, approaches aimed at reducing the effect of bias have been suggested [19, 20, 23, 36-40]. These strategies are based on an understanding of the human tendency to interpret data in a manner that is consistent with one's expectations [41], and which aim to reduce prior expectations about a case by limiting examiners' access to information. They include context-information management (CIM) strategies [37] such as:

- *Working blind* or *blind testing*—where case information is concealed from the examiner that is conducting the tests [17];
- *Linear sequential unmasking*—which requires the latent or crime scene evidence to be examined in isolation before any reference material. A confidence level is specified, but this approach allows some changes to opinions to be made after the reference material is examined, if documented [36, 39, 42]; and
- *The context-manager model*—where another examiner known as the 'case manager' or 'context-manager' has access to all of the contextual information, but only passes onto the examiner the information that is relevant to the examination [19, 20, 37].

As well as other strategies such as:

- *Checklists*—for forensic report writing [38], which may reduce bias by forcing the examiner to focus only on information that is predicted to be most essential to the decision at hand [1]; and
- *Blind peer review*, *blind verification* or *double blind testing* —an independent check or secondary analysis where the checker does not have access to the case information or the original examiner's conclusions [23, 40]. This differs from a technical or administrative review [43] in that the examination is undertaken a second time, independently of the first.

Although a previous global study of forensic examiners and cognitive bias included responses from toxicologists, their responses were excluded from analysis due to low numbers [44]. In addition, no bias-minimizing or bias-reduction strategies have been published for general forensic toxicology casework.

1.3. Aim

Here, we address this knowledge gap by assessing the awareness of contextual bias and potential sources of contextual bias across an international group of forensic toxicologists. Our study also aims to highlight this issue and discuss aspects of forensic toxicology casework that are vulnerable to cognitive bias using the following main objectives:

1. Capture the contextual information reported to be used by forensic toxicologists when interpreting post-mortem toxicology results;
2. Survey the awareness forensic toxicologists on contextual bias;
3. Estimate the proportion of forensic toxicology laboratories that have taken steps to mitigate cognitive bias; and
4. Gather a list of possible bias-minimizing procedures from experts in the field.

2. Methods

2.1. Procedure

We used questionnaires to survey the use of contextual information in forensic toxicology and to assess awareness of contextual bias among practitioners. Early studies in cognitive forensics, such as those conducted by Miller [45, 46], Kerstholt *et al*. [16], and Dror *et al*. [47, 48] involved asking experts to carry out an examination with or without potentially biasing contextual information (see Cooper and Meterko [29] for a detailed review). Whilst this is a useful approach, behaviour can be influenced by different experimental conditions or by observation [49]. For example, some participants may 'figure out' the point of the experiment and change their behaviour out of a desire not to fall prey to an obvious attempt to identify bias [50] and thus give more socially desirable answers (*social desirability response bias* [51]). In addition, for laboratory-based disciplines such as forensic toxicology, it is difficult to re-create a realistic working environment in such experiments. There is also a great deal of variation in work conditions and practices across forensic toxicology laboratories, making it difficult to apply the results of such experiments more generally [7]. The current study did not aim to measure error rates (there are not always 'correct' or 'incorrect' interpretations of toxicological findings), but rather to examine the experiences and opinions of examiners. We therefore used a questionnaire-based design.

2.2. Participants

We collected data from delegates attending the 54th conference of The International Association of Forensic Toxicologists (TIAFT), which took place in Brisbane, Australia from 28 August to 1 September 2016. Five-hundred and ten delegates from 46 countries attended. We approached a random opportunity sample of delegates during the conference and recruited only those who had a reporting role, specifically reporting post-mortem results, and excluded those whose role did not involve routine casework interpretation (*e.g*., analytical scientists, graduate students, researchers and senior managers) or who were involved in limited types of forensic toxicology testing in their laboratory (*e.g.*, only workplace drug testing). In total, thirty-six participants from 23 different countries participated (see Fig. 1 for a map of the countries represented). Some countries were represented by more than one participant (Australia: n = 5, UK: n = 4, USA: n = 3, and Brazil, Germany, New Zealand, South Korea: n = 2). We did not collect data on other demographic characteristics such as age or sex/gender, which have not yet been shown to play an important role in cognitive forensic studies.

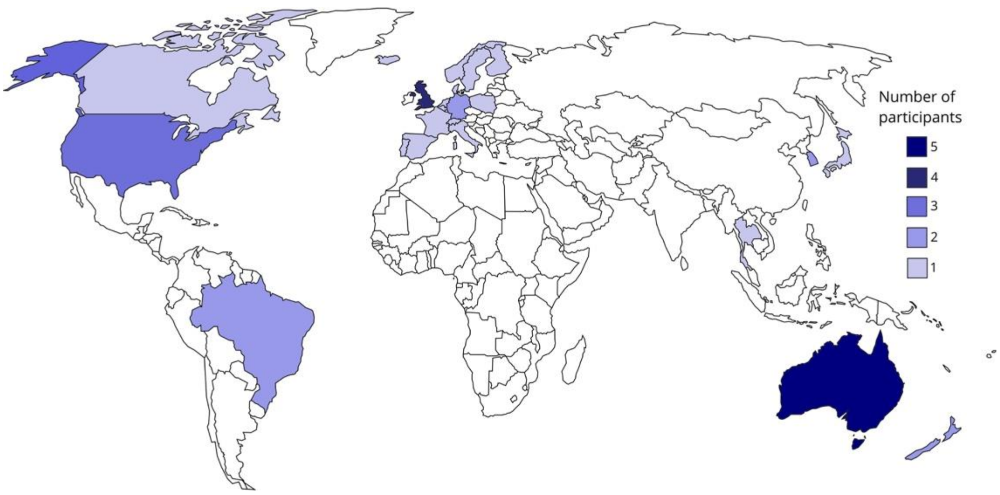

Fig. 1. Location of the laboratories where participants worked. Shading indicates the number of participants from each country.

2.3. Materials

Prior to testing, we gave each potential participant a Participant Information Sheet that detailed the task involved and gave each potential participant the opportunity to ask questions. Those who met the inclusion criteria and were willing to participate then signed an informed consent form before participating in the task. In the first part of the study, we asked participants to read a set of simple post-mortem toxicology results (see Box 1) and then indicate what information they would normally use to interpret these results in their day-to-day casework. Participants could select from a list of options and/or provide examples freely. These options were not intended to be exhaustive and included the most common types of information received by forensic toxicologists, according to the first author's professional experience. On finishing the first task, participants then completed a questionnaire on contextual bias (see Box 2). We ordered the tasks in this way to minimize lack of participant naïveté to the purpose of the study while completing the first part. Specifically, the first question in the questionnaire surveyed general familiarity with contextual bias, with two further questions (Q2 and Q4) designed to test understanding and knowledge of this concept. We defined 'contextual bias' in Box 2 to ensure clarity across all participants on the concept being examined in the questionnaire before they responded, to control for any inconsistent use of terminology within cognitive forensics [52]. Questions 3, 5 and 6 recognise that most forensic toxicologists work within quality-controlled environments and were designed to capture the procedures and processes in place in laboratories. As some participants may have been the only representative of a national forensic laboratory at the conference (and hence identifiable), supplying their country was optional (however, all participants did complete this section). We collected all data in paper format and manually transferred the data to MS Excel for later analysis. Before collecting data from participants, we collected pilot data from two forensic toxicologists on the application and use of the scenario and questionnaire and later refined each based on their responses.

Box 1. The Scenario

Following full drug and alcohol analysis in a post-mortem case, the toxicology results in preserved femoral whole blood were:

(Free) morphine: 0.15 mg/L
Codeine: 0.09 mg/L

No other drugs or alcohol were detected.

Please indicate below what information about this case you would NORMALLY use to interpret these results in your day-to-day casework. Please TICK (✓) as many options as you deem necessary.

- ☐ No case information required
- Circumstances of the death:
  - ☐ Date
  - ☐ Time
  - ☐ Location
  - ☐ A description of the scene
  - ☐ A post-mortem/autopsy report
- Personal details about the deceased:
  - ☐ Age
  - ☐ Profession
  - ☐ Sex
  - ☐ Ethnicity
  - ☐ Personal relationships
  - ☐ Recent periods spent in custody
- Medical information on the deceased:
  - ☐ Medications prescribed
  - ☐ Emergency medical treatment received
  - ☐ Medical history, such as pre-existing disease
  - ☐ History of illicit drug use
- Other *(please specify and continue overleaf if necessary)*

____

____

Box 2. The Questionnaire

"Contextual bias" can occur when a forensic scientist is given information about a case that can subconsciously affect their interpretation of test results.

Question	Yes	No	Not sure
1. Are you familiar with this concept?			
2. Would you feel comfortable explaining it to another forensic toxicologist?			
3. Does your laboratory have a policy on contextual bias?			
4. Have you received any information on contextual bias? *e.g.*, attended a seminar.			
5. Are you aware of any bias-minimizing procedures that would be suitable for forensic toxicology casework? *If Yes, please describe below*			
6. Does your laboratory use any of these? *If Yes, please describe below*			

Please give the following information:

Years of experience as a reporting forensic toxicologist ______

Country where your laboratory is based ____ (optional)

Country where you were trained (if different to above) ______________________________________

3. Results

3.1. Data analysis

Experiences influence our memories and conceptualizations, which can result in biased or inaccurate opinions [53], and a previous study investigated whether forensic examiners differ in their beliefs about bias as a function of their experience [44]. Therefore we first examined the data collected from the questionnaire for any correlation between years of forensic toxicology experience and response ('Yes,' 'No' or 'Not sure') to Q1, Q2, Q4 and Q5. A linear model was fitted using R to predict years of experience based on response. We also analyzed data from the scenario according to the number and types of contextual information used during interpretation and the bias-minimizing strategies suggested. We did not analyse the data stratified by country due to small sampled sizes per country.

3.2. Forensic toxicology experience

The number of years of experience as a reporting forensic toxicologist of the participants ranged from 1–35 years (median $\pm$ SD = 12.5 $\pm$ 8.9 years), see Fig. 2 for the distribution. Here, we found no correlation (p = 0.9844) between years of experience as a forensic toxicologist and response to any of Q1, Q2, Q4 or Q5, although it should be noted that the sample size is small. We excluded Q3 and Q6 from this analysis because they focussed on the laboratory rather than the individual examiner.

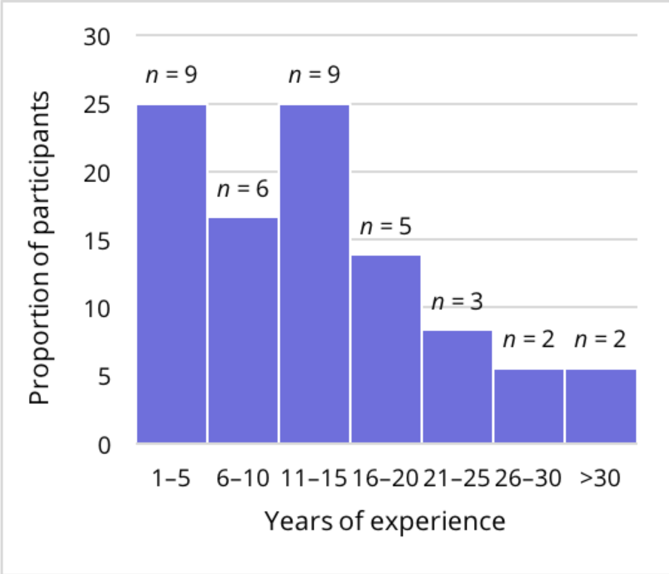

Fig. 2. Distribution of years of experience as reporting forensic toxicologists across participants.

3.3. Scenario responses

Fig. 3 shows the proportion of participants who reported using different types of information (see Box 1) to interpret the post-mortem forensic toxicology results. The number of pieces of information used ranged from 3–15 (median $\pm$ SD = 11 $\pm$ 3) with only two participants (6%) stating that they used no information during interpretation, because their submitting authorities did not provide any. The most common pieces of background information used were medications prescribed to the deceased (*n* = 31, 86%), and history of illicit drug use (*n* = 30, 83%), followed by a description of the scene, and emergency medical treatment received by the deceased (both *n* = 29, 81%).

We also asked participants to provide any additional information not listed in Box 1, which they would routinely use to interpret post-mortem forensic toxicology results. These are listed in the appendix.

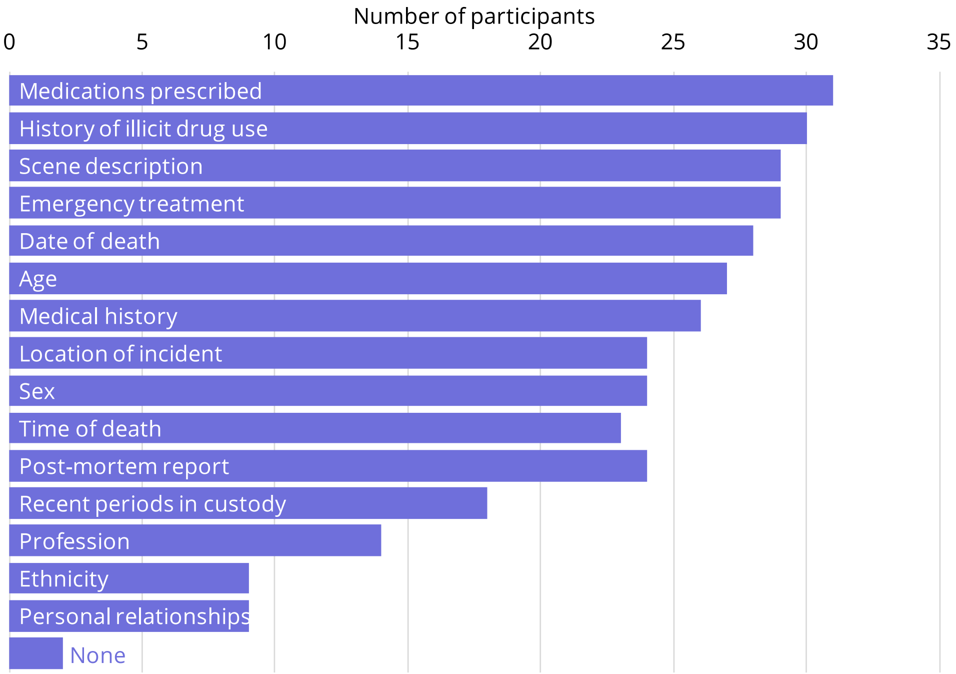

Fig. 3. Information that participants reported to use when interpreting the post-mortem forensic toxicology results.

3.4. Questionnaire responses

In the second part of the study, we administered a questionnaire to assess the general level of familiarity with contextual bias among forensic toxicologists, and to capture any suggested bias-minimizing procedures. Fig. 4 shows the results. Most participants (*n* = 30, 83%) reported being familiar with the concept of contextual bias, with six participants either not sure or stating no familiarity with the concept. Most participants (78%, *n* = 28) also understood the concept to the extent that they would feel comfortable explaining it to another forensic toxicologist. Just over half of participants (53%, *n* = 19) had received information on contextual bias from a formal source such as a seminar, with the other participants having either received no information (8%, *n* = 3), or having obtained information informally from books or journal articles. A minority group of participants (14%, *n* = 5) stated that their laboratory had a policy on contextual bias, with most participants (61%, *n* = 22) stating that no policy existed, and 25% (*n* = 9) responding 'Not sure'. Over half of participants (56%, *n* = 20) knew of one or more bias-minimizing procedure(s) that could potentially be applied to forensic toxicology casework (but were not necessarily in use in their laboratories). These are listed in Table 1. We broadly categorized responses to this question into procedures that affect laboratory work, and those that affect interpretation. Note that multiple participants suggested the same procedure, with the most common being anonymization of case samples. One quarter of participants (25%, *n* = 9) reported actually using bias-minimizing procedures in their laboratory routinely. One participant stated on the questionnaire that debate about contextual bias was ongoing in their place of work.

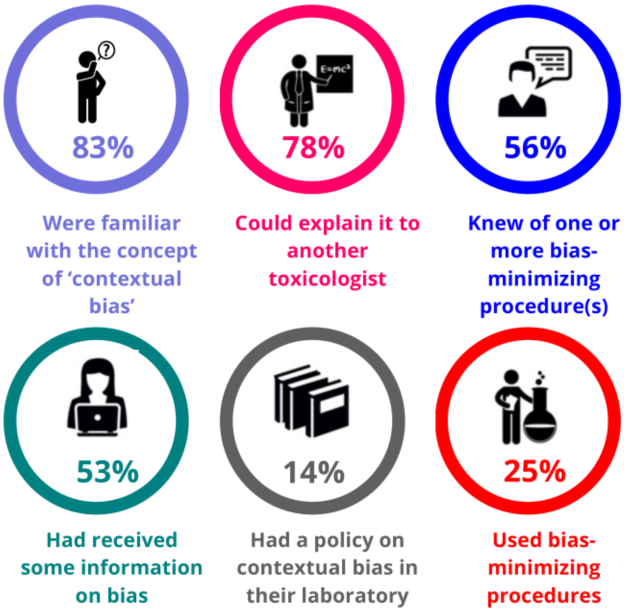

Fig. 4. Proportion of participants responding 'Yes' to Q1–Q6 of the questionnaire.

Two of the participants expressed the view orally during the study or in writing on the scenario, that they were not affected by bias, or that such biases did not exist.

Table 1

Responses to Q5 in Box 2 on bias-minimizing procedures that could be applied to forensic toxicology casework.

Procedures for interpretation
Not to use any background or personal information about the case
Restrict access to background on a case-by-case basis
Consult colleagues with less knowledge of the case – *ad hoc* or regularly
Stay away from information on the case in the media (internet/TV)
Try to interpret with only minimal information first *e.g.*, age and gender only
Basic procedures used in other pattern evidence fields
To state what contextual information you have received
Peer review without referring to the case circumstances
Keep to statements that can be supported by scientific evidence (*e.g.*, published data, own studies)
Procedures for the laboratory
Use of anonymized samples – names replaced with barcodes or numbers
Contextual information concealed† until testing is complete
Analysts are unaware of the circumstances in the case
Use of strict criteria for identifying a compound
Use of a robust quality assurance program

†from laboratory analysts.

4. Discussion

Our study aimed to explore the extent of familiarity with contextual bias among forensic toxicologists, to capture the use of potentially biasing information in the interpretation of toxicology results, and gather examples of potential bias-minimizing strategies specifically for toxicology casework. Working with an international sample of participants, we collected data on the reported use of contextual information during interpretation with a scenario, and surveyed forensic toxicologists' familiarity with contextual bias using a questionnaire.

It is important to note that the impact of cognitive bias on any particular case is larger when the evidence is more difficult to assess [54]. In simple cases, such as DUI of alcohol, where the alcohol concentration is compared to a proscribed limit, the data usually speaks for itself; it is the more difficult cases, where the evidence is borderline, ambiguous [17] or inconclusive, or where samples are of poor quality [48], that cognitive bias could be most problematic. A recent study also showed that cognitive bias is more apparent when forensic examinations are carried out under time pressure [55]—a reality in many forensic laboratories, where backlogs are common [56]—when examiners might inadvertently fall back on automatic decision-making. Another important consideration is that cognitive bias does not necessarily result in an incorrect interpretation of test results [57].

4.1. Use of contextual information

The vast majority (94%) of participants reported using some contextual information in their interpretation of the post-mortem toxicology results. It should be noted that not all contextual information will lead to cognitive bias because, as mentioned in section 1.1, some information is task-relevant to interpretation. For example, the most common pieces of background information used were the drug and medication history of the deceased, which may be useful when considering factors such as tolerance and acute *vs*. chronic use of drugs; the same concentration of methadone (an opioid substitution drug) could be interpreted as consistent with fatal overdose in a drug-naïve individual, but consistent with therapeutic use in a chronic (long-term) user [58]. The next most commonly reported piece of information used was emergency medical treatment received by the deceased, which may be useful in excluding drugs administered in trauma cases, such as morphine, ketamine and midazolam, from interpretation. If ante-mortem hospital blood samples taken during treatment are submitted for analysis, the date and time these were taken is also important for both case strategy and interpretation. Emergency medical treatment was equally prevalent with a description of the scene. Whilst a description of the scene can be useful in determining which tests are appropriate (*e.g.*, in the case of empty medication packets), it can also reveal information that is potentially biasing during interpretation (*e.g*., the presence or absence of drug paraphernalia such as syringes, needles, burned foil, *etc*.). This can lead to only one possible explanation of test results being reported to the customer, when in fact there are several. The wide variation in what or how much contextual information is being used during interpretation may be caused chiefly by what information is received from the submitting authority, rather than by individual expert preferences. The training system and management structure (*e.g.*, opinions of the most senior staff) of laboratories often also play a role in how results are interpreted.

4.2. Familiarity with contextual bias

The majority of participants reported that they were familiar with the concept of contextual bias. In a previous global study across different forensic disciplines that also used a survey design, many examiners had only a limited appreciation of cognitive bias, or saw themselves as impervious to it [44]. Occasionally "some in the forensic community respond in a defensive manner whenever the potential of context influencing decision-making is discussed" [[59], p. 1598], and two participants in this study fell into this category. Cognitive bias has been demonstrated as a potential issue across most forensic disciplines, and experts may be unaware that contextual information is influencing their judgements [60].

4.3. Bias-minimizing strategies

Awareness of bias is necessary in order to avoid what is known as the *bias blind spot*, where people perceive themselves as being less susceptible to bias than others [61]. However, awareness alone is not sufficient to reduce bias: active steps must be taken to address cognitive bias [57]. No single de-biasing strategy has emerged from the literature as being universally applicable [62], therefore, this study aimed to produce a list of bias-minimizing strategies for potential use in forensic toxicology laboratories. We did not record any suggested strategies for minimizing bias when requesting screening tests for a case. However, the move in some laboratories away from multiple drug-specific tests towards a single screening method for 100+ drugs of abuse and prescription/over-the-counter medications by liquid chromatography-mass spectrometry (LC-MS) [63] to be used as standard in all cases will naturally reduce test choices based on expectations. In laboratories where this is not in place, one option is to justify the choice of screening tests in the casefile, because, as Osborne *et al.* [64] discuss, accountability may lead to more cautious and informed decision-making. It should be noted that in some jurisdictions the choice of tests is decided by the submitting authority rather than the receiving laboratory, and may be limited by financial considerations or other local conditions.

At the point of screening, anonymization of samples and/or restriction of background information from analysts, as well as having strict scientific criteria for identification of a drug can help to minimize ambiguous or poor-quality chromatographic/spectral matches being deemed positive based on contextual bias. Applying the criteria consistently, and resisting the urge to 'bend the rules', should also prevent the converse situation, known as *selective attention to evidence* [21], where good-quality matches are deemed negative or ignored.

In terms of case interpretation, several participants suggested limiting the availability of background information to the person writing the expert report (the *reporting toxicologist*). However, because of the targeted nature of many forensic toxicology tests (*e.g.*, volatile solvents in 'glue sniffing' cases), which are often only carried out if the substance is indicated in the case information, the presence of such test results can reveal much of the background to the reporting toxicologist anyway. Contextual information regarding high-profile and well-publicised cases may also be difficult to avoid [23]. In addition, some contextual information is task-relevant during interpretation, and forensic toxicology professional membership organisations advise that some background information is necessary in order to produce a scientifically sound interpretation [30, 65]. Certain toxicologists also use the term *investigative forensic toxicology* where all sources of information in a case are consciously used and correlated with test results [26]. We propose therefore that contextual information not be disregarded completely during interpretation, but that forensic toxicologists should be cognizant that this information will likely be weighed again by the trier of fact, and it is therefore easy for evidence (*e.g.*, signs of intravenous drug use) to be counted multiple times [54]. This phenomenon is known as *double counting* of evidence [66], *double impact* [5] or the *bias snowball* [67], and means that those using the information to form a judgement (*e.g.*, jurors) may believe they are receiving two independent pieces of evidence, and thus give them more weight than they should [66]. In some cases, the contextual information used by the forensic toxicologist during interpretation might be unreliable. For example, evidence of illicit drug use may be removed from a scene before the authorities are informed of the death. In others, the background information may be incomplete or inaccurate, *e.g.*, out-of-date medical records. The case information passed to toxicology laboratories is often that collected during the very early stages of an investigation and can therefore be liable to change as the case develops, without new information necessarily being passed onto the toxicology laboratory. Furthermore, the context may be legally inadmissible (*e.g*., hearsay evidence that the deceased was a drug dealer), but this might not be apparent until there is an attempt to present such information as evidence in Court [68]. It is also important to note that the task of integrating multiple lines of evidence, or deciding what evidence is 'relevant' to a case is appropriate for the jury, judge or Coroner—not the scientific expert [69].

If contextual information is to be made available to the reporting toxicologist for interpretation, a more practical approach may be to introduce a *bias check* during the peer-review process. In this step, the case is reviewed by another reporting toxicologist who has not seen the case background. As with all peer review, the case should be presented to the reviewer with care, avoiding the impression that they should simply seek to confirm the existing interpretation [55], and any changes/disagreements should be noted in the casefile [70]. As reviewers may be influenced by their opinion of the report's author (including their position in the laboratory hierarchy, qualifications, experience or past performance), the process can be strengthened by rotating or randomizing peer reviewers and, if feasible, making the review blind (*i.e.*, the reviewer does not know the identity of the report's author) [57]. Another, related, procedure gathered from this study, is to have regular meetings to discuss cases with colleagues who are not familiar with the case circumstances. This may lead to alternative interpretations of the test results being suggested that the reporting toxicologist had not considered.

Toxicologists should also be open-minded to alternative explanations for test results [71, 72]. For example, in the scenario given in Box 1 the combination of codeine and morphine present in the blood could be a result of the use of both drugs, or a result of the use of heroin (codeine is often seen as a contaminant in street heroin and a high morphine-to-codeine ratio (>1) in blood has been suggested as a marker of heroin use in post-mortem cases [73]). A conservative interpretation would include both possible explanations, thus overcoming contextual bias, *e.g.*, 'the results are consistent with the use of heroin, or with the use of morphine and codeine'. If a toxicologist considers, but decides not to report an alternative explanation, for reasons such as brevity or simplicity, a note could be made in the casefile recording the decision.

Another possible reporting strategy is the use of models to interpret toxicological and circumstantial findings together *e.g*., for heroin-related deaths [74]. Such models enable contextual information to be used in an open and transparent way in case interpretation, and improve the consistency of decision-making [74]. One participant in this study suggested the use of a robust quality assurance (QA) programme as a bias-minimizing procedure (see Table

1), as has been suggested previously [75]. Whilst quality management systems exist to ensure certain quality standards are met, not all decisions made for a case will fall under the QA programme, and not all forensic toxicology laboratories are accredited. In addition, a previous study showed that DNA experts disagreed as to whether or not a suspect could have contributed to a DNA mixture, even when they worked in the same laboratory and followed the same procedures and protocols [69].

Finally, keeping to statements that can be justified with previously published or in-house data, rather than relying on case information, a 'hunch', or 'previous experience', should help forensic toxicologists to mitigate bias.

4.4. Limitations

There are some limitations to this study. Firstly, the sample size is small, which limits the extent to which the results can be generalized. As mentioned previously, not all countries with forensic toxicology laboratories are represented among the data, and the list of countries is limited to laboratories with the resources to send staff to a large international conference. This could mean that the current study did not capture other practices used in smaller, less-well-funded, or more remote laboratories. Although the aim of using an international sample in this study was simply to capture as wide a range of practices as possible, *country* could be a significant source of variation with respect to the potential for cognitive bias and is worthy of more in-depth investigation. Secondly, the case scenario results may not have represented some laboratories' typical casework because the example case involved a single, relatively simple case of a deceased individual. We should therefore be cautious about generalizing the results of the study to the casework context. However, the purpose of the scenario was not to create an exact replica of a forensic toxicology case, but to set the scene before asking the participants about interpretation. Thirdly, biases may be introduced into a forensic toxicology case before it is even submitted to the laboratory. For example, police officers and pathologists can introduce bias with their requests and word choice in the paperwork accompanying samples, or even by their very decision to submit samples [76]. Police and prosecutors also sometimes respond to 'non-supportive' test results by requesting a re-examination [11]. However, investigative outcomes must never be a consideration for any forensic scientist [77].

It should be noted that the bias-minimizing procedures outlined in this paper were suggestions from experts in the field, based on their casework experience and on procedures used in other forensic disciplines. They were not derived from empirical data and have not, to the authors' knowledge, been formally tested in forensic toxicology. Some may be unwieldy and would require a cognitively informed risk assessment [57], adaptation to workflow processes, as well as additional resources [7], which are challenging for many high-throughput laboratories at a time when backlogs are growing [60]. Finally, introducing bias-minimizing strategies to a laboratory will not guarantee that forensic toxicology results are error-free.

Future work in this area could involve a larger study of forensic toxicologists using a web-based collection method in order to capture responses from a wider range of participants. This would enable the capture of an extended range of practices, including those from laboratories that are not usually represented at international conferences.

Other potentially relevant factors to examine, as mentioned earlier, could include the country/region, and the age, and sex/gender of the toxicologist and asking toxicologists to define bias concepts to examine variance in the concepts used across groups. The number of cases reported and times testifying in Court may also be relevant, as some forensic scientists have argued that their casework training and expertise render them immune to bias [44]. The nature of any bias training received (*e.g.*, group seminar *vs*. individual reading) may influence understanding of cognitive bias, and, if accreditation includes the requirement for a policy on cognitive bias and/or strict interpretation procedures, this may reduce the effect of cognitive bias on casework.

5. Conclusions

Here, we explored the reported use of contextual information by forensic toxicologists during interpretation of a set of simple test results in a single case of a deceased individual. The majority of forensic toxicologists participating in our study reported using some potentially biasing contextual information in their interpretation of the results. Participants also showed a high level of familiarity with the concept of contextual bias among toxicologists, although few reported using bias-minimizing policies or procedures in their day-to-day casework. To address this, we also gathered a list of bias-minimizing procedures suggested by experts in the field. We anticipate that these results will provide forensic toxicologists with an opportunity to critically examine their practices and workflow, and make improvements where applicable [57], enabling them to demonstrate to the Court that steps have been taken to reduce the potential for bias in their casework [23].

Declarations of interest: none

Appendix: additional information used for interpretation from the scenario

If it is a death with a putrefied cadaver
Interval between the death and the date of autopsy
Conversation with pathologist
It is imperative that the toxicological interpretations not be performed in a vacuum. It should be done based on a preponderance of the available information
Information from police report
All info available. Not all info would necessarily be required
I wish to have more information about case[s] but mostly I do not have
The type of case: if it is a roadside or labour control?
Full access (in non-high-profile cases) to autopsy and investigation reports
Death circumstances

Acknowledgements

The authors would like to thank the organising committee of the TIAFT 2016 conference for allowing this research to be conducted. HJH would like to thank the forensic toxicologists at ESR in New Zealand and the participants at the

Chartered Society of Forensic Sciences Bias Matters event in September 2016 for useful discussions. We also thank Duncan Garmonsway of the UK Government Digital Service for statistical advice. Dr Sarah Russell of ESR, and Katherine Smith and Steven Baginski of Imperial College London are acknowledged for their comments on the manuscript. The two anonymous referees are acknowledged for their useful comments on the manuscript.

The study was approved by the University of Glasgow, Medical, Veterinary & Life Sciences Ethics Committee (project number 200150170).

References

[1] J.J. Lockhart, S. Satya-Murti, Diagnosing crime and diagnosing disease: bias reduction strategies in the forensic and clinical sciences, J. Forensic Sci., 62 (2017) 1534–1541.

[2] N. Osborne, Commentary on: Lockhart JJ, Satya-murti S. Diagnosing crime and diagnosing disease: bias reduction strategies in the forensic and clinical sciences. J Forensic Sci https://doi.org/10.1111/1556-4029.13453. Epub 2017 Feb 23, J. Forensic Sci., 62 (2017) 1423–1424.

[3] I.E. Dror, R.D. Stoel, Cognitive forensics: human cognition, contextual information, and bias, in: G. Bruinsma, D. Weisburd (Eds.), Encyclopedia of Criminology and Criminal Justice, SPRINGER, New York, 2014, pp. 353–363.

[4] R.D. Stoel, I.E. Dror, L.S. Miller, Bias among forensic document examiners: still a need for procedural changes, Aust. J. Forensic Sci., 46 (2014) 91–97.

[5] M.J. Saks, D.M. Risinger, R. Rosenthal, W.C. Thompson, Context effects in forensic science: a review and application of the science of science to crime laboratory practice in the United States, Sci. Justice, 43 (2003) 77–90.

[6] A. Tversky, D. Kahneman, Judgment under uncertainty: heuristics and biases, Science, 185 (1974) 1124–1131.

[7] R.A. Searston, J.M. Tangen, K.W. Eva, Putting bias into context: the role of familiarity in identification, Law Hum. Behav., 40 (2016) 50–64.

[8] G. Edmond, J.M. Tangen, R.A. Searston, I.E. Dror, Contextual bias and cross-contamination in the forensic sciences: the corrosive implications for investigations, plea bargains, trials and appeals, Law Probab. Risk, 14 (2014) 1–25.

[9] G. Edmond, A. Towler, B. Growns, G. Ribeiro, B. Found, D. White, K. Ballantyne, R.A. Searston, M.B. Thompson, J.M. Tangen, R.I. Kemp, K. Martire, Thinking forensics: cognitive science for forensic practitioners, Sci. Justice, 57 (2017) 144–154.

[10] Forensic Science Regulator, Cognitive bias effects relevant to forensic science examinations FSR, 2015.

[11] S.M. Kassin, I.E. Dror, J. Kukucka, The forensic confirmation bias: problems, perspectives, and proposed solutions, J. Appl. Res. Mem. Cognit., 2 (2013) 42–52.

[12] I. Dror, R. Rosenthal, Meta-analytically quantifying the reliability and biasability of forensic experts, J. Forensic Sci., 53 (2008) 900–903.

[13] S. Waite, J. Scott, B. Gale, T. Fuchs, S. Kolla, D. Reede, Interpretive error in radiology, Am. J. Roentgenol., 208 (2016) 739–749.

[14] M. Page, J. Taylor, M. Blenkin, Context effects and observer bias—implications for forensic odontology, J. Forensic Sci., 57 (2012) 108–112.

[15] J. Siegel, A survey of ethical issues in the forensic sciences, in: K.J. Strom, M.J. Hickman (Eds.), Forensic Science and the Administration of Justice, SAGE, Thousand Oaks, 2015, pp. 87–98.

[16] J. Kerstholt, A. Eikelboom, T. Dijkman, R. Stoel, R. Hermsen, B. van Leuven, Does suggestive information cause a confirmation bias in bullet comparisons?, Forensic Sci. Int., 198 (2010) 138–142.

[17] D.M. Risinger, M.J. Saks, W.C. Thompson, R. Rosenthal, The Daubert/Kumho implications of observer effects in forensic science: hidden problems of expectation and suggestion, Calif. Law Rev., 90 (2002) 1–56.

[18] J.S. Byrd, Confirmation bias, ethics, and mistakes in forensics J. Forensic Identif., 56 (2006) 511–525.

[19] I.E. Dror, Practical solutions to cognitive and human factor challenges in forensic science, Forensic Sci. Policy Manage. Int. J., 4 (2013) 105–113.

[20] B. Found, J. Ganas, The management of domain irrelevant context information in forensic handwriting examination casework, Sci. Justice, 53 (2013) 154–158.

[21] S. Nakhaeizadeh, I.E. Dror, R.M. Morgan, Cognitive bias in forensic anthropology: visual assessment of skeletal remains is susceptible to confirmation bias, Sci. Justice, 54 (2014) 208–214.

[22] National Academy of Sciences, Strengthening forensic science in the United States: a path forward, THE NATIONAL ACADEMIES PRESS, 2009.

[23] N.K.P. Osborne, M.C. Taylor, Contextual information management: an example of independent-checking in the review of laboratory-based bloodstain pattern analysis, Sci. Justice, 58 (2018) 226–231.

[24] B.T. Ulery, R.A. Hicklin, M.A. Roberts, J. Buscaglia, Changes in latent fingerprint examiners' markup between analysis and comparison, Forensic Sci. Int., 247 (2015) 54–61.

[25] O.H. Drummer, Forensic pharmacology and toxicology, in: I. Freckelton, H. Selby (Eds.), Expert Evidence: Law Practice Procedure & Advocacy, THOMSON REUTERS, Pyrmon, NSW, 2009.

[26] E.E. Walsh, E.N. Shoff, M.E. Zaney, G.W. Hime, F. Garavan, D.M. Boland, To test or not to test?: the value of toxicology in a delayed overdose death, J. Forensic Sci., 64 (2019) 314–317.

[27] Parliamentary Office of Science & Technology, Unintentional bias in forensic investigation, POST, 2015.

[28] R. Rao, A. Roche, Substance misuse in older people, Br. Med. J., 358 (2017) j3885.

[29] G.S. Cooper, V. Meterko, Cognitive bias research in forensic science: a systematic review, Forensic Sci. Int., (in press) (2019).

[30] S.P. Elliott, D.W.S. Stephen, S. Paterson, The United Kingdom and Ireland association of forensic toxicologists forensic toxicology laboratory guidelines (2018), Sci. Justice, 58 (2018) 335–345.

[31] C.N. Chatterton, G.R. Jones, Interpretative aspects of toxicological results, in: O.H. Drummer, D. Gerostamoulos (Eds.), Forensic Drug Analysis, FUTURE MEDICINE, London, 2013, pp. 110–123.

[32] R.W. Byard, D.M. Butzbach, Issues in the interpretation of postmortem toxicology, Forensic Sci. Med. Pathol., 8 (2012) 205–207.

[33] President's Council of Advisors on Science and Technology, Forensic science in criminal courts: ensuring scientific validity of feature-comparison methods, EXECUTIVE OFFICE OF THE PRESIDENT, 2016.

[34] Office of Inspector General, A review of the FBI's handing of the Brandon Mayfield case, OIG, 2006.

[35] The Fingerprint Inquiry, The Fingerprint Inquiry Report, APS GROUP SCOTLAND, 2011.

[36] I.E. Dror, W.C. Thompson, C.A. Meissner, I. Kornfield, D. Krane, M. Saks, M. Risinger, Letter to the Editor—Context Management Toolbox: a linear sequential unmasking (LSU) approach for minimizing cognitive bias in forensic decision making, J. Forensic Sci., 60 (2015) 1111–1112.

[37] E.J.A.T. Mattijssen, W. Kerkhoff, C.E.H. Berger, I.E. Dror, R.D. Stoel, Implementing context information management in forensic casework: minimizing contextual bias in firearms examination, Sci. Justice, 56 (2016) 113–122.

[38] P.H. Witt, Forensic report checklist, Open Access J. Forensic Psychol., 2 (2010) 233–240.

[39] D.E. Krane, S. Ford, J.R. Gilder, K. Inman, A. Jamieson, R. Koppl, I.L. Kornfield, D.M. Risinger, N. Rudin, M.S. Taylor, W.C. Thompson, Sequential unmasking: a means of minimizing observer effects in forensic DNA interpretation, J. Forensic Sci., 53 (2008) 1006–1007.

[40] W. Kerkhoff, R.D. Stoel, C.E.H. Berger, E.J.A.T. Mattijssen, R. Hermsen, N. Smits, H.J.J. Hardy, Design and results of an exploratory double blind testing program in firearms examination, Sci. Justice, 55 (2015) 514–519.

[41] R. Rosenthal, Experimenter effects in behavioral research, APPLETON-CENTURY-CROFTS, New York, 1966.

[42] I.E. Dror, A.E. Péron, S.-L. Hind, D. Charlton, When emotions get the better of us: the effect of contextual top-down processing on matching fingerprints, Appl. Cognit. Psychol., 19 (2005) 799–809.

[43] K.N. Ballantyne, G. Edmond, B. Found, Peer review in forensic science, Forensic Sci. Int., 277 (2017) 66–76.

[44] J. Kukucka, S.M. Kassin, P.A. Zapf, I.E. Dror, Cognitive bias and blindness: a global survey of forensic science examiners, J. Appl. Res. Mem. Cogn., 6 (2017) 452–459.

[45] L.S. Miller, Procedural bias in forensic science examinations of human hair, Law Hum. Behav., 11 (1987) 157–163.

[46] L.S. Miller, Bias among forensic document examiners: a need for procedural change, J. Police Sci. Admin., 12 (1984) 407–411.

[47] I.E. Dror, G. Hampikian, Subjectivity and bias in forensic DNA mixture interpretation, Sci. Justice, 51 (2011) 204–208.

[48] I.E. Dror, D. Charlton, A.E. Péron, Contextual information renders experts vulnerable to making erroneous identifications, Forensic Sci. Int., 156 (2006) 74–78.

[49] I.E. Dror, S.A. Cole, The vision in "blind" justice: expert perception, judgment, and visual cognition in forensic pattern recognition, Psychon. Bull. Rev., 17 (2010) 161–167.

[50] D.M. Risinger, The NAS/NRC report on forensic science: a glass nine-tenths full (this is about the other tenth), Jurimetrics, 50 (2009) 21–34.

[51] P. Grimm, Social desirability bias, in: J.N. Sheth, N. Malhotra (Eds.), Wiley International Encyclopedia of Marketing, WILEY, New York, 2010.

[52] S. Satya-Murti, J.J. Lockhart, Needed: consensus and classification for terms used in cognitive, forensic and clinical bias discussions, Forensic Sci. Int., 293 (2018) e10–e11.

[53] P.A. Zapf, I.E. Dror, Understanding and mitigating bias in forensic evaluation: lessons from forensic science, Int. J. Forensic Mental Health, 16 (2017) 227–238.

[54] R. Stoel, C.E.H. Berger, W. Kerkhoff, E.J.A.T. Mattijssen, I.E. Dror, Minimizing contextual bias in forensic casework, in: K.J. Strom, M.J. Hickman (Eds.), Forensic Science and the Administration of Justice, SAGE, Thousand Oaks, 2015, pp. 67–86.

[55] S.V. Stevenage, A. Bennett, A biased opinion: demonstration of cognitive bias on a fingerprint matching task through knowledge of DNA test results, Forensic Sci. Int., 276 (2017) 93–106.

[56] A.K. Jain, J. Feng, Latent fingerprint matching, IEEE Trans. Pattern Anal. Mach. Intell., 33 (2011) 88–100.

[57] A.M. Jeanguenat, B. Budowle, I.E. Dror, Strengthening forensic DNA decision making through a better understanding of the influence of cognitive bias, Sci. Justice, 57 (2017) 415–420.

[58] A.W. Jones, A. Holmgren, J. Ahlner, Blood methadone concentrations in living and deceased persons: variations over time, subject demographics, and relevance of coingested drugs, J. Anal. Toxicol., 36 (2012) 12–18.

[59] R.M. Morgan, S. Nakhaeizadeh, C. Rando, I.E. Dror, Authors' response on research into contextual influences and forensic decision making, J. Forensic Sci., 63 (2018) 1598–1600.

[60] G. Langenburg, Addressing potential observer effects in forensic science: a perspective from a forensic scientist who uses linear sequential unmasking techniques, Aust. J. Forensic Sci., 49 (2017) 548–563.

[61] E. Pronin, M.B. Kugler, Valuing thoughts, ignoring behavior: the introspection illusion as a source of the bias blind spot, J. Exp. Soc. Psychol., 43 (2007) 565–578.

[62] S. Satya-Murti, J.J. Lockhart, Diagnosing crime and diagnosing disease-II: visual pattern perception and diagnostic accuracy, J. Forensic Sci., 63 (2018) 1429–1434.

[63] M. Di Rago, E. Saar, L.N. Rodda, S. Turfus, A. Kotsos, D. Gerostamoulos, O.H. Drummer, Fast targeted analysis of 132 acidic and neutral drugs and poisons in whole blood using LC–MS/MS, Forensic Sci. Int., 243 (2014) 35–43.

[64] N.K.P. Osborne, S. Woods, J. Kieser, R. Zajac, Does contextual information bias bitemark comparisons?, Sci. Justice, 54 (2014) 267–273.

[65] Society of Forensic Toxicologists Inc., American Academy of Forensic Sciences Toxicology Section, SOFT/AAFS Forensic Toxicology Guidelines, SOFT/AAFS, 2006.

[66] W.C. Thompson, What role should investigative facts play in the evaluation of scientific evidence?, Aust. J. Forensic Sci., 43 (2011) 123–134.

[67] I.E. Dror, Biases in forensic experts, Science, 360 (2018) 243.

[68] A. Quigley-McBride, G.L. Wells, Fillers can help control for contextual bias in forensic comparison tasks, Law Hum. Behav., 24 (2018) 295–305.

[69] I.E. Dror, J. Kukucka, S.M. Kassin, P.A. Zapf, When expert decision making goes wrong: consensus, bias, the role of experts, and accuracy, J. Appl. Res. Mem. Cogn., 7 (2018) 162–163.

[70] H.J. Hamnett, A.E. McKie, Developing a procedure for learning and assessing peer review in a forensic science programme, Assess. Eval. Higher Educ., (in press) (2018).

[71] D.C. Burns, When used in the criminal legal process forensic science shows a bias in favour of the prosecution. Discuss, Sci. Justice, 41 (2001) 271–277.

[72] C.A.J. van den Eeden, C.J. de Poot, P.J. van Koppen, The forensic confirmation bias: a comparison between experts and novices, J. Forensic Sci., 62 (2018) 120–126.

[73] S.V. Konstantinova, P.T. Normann, M. Arnestad, R. Karinen, A.S. Christophersen, J. Mørland, Morphine to codeine concentration ratio in blood and urine as a marker of illicit heroin use in forensic autopsy samples, Forensic Sci. Int., 217 (2012) 216–221.

[74] N.C. Stam, D. Gerostamoulos, P.M. Dietze, S. Parsons, K. Smith, B. Lloyd, J.L. Pilgrim, The attribution of a death to heroin: a model to help improve the consistent and transparent classification and reporting of heroin-related deaths, Forensic Sci. Int., 281 (2017) 18–28.

[75] B. Budowle, M.C. Bottrell, S.G. Bunch, R. Fram, D. Harrison, S. Meagher, C.T. Oien, P.E. Peterson, D.P. Seiger, M.B. Smith, M.A. Smrz, G.L. Soltis, R.B. Stacey, A perspective on errors, bias, and interpretation in the forensic sciences and direction for continuing advancement, J. Forensic Sci., 54 (2009) 798–809.

[76] G. Whitman, R. Koppl, Rational bias in forensic science, Law Probab. Risk, 9 (2010) 69–90.

[77] G. Tully, Forensic science in England & Wales, a commentary, Forensic Sci. Int., 290 (2018) e29–e31.