# Cognitive Bias in Forensic Science: The Psychological Source of Forensic Errors *

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**Abstract:** The 2009 release of the National Academy of Sciences report *Strengthening Forensic Science in the United States: A Path Forward*, which published research about the impact of cognitive bias in forensic science, has led the forensic science community in the United States, the United Kingdom, Australia, Netherlands, and other countries to recognize the seriousness of the problem. This article reviews the criticisms of reliability and validity in forensic science and presents classic psychological studies of cognitive bias. These studies have shown that cognitive processes such as sensation and perception, judgment, and decision-making are influenced by such factors as a person's beliefs, experiences, expectations, memories, motivations, cultural background, and the larger context in which events occur. The studies also have shown that cognitive bias can lead to erroneous examination opinions in forensic areas such as handwriting examination, fingerprint identification, and DNA analysis. Finally, the paper summarizes existing options for limiting forensic cognitive bias.

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## I. Introduction

Since the 1970s, cognitive bias has been recognized as a potential problem in the criminal justice system. For example, studies have shown that cognitive bias can affect investigators' judgments, prosecutors' decisions on whether to bring charges, and judges' decisions about what rulings to make.[1] In 2004, after the FBI misidentified a suspect in the case of the Madrid commuter train bombing in Spain, the Justice Department's Office of Inspector General identified confirmation bias as a contributing factor to the misidentification.[2] In 2005 the US Congress commissioned the National Academy of Sciences to investigate the state of forensic science in the US, and the investigation covered the impact of cognitive bias on forensic science.[3] Since then, academic research on cognitive bias in forensic science has increased.[4]

In 2009, the National Academy of Sciences released a report titled "Strengthening Forensic Science in the United States: A Path Forward," noting that many forensic science disciplines have

[1] See Tversky and Kahneman (1974). *Judgment under uncertainty: Heuristics and biases*. science, 185,1124-1131.

[2] See Robert B. Stacey (2005). *Report on the Erroneous Fingerprint Individualization in the Madrid Train Bombing Case*: 1-19.

[3] See National Research Council of the National Academy of Sciences, *Strengthening Forensic Science in the United States: A Path Forward,* p.8.

[4] See Dror, I.E., et al. (2005). *When emotions get the better of us: the effect of contextual top-down processing on matching fingerprints*. Applied Cognitive Psychology, 19: 799-809; Dror, I.E., D. Charlton. (2006). *Why experts make errors*. Journal of Forensic Identification, 56: 600-616; J.H. Kerstholt, R. Paashuis, M. Sjerps ( 2007). *Shoe print examinations: effects of expectation, complexity and experience*. 34; Dror, I. E., & Rosenthal, R. (2008). Meta-analytically quantifying the reliability and biasability of forensic experts. Journal of Forensic Sciences, 53: 900 -903.

problems in standardization, reliability and accuracy, and that examiners' judgments may be influenced by contextual biases, which can weaken the probative value of scientific evidence. The National Academy of Sciences recommended that "the forensic science disciplines need to develop rigorous protocols for performing subjective interpretations, and they must pursue equally rigorous research and evaluation programs. The development of such research programs can benefit significantly from work in other areas, notably from the large body of research that is available on the evaluation of observer performance in diagnostic medicine and from the findings of cognitive psychology on the potential for bias and error in human observers." [5] Since then, the President's Council of Advisors on Science and Technology [6] and the National Commission on Forensic Science [7] in the United States, the Forensic Science Regulator[8] and the House of Lords Committee of Inquiry [9] in the United Kingdom, the Victorian Police Forensic

[5] See supra note 3, *Strengthening Forensic Science in the United States: A Path Forward,* p.188.

[6] See PCAST. (2016). *Forensic Science in Criminal Courts: Ensuring Scientific Validity of Feature-Comparison Methods.* President's Council of Advisors on Science and Technology, Executive Office of the President of the United States, Washington, DC.

[7] See National Commission on Forensic Science. (2015). *Ensuring that Forensic Analysis Is Based upon Task-Relevant Information.* Retrieved from, https://www.justice.gov/archives/ncfs/ file/818196/download.

[8] See The Forensic Science Regulator. (2015). *Cognitive Bias Effects Relevant to Forensic Science Examinations.*
https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/914259/217_FSR-G-217_Cognitive_bias_appendix_Issue_2.pdf.

[9] See House of Lords Science and Technology Select Committee (2019). *Forensic Science and the Criminal Justice System: A Blueprint for Change.*

Science Service[10] in Australia, and Netherlands Forensic Institute[11] have expressed great concern about the problem of cognitive bias in forensic science. These organizations have conducted extensive research and have reached several important results.

Research on the effects of cognitive bias in forensic science has established a field of study called cognitive forensics,[12] which is devoted to the study of factors that may influence the cognitive processes of forensic examiners. Because of the influence of various cognitive factors forensic science is not as objective, scientific, and unbiased as it is believed to be. Studies of wrongful convictions in various countries have shown that a significant percentage of wrongful convictions are caused by flawed and erroneous scientific evidence and cognitive bias is one of the major contributors to such errors, resulting in problems such as false corroboration that is difficult to correct through existing procedural mechanisms such as in-court cross-examination.[13]

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https://publications.parliament.uk/pa/ld201719/ldselect/ldsctech/333/333.pdf.

[10] See Found, B., & Ganas, J. (2013). *The management of domain irrelevant context information in forensic handwriting examination casework*. Science and Justice, 53: 154 -158.

[11] See Stoel, R.D., Berger, C.E., Kerkhoff,W., Mattijssen, E., and Dror, IE.(2015). *Minimizing contextual bias in forensic casework*. In Strom K. and Hickman, M.J. (eds) Forensic Science and the Administration of New York: Sage.

[12] See Dror, I.E., Stoel, R.D. (2014). *Cognitive forensics: human cognition, contextual information, and bias*. in: The Encyclopedia of Criminology and Criminal Justice. Springer, 353-363; *Found, Bryan.* (2015). *Deciphering the human condition: the rise of cognitive forensics*. Australian Journal of Forensic Science, 47 (4): 386- 401.

[13] See Garrett, B.L., Neufeld, P.J. (2009). *Invalid Forensic Science Testimony and Wrongful Convictions*. Virginia Law Review, 95(1): 1-97; Dioso-Villa, R. (2012).

## II. The Dilemma of Forensic Science

The scientific evidence provided by forensic science has made an important contribution to the successful prosecution of perpetrators and the exoneration of the innocent, and many cold cases have been solved with advanced DNA technology.[14] Forensic Science is playing an increasingly important role in the justice system, in part because other evidence (e.g., witness testimony) is perceived to be more susceptible to subjective factors and more difficult to evaluate.[15] In contrast, scientific evidence provided by forensic science disciplines is considered to be the result of objective and impartial scientific processes, and is given a high

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*Without legal obligation: compensating the wrongfully convicted in Australia*. Albany Law Review, 75 (3): 1329-1372; Dioso-Villa, *R.* (2015). *A repository of wrongful convictions in Australia: first steps toward estimating prevalence and causal contributing factors*. Flinders Law Journal, 17: 163-202; Smit, N.M., Morgan, R.M., Lagnado, D.A. (2018). *A systematic analysis of misleading evidence in unsafe rulings in England and Wales*. science & justice, 58 (2): 128-137.

[14] For example, the famous "Baiyin serial murder case" in China was solved by using the Y-STR technology of DNA testing 28 years after the crime was committed. See 谈琳 (Tan Lin), "白银连环杀人案告破凸显科技的力量," 载《科技日报》2016 年 8 月 30 日，第 1 版 ("The solving of Baiyin serial murder case highlights the power of science and technology," in Science and Technology Daily, Aug. 30, 2016, p. 1).

[15] See 杨伟伟 (Yang Weiwei), 罗大华(Luo Dahua),《国外心理学关于证人证言的研究及其启示》,《证据科学》, 2007 年第 1 期 ("Foreign Psychological Research on Witness Testimony and Its Implications," in Science of Evidence, No. 1, 2007); 卫跃宁 (Wei Yuening), 宋振策 (Song Zhence),《被害人陈述的证据能力与证明力规则——一个比较证据法的视角》,《证据科学》, 2017 年第 3 期 ("The Rule Governing the Evidentiary Competency of Victim's Statements and Probative Value – From A Comparative Evidence Law Perspective," Science of Evidence, No. 3, 2017).

degree of probative value in practice. For decades, forensic science disciplines have flourished with minimal criticism. However, in the past decade or so, the reliability and validity of forensic science has been increasingly challenged.[16] These challenges revolve around the following two main themes:

*(1) Weak Theoretical Foundation*

Forensic science is largely an empirical application of other scientific disciplines, yet many forensic tests—such as those used to infer the source of toolmarks or bitemarks—have never been exposed to stringent scientific scrutiny. Most of these techniques were developed in crime laboratories to aid the evidentiary investigation at a particular crime scene, and researching their limitations and foundations was never a top priority.[17] While judgments in forensic science are not entirely subjective, they are usually not subject to adequate testing or analysis.[18] US Judge Souder found the traditional method of fingerprint analysis to be "a subjective, untested, unverifiable identification procedure that purports to be infallible."[19]

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[16] Saks, Michael J. and Koehler, Jonathan J. (2005). *The Coming Paradigm Shift in Forensic Identification Science.* Science, 309 (5736): 892-895.

[17] See supra note 3, *Strengthening Forensic Science in the United States: A Path Forward,* p. 42.

[18] Saul M. Kassin, Dror, I.E., Jeff Kukucka. (2013). *The forensic confirmation bias: Problems, perspectives, and proposed solutions*. Journal of Applied Research in Memory and Cognition, 2: 42-52.

[19] See supra note 3, *Strengthening Forensic Science in the United States: A Path Forward,* p.43.

*(2) Influence of Human Factors*

Most forensic science disciplines lack both objective assessment methods and reliable assessment tools. In these fields, the examiner becomes, in essence, the primary analytical tool.[20] Even in fields with quantifiable assessment methods and instrumentation, people play an important role in every step, including sample collection, test sample identification, sample analysis, and test result interpretation. The lack of objective examination criteria has led to a lack of consistency between the conclusions reached by different examiners, or even the same examiners. Studies have shown that the same examiner analyzing the same data in different contexts may reach different conclusions. [21] The lack of consistency and reliability of examination results undoubtedly indicates that the process of examination is somewhat subjective, and that examiners are susceptible to various cognitive biases in examinations that involve subjective interpretation and assessment. [22]

## III. Psychological Study of Cognitive Bias

Psychological studies have shown that in perceiving, remembering, analyzing, interpreting and using information in life, people are influenced by factors such as context, motivation, expectations and

[20] Dror, I.E., Saul M. Kassin, Jeff Kukucka. (2013). *New application of psychology to law: Improving forensic evidence and expert witness contributions*. Journal of Applied Research in Memory and Cognition, 2(1): 78-81.

[21] See Dror, I.E et al, *Cognitive Bias and Its Impact on Expert Witnesses and the Court*, The Judges' Journal, Volume 54, Number 4, Fall 2015.

[22] See Dror, I.E. (2017). *Human expert performance in forensic decision making: Seven different sources of bias*. Australian Journal of Forensic Sciences, 49 (5): 541-547.

experience, and extraneous factors can distort people's judgments.[23] In other words, the cognitive process is not a passive information processing process but an active meaning-construction process. Human cognitive structure and cognitive mechanisms determine that human beings are not "perfect" cognizers but are susceptible to various cognitive biases in the cognitive process.

Relevant studies have shown that cognitive bias is a phenomenon that systematically, unconsciously, and inevitably deviates from "reality" and is difficult or impossible to avoid by willpower alone.[24] Over the course of human evolution, cognitive bias has developed through subconscious mechanisms of action that make it difficult to detect. The information processing mechanisms in human brains make cognitive bias inherently present in all decision-making actions in every domain. It is difficult for anyone to become immune to cognitive bias—not even forensic science experts.[25]

Failure to understand cognitive mechanisms often leads to ineffective approaches to cognitive bias. For example, misinterpreting cognitive bias as a professional ethics issue and attributing identification errors caused by cognitive bias to unethical behavior of the examiner assumes that cognitive bias can be addressed through professional ethics training and following a professional code of ethics.[26] However, this not only fails to address

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[23] See supra note 1, *Judgment under uncertainty: Heuristics and biases.*

[24] See Pohl, R.F. (2017). *Cognitive Illusions: Intriguing Phenomena in Judgement, Thinking and Memory*. Psychology Press, 3-4.

[25] Dror, I.E., Jeff Kukucka, Saul M. Kassin and Patricia A. Zapf (2018). *No One is Immune to Contextual Bias-Not Even Forensic Pathologists*, Journal of Applied Research in Memory and Cognition, 7(2): 316-317.

[26] See Dror, I.E. (2020). *Cognitive and Human Factors in Expert Decision Making: Six Fallacies and the Eight Sources of Bias.* Analytical Chemistry, A-G.

cognitive bias, but also stigmatizes the examiner and reduces the credibility of forensic examination by implying that the examiner is intentionally rendering an incorrect examination opinion. To effectively address cognitive bias, we need to properly understand the impact of human sensation and perception processes, social cognitive effects, reasoning styles, motivation and emotions on human cognitive processes, and the mechanisms that lead to cognitive bias.

*(1) Sensation and Perception*

Cognitive psychology distinguishes between sensation and perception processes by which individuals recognize and understand things in the outside world. Sensation is the initial number of processes that an individual uses to perceives environmental energy and encode it.[27] Perception is the mental process in which meanings, relationships, situations, judgments, past experiences, and memories come into play. [28] In other words, perception is the process of attaching meanings to sensations. The formation of perception consists of two processes: top-down processing and bottom-up processing. Bottom-up processing means that the perceiver starts with small pieces of information in the environment and combines them in various ways to form a perception. [29] Top-down information processing refers to the

[27] Harvey Richard Schiffman, Sensation and Perception, translated by Leshan Li (李乐山) et al,《感觉与知觉》, 西安交通大学出版社(Xi'an Jiaotong University Press), 2014 edition, p. 2.

[28] Ibid.

[29] US Kathleen M. Galotti, Cognitive Psychology (3rd ed.), translated by Wu Guohong (吴国宏) et al.,《认知心理学》（第三版）陕西师范大学出版社(Shaanxi Normal University Press), 2005 edition, p. 32.

processing guided by the prevailing context, past experiences, and expectations that arise from both.[30] Thus, top-down information processing is susceptible to context and expectation effects,[31] making people subject to the influence of their own goals, experiences, expectations, memories, motivations, and cultural contexts when interpreting things or events.[32]

Human cognitive resources are limited, and in order to efficiently process the large amount of information input from the outside world, the human brain has developed a variety of cognitive mechanisms (e.g., selective attention, chunking information, automaticity, etc.).[33] These cognitive mechanisms are derived from past experiences, knowledge, and expectations, and they influence the way in which input information is processed. This conceptually-driven processing reflects top-down information processing and is prevalent in many cognitive processes. Top-down information processing is at the core of human intelligence and expertise. Although top-down information processing usually leads to good decisions, this type of information processing tends to focus on specific information and neglect other (potentially important) information. As experience and knowledge accumulate, top-down cognitive mechanisms become more powerful, eventually leading

[30] Ibid, p. 43.

[31] Ibid, p. 41.

[32] Philip Zimbardo, Robert Johnson, and Vivian McCann, Zimbardo's General Psychology, translated by Qian Jing (钱静) and Huang Yuping (黄钰苹) et al., 《津巴多普通心理学》, 中国人民大学出版社 (China Renmin University Press), 2016 edition, p.106.

[33] See Dror, I. E. (2011). *The paradox of human expertise: Why experts can get it wrong.* In N. Kapur (Ed.) *The paradoxical brain*. Cambridge: Cambridge University Press, 177-188.

people to become experts in a particular field. Thus, experts rely on top-down cognitive mechanisms to practice superior expertise. The efficacy of human judgment usually increases when cognitive mechanisms increasingly rely on top-down information processing. Nevertheless, although expertise and top-down information processing can lead to superior overall efficacy, it also has potential weaknesses and flaws, such as limiting flexibility of decision-making, ignoring important information, falling into tunnel vision, and causing cognitive biases, which reduce the accuracy of expert judgment.[34]

In one study, researchers showed participants a number of photographs of adults and children and asked them to determine the facial similarity of the people in the photos. When participants learned that there was a blood relationship between the adult and the child, participants perceived them to have higher facial similarity – even though the two people in the photos were not, in fact, related.[35] Other studies have similarly shown that participants perceive a suspect's photograph to have a higher resemblance to a computer-generated photograph when they believe the suspect is guilty,[36] and participants hear more information about the crime in a lower-volume recording if they believe the recording was left by

[34] Ibid.

[35] See Bressan, P., & Dal Martello, M. F. (2002). *'Talis pater, talis filius': Perceived resemblance and the belief in genetic relatedness*. Psychological Science, 13: 213-218.

[36] See Charman, S. D., Gregory, A. H., & Carlucci, M. (2009). *Exploring the diagnostic utility of facial composites: Beliefs of guilt can bias perceived similarity between composite and suspect*. Journal of Experimental Psychology Applied, 15: 76-90.

the suspect.[37] Although similar influences may result from motivation, the above-referenced studies suggest that pre-existing experiences, knowledge, and expectations do influence people's judgments and that people unconsciously and seamlessly weave their perceptions of the world into their understanding of the world. Similarly, forensic examiners unconsciously and seamlessly weave their pre-existing perceptions into their understanding of the prosecution's case work during the examination process.

*(2) Effect of Social Cognition*

Psychologist Rosenthal's classical experiments demonstrate the existence of the *expectation effect*, which means that when we form a judgment about ourselves or others and create an expectation, this expectation motivates us to act accordingly to achieve that expectation.[38] While expectation shapes our perceptions, it is also influencing our actions. In the world of criminal justice, people's behavior is also influenced by pre-existing beliefs. One study asked participants to review a simulated criminal investigation record that included some weak circumstantial evidence pointing to a suspect. Some participants were asked to make an initial assumption about the offender and to explain that assumption. Participants who followed this request would continually look for other evidence to support the evidence on which they based their hypothesis. Thus, a suspect who is only marginally suspicious became the prime

[37] See Lange, N. D., Thomas, R. P., Dana, J., & Dawes, R. M. (2011). *Contextual biases in the interpretation of auditory evidence*. Law and Human Behavior, 35: 178-187.

[38] See Rosenthal, R., & Fode, K. (1963). *The effect of experimenter bias on performance of the albino rat*. Behavioral Science, 8: 183-189.

suspect.[39] As David G. Myers says, one additional reason why false beliefs are so resistant to refutation is our beliefs sometimes lead us to act in ways that elicit an apparent confirmation of our beliefs. So our beliefs about others can turn out to be self-fulfilling prophecies.[40]

The *primacy effect* also affects social cognition.[41] Because the impression of the initial information is deeper, stronger, and not easy to change, people tend to form impressions about others based on the initial information they receive, and even interpret new information based on this impression. After the first impression is formed, it is often difficult to change, thus forming a more serious stereotype. Group stereotypes can guide our expectations of group members, causing individuals to interpret the behavior and personality traits of a group member through tinted glasses. Stereotypes can combine attributes that are not easily understood and assign meaning and structure to these attributes. Subliminal exposure to words related to hostility could lead people to view a person who had behaved in an ambiguously hostile manner more negatively.[42] For example, African Americans are perceived as

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[39] See O'Brien, B. (2009). *Prime suspect: An examination of factors that aggravate and counteract confirmation bias in criminal investigations*. Psychology. Public Policy and Law, 15: 315-334.

[40] Translators' note: the quote by David G. Myers is translated from a Chinese edition of Myer's book *Outline of Social Psychology (6th ed.)*, translated by Hou Yubo (侯玉波), Liao Jiangqun (廖江群) et al., 人民邮电出版社 (Posts & Telecom Press), 2014 edition, p. 83.

[41] The primacy effect is a phenomenon in which the initial information has a strong influence on the formation of a person's impression.

[42] Kunda, Z. (1999). Social cognition: Making sense of people. The MIT Press, p.319.

aggressive by white Americans. This group stereotype was activated when researchers showed words such as blues, rhythm, welfare, basketball, and other words associated with people of African descent. Another study showed that participants who had been primed subliminally with African American faces responded in a more hostile manner.[43] This suggests that even brief exposure to photos of African Americans is sufficient to activate negative stereotypes of this group.

*(3) Reasoning Style, Motivation and Emotion*

People's reasoning often does not conform to the rules of formal logic and is often influenced by knowledge and beliefs. When people reason with specific social information content, they reflect the *belief bias effect*, which means that people may ignore logic in their reasoning and tend to accept plausible conclusions and reject implausible ones, while judging the plausibility and implausibility of conclusions often relies on heuristics or shortcuts.[44] Tversky's and Kahneman's studies demonstrate that people are naturally dependent on various heuristics, and although these heuristics are often beneficial, they may also produce systematic errors in judgment, especially in the presence of strong expectations.

*Confirmation bias* is the unconscious tendency of individuals to seek, select, and interpret new information in a way that confirms their

[43] See id. note, p.321.

[44] 王沛 (Wang Pei), 贺雯 (He Wen):《社会认知心理学》,北京师范大学出版社 2014 年版，第 391 页("Social Cognitive Psychology," Beijing Normal University Press, 2014, p. 391).

existing beliefs, hopes, or expectations.[45] That is, when individuals judge and reason about their beliefs or assumptions, they tend to find supporting arguments more convincing and consciously or unconsciously seek information and explanations that are consistent with their existing beliefs or assumptions and ignore those that may be inconsistent with them. [46] Although confirmation bias is primarily manifested as validation of pre-existing beliefs, it is also driven by individuals' goals and expectations. Thus, confirmation bias and expectation effects are closely related.

Judgments in the criminal justice field can be influenced by pre-existing beliefs. In one study, researchers randomly assigned interrogators to either a presumed guilty group or a presumed innocent group. Interrogators who presumed guilt asked more incriminating questions, conducted more coercive interrogations, and tried harder to get the suspect to confess. In turn, this more aggressive style made the suspects sound defensive and led observers who later listened to the tapes to judge them as guilty, even when they were innocent. Follow-up research has confirmed variants of this latter chain of events in the context of suspect interviews.[47]

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[45] Nickerson, R. S. (1998). *Confirmation bias: A ubiquitous phenomenon in many guises*. Review of General Psychology, 2: 175-220.

[46] 吴修良 (Wu Xiuliang), 徐富明 (Xu Fuming), 王伟 (Wang Wei), 马向阳 (Ma Xiangyang), 匡海敏(Kuang Haimin), 《判断与决策中的证实性偏差》,《心理科学进展》2012 年第 7 期 ("Confirmation bias in judgment and decision making," Advances in Psychological Science, Vol. 7, 2012).

[47] See supra note 18, *The forensic confirmation bias: Problems, perspectives, and proposed solutions*.

Research has shown that when engaging in "hot cognition" (i.e., cognitive processes that are driven by our desires and feelings), our goals and emotions can bias our judgments. [48] Strong expectations unconsciously motivate us to seek, perceive, interpret, and create new evidence to confirm our existing beliefs. Motivated reasoning is pervasive, and motivation can indirectly influence reasoning through two types of goals: accuracy goals (i.e., the goal of obtaining the most accurate conclusion) and directional goals (i.e., the goal of reaching a particular conclusion). Directional goals can bias judgment and reasoning, and it is difficult for people to recognize that their perceptions are influenced by preferences or desires.[49]

The influence of emotions on reasoning is manifested in emotionally consistent judgments. When we are in a good mood, we tend to give more positive answers, while in a bad mood, we tend to give more negative answers. That is to say, our judgments are consistent with our own emotions. For example, relative to participants in a neutral mood, sad participants reported more aches and pains and greater discomfort whereas happy participants reported fewer such symptoms. [50] Emotions influence how we understand and interpret important events in our lives.

## IV. Cognitive Biases in Forensic Science

Numerous studies have shown that individuals' pre-existing beliefs, expectations, and the context in which they are placed can influence

[48] See supra note 43, Social cognition: Making sense of people, p.262.

[49] Ibid., p.212.

[50] Ibid., p.248

the judgment and behavior of investigators,[51] alibi witnesses,[52] eyewitnesses,[53] expert witnesses,[54] jurors,[55] judges,[56] and other participants in judicial activities. Cognitive science reveals many laws governing judgment and decision-making that are often described as heuristics, biases, or effects, as well as fallacies or errors when they lead to errors.[57] The large and complex spectrum of cognitive biases has led to the impression that the study of cognitive biases in forensic science is "haphazard" in the sense that different scholars use different terminologies and give different explanations for cognitive biases, such as confirmation bias,

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[51] See Narchet, F. M., Meissner, C. A., & Russano, M. B. (2011). *Modeling the influence of investigator bias on the elicitation of true and false confessions*. Law and Human Behavior, 35: 452 465.

[52] See Marion, S., Kukucka, J., Collins, C., Kassin, S. M., & Burke, T. M. (2016). *Lost proof of innocence: The impact of confessions on alibi witnesses*. Law and Human Behavior, 40: 65-71.

[53] See Hasel, L. E., & Kassin, S. M. *On the presumption of evidentiary independence: can confessions corrupt eyewitness*. Psychological Science, 20: 122-126.

[54] See Dror, I. E., & Cole, S. A. (2010). *The vision in blind justice: Expert perception, judgment, and visual cognition in forensic pattern recognition*. Psychonomic Bulletin & Review, 17: 161-167

[55] See Lange, N. D., Thomas, R. P., Dana, J., & Dawes, R. M. (2011). *Contextual biases in the interpretation of auditory evidence*. Law and Human Behavior, 35, 178-187.

[56] See Halverson, A. M., Hallahan, M., Hart, A. J., & Rosenthal, R. (1997). *Reducing the biasing effects of judges' nonverbal behavior with simplified jury instruction.* Journal of Applied Psychology, 82: 590-598.

[57] Gary Edmond et al. *Contextual bias and cross-contamination in the forensic sciences: the corrosive implications for investigations, plea bargains, trials and appeals*. Law, Probability and Risk, Volume 14, Issue 1, March 2015, Pages 1–25.

context effect, expectation effect, anchoring effect, motivation bias, role theory, priming effect, tunnel vision, and so on.

In order not to make the study of cognitive biases in forensic science look so "haphazard," some scholars use forensic confirmation bias to summarize the class of effects through which an individual's pre-existing beliefs, expectations, motives, and situational context influence the collection, perception, and interpretation of evidence during the course of a criminal case.[58] Some scholars use context effects to summarize the influence of stimulus itself, the situation, and the previous experience or expectations of the subject.[59] However, these generalizations may confound cognitive biases that have different mechanisms of occurrence.

It has been argued that cognitive biases can be classified as psychophysical based errors, association-based judgment errors, and strategy-based errors, according to the mechanism of occurrence. [60] *Psychophysical-based errors* are caused by nonlinear transformation of stimuli such as the reference point effect,[61] and

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[58] See supra note 18, *The forensic confirmation bias: Problems, perspectives, and proposed solutions*.

[59] See supra note 57, *Contextual bias and cross-contamination in the forensic sciences: the corrosive implications for investigations, plea bargains, trials and appeals.*

[60] Arkes, H.R. (1991). *Costs and Benefits of Judgment Errors: Implications for Debiasing,* 110 Psychological Bulletin, 110: 486-498, as cited in Cheng, Yu-Ming, "Cognitive Biases in Decision Judgments and Their Intervention Strategies," Decision Reference, No. 10, 2007.

[61] The reference point effect refers to the fact that individuals choose different reference points in different contexts, resulting in different judgments about the same stimuli.

the simultaneous contrast effect.[62] Association-based errors refers to the priming cognition evoked by the stimulus, which activates mostly information and concepts related to the prime, as a result of which reasoning and decision-making can only be performed within a limited scope and framework.[63] Examples include context effects, tunnel vision, and priming effects. *Strategy-based errors* occur when subjects use a suboptimal strategy [64] e.g., confirmation bias, anchoring effect, etc.

Since cognitive biases have different mechanisms of occurrence and complex influencing factors, it is not advisable to use fundamental concepts from the micro level or generalized concepts from the macro level to conduct applied study of cognitive biases in forensic science. The use of fundamental concepts from the micro level not only gives an impression that the field is "haphazard" but also is not suitable to grasp forensic cognitive biases at the macro level. The use of generalized concepts from the macro level can eliminate the impression that the field is "haphazard," but the "false uniformity" will conceal the differences in mechanisms of occurrence of different cognitive biases, which is not suitable for the targeted discussion and the formulation of corresponding mitigation strategies to be deployed to reduce different cognitive biases.

This paper argues that from the perspective of the cognitive system, cognition can be defined as: the process of cognizing cognitive

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[62] The simultaneous contrast effect means that an individual's perception of the brightness of an area depends not only on the brightness of that area, but also on the background brightness of that area.

[63] See supra note 60, *Costs and Benefits of Judgment Errors: Implications for Debiasing.*

[64] Ibid.

objects by cognitive subjects in a specific cognitive context. The cognitive subject of forensic science refers to forensic staff such as experts, examiners and analysts with expertise in forensic science; the cognitive context of forensic science refers to the location, place and environment where forensic staff conduct forensic work, including case sites, laboratories, offices, etc.; the cognitive object of forensic science refers to the material that needs to be examined and analyzed by forensic staff to reach an expert opinion, such as fingerprints, handwriting, and DNA samples. Therefore, cognitive bias can be defined as *a cognitive subject's misperception of a cognitive object in a specific cognitive context*. Therefore, cognitive biases can be divided into *cognitive subject bias*, *contextual cognitive bias*, and *cognitive object bias*. Cognitive subject bias is caused by subjective factors such as beliefs, expectations, motivations, emotions, roles, and identities possessed by the cognitive subject; contextual cognitive bias is caused by environmental factors (contextual information, environmental cues or suggestions); cognitive object bias is caused by the state and physical properties of the cognitive object (e.g., the clarity and integrity of fingerprints, the quantity and quality of DNA). Cognitive object biases are essentially physical biases and are not discussed in this paper. Only cognitive subjectivity bias and cognitive contextual bias, which are essentially psychological biases, are discussed in this paper.

*(1) Cognitive Subject Bias*

Cognitive subject biases are specifically manifested in the field of forensic science as expectation effects, confirmation bias, motivation bias, and role effects.

The influence of expectation effects on forensic science was first demonstrated by Miller.[65] To test whether expectations induced by irrelevant information affect handwriting examinations, Miller had 12 participants trained in handwriting examination conduct a simulated handwriting examination experiment in which they were told to determine whether a suspect had forged a check. The control group was presented with a sample of the suspect's handwriting and a set of forged checks with handwriting on them, and all participants in this group correctly concluded that the suspect had not forged the checks. The experimental group was provided with a sample of the suspect's handwriting and a forged check, in addition to a letter stating that the suspect had been identified by two eyewitnesses. As a result, 2/3 of the participants in the experimental group concluded that the suspect had forged the check, when in fact the suspect had not. The experiment suggests that participants exposed to incriminating evidence formed the belief that the suspect was guilty and that belief influenced their judgment. Another study also showed that knowledge of a prior confession would taint individuals' perceptions of handwriting evidence.[66] The experimental scenario involved a bank robbery in which the robber had handwritten a note to a bank employee. A suspect was arrested and signed a Miranda waiver. Participants were required to examine the handwriting on the bank note and the Miranda waiver for consistency. The study found that when told that the defendant had confessed to a bank robbery— even though he went on to recant the confession, claiming it was coerced and false—participants

[65] See Miller, L. S. (1984). *Bias among forensic document examiners: A need for procedural changes*. Journal of Police Science and Administration, 12: 407 -411.

[66] See Kukucka, J., & Kassin, S. M. (2012). *Do confessions taint juror perceptions of handwriting evidence?* Paper presented at the Annual Meeting of the American Psychology- Law Society San Juan, Puerto Rico, March 14-17.

were significantly more likely to conclude that the two handwriting samples looked more similar and that the defendant had both authored the note and committed the robbery. Other studies have shown that handwriting examinations can also be affected by confirmation bias. [67]

Fingerprint analysis is also susceptible to confirmation bias. Dror, Charlton, and Peron examined the effect of pre-existing expectations on fingerprint examiners. [68] The study invited five experienced fingerprint experts to examine latent prints. Prior to examination, these experts were told that the fingerprints they were examining were taken from a high-profile case of identification error (the Madrid bombing case), thus creating an extraneous context that the prints were a mismatch. However, the experts were unaware that the fingerprints were actually taken from their own past casework from a couple of years earlier in which they all reached the conclusion that the fingerprints were a match. Due to the influence of biased information, four of the five experts concluded that the fingerprints were a mismatch, contradicting their previous decisions, suggesting that biased information reduces the reliability of fingerprint examination. Subsequently, in another experiment, Dror and Charlton provided eight pairs of fingerprints from real cases to six other fingerprint experts, each of whom had examined those eight pairs in previous cases and reached match or mismatch conclusion. [69] The fingerprints were either not

[67] See Kukucka, J., & Kassin, S. M. (2014). *Do confessions taint perceptions of handwriting evidence? An empirical test of the forensic confirmation bias*. Law and Human Behavior, 38(3): 256-270.

[68] See Dror, I. E., Charlton, D., & Peron, A. (2006). *Contextual information renders experts vulnerable to making erroneous identifications*. Forensic Science International, 156: 174 -178.

[69] See supra note 4, *Why experts make errors*.

accompanied by any information, or were accompanied by information such as "the suspect was in custody when the crime was committed" (for manipulations aimed at biasing the expert to judge the prints as a mismatch), or by information like "the suspect confessed to the crime" (for manipulations aimed at biasing the experts to find a match). The results showed that the information that the suspect was already in custody at the time of the crime caused the experts to change their previous correct conclusion in 17% of the cases. A meta-analysis of the above two studies by Dror and Rosenthal showed that the reliability of six fingerprint experts ranged from 0.33 to 0.80, implying that fingerprint examinations are highly subjective. [70]

Bloodstain pattern analysis was similarly affected by confirmation bias. In one study, researchers invited 27 experienced bloodstain pattern analysts and asked them to determine the pattern of bloodstains, each accompanied by an illustration suggesting the presence of a certain pattern. [71] However, the bloodstain pattern of the illustration implied may not actually exist, which could lead to false conclusions. The results of the study showed that the incorrect pattern type approximately doubled the error rate of participants' bloodstain pattern classification. The participants in another study were 39 skilled bloodstain pattern analysts.[72] Initially, in the absence of any biased information, the researchers asked the participants to

[70] See supra note 4, *Meta-analytically quantifying the reliability and biasability of forensic experts.*

[71] See Taylor, M. C., Laber, T. L., Kish, P. E., Owens, G., & Osborne, N. K. P. (2016). *The reliability of pattern classification in bloodstain pattern analysis*. Journal of Forensic Sciences, 61: 922-927.

[72] See Osborne, N. K. P., Taylor, M. C., Healey, M., & Zajac, R. (2016). *Bloodstain pattern classification: Accuracy, effect of contextual information and the role of analyst characteristics*. Science & Justice, 56: 123-128.

analyze the bloodstains to determine the presence of a specific bloodstain pattern. After drawing preliminary conclusions, participants were allowed to review information such as autopsy reports, witness testimonies, etc., and modify their preliminary conclusions accordingly to form a final conclusion. The results of the experiment found that all participants viewed at least one type of extraneous information; after learning about the extraneous information, 90% of the participants modified their preliminary conclusions. The modifications indicated that many participants (79%) initially determined that a bloodstain pattern was present, but later concluded that it was not, and conversely some participants (13%) initially determined that a bloodstain pattern was not present, but later determined that it was. This suggests that extraneous information influenced these analysts' judgments.

The field of forensic anthropology is equally affected by confirmation bias and expectation effects. In one study, Nakhaeizadeh et al. examined the effect of expectation effects on the assessment of skeletal remains. [73] The experiment required 41 trained examiners to assess the sex, race, and age of the skeletal remains. Participants in the experimental group were given biased information such as whether the skeletal remains were from young white males or older Asian females; participants in the control group were not given such information. The results showed that 31% of the participants in the control group judged the skeletal remains as male; in contrast, 72% of the participants in the experimental group, which generated the expectation of male cadavers, judged the skeletal remains as male. It is evident that after being informed of the biased information, participants in the

[73] See Nakhaeizadeh, S., Dror, I. E., & Morgan, R. (2014). *Cognitive bias in forensic anthropology: Visual assessment of skeletal remains is susceptible to confirmation bias*. Science & Justice, 54: 208-214.

experimental group developed some expectation of the skeletal remains and thus assessed the characteristics of the skeletal remains based on this expectation. Another study asked 99 experienced forensic anthropologists to evaluate the same skeletal remains for trauma.[74] Some of the experts were told that the bones were recovered from mass graves following a holocaust, which implies a high probability of trauma presence; some were told that the bones were recovered from archaeological sites, which implies a low probability of trauma presence; and some were not given any information. The results showed that the experts who were given information about the mass grave were more confident that signs of trauma were present on the bones than those who were given information about the archaeological site. This again suggests that the judgment of the examiners was influenced by expectations.

DNA analysis is considered the "gold standard" of scientific evidence analysis due to its scientific nature and objectivity.[75] However, Krane et al. showed that DNA evidence is not always robust, and that ambiguity allows contextual information to influence DNA analysis.[76] Forensic examiners typically use electrophoretic mapping when analyzing DNA evidence. This equipment creates stable positions on chromosomes (i.e., motifs) and measures the presence of alleles (genetic variants). The presence of alleles on the locus is indicated by "peaks" or "bumps,"

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[74] See Nakhaeizadeh, S., Hanson, I., & Dozzi, N. (2014). *The power of contextual effects in forensic anthropology: a study of biasability in the visual interpretations of trauma analysis*. Journal of Forensic Sciences, 59: 1177-1183.

[75] Lynch, M. (2003). *God's signature: DNA profiling, the new gold standard in forensic evidence*. Endeavor, 27: 93–97.

[76] Krane DE, Ford S, Gilder JR, Inman K, Jamieson A, Koppl R, et al. (2008). *Sequential unmasking: a means of minimizing observer effects in forensic DNA interpretation*. Journal of Forensic Science, 53(4): 1006-7.

and the absence of bumps may indicate the absence of alleles. This method allows the examiner to match the suspect's DNA with DNA extracted from the crime scene. However, sometimes many factors (e.g., environmental contamination) make it difficult to determine whether an allele is present on a locus, introducing noise and uncertainty into the analysis. [77] Noise obscures DNA evidence and increases the chances that contextual information unrelated to the test will influence the analyst.

A study has shown that DNA analysts are susceptible to errors caused by confirmation bias when analyzing complex DNA mixtures. [78] The experiment was designed based on a real gang rape case, in which one of the assailants testified against the other suspects in return for a lesser sentence as part of his cooperation in a plea bargain deal. The testimony of the admitted rapist would not be admitted without corroborating evidence. Knowing this, DNA analysts analyzed the DNA mixture, and concluded that the DNA mixture from inside the victim's body cannot prove the innocence of those suspects charged. One suspect, however, consistently denied his involvement in the gang rape. To examine the impact of confirmation bias, the researchers had 17 independent DNA analysts analyze the same DNA mixture samples from the case again, without the influence of other extraneous information. As a result, only one examiner concluded that the suspect "cannot be excluded," examiners concluded "inconclusive," and 12 examiners concluded "exclude." It is evident that the DNA experts in that gang rape case were influenced by confirmation bias and

[77] Lee Curley, James Munro, Martin Lages, Rory Maclean.(2019). *Assessing Cognitive Bias in Forensic Decisions: A Review and Outlook*. Journal of Forensic Sciences, Early View.

[78] See Dror I, Hampikian G. *Subjectivity and bias in forensic DNA mixture interpretation*. Science & Justice, 51(4): 204 -8.

interpreted the DNA mixture in a way that would corroborate the testimony of that cooperator. Further research has shown that where complex and obscured mixtures are analyzed, due to the presence of subjectivity, analysis is more susceptible to irrelevant contextual information and subjective reasoning. [79]

Thompson elaborated on the interaction between context and ambiguous evidence, noting that subjective interpretation of ambiguous DNA evidence is most likely to lead to false positive results (e.g., incarceration of an innocent person).[80] Uncertainty arises in the interpretation of analytical results if the DNA sample is small or has degraded. This uncertainty is difficult to correct by subsequent analysis because the sample may have been consumed in the initial testing, making it impossible for retesting. Thus, a limited sample is more likely to be subjectively interpreted by the examiner who develops such interpretation based on the suspect's confession or other evidence (contextual information unrelated to the analysis). Thompson further noted that it is inappropriate for forensic staff to consider contextual information unrelated to their work because unlike the trier of fact, their role is to provide an evidentiary opinion as an expert.[81] It is the task of the trier of fact to consider expert opinions together with contextual information in an integrated manner. Thus, because of the difference in roles

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[79] Butler M, Kline MC, Coble MD. (2018). *NIST interlaboratory studies involving DNA mixtures (MIX05 and MIX13).* Forensic Science International: Genetics, 37: 81-94.

[80] See Thompson WC. (1977). *Accepting lower standards: the national research council's second report on forensic DNA evidence.* Jurimetrics Vol. 37, No. 4 (Summer 1997), pp. 405-424.

[81] Thompson WC. (2011). *What role should investigative facts play in the evaluation of scientific evidence?* Australian Journal of Forensic Science, 43(2)(-3): 123-134. Australian Journal of Forensic Science, 43(2): 123-134.

each plays in the legal system, contextual information should be used by the trier of fact (because it is relevant information), rather than the forensic staff. Thompson's research shows that even objective scientific procedures can be influenced by irrelevant contextual information whenever subjective interpretation is involved.[82]

The influence of confirmation bias as well as expectation effects on forensic science is widespread and has been found in the fields of fire investigation,[83] forensic pathology,[84] crime scene investigation[85] in addition to handwriting examination, fingerprint examination, bloodstain pattern analysis, forensic anthropological assessment, and DNA analysis.

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[82] Thompson WC. (2009). *Beyond bad apples: analyzing the role of forensic science in wrongful convictions.* Southwest University Law Review, 37: 971 Southwest University Law Review, 37: 971 -994.

[83] See Bieber, P. (2012). *Measuring the impact of cognitive bias in fire investigation,* in Proceedings of the 5th International Symposium on Fire Investigation Science and Technology 3, 15 (International Symposium on Fire Investigation Science and Technology, National Association of Fire Investigators, International 2012).

[84] See W.R. Oliver, X. Fang. (2016). *Forensic pathologist consensus in the interpretation of photographs of patterned injuries of the skin.* Journal of Forensic Science, 61: 972-978; W.R. Oliver. (2017). *Reasons for lack of consensus in forensic pathologist interpretation of photographs of patterns of injury of the skin.* Journal of Forensic Science, 62: 674-680; W.R. Oliver. (2017). *Effect of history and context on forensic pathologist interpretation of photographs of patterned injury of the skin.* Journal of Forensic Science, 62:1500-1505.

[85] See C.A.J. van den Eeden, C.J. de Poot, P.J. van Koppen.(2016). *Forensic expectations: Investigating a crime scene with prior information.* Science & Justice, 56: 475-481; C.A.J. van den Eeden, C.J. de Poot, P.J. van Koppen. (2019). *The forensic confirmation bias: a comparison between experts and novices.* journal of Forensic Science, 64(1): 120-126.

Research has shown that confirmation bias is sometimes driven by motivations, such as *the need for cognitive closure*. The need for cognitive closure refers to a cognitive motivation that individuals exhibit during information processing, which is eagerness to get an answer.[86] In criminal investigations, when a suspect is potentially suspected of committing a crime, investigators with a high need for cognitive closure are more reluctant to accept evidence that is inconsistent with the case theory than investigators with a low need for cognitive closure. The impact of confirmation bias is reduced when investigators are aware of the possible existence of other suspects. [87]

To examine whether the internal motivations of examiners influence their tendency to make certain judgments, the researchers conducted semi-structured interviews with 13 experienced fingerprint examiners. [88] The results found that although the examiners perceived themselves as objective, they showed a strong interest in capturing criminals and solving cases in some serious, high-profile cases. They expressed a strong need for the case to be resolved with a successful conclusion, and a hope that their examination results would help the courts secure a successful

[86] 刘子旻 (Liu Zimin), 时勘 (Shi Kan), 万金 (Wan Jin), 陈晨 (Chen Chen),《认知闭合需要研究梳理与未来走向》,《心理科学进展》2018 年第 4 期 ("Cognitive closure needs research combing and future direction," Advances in Psychological Science, Vol. 4, 2018).

[87] See supra note 46,《判断与决策中的证实性偏差》(Confirmation bias in judgment and decision making).

[88] See Charlton, D., Fraser-Mackenzie, P. A. F., & Dror, I. E . (2010). *Emotional experiences and motivating factors associated with fingerprint analysis*. Journal of Forensic Sciences, 55: 385 -393.

conviction; many examiners described a sense of pleasure and satisfaction in arriving at matching results and enjoyed the joy of having their test results accepted. At the same time, some examiners expressed a fear associated with making mistakes in fingerprint examination, especially with getting false-positive results that could lead to the conviction of an innocent person. Therefore, some examiners deliberately make conservative examination conclusions, supposedly to avoid such errors.[89]

The examiner will also be influenced by external motivation. When investigators ask examiners to produce test results in their favor, examiners may be influenced by such extrinsic motivations to do so. One of the most egregious situations is when investigators openly told the examiner what they hoped the requested test would conclude.[90] Alternatively, investigators may suggest to examiners that their previous test results are inappropriate and should be altered by selectively asking them to test again.[91]

Role effects are where scientists identify themselves within adversarial judicial systems as part of either the prosecution or defense teams, and this may introduce subconscious bias which can influence decisions especially where some ambiguity exists.[92] For

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[89] However, further experimental studies are needed to determine whether and how internal motivation actually influences the examiners' judgments.

[90] Risinger, D. M., Saks, M. J., Thompson, W. C., & Rosenthal, R. (2002). *The Daubert/Kumho implications of observer effects in forensic science: Hidden problems of expectation and suggestion.* California Law Review, 90: 1-56.

[91] Saks, M. J., Risinger, D. M., Rosenthal, R., & Thompson, W. C. (2003). *Context effects in forensic science: A review and application of the science of science to crime laboratory practice in the United States.* Science & Justice, 43: 77-90.

[92] See supra note 8, *Cognitive Bias Effects Relevant to Forensic Science Examinations.*

example, in fiber examinations when potential contact between two textile items is under consideration but no matching fibers are found, cognitive bias may be seen from a scientist acting on behalf of the prosecution, and interpreting the findings as neutral rather than considering whether the absence of matching fibers might support the view that the contact had not occurred. [93]

The reality of forensic staff as part of a team, on the side of "one party" (also called expert clientelism), affects their ability to remain impartial, objective, and unbiased. This affects not only how they present evidence in court, but also how they conduct forensic analysis. The impact of the role effects was confirmed in a study. [94] The study had 108 forensic psychologists and psychiatrists conduct risk assessments on the same suspects, with some participants being told they were providing assessment services for the defense and others being told they were providing assessment services for the prosecution. For the same suspects, those who believed they were working for the prosecution tended to assign higher risk scores to offenders, whereas those who believed they were working for the defense tended to assign lower risk scores to the same offenders; the effect sizes ranged up to 0.85. The results provided strong evidence of an "adversarial allegiance" or "adversarial bias" among some forensic experts in adversarial legal proceedings.

*(2) Cognitive Contextual Bias*

[93] Ibid.

[94] See Murrie, D. C., Boccaccini, M. T., Guarnera, L. A., & Rufine, K. A. (2013). *Are Forensic Experts Biased by the Side that Retained Them?* Psychological Science, 24(10): 1889-1897.

Cognitive contextual biases are specifically manifested within the field of forensic science as contextual effects and presentation effects.

Irrelevant suggestive information can influence the examiner's analysis. However, research has shown that non-suggestive information can also influence the examiner's judgment, an effect sometimes referred to as contextual bias rather than confirmation bias. This is because non-suggestive information does not lead to certain expectations on the part of the examiner, but rather has an impact by eliciting stereotypes, evoking negative emotions, etc. [95]

Examiners may be so outraged by crime that they want to put "guilty" suspects in jail. Examiners may also be more or less interested in crimes committed by specific races, genders, social classes, or employment groups (e.g., prostitutes). [96] One study showed that simply knowing a suspect's gender, age, race, and religion can influence an examiner's judgment. [97] The researchers first had participants read a simulated police report about a stereotypical crime (e.g., child molestation) or a non-stereotypical crime (identity theft) and then asked them to determine whether the suspect's fingerprints matched those from the crime scene. When conducting the examination, participants were allowed to access personal information about the suspect (e.g., race, gender,

[95] Jeff Kukucka. (2018). *Confirmation Bias in the Forensic Sciences: Causes, Consequences, and Countermeasures*. In Wendy J. Koen and C. Michael Bowers. The Psychology and Sociology of Wrongful Convictions. Academic Press.

[96] See supra note 59, *Contextual bias and cross-contamination in the forensic sciences: the corrosive implications for investigations, plea bargains, trials and appeals.*

[97] See Smalarz, L., Madon, S., Yang, Y., Guyll, M., & Buck, S. (2016). *The perfect match: do criminal stereotypes bias forensic evidence analysis?* Law and Human Behavior, 40, 420-429.

etc.). The results of the experiment found that, in complete contrast to personal information indicating that the suspect was Asian female (which does not have a strong stereotypic association with child molesters), participants were often more likely to misjudge the fingerprints as a match when personal information indicated that the suspect was white male (which has strong stereotypic association with child molesters). However, for the crime of identity theft, which is not strongly associated with a criminal stereotype, the suspect's characteristics did not affect participants' judgments. It is evident that the suspect's personal information activated certain criminal stereotypes in fingerprint examiners and influenced their judgments.

Another study found that the emotional state of individual towards the crime biased forensic decision-making. [98] In that study, participants were asked to judge whether ambiguous fingerprints matched. Some fingerprints were given without any contextual information, and others were presented with information that they were taken at a violent crime scene (e.g., a murder) and accompanied by a bloody photograph (e.g., an autopsy photograph of the victim). Although this information did not imply that the suspect was guilty, participants who understood the nature of the case and saw the bloody photographs often identified the fingerprints as a match, compared to situations in which no contextual information was given. The researchers suggest that such contextual information influenced the participants' emotions, and that the evoked emotions in turn influenced their judgments.

It has been suggested that bite-mark evidence has a highly emotive provocative influence and thus the judgment of forensic

[98] See supra note 4, *When emotions get the better of us: The effect of contextual top-down processing on matching fingerprints.*

odontologists is often influenced by emotional information.[99] To test the possibility of this influence, the investigators had dental students and non-dental students compare bite-marks on the victim's skin to the suspect's dentition surface.[100] The experiment began by briefing participants on the physical comparison method of bite-mark analysis, and six practice trials were conducted prior to the formal experiment. In the formal experiment, some of the bite-marks and dentition surfaces were accompanied by real crime scene photographs and some of the captioned photographs were accompanied by a subliminal prime, in which the words "same" and "guilty" were presented, which the investigators believed would lead to matching judgments. However, the results of the experiment showed that when these factors were present, participants were actually less likely to make matching judgments. The researchers speculate that these factors made participants feel more responsible for their decisions, which made them more conservative in their judgments.

In addition, public, media, politics, and institutional pressures (e.g., demands to ascertain the facts of a case) and work environments (e.g., long hours) can affect the judgment of examiners, which can adversely affect their work or make it difficult to devote sufficient time and resources to other examination tasks, especially when faced with large numbers of crime cases.[101] Studies have shown that fatigue can affect examiners' visual working memory and decision-

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[99] See Page, M., Taylor, J., & Blenkin, M. (2012). *Context effects and observer bias: Implications for forensic odontology*. Journal of Forensic Sciences, 57: 108-112.

[100] See Osborne, N. K. P., Woods, S., Kieser, J., & Zajac, R. (2014). *Does contextual information bias bitemark comparisons?* Science & Justice, 54: 267-273.

[101] See supra note 58, *Contextual bias and cross-contamination in the forensic sciences: the corrosive implications for investigations, plea bargains, trials and appeals.*

making.[102] The participants in the study, who were fingerprint examiners with actual work experience, were asked to perform fingerprint examinations first in the morning while participants reported still being relatively alert; and the participants' examination activities were recorded by an eye-tracker. Later, after completing an extremely difficult visual perception training that caused visual fatigue, the participants were asked to perform the fingerprint examination again and to record the eye movements. The result showed that participants have difficulty placing multiple features into working memory when tired. In addition, the participants tended to terminate the search process earlier and draw hasty conclusions. Another study showed that workplace stress and well-being can also influence forensic staff's decision-making.[103]

Presentation effects refer to the way in which the presentation of the examination material can influence the judgment of the examiner. A study has shown that the presentation of fingerprints in AFIS (Automated Fingerprint Identification System) can lead to base rate bias.[104] AFIS employs a large-scale database retrieval technique which is able to provide fingerprint examiners with a ranked list of possible matches to fingerprints of unknown origin. In most cases, if a match exists, the fingerprint will be at the top of

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[102] See Thomas Busey, Henry J. Swofford, John Vanderkolk, Brandi Emerick. (2015). *The Impact of Fatigue on Latent Print Examinations as Revealed by Behavioral and Eye Gazing Testing.* Forensic Science International, 251: 202-208.

[103] Amy M. Jeanguenat, Dror, I. E. (2017). *Human Factors Effecting Forensic Decision Making: Workplace Stress and Well-being.* Journal of Forensic Sciences, 63(4): 1-4.

[104] See Dror, I. E., Wertheim, K., Fraser-Mackenzie, P., & Walajtys, J. (2012). *The impact of human-technology cooperation and distributed cognition in forensic science: Biasing effects of AFIS contextual information on human experts*. Journal of Forensic Sciences, 57: 343–352.

the list. This base rate leads the examiner to expect that the matching fingerprint is at the top of the list. The experimental results found that when the matching time was short, examiners were more likely to make false identifications, false exclusions, or incorrectly judge a matching fingerprint as inconclusive. Also, they were more likely to incorrectly identify fingerprints at the top of the list (which one would expect to be a match) as a match and fingerprints at the bottom of the list as a mismatch. Technology is often viewed as a solution to human cognitive bias, but AFIS increases the risk of creating cognitive bias. The successful use of technology depends on the consideration of the human factor in order to correctly and efficiently allocate cognitive resources.[105] For example, random ordering of the list of fingerprints returned by AFIS search can break the base rate expectation. In addition, reviewers usually have an expectation that all results identified as matches by the initial examinations are correct. Introducing non-matches but "look-alike" fingerprints in the review process can remove this expectation from the reviewer.[106]

The manner in which the test samples are submitted can also create cognitive bias. Typically, investigators submit only two test samples: an evidentiary sample taken from the crime scene and a reference sample taken from the suspect. It has been argued that this type of submission may invariably induce examiners to make

[105] Dror IE, Mnookin J. (2010). *The use of technology in human expert domains: challenges and risks arising from the use of automated fingerprint identification*. Law Probability and Risk, 9(1): 47-67.

[106] See Dror IE. (2014). *Practical solutions to cognitive and human factor challenges in forensic science*. Forensic Science Policy & Management An International Journal, 4:105-113.

matching judgments.[107] Even without the influence of any other extraneous information, the examiner may form the belief that the investigator has good reason to believe that the suspect is guilty and that is why the two samples were selected for testing. In other words, the examiner believes that "investigators do not select suspects or evidence at random; they select only evidence that they have reason to believe is relevant to the crime.[108]

*(3) Mechanisms of Action of Forensic Cognitive Bias*

The negative effect of forensic cognitive bias is achieved through two mechanisms, namely, the bias cascade effect and the bias snowball effect.

The bias cascade effect is the generation of cognitive bias as a result of irrelevant information cascading from one stage to another.[109] For example, sometimes the investigator collecting evidence from the crime scene and the examiner examining the evidence in the laboratory are the same person. Investigators who collect evidence at the crime scene are exposed to a variety of contextual information most of which is necessary for them to complete their work at the scene. After collecting evidence, they then work as examiners to examine and interpret the evidence in the laboratory. At this time, the contextual information learned from the crime scene may be irrelevant to the examination work but may cause

[107] See Whitman, G., & Koppl, R. (2010). *Rational bias in forensic science.* Law, Probability, & Risk, 9: 69-90.

[108] See supra note 91, *The Daubert/Kumho implications of observer effects in forensic science: Hidden problems of expectation and suggestion.*

[109] Dror IE; Ruth M. Morgan; Carolyn Rando; and Sherry Nakhaeizadeh. (2017). *The Bias Snowball and the Bias Cascade Effects: two Distinct Biases that May Impact Forensic Decision Making.* Journal of Forensic Sciences, 62(3): 832-833.

cognitive contamination to the examiners, and this way of working is extremely prone to cognitive bias. Although there are many forms of bias cascade effect, they have one thing in common--that is, irrelevant information cascading from one time period to another. Controlling the bias cascade effect can be achieved by controlling the flow of information between different stages in the judicial process.

The bias snowball effect refers to the increasing of bias as irrelevant information from a variety of sources is integrated and each piece of irrelevant information influences the other. [110] One study found that examiners conducting handwriting examinations were more likely to conclude that there was a match when they learned of a suspect's admission of guilt, even if the two handwriting samples did not, in fact, match.[111] The bias snowball effect may also affect the objective examination of other evidence. When an examiner who is analyzing one piece of evidence learns the results of another scientific evidence examination (biased or unbiased), his examination may be influenced. For example, after a bite-mark examiner learns that a suspect has been identified by DNA evidence, this will affect the results of the bite-mark examination. When the examiner concludes that the bite-marks match, it looks as if it were based solely on the examination of the bite-marks. When different, seemingly independent pieces of evidence (e.g., bite-marks and DNA evidence) interact with each other, their probative value is reduced. Furthermore, this will result in double counting of the same evidence. When the bite-mark examiner is aware of and influenced by the DNA test results, the DNA evidence will be used twice in the combined decision-making judgment: once indirectly through the bite-mark evidence, and once

[110] Ibid.

[111] See supra note 21, *Cognitive Bias and Its Impact on Expert Witnesses and the Court.*

directly through the DNA evidence. The bias snowball effect is not limited to the field of forensic examination--an eyewitness may also be influenced by knowledge of other evidence about the suspect, and in turn, eyewitness testimony may influence the interpretation of other evidence.

## V. Responses to Forensic Cognitive Bias

It would be unwise to conduct too much research on the question of whether cognitive bias exists in forensic science. What needs to be done now is to develop methods to minimize cognitive bias by thinking rationally about what information is unnecessary, what information is pertinent to the examination task and under what conditions and what is the appropriate order to conduct the examination.[112] In general, information that is not relevant to the examination task can influence the judgment and decision-making of the examiner, so there should be measures in place to ensure that forensic scientists rely solely on task-relevant information when performing forensic analyses.[113] Research has shown that the following methods are effective ways to control forensic cognitive bias.

### *(1) Case Manager*

Contextual bias may have a subliminal effect. Thus, even if the examiner wants to work honestly and objectively, exposure to task-irrelevant information can bias the examination. In addition, the unconscious nature of contextual bias means that people do not

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[112] Risinger, M. D. (2009). *The NAS Report on forensic science: A glass nine-tenths full (this is about the other tenth)*. Jurimetrics, 50: 21-34.

[113] See supra note 7, *Ensuring that Forensic Analysis Is Based upon Task-Relevant Information*.

perceive the effects of contextual bias. Therefore, even if examiners honestly believe that they are working in the most objective manner, task-irrelevant information can bias their examinations. The easiest way to avoid bias from irrelevant information is to use blind testing. Often, examiners are exposed to extraneous information from a variety of sources, such as through direct contact with investigators, victims and their families. Therefore, it is important to avoid undue influence from irrelevant information on the examiners as much as possible and to avoid exposing them to unnecessary task-irrelevant information.

The use of a case manager to manage the contextual information serves the purpose of blind testing. In a forensic science laboratory, two roles should be distinguished: the case manager and the examiner. The case manager knows all the information about the case, and the examiners can only access information pertinent to their specific examination task.[114] Thus, the case manager can communicate with the investigators to decide which evidence to test and then assign the evidence to the examiners. It is up to the case manager to decide what information is pertinent to the examination and what information is irrelevant, and to provide the examination with only task-relevant information. The examiner may eventually learn more about the case, but only after completing the examination task and documenting the results. The laboratory may designate one person to serve as the case manager for multiple examiners or have examiners rotate in the role of the case manager. The rotating approach is particularly suitable for smaller forensic laboratories; even in laboratories with only two examiners, these two can act as case managers for each other, so that in important

[114] See Thompson W.C. (2011). *What role should investigative facts play in the evaluation of scientific evidence?* Australian Journal of Forensic Science, 43(2-3): 123-34.

examinations, both people can avoid accessing task-irrelevant information. This approach has been adopted in document examination [115] and firearms examination. [116] The Victoria Police Forensic Services Department in Australia adopted the case manager method in document examination to remove unnecessary information from case files (e.g., charges against suspects, suspects' guilty pleas, etc.). The results showed that the use of case managers is not complex, overly time-consuming or expensive, and examiners can confidently state that "the opinions formed are based only on the evidence examined". [117]

*(2) Linear Sequential Unmasking*

The case manager model aims to prevent cognitive bias by ensuring that examiners are not exposed to task-irrelevant information. However, certain information capable of causing cognitive bias is relevant to the examination process. In such cases, it is not possible to simply exclude such information, but rather a scientific sequence of examinations needs to be defined which specifies when and under what conditions the examiners can access such information. To this end, Krane, et al. first proposed the use of the "sequential

[115] See supra note 10, *The management of domain irrelevant context information in forensic handwriting examination casework.*

[116] See E.J.A.T. Mattijssen, W. Kerkhoff, C.E.H. Berger, Dror IE, R.D. Stoel. (2016). *Implementing context information management in forensic casework: minimizing contextual bias in firearms examination*, Science & Justice, 56: 113-122.

[117] See supra note 10, *The management of domain irrelevant context information in forensic handwriting examination casework.*

unmasking" procedure in DNA analysis.[118] This procedure was later extended to all areas of forensic science by Dror, et al., who named the method "linear sequential unmasking" (LSU).[119]

Sequential unmasking requires that the examiner to first examine the sample taken from the crime scene and record the results before he or she can learn about reference materials (i.e., information about the suspect or other known information) that are relevant to the examination task. In this way, the examination proceeds from the evidence to the suspect, preventing backward and circular reasoning from suspect to evidence. After completing the initial examination and recording the results, the examiner can reanalyze and revise the initial results based on the reference material. The sequential unmasking procedure allows the examiner to revise the examination results without restrictions on conditions or number of times, but the revisions must be recorded to reflect the presence of cognitive bias effects. Unlike the sequential unmasking procedure, the linear sequential unmasking procedure requires a limit on the number of revisions and conditions under which a revision can be made by the examiner. The limit depends on the examiner's level of confidence in the initial examination. However, in-depth research is needed to determine what confidence level corresponds to what limit on the number of revisions. In summary, the (linear) sequential unmasking procedure defines a linear reasoning process (from evidence to suspect) for forensic science

[118] See Krane, D. E., Ford, S., Gilder, J. R., Inman, K., Jamieson, A., Koppl, R, et al. (2008). *Sequential unmasking: A means of minimizing observer effects in forensic DNA interpretation*. Journal of Forensic Sciences, 53(4): 1006-1007.

[119] See Dror, I. E., Thompson, W. C., Meissner, C. A., Kornfield, I., Krane, D., Saks, M., et al. (2015). *Context management toolbox: A linear sequential unmasking (LSU) approach for minimizing cognitive bias in forensic decision making*. Journal of Forensic Sciences, 60(4): 1111-1112.

examinations, limits circular reasoning, and provides flexibility to the examiner's work while reasonably limiting the effects of bias.

Although the (linear) sequential unmasking process has been criticized in terms of economic cost[120] and efficiency,[121] there have been forensic science laboratories that have adopted the principles of linear sequential unmasking. For example, the Netherlands Forensic Institute has adopted linear sequential unmasking measures in DNA analysis, document examination and firearms examination and has proved to be successful.[122] The successful practice of the Victoria Police Forensic Services Department has demonstrated that the linear sequential unmasking process is easy and cost-effective to operate.[123] Similar procedures have been adopted by forensic science laboratories in the United States. For example, the FBI laboratory has adopted a similar latent fingerprint analysis procedure (linear ACE-V procedure); the Virginia Department of Forensic Science and the Minnesota Bureau of Criminal Apprehension have adopted similar procedures.[124] In

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[120] See Charlton, D. *Standards to avoid bias in fingerprint examination: are such standards doomed to be based on fiscal.* Journal of Applied Research in Memory and Cognition, 2, 71-72.

[121] See Triplett, M. *Errors in forensics: Cause(s) and solutions.* Journal of Applied Research in Memory and Cognition, 2, 48 -49.

[122] See supra note 11, *Minimizing contextual bias in forensic casework.*

[123] See supra note 10, *The management of domain irrelevant context information in forensic handwriting examination casework.*

[124] See Office of the Inspector General US Department of Justice (2011) *A Review of the FBI's Progress in Responding to the Recommendations in the Office of the Inspector General Report on the Fingerprint Misidentification in the Brandon Mayfield Case,* Office of the Inspector General US Department of Justice, Washington, DC, 1-53.

conclusion, in order to counter the negative impact of cognitive bias on forensic science, modifications to testing procedures will be the way forward for forensic science and are desirable to ensure that forensic testing is conducted objectively and fairly.

*(3) Evidence Lineups*

The blind test and the case manager model can prevent the examiner from being influenced by the suspect's confession, eyewitness identification results, and other task-irrelevant information. However, it does not prevent the examiner from being influenced by the unreasonable expectation, which is anyone identified as a suspect may be the perpetrator. In the current practice of forensic science, examiners typically only compare an evidentiary sample to a reference sample to determine whether the two samples are from the same individual. This type of testing may allow the examiner to speculate that the investigator has other evidence to prove the guilt of the suspect, and this unreasonable speculation can influence the examiner's judgment.[125] To eliminate such influence, a method worth considering is the use of evidence lineups.[126] The evidence lineup procedure is similar to the lineup identification used in eyewitness identification procedures. The examiner compares the evidentiary sample with a set of evidence lineups that mix filler and reference samples. The examiner would be blind to which items of evidence in the evidence lineup are fillers which are known mismatch samples and which are the true questioned evidence. The examiner's job is to determine which

[125] See supra note 107, *Rational bias in forensic science*.

[126] See Saks, M. J., Risinger, D. M., Rosenthal, R., & Thompson, W. C. (2003). *Context effects in forensic science: A review and application of the science of science to crime laboratory practice in the United States*. Science & Justice, 43, 77-90.

sample, if any, in the evidence lineup, is a match to the evidentiary sample.

However, the use of such evidence lineups faces certain critiques and challenges. First, it is a challenge to generate filler samples and to select the right filler samples for the evidence lineup. For forensic science disciplines with large sample databases (e.g., fingerprint databases), generating filler samples is relatively easy, but it can be difficult for other forensic disciplines. So more research on the issues of filler samples in other disciplines is needed to develop the best method to generate and select filler samples. [127] Second, it has been argued that evidence lineups unreasonably increase the difficulty of examination task. But this practice may not impede forensic examiners due to their specialized knowledge. And in important cases, by simply requiring the examiner to do more tests, the evidence lineup approach eliminates the examiner's unreasonable expectations and beliefs and makes the results more objective.[128]

*(4) Blind Verification*

In the verification phase, single and double-blind procedures should be used whenever possible. This procedure requires that the verifier be blind to preliminary findings of the initial examiner. If possible, the verifier shall also be blind to the identity of the initial examiner. Likewise, the examiner cannot pick the verifier. Cross-laboratory verification is a desirable approach to provide an

[127] Reese, E. J. (2012). *Techniques for mitigating cognitive biases in fingerprint identification*. UCLA Law Review, 59, 1252-1290.

[128] See supra note 95, *Confirmation Bias in the Forensic Sciences: Causes, Consequences, and Countermeasures*.

independent method to test the reliability of initial test results.[129] In addition, most forensic laboratories only verify positive test results, and the vast majority of positive test results are confirmed after verification. Therefore, it is recommended that all test results be verified (i.e., matching, exclusion, and non-conclusive results). Where a laboratory operates a practice of only verifying positive results, a strong base-rate expectancy may be created in the mind of the verifier leading them to expect a match. Allowing verifiers to work in an environment that is as free of "cognitive contamination" as possible can help to reduce the base-rate expectation.

*(5) Professional Training*

Being aware of the existence of cognitive biases and motivated to correct them is a necessary condition to overcome the effects of cognitive biases.[130] Therefore, professional trainings on cognitive bias must be provided to examiners in order to make them aware of the dangers and effects of cognitive contamination as well as the existence of cognitive bias and its effects on examination work, so that examiners no longer view cognitive bias as a professional ethical issue with the belief that cognitive bias can be overcome by willpower alone. Professional training should teach examiners to remain open to various testing hypotheses and to consider competing hypotheses in an integrated manner, which allows examiners to notice more information and to analyze various information more thoroughly and carefully, thus making it easier to

[129] See Stevenage, S.V., Bennett, A. (2017). *A biased opinion: demonstration of cognitive bias on a fingerprint matching task through knowledge of DNA test results.* Forensic Science International. 276: 93-106.

[130] Lilienfeld, S. O., Ammirati, R., & Landfield, K. (2009). *Giving debiasing away: Can psychological research on Correcting cognitive errors promote human welfare?* Perspectives on Psychological Science, 4, 390-398.

detect contradictions. [131] Only when cognitive biases are correctly understood will examiners become less resistant to debiasing, so that debiasing strategies can be effectively implemented.

At the same time, investigators, prosecutors, and judges need to receive training related to forensics and cognitive bias so that they understand how examiners arrive at their opinions. Judges in particular should be educated with regard to the procedures by which forensic examiners reached their conclusions. And they should be trained to ask questions like "what did the examiner know and when did he or she know it?" in order to improve judges' ability to evaluate forensic examination opinions.[132]

## VI. Shortcomings of Existing Research and Future Research Prospects

Existing studies have examined the various manifestations of cognitive bias in forensic science, the ways in which cognitive bias affects forensics, and have proposed countermeasures to mitigate the effects of cognitive bias. However, some of the studies are inadequate and need to be further improved.

*(1) The mechanisms of action and coping methods of each cognitive bias need to be further explored*

At present, different scholars have conducted different studies on cognitive biases in forensic science, analyzing the effects of cognitive biases in forensic science respectively from the perspectives of confirmation bias, contextual effect, expectation

[131] See supra note 46, *Confirmation bias in judgment and decision making.*

[132] See supra note 18, *The forensic confirmation bias: Problems, perspectives, and proposed solutions.*

effect, and role effect. However, there is a lack of discussion on the influencing factors and mechanisms of action of each cognitive bias and the interrelationships among them, and some studies even confuse different cognitive biases. For example, using forensic confirmation bias to generalize the influence of individuals' pre-existing beliefs, expectations, motivations, and contexts on the collection, perception, and interpretation of evidence in the course of a criminal case confuses the relationship between confirmation bias as a strategic bias and contextual bias as a relevance bias. Only by distinguishing between cognitive biases with different influencing factors and mechanisms of action can appropriate mitigating strategies be developed for specific cognitive biases. For example, case managers can be used to control biases caused by irrelevant information; randomization strategies can be used to reduce biases caused by base-rate expectation; and linear sequential unmasking can be used to manage biases generated by reference materials. Therefore, future research should provide an in-depth discussion of the factors and mechanisms that influence various cognitive biases in forensic science, so that different cognitive biases can be effectively controlled.

*(2) Experimental rigor and ecological validity need to be enhanced*

Despite the dramatic increase in research related to cognitive biases in forensic science, some of the studies lacked experimental rigor and ecological validity. Therefore, future research needs to employ scientifically sound experimental designs and investigate the effects of contextual biases on operational accuracy.

In terms of experimental rigor, some studies which support the idea that contextual bias has a negative impact on forensic judgments suffer from methodological flaws, such as small sample sizes that

weaken the persuasiveness and generalizability of the studies.[133] In the study by Dror et al. the sample size was only five and lacked a control group, making it difficult to determine whether contextual bias actually influenced forensic decision-making and to further generalize the findings.[134] Studies examining the effect of irrelevant information on forensic judgment did not measure the accuracy of the test results, which made it difficult to infer whether contextual bias positively or negatively influences forensic staff's decisions. Another methodological flaw is that there was variation in the experimental design and the difficulty of tasks involved in the hypotheses, which made it difficult to distinguish across studies whether the effects of contextual bias were caused by contextual information or by task difficulty.

In terms of ecological validity, it was difficult to determine the general representativeness of the experimental results. While some experiments were conducted on forensic staff in their daily work settings, others were conducted on college students in experimental settings. The difference between these two types of experiments is related to what Towler, et al. calls operational accuracy and cognitive accuracy.[135] Studying forensic decision-making of forensic examiners in an operationally valid real-world setting examines operational accuracy, whereas studying forensic decision-making of forensic examiners in an experimental setting examines cognitive accuracy because the commonly used testing instruments

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[133] See Cooper GS, Meterko V. (2019). *Cognitive bias research in forensic science: a systematic review*. Forensic Science International, 297: 35-46.

[134] See supra note 68, *Contextual information renders experts vulnerable to making erroneous identifications*.

[135] See Towler A, White D, Ballantyne K, Searston RA, Martire KA, Kemp RI. (2018). *Are forensic scientists experts?* Journal of Applied Research in Memory and Cognition, 7(2):199-208.

and scales may be inapplicable, i.e., operationally invalid under experimental conditions. Currently, most studies focus on cognitive accuracy rather than operational accuracy, which means that the impact of contextual bias in real work is not fully understood at present.

*(3) The positive role of cognitive bias on forensic science is yet to be recognized*

Studies by Searston et al[136] and Kerstholt et al[137] have shown that contextual bias does not necessarily lead to poor decisions. Therefore, further research is needed to investigate when irrelevant contextual information plays a positive role. Some psychologists have argued that heuristics (cognitive shortcuts) and contextual biases actually contribute to accurate decision-making.[138] They argue that contextual information may be beneficial in decision-making because context supports our limited cognitive processes (e.g., heuristic thinking). Our minds have evolved to adapt to our context, and our heuristic toolbox allows us to quickly access the most important information (whether it is relevant to the task or not) in order to make a decision, rather than making a decision after integrating all the information. In other words, contextual information that may cause bias may also facilitate accurate and fast decision-making. It has been argued that some irrelevant contextual information helps forensic examiners to prioritize the most

[136] See Searston RA, Tangen JM, Eva KW. (2016). *Putting bias into context: the role of familiarity in identification.* Law and Human Behavior, 40(1): 50-64.

[137] See Kerstholt J, Eikelboom A, Dijkman T, Stoel R, Hermsen R, van Leuven B. (2010). *Does suggestive information cause a confirmation bias in bullet comparisons?* Forensic Science International, 198(1-3): 138-42.

[138] See Goldstein DG, Gigerenzer G. (2002). *Models of ecological rationality: the recognition heuristic.* Psychological Review, 109(1): 75-90.

meaningful samples when they are overwhelmed.[139] Irrelevant contextual information does not always lead to errors, and sometimes there may be positive effects. This view differs from the vast majority of research findings and is subject to future research to verify.

## VII. Concluding remarks

"No matter how perfect and superior a country's legal system is, if it is not able to find the problems and amend them in time, its legal loopholes will become bigger and bigger and become more difficult to fill, and when its loopholes reach a certain point not only it will fail to meet the basic need for society governance, but even produce new negative effects".[140] Therefore, the legal system should evolve and improve with the deepening of the understanding of human nature. The human factor plays a crucial role in forensic science, and only with a deep understanding of the human factor can a scientific, sound, and humane legal system be designed. The implicit and imperceptible nature of cognitive bias leads to the fact that identification errors caused by cognitive bias are difficult to detect in subsequent procedures such as laboratory verification, in-court cross-examination, and appeals; false corroboration caused by cognitive bias, fueled by the corroboration theory promoted by our judicial practice, will undoubtedly result in wrongful

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[139] See Budowle B, Bottrell MC, Bunch SG, Fram R, Harrison D, Meagher S, et al. (2009). *A perspective on errors, bias, and interpretation in the forensic sciences and direction for continuing advancement*. Journal of Forensic Science, 54(4): 798-809.

[140] 稂志诚 (Lang Zhicheng), 陈如超 (Chen Ruchao)：《中国刑事错案中的鉴定问题——基于 50 例案件的实证研究》，《中国司法鉴定》2016 年第 3 期 (Identification problems in criminal wrongdoing in China - an empirical study based on 50 cases," in Chinese Journal of Forensic Sciences, No. 3, 2016).

convictions that are difficult to overturn. Therefore, the best way to deal with the problem of cognitive bias in forensic science is to adopt a response plan that focuses on preventive strategies. The understanding of cognitive science and experimental psychology can enable forensic science staff to better understand the role and influence of human factors in forensic science, the shortcomings and loopholes of current forensic examination procedures, and the cognitive superiority and cognitive limitations of examiners; it can enable fact-finders (including judges and people's assessors) to look more rationally and objectively at the corroboration of evidence, especially the corroboration of scientific evidence.