Running Head: Is bias beneficial?

Title: **Assessing cognitive bias in forensic decisions: A review and outlook.**

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ABSTRACT

In recent years, a number of studies have demonstrated that forensic examiners can be biased by task-irrelevant contextual information. However, concerns relating to methodological flaws and ecological validity attenuate how much the current body of knowledge can be applied to real-life operational settings. The current review takes a narrative approach to synthesising the literature across forensic science. Further, the review considers three main issues: 1) primary research on contextual bias within forensic science; 2) methodological criticisms of this research; 3) an alternative perspective that task-irrelevant contextual information does not always lead to error. One suggestion for future research is outlined, which is that studies on contextual bias in forensic decisions should be conducted in collaboration between forensic scientists and cognitive psychologists. Only then can rigorous and ecological valid experiments be created that will be able to assess how task-irrelevant contextual information influences forensic analysis and judgments in operationally valid settings.

Keywords: forensic science, forensic psychology, decision science, bias, forensic assessment, decision making.

Evidence derived from traces of DNA is considered the gold standard of forensic science (1) and is strongly weighted by jurors when reaching a verdict (2). Within the courtroom, DNA evidence is viewed as an important tool when deciphering the guilt of a suspect. In addition to DNA evidence, different types of forensic evidence are typically analysed by forensic examiners to assist the court in its determination on substantive technical issues, which in turn may aid the jury in reaching a verdict (e.g., fingerprint analysis, DNA analysis, and footprint examinations (3). Forensic evidence often arises from two broad categories of investigation (although the reader should be aware that not all forensic evidence fits neatly within these two types of investigation e.g. forensic pathology): 1) More subjective analyses often using pattern-matching techniques such as 'match' and 'non-match' in fingerprint analysis; and 2) More objective analyses using statistical testing and thresholds such as in DNA analysis (4). Recent research has highlighted that forensic evaluations of the first type may be affected by task-irrelevant contextual information (5) and that subjectivity in pattern-matching techniques may have contributed to miscarriages of justice, in some cases resulting in the payment of significant compensations (6,7).

Dror and Hampikian (3) and Krane (14) suggested that task-irrelevant contextual information may even influence the evaluation of DNA evidence, the gold standard of forensic evidence. Their findings may have serious implications for both prosecution and defence due to the central importance and extensive use of DNA-related forensic evidence in the exoneration and incarceration of individuals (15). It may also call into question the validity of a significant number of verdicts, as some verdicts may have been based on biased forensic evaluations. Any bias in forensic scientists caused by task-irrelevant contextual information may therefore be a real cause for concern within the forensic science community (8).

The National Academy of Sciences (9) and the UK Forensic Science Regulator (10) have suggested that forensic evaluations of pattern-matching techniques may be significantly

affected by task-irrelevant contextual information when ambiguous and task-relevant forensic information needs to be interpreted (5, 11). In the following we use 'contextual information' as an umbrella term for (seemingly) task-irrelevant or extraneous information for the forensic analyses at hand. Contextual bias is then the effect that task-irrelevant contextual information has on the forensic examiners' decisions (5). A prominent example of a contextual bias is the confirmation bias that occurs when an initial hypothesis or prior beliefs influences how a decision maker interprets and/or searches for information, typically preferring information that supports their expectations (12,13).

In this review we first discuss the empirical evidence of the effects that task-irrelevant contextual information has on forensic scientists, followed by a discussion of the ecological validity and experimental rigour of these studies. Then we will argue that use of task-irrelevant contextual information does not always equal error. This argument is based on scientific evidence from the forensic science community and literature on decision science. Furthermore, we aim to highlight potential issues with some of the current research on contextual bias in forensic scientists and provide an alternative perspective on the influence of task-irrelevant contextual information on forensic scientists.

Contextual Biases in Forensic Scientists.

In recent years, research has highlighted that forensic science may not be as objective as commonly assumed by legal professionals and forensic scientists (16). For instance, Dror et al. (5) found that if ambiguous latent fingerprints (prints recovered from a crime scene that are invisible to the naked eye) were presented alongside task-irrelevant contextual data, including emotionally resonant images and stories, then fingerprint examiners were increasingly likely to find a 'match' between prints found at the crime scene and a reference

sample from the accused even if it did not exist. Dror, Wertheim, Fraser-Mackenzie and Walajtys (17) further found that when fingerprint examiners were using an Automated Fingerprint Identification Systems (AFIS; a digital system that allows fingerprints to be stored, and searched for), latent fingerprints from the top of the AFIS list were much more likely to be matched incorrectly than fingerprints from the bottom of the AFIS list. Kukucka and Kassin (18) found that handwriting comparisons were also influenced by the knowledge of confessions. Further, Cooper and Meterko (19) conducted a systematic review and found that task-irrelevant contextual information can influence the judgments of forensic scientists. This shows that forensic examiners, just like other decision makers, are influenced by (seemingly) task-irrelevant information when making a decision. This inclusion of task-irrelevant information in the decision processes of forensic scientists may invoke prior beliefs which may bias how ambiguous forensic evidence is perceived and may lead to more incorrect decisions being made. This can have serious ramifications for decisions on the guilt and innocence of suspects in criminal cases.

Despite the apparent robustness of these effects, demonstrated in replications across different forensic evaluations (Cooper and Meterko (19), some decision scientists have argued that biases and fallacies may be an artefact of experimental designs and not necessarily the result of cognitive processing in a natural or typical environment (20). Therefore, these findings on contextual bias may lack generalisability, and may be confined to psychologist's laboratories.

Nevertheless, high profile, real-life cases suggest that contextual bias in forensic examiners may not be confined to psychological studies. In 2004, the Federal Bureau of Investigation (FBI) mistakenly identified a Muslim male as being responsible for the Madrid train bombings (16). The examiners had drawn the 'match' from a database that contained known prints. After this initial false positive, a number of other experts confirmed the false positive result (16). This real-life case demonstrated that forensic examiners who were provided with

task-irrelevant contextual information (i.e., surrounding the initial false positive) were more likely to confirm a match rather than disconfirm it. Dror et al. (16) then used this real-life example in an experimental manipulation, with five fingerprint experts acting as participants in this study. Participants were given prints from a crime scene, prints from a suspect, and were provided with task-irrelevant contextual information. The context they were provided with was that the prints had been incorrectly identified by FBI experts when they were analysing evidence from the Madrid train bombing. Unknown to the fingerprint experts, they had previously identified the same prints as a match in another real-life case from their own case history. Four out of five participants changed their decision based on the task-irrelvant context provided, thus demonstrating that forensic examiner decision making can be easily influenced by task-irrelevant contextual information.

The potential for contextual bias extends to the evaluation and interpretation of different types of evidence, the most surprising of which is DNA evidence. Dror and Hampikian (3) used a DNA mixture (biological material gained from more than one individual (21) from a real case of gang rape to test whether or not ambiguous DNA evidence is also susceptible to task-irrelevant contextual information. In this case, one of the individuals who had participated in the rape testified against another member (from which the target DNA was acquired) in exchange for a lower sentence and the forensic examiners concluded that the target DNA could not be excluded from the DNA mixture. In Dror and Hampikian's (3) study, the same material was presented to 17 new forensic examiners, but without any task-irrelevant contextual information about the defendant/accused (i.e., the testimony from the assailant). From the 17 examiners, 12 decided that the target DNA could be excluded and four found that the DNA evidence was inconclusive. This study illustrates that the interpretation of ambiguous DNA evidence is not consistent, and that it can be influenced by task-irrelevant contextual information.

The potential for subjectivity when interpreting complex and ambiguous DNA mixtures was demonstrated in two further studies: DNA MIX05 and DNA MIX13 (22). MIX05 was a study in which 69 forensic science laboratories evaluated and interpreted a two-person DNA mixture in four separate sexual assault mock trials (22). The results of MIX05 showed that forensic scientists were more consistent when making judgements on major contributors (i.e., a complete, or almost complete, DNA profile from a contributor is present) in two-person DNA mixtures when the genotypes of the contributors were not similar (23), and that they were less consistent when making judgments on minor contributor genotypes (23). In the MIX13 study, 108 forensic laboratories were presented with five complex mock crimes with up to four possible contributors to the DNA mixture (22). The main finding of this study was that DNA mixture interpretations varied significantly across different forensic laboratories (23). Both MIX05 and MIX13 showed that DNA mixtures can be complex and ambiguous, which leaves this type of evidence open to influence from task-irrelevant contextual information (3) and subjective reasoning.

Ambiguity of DNA evidence can be affected by other factors such as environmental contamination (e.g., low template DNA - amplifying a limited amount of DNA so that it can be analysed (24), temperature at crime scene). Krane et al. (25) suggested that DNA evidence is not always strong and that ambiguities allow task-irrelevant contextual information to influence analysis and judgments. Forensic examiners typically use electropherograms when analysing DNA evidence. This equipment establishes stable positions on chromosomes (i.e., loci) and measures the presence of alleles (genetic variations (26). The presence of an allele on a loci is represented on the user interface by a ‘peak’ or ‘bump’, and the lack of a bump may indicate that an allele is absent (14). This method of analysis allows examiners to compare the DNA of a suspect with a DNA sample found at a crime scene. Sometimes, however, a number of factors (e.g., environmental contamination) can make it difficult to

identify whether or not an allele is present on a loci (i.e., peaks may be present but small), thus introducing noise and uncertainty in the analysis (14). Krane (14) proposed that this noise makes DNA evidence ambiguous, increasing the opportunity for task-irrelevant contextual information to affect forensic examiners when analysing said DNA evidence.

Thompson (27) elaborated on the interaction between context and ambiguous evidence and suggested that false positives (e.g., the incarceration of innocent individuals) were most likely to occur due to subjective interpretations of ambiguous DNA evidence. Further, Thompson (27) proposed that ambiguity arises from DNA results if the sample is small and/or degraded (27). Limited DNA samples are also least likely to be retested, simply because the samples may have been used-up in the initial testing. As a consequence, these limited samples are more likely to be open to subjective interpretations by the forensic scientist, which may then influence how the jury perceives the defendant (27). These subjective interpretations of DNA evidence may be the result of the forensic scientist having knowledge of the case and/or suspect (i.e., task-irrelevant contextual information; 28). Thompson (29) further suggested that it is inappropriate for forensic scientists to consider task-irrelevant contextual information, as their role is not trier of fact (they are not the jury) but to provide expert opinion on a piece of circumstantial evidence only. This expert opinion should then be used alongside contextual information by the trier of fact to assess the guilt of the defendant (29), thus highlighting that contextual information should be used by the jury (and it is thus task-relevant to them) and not the forensic scientists as their roles differ in the legal system. Thompson's research (27, 29, 30) therefore indicates that presumably objective scientific procedures have the potential to be influenced by task-irrelevant contextual information as soon as subjective interpretations are involved.

A recent study by Kukucka, Kassin, Zapf and Dror (31) showed that forensic experts find it difficult to acknowledge contextual bias in their own decision-making. Forensic decision

makers were more likely to detect contextual bias in other forensic domains, less likely to detect contextual bias in their own domain, and least likely to acknowledge contextual bias as a factor that might influence their own judgements (31). This lack of awareness surrounding contextual bias in forensic decision making shows that forensic scientists may be unconsciously integrating subjective task-irrelevant contextual information alongside objective information in their forensic analysis when making matching decisions between a sample and a target. Furthermore, the effects of task-irrelevant contextual information on the decision making of forensic scientists may be hidden from view in forensic science, and this may have been cause by another bias named the over-confidence effect (31). This is because the over-confidence effect prevents decision makers from reflecting on their abilities and susceptibility to biases (e.g., contextual bias).

In summary, the aim of the current section was to highlight some issues in the literature on contextual information and its effects on forensic analysis and judgments. The current body of research has been primarily focussed on contextual bias and the negative effects it can have on forensic scientists. The next two sections will present an alternative perspective on the effects of task-irrelevant contextual information on forensic judgments.

Experimental rigour and ecological validity in investigations on contextual bias.

Despite the amount of evidence suggesting that contextual information can bias forensic scientists, there are two main issues with some of the literature that may attenuate how much the current body of knowledge can be applied to real world investigations: 1) experimental rigour (which will encompass for the purposes of this article, all aspects of experimental investigations such as sample size, recruitment, randomization processes); 2) ecological validity. Each issue will be addressed in turn.

First, as noted in Cooper and Meterko's (19) systematic review, some of the research used in support of the negative effects that contextual biases have on forensic decisions have methodological flaws. Cooper and Meterko (19) highlighted that sample sizes in articles investigating contextual bias have been too small or limited, thus attenuating the power and generalisability of the analyses. For example, in Dror et al.'s (16) study on the effects of contextual information the sample size was only 5 making it difficult to generalise from the study's findings. Related to this, many of the studies in Cooper and Meterko's (19) systematic review had not conducted statistical analysis correctly, as tests were sometimes conducted despite statistical assumptions being breached (e.g., chi-square analysis conducted despite expected frequencies being too low). In addition, Cooper and Meterko (19) stated: "…none of the studies provided information about the randomization procedures, as is recommended for randomized clinical trials" (p.42), highlighting that these studies are not proper experiments. Similarly, Dror et al.'s (16) study lacked a control group, making it difficult to infer effects of contextual bias on forensic judgements. Another methodological flaw that was highlighted by Cooper and Meterko (19) was that studies investigating the effects of task-irrelevant contextual information in forensic science differed in how naive the participants were about experimental designs and hypotheses. This makes it difficult to compare across studies and differentiate when the effects of contextual bias were down to the presentation of task-irrelevant contextual information or when it was simply caused by demand characteristics.

A second important question surrounding the experimental literature on contextual biases is, to what extent do laboratory experiments that induce bias translate to typical forensic decision-making? This question is difficult to answer, as some research tested forensic scientists and the effects of task-irrelevant contextual information in the normal working environments of forensic scientists (Dror et al. (16), whereas other studies have been

conducted using small student-based samples in artificial environments (Dror et al. (5). These different methods of investigating forensic bias relate to what Towler et al. (32) called operational and perceptual accuracy. Operational accuracy is tested when the decision making of forensic scientists are tested in studies that represent real-life casework in operationally valid settings. In contrast, perceptual accuracy is measured in an experimental setting that is representative of real-life case work, but is not operationally valid, as commonly used tools and scales might not be available (32, 33). Most research to date has focussed primarily on perceptual accuracy over operational accuracy, meaning that the effects of contextual bias in real-life forensic decisions is still not fully understood (32), and consequently needs more investigation.

In summary, despite the steep increase of research relating to contextual bias in forensic science, some of the research is lacking experimental rigour and ecological validity. Therefore, before recommendations and conclusions can be drawn about the effects of task-irrelevant contextual information on forensic scientists in their daily decisions, future studies need to address the effects of contextual bias on operational accuracy in ecologically valid settings using proper experimental designs. In light of these methodological limitations, the next section of this review will discuss an alternative view on the effects of task-irrelevant contextual information in forensic judgments.

The Good, the Bad, and the Biased: Do biases equal error?

Although task-irrelevant contextual information might lead to biased decisions, this does not necessarily mean that forensic examiners who are presented with task-irrelevant contextual information will make more incorrect decisions. The aim of the current section, therefore, is to present commentary, theory and research supporting the idea that task-irrelevant contextual

information does not necessarily lead to inaccurate decision making and that sometimes subjective interpretation of forensic evidence based upon task-irrelevant contextual information may even promote accurate decision making.

Searston, Tangen and Eva (34) conducted three experiments to investigate whether or not task-irrelevant contextual information had an effect on the accuracy of forensic judgments when analysing latent fingerprints, or whether it simply caused a response bias. In their second experiment, Searston et al. (34) found that decisions made by forensic examiners can be biased by familiarity. Their experiment consisted of a learning phase followed by a test phase. In the learning phase, participants were given contextual information surrounding a case, then asked to make a decision (match vs. non-match). Participants were provided with feedback in this initial stage, allowing participants to learn a false (i.e., experimentally induced) association between the decision accuracy and the given task-irrelevant context. Familiarity with the task-irrelevant context was associated with a decrease in accuracy, suggesting that familiarity may bias decisions and can lead to more inaccurate decisions making.

In Searston et al.'s (34) third experiment, they investigated whether similar fingerprints from previous mock trials could bias judgements in subsequent trials and thus change the accuracy of the decision maker. In this experiment, no context was provided, and participants were given the same latent fingerprints twice, once in the learning phase (with feedback) and once in the test phase (without feedback). Participants performed worse in the test phase in comparison to the learning phase. This suggests that familiarity with fingerprints might bias individuals to make a decision consistent with the decision they made on a previous case with a similar looking fingerprint, thus biasing the forensic examiner and potentially leading to less accurate decisions.

Further, Searston et al.'s (34) second and third experiment showed, in line with previous research, that task-irrelevant contextual information can cause individuals to make a biased or incorrect decision. However, in experiment three, the contextual bias did not originate from task-irrelevant contextual information regarding a case or a suspect, rather the contextual bias was related to the experience of the forensic scientists with familiar pieces of evidence (47); thus, the task-irrelevant information was their familiarity with similar fingerprints. In other words, the more experience a forensic scientist had in evaluating fingerprints, the more fingerprints they have seen, the more they were vulnerable to Searston et al.'s (34) familiarity effect. Goldstein and Gigerenzer (35) suggested that the experience an individual has with a particular environment can influence the accuracy of their decision making. None or too much experience can have a negative effect on decision making because if you have no knowledge of an environment you will not be able to reliably discriminate between two outcomes. On the other hand, if you have too much information available to you, the complexity of the decision increases which can make it more difficult to make the correct choice. They suggested that individuals with intermediate knowledge of an environment may make the most accurate decisions, as they use just enough information to discriminate between the options but not too many cues to be confused and overwhelmed by the information (35). However, it should be mentioned that in Goldstein and Gigerenzer's (35) research the participants were students (American and German students, respectively) who were asked to make decisions surrounding particular aspects of American cities (e.g. the more populous city out of the two cities presented). Obviously, their work (35) does not directly apply to forensic science, but their theoretical ideas on bounded rationality may help to understand why expertise can affect decision making in paradoxical ways.

Dror (36) offered an alternative explanation for why expertise may have a negative influence on forensic examiners. He suggested that expertise allows forensic experts to create schemas

(mental models) of decisions and their associated environments, which can then create rigid thinking processes, thus limiting creativity and biasing the decision outcome to their previous experience. Similar to Searston et al. (34), Dror (36) suggested that familiarity with task-irrelevant contextual and task-relevant non-contextual (i.e., forensic evidence) information may cause an error, rather than the task-irrelevant contextual information itself. Expertise may lead to forensic decision makers utilising top-down processes more than bottom-up processes, which may cause the decision maker to rely on familiar information more than novel information. This may have some negative outcomes: 1) the forensic decision maker may overestimate the importance of familiar information which may be mostly or entirely irrelevant to the decision at hand; 2) the forensic decision maker may underestimate the importance of novel relevant information (36, 37). These top-down processes, however, will typically lead to more accurate decision making in in a stable and reliable environment, but may lead to increased errors in more complex and unstable environments (i.e., with ambiguous information (16, 36, 37).

However, Searston et al.'s (34) first experiment highlighted that task-irrelevant contextual information does not *always* lead to inaccurate decisions, suggesting that *some* task-irrelevant contextual information may randomly affect accuracy (38). They found that case severity (high vs. low) had an impact on the response bias of forensic examiners but did not influence their overall accuracy. In other words, forensic examiners were more likely to "match" a sample with a target in cases with high severity than in cases with low severity, but this tendency was not indicative of whether a correct match was established or not. Therefore, it can be said that task-irrelevant contextual information is *not necessarily* a significant contributor to erroneous judgement.

Langenburg, Champod and Wertheim (39) found similar effects when comparing the effect of context and expertise on errors and bias for matching unknown fingerprints with a fingerprint exemplar (39). They found that novices were influenced more by task-irrelevant contextual information than experts, and that the novice group made significantly more errors (number of errors = 46) than the expert group (number of errors = 4). This is in contrast to the findings discussed above, demonstrating that effects of expertise are complex, and are likely to be mediated by different types of task-irrelevant contextual information and various categories of decisions. Further, this highlights that the presence of task-irrelevant contextual information and the resulting contextual bias does not always lead to inaccurate decision making in expert forensic scientists.

Kerstholt et al. (40) investigated whether task-irrelevant contextual information had an effect when assessing whether a bullet was fired from a certain firearm or not in two separate studies. The first investigation found that task-irrelevant contextual information had no effect on the decision outcome. In the second investigation, the researchers compared the decision of a first forensic scientist (the person who conducted the initial assessment) with the decision made by a second forensic scientist (the person who conducted the second assessment) in real-life cases. It was expected that the first examiners response would have been more biased as they would have had more task-irrelevant contextual information available to them. The second examiner, however, gave a more biased answer/response and were more likely than the first examiner to conclude that the firearm did fire the bullets. In addition, Kerstholt, Paashious, and Sjerps (41) found that task-irrelevant contextual information did not influence assessments in shoe print examinations. In summary, the studies by Searston et al. (34), Langenburg et al. (39), and Kerstholt et al. (40) highlight that contextual bias does not necessarily lead to more inaccurate decision making. Therefore, contextual bias should not

always be seen as negative, and more research is needed to consider when contextual bias can be beneficial and when it has no effect.

Some researchers have suggested that heuristics (cognitive short-cuts) and contextual bias can actually lead to more accurate decision making (35, 42). For instance, Goldstein and Gigerenzer (35, 42) tested fast and frugal heuristics that allow decisions to be made both quickly and accurately. They claimed that contextual/environmental (both task-relevant and task-irrelevant) information may be beneficial when making decisions as it serves as a scaffold for our limited cognitive processes (i.e., heuristics). Further, they suggested that our minds have evolved to adapt to our environment, and that we have a toolbox of heuristics that allow us to access the most important information (whether that be relevant to the task or not) quickly, rather than integrating all the information, to make a decision. These heuristics vary according to their 'satisficing rule' (from using one cue to a number of cues), but in each of the heuristics, it is the most valid information (i.e., a cue that allows two outcomes to be discriminated against) that allows us to make good decisions quickly. In other words, information that biases decision processes may promote accurate and quick decision making. Gigerenzer and Goldsetin (42) also suggested that through interaction with the environment, we learn which pieces of information (both task-irrelevant and task-relevant) are most likely to be associated with the correct outcome, thus allowing fast and frugal decisions to be made. Furthermore, the fast and frugal paradigm has contributed two important findings to psychological decision research: 1) that the utilisation of environmental/contextual information is crucial to make accurate decisions; 2) contextual bias may be beneficial to decision making.

Within an ecologically valid forensic setting it is indeed possible that some task-irrelevant contextual information may actually be beneficial. For instance, Towler et al. (32) stated that: "*Unlike most experiments, the ratio of targets to non-targets in forensic contexts is almost certainly*

not 50:50" (p.204). In real-life forensic examinations, there will be a higher chance of samples being a match than a non-match (32). Therefore, task-irrelevant contextual information that biases forensic scientists in favour of the prosecution may actually induce correct decision making, even though the practice of utilising task-irrelevant contextual information may be ethically questionable and not justifiable legally (29); this is related to the 'criminalist paradox'. In addition, Rudin and Inman (43) suggested that if a forensic scientist is unaware of the task-irrelevant context surrounding the case, they may conduct tests that are either worthless or dangerous (i.e., lead to injustice). They propose that task-irrelevant context is needed so that forensic scientists know which question to answer and this then informs the tests that are conducted and the evidence which is collected. They propose that contextual ignorance may have more of a negative effect on forensic evaluations than contextual bias does. Furthermore, in real-life laboratories task-irrelevant contextual information and contextual bias may aid forensic scientists to evaluate forensic evidence.

Whitman and Koppl (44) have suggested that the utilisation of task-irrelevant contextual information in forensic examiners may even be a rational endeavour. This is because the decision that is reached will be informed by both prior beliefs surrounding the guilt of the accused (which may have arisen from information from the police, and the subjective weight they place on incarcerating the guilty vs. the innocent) and evidence; thus, mirroring the updating of priors in Bayesian inference. Further, Evett, Jackson, and Lambert (45) proposed that DNA caseworkers use the Case Assessment and Interpretation (CAI) model. This model requires forensic scientists to seek as much task-irrelevant contextual information as possible from the investigator. Evett et al. (45) also suggested that the utilisation of task-irrelevant contextual information allows examiners to update their beliefs in a manner that mirrors a Bayesian inference process, thus hinting that task-irrelevant contextual information may allow forensic scientists to perform more rationally. Furthermore, forensic examiners who

use task-irrelevant contextual information may do so in a manner that is associated with rational decision making.

However, despite the potential positive effect of contextual bias on the analysis of forensic evidence, it may be legally/ethically unsuitable to use task-irrelevant contextual information as it may lead to a 'criminalist paradox' (29) (p.130). Thompson (29) stated that task-irrelevant contextual information may aid forensic scientists to make the correct decision, as a forensic scientist may be aided in finding a correct match between fingerprints when they have learned that the suspect, from whom the latent fingerprints have been collected, has confessed. The problem arises when jurors have to make an appropriate verdict. According to standard Bayesian inference, jurors should integrate each piece of information gained from evidence surrounding the guilt of the defendant independently of one another in order to arrive at a decision (29, 46). However, if jurors are integrating confession evidence and forensic evidence independently of one another, when really each piece of evidence is correlated, then jurors may conclude that the likelihood of the suspect being guilty is much higher than it actually is (29).

For example, in a case which led to Josiah Sutton being incorrectly convicted of rape, the interpretations of a DNA mixture were influenced by the identification of the victim (30). It was also reported that the victim's testimony in court may have been influenced by the knowledge of the DNA results. The case against Josiah Sutton, according to Bayesian inference, was weak as each piece of evidence was dependent on the other but was perceived as strong by the jury as they expected that each piece of evidence originated from independent sources (30). Furthermore, task-irrelevant contextual information may aid individual forensic analysts to make a correct judgement but may have serious negative implications surrounding the outcome of a trial by jury.

Nevertheless, despite the 'criminalist paradox' academics and practitioners in the forensic science community have commented on the utility of task-irrelevant contextual information. For instance, Budowle et al. (38) suggested that some task-irrelevant contextual information aids the decision-making process of forensic examiners to prioritise the most meaningful samples when there is a plethora of samples. Therefore, similar to Gigerenzer and Goldstein's (42) fast and frugal heuristics, information from the environment (i.e., task-irrelevant contextual information which relates to individuals involved in a case) may aid forensic decision makers to process and analyse the most useful samples, thus allowing the forensic examiner to make an accurate decision despite using limited resources (both cognitive and evidentiary (38). Kruse (47) advocated that task-irrelevant contextual information surrounding a case (i.e., when the case occurred), familiarity with previous cases (experience of analysing similar types of materials), and advice from colleagues allow forensic scientists to better evaluate forensic evidence. Further, Elaad (48) proposed that task-irrelevant contextual information may have a positive relationship with the accuracy of a judgement and does not always cause an inaccurate judgement to be reached. Butt (49) even suggested that the negative effects of contextual bias are overestimated in psychological literature, and that task-irrelevant contextual information may influence forensic scientists in a positive manner.

A final aspect that is usually neglected in the debate on task-irrelevant context vs. no context is the trade-off between statistical bias and variability commonly encountered in statistical modelling (50,51). In statistical modelling, various statistical assumptions can be placed upon a model resulting in models of different complexity making different predictions. This dependency between statistical bias and variance relates to under/overfitting of data and cross-validation (50, 51). When a complex or specific model makes more consistent (less variable) predictions then model predictions/decisions tend to be more biased, especially when new data needs to be evaluated, and vice versa (50, 51). Relating this to forensic

science, if task-irrelevant contextual information is utilised by forensic scientists, this may lead to a selection of "more appropriate or specific" tests, as suggested by Rudin and Inman (43). Thus, they are more consistent in their decision making but potentially more biased by the task-irrelevant contextual information. Contrary, if no contextual bias is introduced in the decision making of forensic scientists, they may be less restricted in the tests used, meaning that more unspecific tests may be conducted (43), leading to less consistent decisions. The variance and bias trade-off may also explain Dror and Hampikian's (3) results. This is because the 'biased' real-life forensic examiners gave more consistent results, whereas the forensic examiners in the experiment (N =17) who had no context information gave more variable decisions, with 12 deciding the target DNA could be excluded, four finding the DNA was inconclusive and one believing the DNA was a match.

In summary, the current section has presented the alternative perspective that task-irrelevant contextual information does not always lead to error and that task-irrelevant context may sometimes aid forensic decision makers (43). As this perspective differs from the vast majority of research that has been conducted in artificial laboratory experiments, we suggest that studies on contextual bias in forensic decisions should be conducted in collaboration between forensic scientists and cognitive psychologists. Only then can rigorous and ecological valid experiments be created that will be able to assess how task-irrelevant contextual information influences forensic analysis and judgments in operationally valid settings (52). In addition, only when this research has been conducted can conclusions and recommendations be made regarding the effects of task-irrelevant contextual information and contextual bias on forensic judgments and analysis.

Conclusion

The current body of knowledge surrounding the effects of task-irrelevant contextual information on forensic judgments and analysis has mostly suggested that task-irrelevant contextual information may cause contextual bias in forensic examiners when analysing different types of forensic evidence (e.g., fingerprint analysis, handwriting, and DNA mixture analysis). It has also been suggested that contextual bias may have a negative influence on the accuracy of the decisions made by forensic scientists. However, because of methodological flaws (inaccurate inferential statistics; small sample sizes; no information on the allocation of groups) and problems with the ecological validity of previous experiments, these results may not generalise to the real-life judgments made by forensic scientists. Therefore, the current review aimed to present an alternative perspective that has been commented on by forensic scientists, researched by academics and is supported by the theoretical framework of bounded rationality. This alternative perspective is that task-irrelevant contextual information (and the associated contextual bias) may not always influence forensic decisions in a negative way, and that task-irrelevant context may aid forensic scientists when making decisions regarding forensic evidence. To test this alternative perspective, we recommend that forensic scientists and cognitive psychologists collaborate (52) to create rigorous and ecologically valid experiments that will be able test the effects that task-irrelevant contextual information and contextual bias have on forensic scientists in operationally valid settings.

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