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Practical Solutions to Cognitive and Human Factor Challenges in Forensic Science

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ABSTRACT The growing understanding of the central role of human factors and cognition in forensic science has paved the way to develop and implement practical solutions to enhance work in forensic laboratories. Cognitive insights provide relatively simply practical solutions to minimize bias by increasing examiners' independence of mind. These derive from understanding the spectrum of biases–not only those that can arise from knowing irrelevant case information, but also biases that emerge from base rate regularities, working 'backwards' from the suspect to the evidence, and from the working environment itself. Cognitive science's contribution to forensic work goes beyond fighting bias, it suggests ways to enhance examiners' work with technology (distributed cognition), as well as how best to select candidates during recruitment. Taking human cognition into account, such as with a triage approach and case managers, can enhance the quality and effectiveness of the work carried out by forensic examiners. This paper details practical solutions that emerge from a cognitive perspective that understand human expertise and performance. Such cognitively informed approaches should be integrated within forensic work on an ongoing basis.

KEYWORDS Confirmation bias, decision making, cognitive contamination, base-rate, technology, contextual influences, cognitive forensics, case managers, triage

The recent progression in forensic science to understand and acknowledge that the human examiner is the main instrument of analysis in many forensic domains has raised a whole set of new and exciting challenges. A critical point in this development was the National Academy of Sciences report on strengthening forensic science (NAS 2009), stating that:

> A body of research is required to establish the limits and measures of performance and to address the impact of sources of variability and potential bias. Such research is sorely needed, but it seems to be lacking in most of the forensic disciplines that rely on subjective assessments of matching characteristics. These disciplines need to develop rigorous protocols to guide these subjective interpretations and pursue equally rigorous research and evaluation programs. The development of such research programs can benefit significantly from other areas, notably from the large body of research 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 (p. 8).

There are a few misconceptions of what bias is and how best to address and minimize it (Pronin 2006). For example, often the issues of cognitive bias and

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contextual influence are incorrectly seen as ethical issues. Cognitive bias is a result of computational tradeoffs carried out in the brain, not an intentional act that one consciously takes (or can 'switch off' at will) (e.g., McClelland and Rumelhart 1981; Wilson and Brekke 1994).

Since the NAS report (2009), much has been written about the potential of bias in conducting forensic work, including in document analysis (Found and Ganas 2013), fire investigation (Bieber 2012), odontology (Page et al. 2012; Osborne et al. 2014), forensic anthropology (Nakhaeizadeh, et al. 2013), and even forensic domains such as fingerprinting (Dror and Rosenthal 2008) and DNA (Dror and Hampikian 2011).

However, the growing cognitive understanding of these issues has not been systematically translated into practical solutions and ways to minimize the effect of cognitive bias. Indeed, the NAS (2009) inquiry makes a specific recommendation in this regard (Recommendation no. 5):

> The National Institute of Forensic Science (NIFS) should encourage research programs on human observer bias and sources of human error in forensic examinations. Such programs might include studies to determine the effects of contextual bias in forensic practice (e.g., studies to determine whether and to what extent the results of forensic analyses are influenced by knowledge regarding the background of the suspect and the investigator's theory of the case). In addition, research on sources of human error should be closely linked with research conducted to quantify and characterize the amount of error. Based on the results of these studies, and in consultation with its advisory board, NIFS should develop standard operating procedures (that will lay the foundation for model protocols) to minimize, to the greatest extent reasonably possible, potential bias and sources of human error in forensic practice. These standard operating procedures should apply to all forensic analyses that may be used in litigation (p. 24).

NAS (2009) has made a very important contribution in highlighting the need to address the human cognitive issues in forensic science. However, similar to the Office of the Inspector General's review of the FBI's handling of the Brandon Mayfield case (OIG 2006), they limit their conceptualization of cognitive issues and focus mainly on confirmation bias ("whether and to what extent the results of forensic analyses are influenced by knowledge regarding the background of the suspect and the investigator's theory of the case," NAS recommendation 5).

Cognitive contamination of forensic examiners emerges from a whole spectrum of sources, and it is not limited to the impact of knowing irrelevant case information. In order to effectively combat biases and cognitive contamination, one needs to understand the multitude of factors that affect forensic examiners' ability to conduct their work impartially and unbiased. These factors go well beyond the examiners' exposure to irrelevant case information (such as what the detective thinks, whether the suspect confessed to the crime, and whether s/he was identified by witnesses and other case evidence, etc.).

Cognitive biases, for example, also emerge from working "backwards" from the suspect to the evidence; such circular reasoning, working to a 'target,' introduces examiners' biases in how evidence is perceived and evaluated. Further biases are introduced by base-rate regularities (such as verifications of positive matches and finding AFIS hits at the top of the candidate list), which cause expectations before the actual examination takes place, thus introducing a variety of cognitive affects on the examiners' work. If we limited our conceptualization of cognitive bias to case information, then we are not taking into account a variety of other sources for bias and cognitive contamination, and may not take the appropriate steps to deal with them.

Research has examined the expertise of forensic examiners and has demonstrated their high-level capabilities (e.g., Ulery, Hicklin, Buscaglia, and Roberts 2011). However, to reach such high performance levels one has to enable forensic examiners to work to their abilities, without influence and cognitive contamination that can bias their judgment and decision making. Indeed the studies of 'error rates' most often do not include biasing information, and hence to enable such performance we need to assure that the work in casework is also "bias free."

Cognitive biases (whether it is confirmation bias or other types of biases) are only one aspect of cognitive and human factors issues that the forensic community must address. There are a whole set of issues around "cognitive forensics." Cognitive forensics includes a whole array of cognitive issues on how human cognition relates to forensic science and how cognitive knowledge can guide and enhance forensic work. These issues relate from how to optimize the way forensic examiners work with technology (i.e., distributed cognition), to how best to identify applicants during recruitment who are the most talented for the job.

In this paper cognitively informed practical solutions are suggested. These are not limited to dealing with and minimizing cognitive bias, per se, but the wider perspective that emerges from the understanding of human cognition and its central role in forensic work. The solutions suggested take into account the work and financial realities of forensic laboratories (Charlton 2013), and hence attempt to suggest actions that require relatively minimal effort and resources. The paper focuses on the practical solutions with minimal reference and elaboration to the underlying science (the readers who are interested in more information about the scientific foundations of cognitive bias are referred to the relevant literature, e.g., Nickerson 1998).

BASE RATE

People, and experts in particular, learn from experience–this is one of the important cornerstones of intelligence and expertise. Given that our brain and cognitive capacity have limited resources, we optimize cognitive processing, which takes into account our past experiences. This is a very effective cognitive mechanism. However, this can be a problem (see an illustration in Figure 1). Take, for example, security X-ray screeners at the airport. Every day they look for weapons and bombs on the X-ray monitor, but almost never find any. Similarly, in the medical domain in intensive care units (ICU), medical monitors go off all the time, but in the vast majority of cases it is a false alarm (Alameddine et al. 2009; Donchin 2002). The human brain picks up on these base rate regularities, and adjusts cognitive attention and processing accordingly. A conscious and sincere effort to ignore base rate regularities, by itself, is doomed for failure.

Are such base rate regularities a problem in forensic science? Yes, in many ways. For example, in many laboratories verification is mainly performed on positive identifications (or the verifier knows what the first examiner has decided). In the vast majority of verifications of a positive identification, the second examiner verifies the work of the first examiner. This is a textbook example of a base rate regularity. Over time the verifier develops an expectation to agree with the positive identification of the first examiner. Regardless of how much effort and attention they try to put into the verification, the base rate regularities modify their cognitive processing.

What solutions can be used to combat and counter this base rate problem? One solution is to have blind verification (so the verifier does not know what the first examiner did and concluded) and to verify all forensic decisions, thereby not enabling the verifier to know what decision they are verifying. In such blind verification, the verifier focuses their entire work on the evidence and comparisons without being cognitively contaminated by the work and conclusion of the initial examiner. Although such procedures are in place in some forensic laboratories, they require more effort and work.

Count how many 'F's are in the following box (try it):

FINISHED FILES ARE THE RE
SULT OF YEARS OF SCIENTI
FIC STUDY COMBINED WITH
THE EXPERIENCE OF YEARS...

FIGURE 1 How many 'F's do you see in the above box (try it)? Most people see 3 or 4, some 5, but rarely people see all of the 'F's, there are actually 6 of them. The reason many people miss some of the 'F's is because we are experts in reading. Our base rate experience tells us (our unconscious brain) that words such as 'of,' 'the,' and 'a' do not carry much meaning and weight, and therefore, based on our expectation, we tend to automatically ignore them.

Another solution, much simpler than to implement blind verification across all decisions, is to combat the base rate problem by countering the cognitive expectation of the verifier. This approach has been adopted and implemented in airport X-ray security. It entails including in the work stream dummy cases that counter the base rate. In the X-ray security setting it means including fake bombs in suitcases (Schwaninger 2006; see also the Threat Image Projection (TIP) program on the Transportation Security Administration (TSA) website).

In the forensic setting it means including nonmatches 'look-alike' within the stream of verifying identifications (they must be look-alike, so they are not easily detected). Introducing these fake/dummy cases can be done in a variety of ways, depending on the specific operations of the laboratory. For example, it can be a real case whereby the supervisor changes the evidence (e.g., marks, when it goes to the verifier; that is, changing a 'real match' with marks that are very similar but are not a match). Alternatively, the supervisor can give for verification a whole file that is fabricated. What is important is that the verifier receives a case which they think is real, which they think was concluded as an identification match, when in reality the evidence looks very similar, but is not actually a match.

There is no need to include many such fake/dummy cases, just a few can be very effective in countering the base rate and making the verification process more cognitively engaging and effective. Furthermore, such a solution is a very good quality control measure. If the fake/dummy look-alike cases are indeed found in the verification stage, then there is data to show that the verification process is indeed working (similarly to the X-ray security screener who finds the fake bomb). Of course, if the second forensic examiner verifies as an identification the fake/dummy look-alike case, then that is an indication that the verification process requires attention (similarly to an X-ray security screener who fails to detect the fake bomb).

TECHNOLOGY AND DISTRIBUTED COGNITION

The introduction of technology has greatly enhanced forensic work and capabilities, and we can expect this trend to continue, if not to increase even further. However, as these technologies get more and more complex, as they intertwine and collaborate more and more with the human examiner (i.e., distributed cognition), they also present challenges from a cognitive perspective.

First, following on from the base-rate issue, technology often creates such regularities. For example, automated fingerprint identification systems (AFIS) present a list of candidates to the human examiner. However, in the vast majority of cases a positive hit is most likely to be at the top of the list. Over time this technology-induced base rate regularity causes examiners to adapt to this expectation. Indeed, examiners spend less time examining candidates as they go down the list (i.e., even when the same exact candidate is presented, they spend less time on the comparison when the candidate is presented lower on the list–see Dror et al. 2012). As a consequence of the base rate expectation examiners do not only spend more time on the candidates on the top of the list, but they are more likely to make a false positive decision (wrong identification) on an item that is presented on the top of the list where they expect to find a hit, and to make more false negative decision (miss an identification) lower on the list where they do not expect to find a hit.

Solutions to this problem can entail randomizing the order of candidates on the list, causing forensic examiners over time to find hits in different positions on the list, and hence eliminating the base rate regularity. Removing such meta-data is a simple thing to do and can be done by the technology provider. Another solution is to provide reward and motivation to examine the entire list (training and procedures that state you must carefully go over the entire list is not cognitively sufficient or effective to counter the effects of base rate). Such reward and motivation may entail a significant prize for each correct identification made on a candidate that is further down the list.

However, although such solutions are effective, they will cause examiners to work more slowly, as now they will actually and carefully check those candidates that are lower down on the list. A simpler solution, which takes into account workflow and time, would entail shortening the lists and randomizing their positions. Currently many forensic laboratories have lists with 15 candidates, some even with 50. How long should a list be? Well, that can be determined empirically by data and the objective of each forensic laboratory: Once an objective has been determined, e.g., 95%, then the laboratory should check their past hits and see how long a list should be to reach their criteria. Hence, each laboratory can easily determine, based on data, how much to shorten their list, but still maintain the hit rate they want to reach. Of course, this relates to high volume crimes, but not to special cases (to be determined by the laboratory, e.g., homicide, terrorism, armed robbery), where longer lists should be produced and randomized (see the 'Triage' approach below).

A second example of issues with technology and distributed cognition is that in many forensic domains the human examiner needs to determine 'relative similarity' to decide if a mark from a crime scene and a known come from the same source. However, with technology the ability to find a known that is very similar to the evidence from the crime scene but is not from the same source is very high. Such incidental similarities are now much more likely to occur than before technology was involved (where suspects were few and were selected because of different reasons–e.g., had a criminal record, found near the crime scene, etc.). With technology, the known is selected based on their actual similarity to the mark from the crime scene, and the selection is a result of a huge search on a database–hence the increased chance of finding incidental similarities (Dror and Mnookin 2010; see Busey et al. 2014 for a discussion of this issue and optimizing the size of databases).

Therefore, the introduction of technology has introduced a profound change in the working environment in forensic laboratories. The criteria for making an identification based on relative similarity, the point of 'sufficient similarity' to determine that both come from the same source, i.e., an identification, must be changed and modified to take into account the increased chance of finding such levels of similarity due to the powerful ability of the technology to search huge databases and find such similarities. Managers of forensic laboratories that rely on sophisticated technology must consider the cognitive implications of incorporating such technology in the work. Technologies offer great opportunities, but their use in forensic work must take into account their effects on the work of the human examiners.

INDEPENDENCE OF MIND

A critical element of forensic work is that it is as objective, impartial, and free from pressure as much as possible. Such independence of mind is paramount so as to enable the forensic examiners to make their decisions based on the evidence at hand without cognitive contamination. This is not easy to achieve as influences on the forensic examiner come from a variety of sources. Hence, we can only strive to achieve independence of mind. However, just as the forensic examiners are aware and go out of their way to take steps to minimize physical contamination of the evidence, they also need to be aware and take steps to minimize possible cognitive contamination.

First, examiners must be trained so they are aware of the dangers and influences of cognitive contamination. If examiners do not believe they exist, or that they are immune to such influences, or that it is an ethical issue, and that they can 'block it out' by mere willpower, then it is impossible to implement solutions to minimize contextual bias and increase independence of mind. Therefore, the first step in adopting solutions to these issues is that forensic examiners get training about cognitive factors in making forensic comparisons. Such training has been recommended by the NIST/NIJ (2012) expert group on human factors (Recommendation 8.5) and is in line with the NAS report (2009).

Indeed, many laboratories now provide such cognitive training to their examiners. For example, in the United States, examiners in Los Angeles (LASD and LAPD), New York State (NYPD and other forensic laboratories in the state), and the FBI have received such cognitive training; as well as examiners in other countries (e.g., in the U.K., the London Metropolitan Police and many other police forces; and a variety of other police forces and agencies in the Netherlands, Finland, and Australia). This has been an important step forward. However, although training is necessary, it is not sufficient. Other solutions are required in tandem.

Second, in addition to training about cognitive factors in making forensic comparisons, examiners should be 'freed' from information that is totally irrelevant to their work but may influence them, and hence impede their independence of mind. The challenge in this solution is that there are many different sources of such contaminating influences. The simple and obvious one, as pointed out in the NAS report (2009), is contextual influences about the case (e.g., "influenced by knowledge regarding the background of the suspect and the investigator's theory of the case" see NAS recommendation 5). Such information can easily be masked, and therefore not bias the human examiner. It enables them to focus and concentrate on the evidence itself, producing more objective and impartial findings–and saves time too, as they focus on the work, rather than wasting time engaging with irrelevant information.

Clearly, if information is irrelevant and not needed for the forensic work, but can potentially influence the forensic examiner, then it should not be presented to the examiner. However, even information that is relevant to the forensic work should be given with caution and consideration of its potentially biasing effects. Such consideration may suggest giving it to the examiner nevertheless, but only when they need it, to delay it as much as possible; one approach that adopts this solution is sequential unmasking (Krane et al. 2008). Other approaches suggest to conduct a cost-benefit analysis, or to use methods that reveal and show the effect (if any) of the biasing information (Dror 2012).

Other sources of influences and contamination is when forensic examiners work from the suspect to the evidence, rather than from the evidence to the suspect. Forensic work should work linearly, first examining the evidence, in isolation from a "target" comparison. Only after the evidence has been examined, analyzed, and characterized should the human examiner be exposed to the target for comparison. This guarantees that the evidence was not evaluated in light of the target, with the target comparison affecting and influencing cognitive processing (Dror 2009). The FBI has modified its procedures to promote such linear examination: Their new standard operating procedures (SOPs) now "include some steps to avoid bias: examiners must complete and document analysis of the latent fingerprint before looking at any known fingerprint" (OIG 2011, p. 27). A similar approach has been adopted by the NIST/NIJ (2012) expert group, recommendation 3.2, states, "Modifications to the results of any stage of latent print analysis (e.g., feature selection, utility assessment, discrepancy interpretation) after seeing a known exemplar should be viewed with caution. Such modifications should be specifically documented as having occurred after comparison had begun." (For details about this idea, see Dror 2009).

The effects on the human examiner are not limited to base rate and contextual information; examiners are often under direct and indirect pressures from their working environment. These may include the effects of being a police officer (many forensic examiners are sworn police officers), communicating with the investigating detective, or even just working within the police. Indeed, the NAS report (2009) recognized such influences, and recommended that forensic laboratories should not be part of the police (Recommendation 4: "removing all public forensic laboratories and facilities from the administrative control of law enforcement agencies or prosecutors' offices." See also the call for independent crime laboratories by Giannelli 1997). Indeed, Washington D.C. has recently removed the forensic laboratories from the police and established the District of Columbia Consolidated Forensic Laboratories, an entity that is formally separate from the police.

There is no question that the mere presence of the forensic laboratory within, and as part of, the police has a whole range of effects and influences. One possible effect is lack of impartiality and bias as a result of mere affiliation and allegiance (Murrie et al. 2013). However, one must also consider the importance of communication between the police and forensic laboratory, and what such a separation means. Furthermore, if and when forensic laboratories are separate from the police, they will be within another setting, within other constraints and influences. What is important is to maximize the independence of the forensic work, and that it is as isolated as possible from pressures and influences. Such precautions and steps to ensure maximum independence need to be taken regardless of whether the forensic laboratory is within the police or not (Dror 2009).

TRIAGE

One of the most important suggestions is to set up the forensic laboratories to work cognitively effective. In this respect it is recommended to adopt a triage approach. Not all cases can (and should) be treated in the same way. Imagine in a medical setting that whether a patient comes in with a complex and acute condition or with a simple scratch on their finger, both would be dealt with in the same way. That does not seem to make sense. Similarly, it does not make sense, from a cognitive perspective, to consider and use procedures (for example, in combating bias) in the same way in each case. It seems that sometimes the procedures are an "overkill," whereas in other cases they are not sufficient. The danger of bias is dependent on the complexity of the case (as the decision is more difficult, nearer to the threshold, bias is more likely to effect the decision outcome), and the level and type of contextual bias is also very important (some cases have minimal biasing context, and other cases are full of potential biasing contextual information). Hence, more susceptible to bias are difficult decisions made within biasing contextual information, the 'danger zone'.

Given that it is quite simple to classify cases into different levels of difficulty and vulnerability to bias, it is suggested that a triage approach can stream cases into different procedures. If a forensic laboratory has the resources and time to do blind verifications in all cases, across all decisions, that's wonderful; however, many laboratories are not able to implement such procedures across the board. Why not use such procedures (and others) selectively, as and when needed. At the beginning of the paper, when discussing base rate and how to balance the need to randomize the positions of candidates against the increase that entails in work time to go over the list, such a triage approach was already suggested: In normal high-volume crime, it's important to cut the length of the randomized AFIS list so it is much shorter; however, in special cases, longer randomized lists are warranted.

It is up to the forensic laboratory to determine the criteria of what constitutes a special case, and how to implement the triage. The point is that it is not very cognitively efficient or wise not to adjust and to use the most appropriate procedures that best fit the case at hand. "For forensic science to successfully take on the issue of contextual bias, it is important that one correctly considers the risks, that measures are taken when needed, and that they are proportionate and appropriate" (Dror 2012). This is not limited to issues of bias, but to base rate and other challenges facing forensic laboratories. A one-size-fits-all approach–currently in use in most forensic laboratories–does not make sense. The triage approach enables laboratories to put the right resources and efforts when and where they are needed, allowing them to conduct high-quality forensic work in an effective way.

CASE MANAGERS, INTERPRETATION, AND CONTEXT MANAGEMENT

In order to implement the triage approach (see above), as well as to determine if and what information is relevant to the forensic examiner, it is necessary for someone to see and evaluate the potentially biasing information. Furthermore, forensic work often requires interpretation of the evidence within the entirety of the case, as well as working closely with detectives and prosecutors (e.g., Evett 2009; Jackson, Aitken, and Roberts 2013). These are all potentially highly biasing contexts, but are paramount for conducting forensic work. Furthermore, to determine if and which forensic tests are needed, one must be exposed to a whole range of information.

The simple and practical solution to this quandary is to divide this work among examiners. One examiner sees all the case information and context, determines what tests are needed, etc., and then gives the actual examination and comparison work to another examiner who was not exposed to the biasing information. Similarly, the examiner working with the detectives provides the materials to another examiner to do the actual forensic comparison work.

The crucial point here is that the examiner who is doing the actual comparison work, carrying out the forensic analysis, is isolated from the contextual and interpretative issues: They conduct the forensic work blind, in isolation from the contexts that are not relevant to the actual forensic work, so they can work independently and are as impartial as possible.

Such case managers can be permanent roles within the forensic laboratory, or can be rotating roles on a continuous basis. When it is a rotating role, in some cases an examiner acts in the role of a case manager, whereas in other cases they are the forensic examiner carrying out the actual forensic comparison work.

Similarly, in smaller jurisdictions often the crime scene investigator who collects the evidence (and is thus exposed to a variety of information and context) is the same person who then goes and conducts the actual laboratory comparison work. To avoid the cognitive biases we have discussed, all that is needed is to manage the context. This can be easily achieved by swapping over the roles: While examiner A collects evidence from scene X, and examiner B from crime scene Y, they switch, so examiner A does the laboratory comparison work from crime scene Y, and examiner B does the laboratory work from crime scene X. Thus, they conduct the laboratory forensic comparison on "context-free" evidence, and are able to minimize bias by managing the contextual and irrelevant information.

This solution is very similar to the use of case managers, and to other solutions suggested, they all work towards enabling forensic work to take place, but making sure context and potentially biasing information is isolated and managed in a way that minimizes cognitive contamination. This way forensic examiners are impartial and objective as much as possible.

COGNITIVE PROFILES AND RECRUITMENT

The cognitive issues in forensic science and the ways cognitive science can contribute to this domain are many and not limited to bias. An example of such a contribution is in understanding the cognitive building blocks of this profession–the talent that underpins being a forensic examiner, what is termed "cognitive profile." Cognitive profiles specify the abilities needed to perform the job. Such endeavors have been taken in many professional domains, as cognitive profiles allow us to characterize the people who can best do the work (e.g., medical experts, Caminiti 2000; Fernandez et al. 2011; U.S. Air Force pilots, Dror, Kosslyn, and Waag 1993).

The logic behind such cognitive profiles is that: "Different professions require different abilities. This is obvious when one considers what distinguishes accountants from interior decorators, but the observation applies to all specialized professions . . . special abilities enable people to excel in occupations that depend critically on specific mental processes" (Dror, Kosslyn, and Waag 1993, p. 763). And forensic work is no exception;

on the contrary, in much of this domain the human examiners are the main instrument of analysis, and hence play a critical role.

Once such cognitive profiles are established, then they provide a benchmark, an objective, for developing tests that specifically measure and quantify those abilities. This is critical in allowing us to select the best people for the job. Forensic science enjoys popularity and hence is in a "buyer's market" with many applicants for each position. Such tests allow us to take advantage of the available pool of candidates wanting to be forensic examiners.

Tests for recruitment must:

1. Be scientifically developed and validated. The vast majority of tests currently used in the forensic domain have not been scientifically developed or validated. There is a whole domain and expertise in developing such tests and for their validation (Borman 1997).
2. Be relevant to the abilities needed to do the job. For example, the Form Blindness test widely used in the fingerprint domain includes abilities that relate to right angle corners, which is not relevant or needed in examination of fingerprints. That is why it is important to have cognitive profiles that explicate the exact abilities needed for a job. Some forensic laboratories do use well-designed and validated tests, but these tests are ready-made and off-the-shelf tests are not specific for the abilities needed for the forensic examination at hand. Even validated and well-designed tests are no good if they measure irrelevant abilities.
3. Examine the underlying abilities, the raw talent that underpins being an expert. Hence, recruitment tests should not use actual forensic evidence, but the cognitive building blocks. In fingerprinting, for example, such abilities include relevant attention allocation, visual mental imagery, dealing with and filtering noise, visual search, and perceiving and comparing curvatures and orientation.

By selecting the best people for the job, the forensic laboratory will not only have examiners that perform better and faster, but there are also clear implications to training. By selecting the right people, training needs and time are reduced (Zamvar 2004). Furthermore, beyond the laboratory perspective, it is also fairer on a personal level for the people involved if we recruit those who can do the job well.

SUMMARY

Forensic science greatly relies on the human examiners—they are often the main instruments of analysis. This has been recognized by the NAS report (2009) and now is a major challenge in enhancing forensic work. Cognitive bias is now a recognized issue, but often misconceptualized and limited to confirmation bias. Bias has many forms and many origins, one of which is contextual information. Others include base rate regularities, working from the suspect to the evidence, allegiances, and working environment. There are many factors that shape examiners' perception and decision making. It is important for forensic examiners to be as impartial and objective as possible, and work toward their independence of mind.

The relevance of human cognition to forensic science is not limited to cognitive bias, but covers a whole range of issues, from use of technology and distributed cognition to developing cognitive profiles and tests that enable to recruit the best people for the job.

All these different aspects of forensic work (and there are more than those explicated in the paper) are intimately connected to human cognition. Cognitive science can provide practical solutions to enhance forensic work and make critical contributions to forensic science.

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REFERENCES

Alameddine, M., K. N. Dainty, R. Deber, and W. B. Sibbald. 2009. The intensive care unit work environment: Current challenges and recommendations for the future. *Journal of Critical Care* 24:243–248.

Bieber, P. 2012. Measuring the impact of cognitive bias in fire investigation. *International Symposium on Fire Investigation, Science and Technology* 3–15.

Borman, W. C., M. Hanson, and J. W. Hedge. 1997. Personnel selection. *Annual Review of Psychology* 48:299–337.

Busey, T., Silapiruti, A., and Vanderkolk, J. 2014. The relation between sensitivity, similar non-matches and database size in fingerprint database searches. *Law, Probability and Risk*, in press.

Caminiti, M. F. 2000. Psychomotor testing as predictors of surgical competence: The predictive value of aptitude tests. *Focus Surgical Education* 2(17):20–22.

Charlton, D. 2013. Standards to avoid bias in fingerprint examination? Are such standards doomed to be based on fiscal expediency? *Journal of Applied Research in Memory and Cognition* 2(1):56–57.

Donchin, Y., and F. J. Seagull. 2002. The hostile environment of the intensive care unit. *Current Opinion in Critical Care* 8:316–320.

Dror, I. E. 2009. How can Francis Bacon help forensic science? The four idols of human biases. *Jurimetrics: The Journal of Law, Science, and Technology* 50:93–110.

Dror, I. E. 2012 Combating bias: The next step in fighting cognitive and psychological contamination. *Journal of Forensic Sciences* 57(1):276–277.

Dror, I. E., and G. Hampikian. 2011. Subjectivity and bias in forensic DNA mixture interpretation. *Science and Justice* 51:204–208.

Dror, I. E., S. M. Kosslyn, and W. Waag. 1993. Visual-spatial abilities of pilots. *Journal of Applied Psychology* 78(5):763–773.

Dror, I. E., and J. Mnookin. 2010. The use of technology in human expert domains: Challenges and risks arising from the use of automated fingerprint identification systems in forensics. *Law, Probability, and Risk* 9(1):47–67.

Dror, I. E., and R. Rosenthal. 2008. Meta-analytically quantifying the reliability and biasability of forensic experts. *Journal of Forensic Sciences* 53:900–903.

Dror, I. E., K. Wertheim, P. Fraser-Mackenzie, and J. Walajtys. 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(2):343–352.

Evett, I. 2009. Evaluation and professionalism. *Science and Justice* 49:159–160.

Fernandez, R., I. E. Dror, and C. Smith. 2011. Spatial abilities of expert clinical anatomists: Comparison of abilities between novices, intermediates, and experts in anatomy. *Anatomical Sciences Education* 4(1):1–8.

Found, B., and Ganas, J. 2013. The management of domain irrelevant context information in forensic handwriting examination casework. *Science and Justice* 53(2):154–158.

Giannelli, P. 1997 The abuse of scientific evidence in criminal cases: The need for independent crime laboratories. *Virginia Journal of Social Policy and the Law* 4:439–478.

Jackson, G., C. Aitken, and P. Roberts. 2013. *Case assessment and interpretation of expert evidence: Guidance for judges, lawyers, forensic scientists and expert witnesses.* London, UK: The Royal Statistical Society.

Krane, D., S. Ford, J. Gilder, K. Inman, A. Jamieson, R. Koppl, I. Kornfield, D. Risinger, N. Rudin, M. Taylor, and W.C. Thompson. 2008. Sequential unmasking: A means of minimizing observer effects in forensic DNA interpretation. *Journal of Forensic Sciences* 53(4):1006–107.

McClelland, J. L., and D. E. Rumelhart. 1981. An interactive activation model of context effects in letter perception: Part 1. An account of basic findings. *Psychological Review* 88:375–407.

Murrie, D., M. Boccaccini, L. Guarnera, and K. Rufino. 2013. Are forensic experts biased by the side that retained them? *Psychological Sciences*. doi: 10.1177/0956797613481812.

Nakhaeizadeh, S., I. E. Dror, and R. Morgan. 2013. Cognitive bias in forensic anthropology: Visual assessment of skeletal remains is susceptible to confirmation bias. *Science and Justice.* doi:10.1016/j.scijus.2013.11.003.

National Academy of Sciences (NAS). 2009. *Strengthening forensic science in the United States: A path forward*. Washington, DC: NAS.

National Institute of Standards and Technology/National Institute of Justice. 2012. *Expert working group on human factors in latent print analysis. Latent print examination and human factors: Improving the practice through a systems approach*. Washington, DC: US Department of Commerce, National Institute of Standards and Technology.

Nickerson, R. S. 1998. Confirmation bias: A ubiquitous phenomenon in many guises. *Review of General Psychology* 2:175–220.

Office of the Inspector General. 2006. *A review of the FBI's handling of the Brandon Mayfield case.* Washington, DC: Office of the Inspector General, Oversight and Review Division, US Department of Justice.

Office of the Inspector General. 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.* Washington, DC: Office of the Inspector General, Oversight and Review Division, US Department of Justice.

Osborne, N., S. Woods, J. Kieser, and R. Zajac. 2014. Does contextual information bias bitemark comparisons? *Science and Justice*. doi:10.1016/j.scijus.2013.12.005.

Page, M., J. Taylor, and M. Blenkin. 2012. Context effects and observer bias—implications for forensic odontology. *Journal of Forensic Science* 57:108–112.

Pronin E. 2006. Perception and misperception of bias in human judgment. *Trends Cognitive Science* 11:37–43.

Schwaninger, A. 2006 Threat image projection: enhancing performance? *Aviation Security International* December:36–41.

Ulery, B. T., R. A. Hicklin, J. Buscaglia, and M. A. Roberts. 2011. Accuracy and reliability of forensic latent fingerprint decisions. *Proceedings of the National Academy of Science of the United States of America* 108(19):7733–7738.

Wilson T. D., and N. Brekke. 1994. Mental contamination and mental correction: Unwanted influences on judgments and evaluations. *Psychological Bulletin* 116:117–142.

Zamvar, V. 2004. No time to train the surgeons: choosing trainees carefully may be the solution. *British Medical Journal* 328:1,134–1, 125.