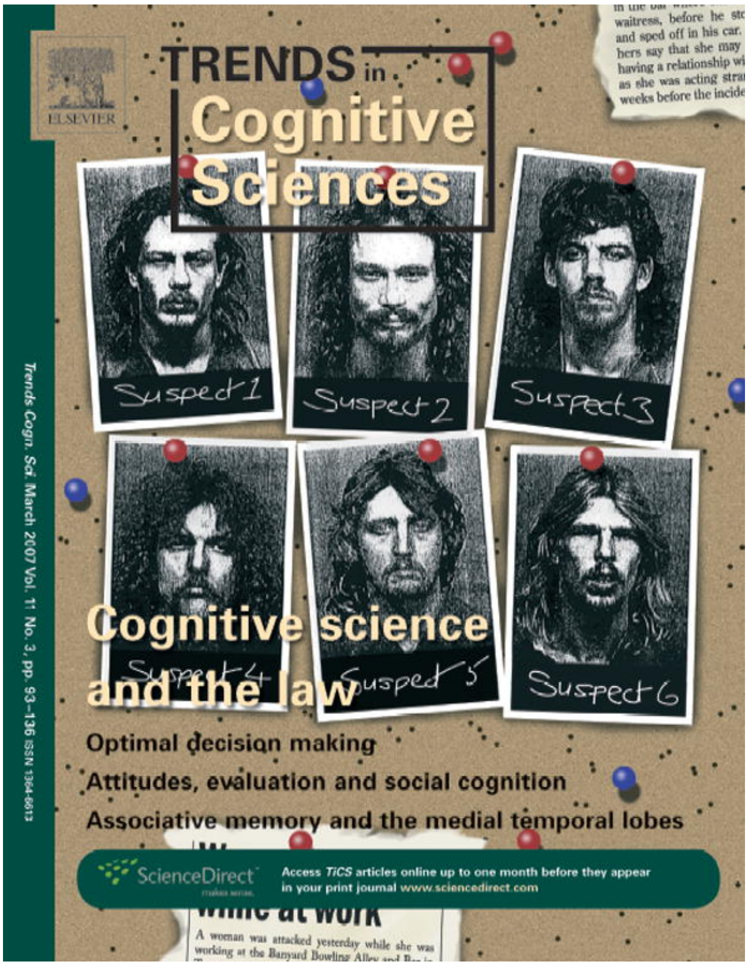
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Cognitive science and the law

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Numerous innocent people have been sent to jail based directly or indirectly on normal, but flawed, human perception, memory and decision making. Current cognitive-science research addresses the issues that are directly relevant to the connection between normal cognitive functioning and such judicial errors, and suggests means by which the false-conviction rate could be reduced. Here, we illustrate how this can be achieved by reviewing recent work in two related areas: eyewitness testimony and fingerprint analysis. We articulate problems in these areas with reference to specific legal cases and demonstrate how recent findings can be used to address them. We also discuss how researchers can translate their conclusions into language and ideas that can influence and improve the legal system.

Introduction

Certain types of forensic evidence are significantly hampered by normal human fallibility. Generally, this occurs when one instance of a physical stimulus (e.g. the remembered face of a criminal or a fingerprint lifted from a crime scene) must be compared with a putative second instance of the same stimulus (e.g. a suspect in a lineup or a suspect's fingerprint). The problem is that one or both instances of the stimulus can be corrupted by perceptual, memorial or judgmental noise. Thus, the process of making an optimal matching decision is a complex perceptual and cognitive skill, and recent court decisions have highlighted the vulnerability of this type of 'comparative judgment'. Courts do not usually exclude testimony based on comparative judgments, but they recognize that it is subject to human fallibility and that cognitive science can improve elements of this comparison process.

Here, we discuss issues that originate in ongoing court challenges but have made their way into the laboratory in the form of forensically relevant scientific questions. We ground our discussion in a consideration of eyewitness testimony and latent-fingerprint evidence, which we address from the perspectives of their forensic relevance and how cognitive scientists can convey their relevance to judges and juries.

Eyewitness testimony

Box 1 describes a legal case in which eyewitness testimony was pivotal. This case illustrates several topics in perception and memory, which are discussed below.

Viewing conditions, post-event information and witness confidence

The Alaska case parallels laboratory situations in which an initially poor memory is supplemented by suggestive, but potentially false, post-event information [1–5], thereby leading to an eventual memory which, although potentially strong and confidence evoking, is incorrect in important respects. Typically, this kind of case includes two elements:

(i) A witness views a crime being committed under suboptimal perceptual circumstances (e.g. poor lighting, a lengthy distance or intoxication).

(ii) The witness is exposed to suggestive post-event information (e.g. seeing and identifying a suspect in a biased identification procedure).

It is reasonable to expect that, when these elements are present, the witness uses post-event information to supplement and reconstruct his or her memory of the crime so that the originally poor (or nonexistent) memory of the perpetrator is replaced with a stronger representation of the suspect. Later, when testifying at the trial, the witness believes that they are basing their confident identification of the defendant on a memory that was formed at the time of the original event, whereas they are actually basing it on their reconstructed memory that was formed at the time of the identification procedure.

Identification procedures as forms of post-event information

There are many forms of suggestive post-event information to which a witness can be exposed, the most common of which is an identification procedure. The nature of identification procedures has been widely discussed in the psychological literature, most extensively by Gary Wells and colleagues [6–10].

The majority of real-life identification procedures are showup procedures and lineup procedures. In a showup procedure, a witness is presented with a single suspect and asked, 'Is this the person you saw commit the crime?'. In a lineup procedure, the suspect and five 'fillers' (i.e. individuals who fit the perpetrator's description but who have no association with the crime) are shown to the witness, who must decide which, if any, of the lineup members is the perpetrator.

A key challenge is to administer an identification procedure that is unbiased (i.e. that does not entail an unreasonably high probability of a witness choosing an innocent suspect). The consequences of such bias are twofold. Firstly, a high probability of an innocent suspect being identified is inimical to judicial philosophy. Secondly, a more insidious but equally harmful consequence is that the

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Box 1. Eyewitness testimony: a murder in Alaska

On 10 October 1997, a group of young men committed several acts of mayhem in Fairbanks, Alaska [37]. Their rampage, which culminated in the murder of a teenage boy, eventually resulted in the arrests of four suspects, two of whom were tried for the crimes. The centerpiece of the case for the prosecution was the testimony of Arlo Olson who, while drunk, had seen the perpetrators at night and from a distance of 450 ft. Despite these perceptual disadvantages, Mr Olson picked the defendants from photographic lineups. At the trial, almost two years later, Mr Olson pointed to the two defendants and testified, with a good deal of confidence and drama, that they were the people he had seen commit the crime.

The defense attorney called Geoffrey Loftus (co-author of this paper) to testify as an expert witness at the trial. His task was to educate the jury about research in cognition that related to three issues: perceptual problems attendant to Mr Olson's original ability to perceive and memorize the perpetrators; why Mr Olson might have selected the defendants from lineups despite these problems; and why Mr Olson might have had a clear and confidence-evoking, yet potentially false, memory of the defendants as the people he had seen commit the crime.

appearance of an innocent suspect who is identified in a biased identification procedure can act as a source of post-event information: an originally hazy memory of the perpetrator is replaced by a stronger memory of the suspect. This reconstructed memory can then form the basis for a subsequent, inappropriately high-confidence identification by the witness during the trial.

Showup procedures. A showup procedure is, in memory-research parlance, an old–new recognition procedure, the results of which can be described using two measures: memory strength (e.g. d') and bias (e.g. β). In a real-life showup procedure, unlike its laboratory analogue, there is only a single 'trial'. Because there is no way of knowing whether an 'old' response (e.g. 'That is the guy!') is a hit or a false alarm, there is no way of distinguishing strength, which is of primary importance, from bias, which matters little. This difficulty can be conveyed by an expert to a jury, as follows.

An unbiased lineup procedure is truly a test of the match between the suspect's appearance and the witness's memory of the perpetrator: an innocent suspect is falsely identified only if he matches the witness's memory of the perpetrator better than do the five fillers. By contrast, in a showup procedure, a positive identification of the suspect probably depends, at least in part, on the match between the suspect's appearance and the witness's memory of the perpetrator, but it almost certainly depends on other irrelevant bias factors too, including the witness's expectations that the suspect is the perpetrator, the pressure on the police to make a positive identification and the witness's desire to have someone arrested. In short, one cannot assess, in a principled manner, how much credence to put on a witness's positive identification in a showup procedure.

Lineup procedures. An unbiased lineup procedure is a bona fide measure of the match between the suspect's appearance and the witness's memory of the perpetrator. The key term here is 'unbiased', which refers to a lineup in which an innocent suspect has no greater chance of being identified by the witness than do the fillers. However, there are many ways in which lineups can be biased:

(i) *Physical bias (fillers not fitting the witness's description)*. The central challenge for a police officer who is constructing a lineup is how to select the fillers. Wells *et al.* [10] point out that the key rule is that the fillers should fit the witness's description of the perpetrator. For example, if the witness has described the perpetrator as 'a white male with a gap in his front teeth', then all the fillers should fit this description. If any do not, then the witness can rule them out immediately and the 'functional size' of the lineup is reduced from 6 to $6 - n$ where 'n' is the number of fillers that fail to fit the witness's description.

(ii) *Physical bias (oddball)*. A lineup, particularly a photo lineup, can also be biased if the suspect's picture is physically different from the fillers' [11]. For example, if the suspect's picture is notably larger or smaller than the fillers' or set against a different background, the witness can infer that the oddball is the suspect. Sometimes the oddball effect is obvious, but it can also be subtle (Box 2).

(iii) *Lack of double-blind procedures*. The logic of double-blind procedures, which are obligatory in many kinds of scientific research, carries over to lineup procedures. The rule is that the police officer who administers the lineup cannot know who the suspect is. Application of this rule (which, in practice, is almost never followed) would exclude the possibility of the officer providing information to the witness about the suspect. It would be churlish to suggest that police officers would do this obviously and/or deliberately, but it can easily be done subtly and/or inadvertently. Geoffrey Loftus had the rare opportunity to view a videotape of two witnesses being shown a photo lineup. After inspecting the six photos, the first witness began to focus on one of the fillers. The police officer, betraying some exasperation, responded, 'Is there anyone else you think it might be?'. After inspecting the six photos, the second witness began to focus on the suspect. The police officer responded, 'Just sign your name across his picture' (which is the standard means by which a witness indicates identification of a lineup member). Such a discrepancy could not have occurred if the officer had been blind to the suspect's identity.

(iv) *Unconscious transference*. Unconscious transference [12] refers to a situation in which a witness has had the opportunity to view the suspect at some time other than at the crime (e.g. the witness and the suspect live in the same neighborhood). By virtue of such opportunity, the suspect's appearance could be familiar to the witness. By contrast, other lineup members would not look familiar to the witness. Therefore, an identification of the suspect by the witness might be based on this differential degree of familiarity.

Lineups versus showups. Lindsay and colleagues [13] have attempted to compare showup and lineup procedures with respect to error rates. Although the results are complex, the basic conclusions are (i) when the suspect does not resemble the perpetrator, there is a small overall accuracy edge for showup procedures, but (ii) when an innocent

Box 2. An oddball in the lineup

In most cases, an 'oddball' suspect picture is obvious (e.g. the suspect is wearing street clothes, whereas all fillers are wearing prison garb). The photo lineup in Figure I illustrates a subtler bias, perhaps involving expression. One of the lineup members presented here was accused of committing a heinous crime in Tacoma, Washington [38]. The Pierce County Public Defender asked Loftus to assess the fairness of the lineup. To implement the appropriate double-blind procedures, Loftus sent the lineup to Thomas Busey without telling him who the suspect was. Busey showed the lineup to a sample of people in Indiana, telling them only that one of the lineup members was suspected of a crime and asking them to guess the suspect. The suspect was chosen 26% of the time, which is considerably above the chance rate of 17%*.

Figure I. Lineup used in Ref. [38], which demonstrates the oddball bias.

suspect resembles the perpetrator, false identifications are more likely to occur in showup procedures. However, in a real-life showup procedure, unlike in a laboratory experiment, one can never separate the degree to which a positive identification is made on the basis of memory strength versus on the basis of bias factors, such as peer pressure and expectations.

Research on perceptual factors

Many factors influence the ability of an eyewitness to perceive and encode the perpetrator's appearance (e.g. viewing time, lighting conditions and degree of focused attention). These factors divide into those from which precise conclusions can be made, at least in principle, and those from which only statistical conclusions can be made. One factor from which only statistical conclusions can be drawn is exemplified by the cross-racial effect. Numerous studies have shown that, on average, people are less able to identify members of other races than members of their own race [14]. However, this statistical finding does not enable one to conclude that, say, an African–American witness who has viewed a crime committed by a Caucasian perpetrator has a precisely identifiable constraint on the information that he or she can encode about the perpetrator's appearance (reviewed in Refs [14,15]).

An example of a factor from which precise conclusions can be made is distance. The relevance of distance in the Alaska murder case (the witness viewed the perpetrator from a distance of 450 ft) triggered a research project [16], which aimed (i) to quantify the effect of distance on limitations of perceptual information, and (ii) to use the results as a tool for creating demonstrations of such limitations for lawyers and juries.

The logic behind the study relied on a well-known property of a witness's visual system: like every image-processing system, the visual system spatially filters what it sees – that is, it removes details (e.g. of a face). The size of the removed details is directly proportional to the distance of the face from the witness [17–19]. From a legal perspective, an important consequence of this finding is that viewing an object from a distance is equivalent to blurring it by an amount that is determined by that distance. One can represent a face, or any object, viewed from a distance in two ways. The first, most straightforward, way is to resize the image of the face so that it subtends the appropriate visual angle, which decreases with distance. The second way, the validity of which depends on the inferred workings and measured filter parameters of the human visual system, is to blur the image by a specifiable degree, which increases with distance. Figure 1a shows an image of Julia Roberts' face that has been sized and filtered to produce equivalent representations of the effect of two distances.

Based on this research, one can demonstrate to a jury the loss of information about an object that corresponds to witness–object distance by preparing a suitably blurred version of the object in question. The object in question is usually a perpetrator's face that has been viewed by a witness from an identifiable distance, as in the Alaska case. Figure 1b shows the face of a celebrity that has been filtered to represent the information loss that is attendant

* Suspect is in the middle of the top row.

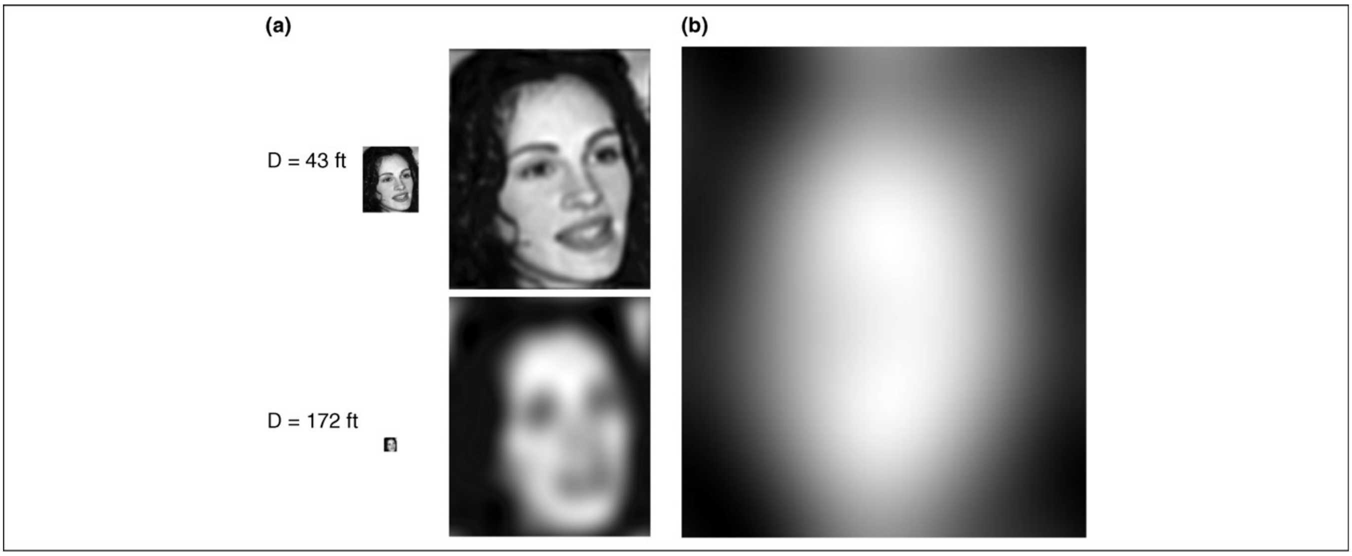

Figure 1. Stimuli used to compare filtering with size changes. **(a)** Two theoretically equivalent representations of a face viewed from distances (D) of 43 ft and 172 ft: resizing (left panels) and blurring (right panels). Left panels are valid when viewed from a distance of 11 in. **(b)** Mystery celebrity blurred to simulate a distance of 450 ft†.

to a 450 ft viewing distance. This procedure has also been applied to a cigarette pack that, from a distance of 250 ft, was perceived to be a bag of marijuana [20], and to a tomato plant that, from an altitude of 1200 ft, was perceived to be a marijuana plant (personal communication to G. Loftus). The answers provided by research, such as that described above, must eventually make their way back into the courtroom, and Box 3 provides some guidelines when presenting research to jurors.

Latent-fingerprint evidence

Recent cases involving the use of fingerprint evidence have raised questions that can be addressed by cognitive scientists (see Box 4 for one high-profile case). As with lineups, the latent-print individualization decision process is particularly troublesome because identification is a criterion-based judgment that is based on the perceived similarity between two images; it is often difficult to balance the perceived similarity against the prior probability of obtaining that similarity. In the Madrid case, the FBI examiners were apparently overly impressed by the similarity of the Madrid print and the one returned by the Integrated Automated Fingerprint Identification System, and several independent examiners were apparently affected by the decision that was made by other examiners; both of these factors might have affected the verification process [21].

The issues of a poorly defined criterion for a match and the potential contextual biases that arise from additional information about the case have left fingerprint evidence open to criticism from the defense. This matter was formalized by the US Supreme Court in Daubert vs Dow [22], which defined criteria for admission of expert testimony at trials. For fingerprints, the defense argued that latent-print examiners have no special skills and that the fingerprint evidence should be shown to the jury without rendering a final opinion. Although the judge in the case ultimately rejected this claim [23], the challenge left open the question of whether latent-print examiners possess abilities beyond those of a novice – an issue that cognitive scientists have begun to examine.

Box 3. The role of a perception and memory expert

A question that often triggers heated legal wrangling is whether and how a perception and memory expert can provide useful information to the jury. The appropriateness of such experts is described by numerous scholars [2,11,39].

The central issue that is discussed by an eyewitness expert is that, contrary to common sense, a confident witness need not be an accurate witness. This issue is gradually coming to the attention of judicial authorities, as exemplified by a recent memo from New Jersey Attorney General James Farmer, which accompanied new guidelines for identification procedures. Farmer noted the importance of guarding against identification procedures that might invest a witness with a false sense of confidence, stating that 'Studies have established that the confidence level that witnesses demonstrate regarding their identifications is the primary determinant of whether jurors accept identifications as accurate and reliable.' This is certainly correct, and an eyewitness expert is in a position to alert jurors to situations that, on the basis of scientific studies, are known to lead to such a false sense of confidence.

First, it is important to establish why a confident witness sways jurors. This is because, in most everyday life, high confidence is predictive of high accuracy. Therefore, it makes sense that an average juror would believe, intuitively, that high confidence is always associated with high accuracy, or at least that the juror should use such predictive power as a default assumption in evaluating the credibility of a witness's identification. However, contrary to intuition, this predictive power can break down. Indeed, scientific research has delineated the circumstances under which such a breakdown occurs: poor viewing circumstances, combined with subsequent post-event information of dubious accuracy.

Although this combination of circumstances is rare in most people's experience, it is common in many crimes, such as the Alaska case (Box 1). It is also clear, based both on common sense and on laboratory studies, that a highly confident eyewitness can be persuasive to a jury [39]. Accordingly, the main purpose of a perception and memory expert is to describe to the jury these counterintuitive, but scientifically understood, circumstances under which confidence should not be taken as a predictor of accuracy. The job of the attorney is to demonstrate to the jury that the facts of the case mirror these circumstances.

† Mystery celebrity is a different view of Julia Roberts.

Box 4. Terrorism in Madrid and latent-print evidence

On 11 March 2004, ten simultaneous explosions ripped through commuter trains in and around Madrid, Spain. The US Federal Bureau of Investigation processed a copy of a latent fingerprint found on a bag of detonators into the Integrated Automated Fingerprint Identification System (IAFIS), which uses salient features called 'minutiae' to find candidate matches. The fourth best match belonged to Brandon Mayfield, an Oregon attorney and a Muslim, who had married an Egyptian immigrant. He had represented a convicted terrorist in a child custody dispute in Portland and had known contacts with suspected terrorists. Three FBI examiners and one external expert examiner agreed that the two prints came from the same source. They expressed confidence in their judgments, using language such as 'positive – 100% identification' [40]. Mayfield was arrested on 6 May 2004.

However, latent-print examiners from the Spanish national police did not agree with the FBI identification and, based on a better fingerprint match, identified another suspect, Ouhnane Daoud, a known Algerian terrorist who had loose al-Qaeda connections. Mayfield was released, and the FBI apologized for the error. They cited several factors that contributed to the error, including the use of a poor-quality digital image of the initial latent print, lack of access to the original bag of detonators and the unusual similarity of the latent print to Mayfield's print. Mayfield was recently awarded a $2 million settlement.

Several panels that probed the mishandling of the case by the FBI suggested additional contributing factors and discounted the image-quality explanation. The initial examiner failed to conduct a complete analysis of the latent print, which resulted in the failure to recognize important unexplained differences between the two prints. Overconfidence in the IAFIS results and the pressure of working a high-profile case also contributed to the error. Several panelists also felt that the external verification procedures were tainted by knowledge of the initial examiner's conclusion and supervisory status [40].

Research on perceptual factors

Latent-print examinations can take hours to complete and can involve changes in both perceptual and cognitive processes. To address the question of whether experts differ from novices, Busey and Vanderkolk [24] used a two-alternative forced-choice task to address the role of added noise, partial masking and memory delays on a task that might tap some of the processes that underlie latent-print examinations (Figure 2). The major conclusion was that expert print examiners appeared to rely on a configural-processing mechanism when viewing prints, similar to that used when viewing upright faces, which addresses the question that was raised in the Daubert case [22] of whether experts and novices differ. The introduction of configural processing by experts seems to represent one difference between the groups. We supported this conclusion with an EEG/ERP study that used upright and inverted faces, and fingerprints [24]. Faces and inverted faces show differences in several ERP components, most notably the N170, which is a negative-going component that occurs over the left and right parietal–occipital region of the scalp [25]. We found the same pattern with fingerprints: upright fingerprints showed an earlier N170 than the inverted fingerprints in two tasks, but only for experts [24]. Thus, if configural processing for upright faces contributes to the face inversion effect, the same seems to be true for fingerprints. This suggests that the same learning mechanisms that support expertise with faces also affect learning of other stimuli. However, it should be noted that the same neurons need not be involved to suggest that similar processes are involved, but similar principles dictate the transition from processing that might involve individual features to one that begins to incorporate more holistic or configural processing [25,26].

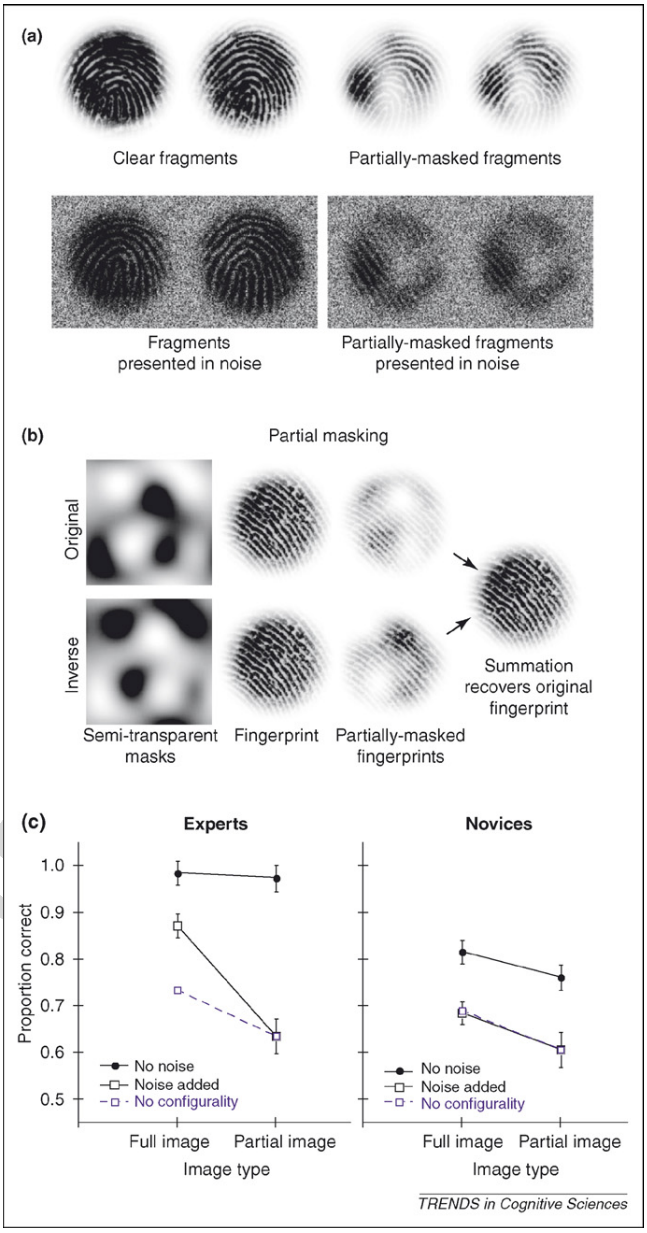

Figure 2. Data from Busey and Vanderkolk [24] that are consistent with configural processing in expert latent-print examiners but not in novices in an X–AB task. Observers viewed one fingerprint fragment without noise for one second; this was followed by a mask and then two fragments. **(a)** Four conditions used to simulate the transformations that latent prints often undergo. **(b)** Partial images are created by multiplying a mask and its inverse with the full print to create partially-masked fingerprints, which implies that, in noise, each partial image contains exactly half the information of a full print. This enables a probability summation model to be used, which assumes that the value of one half does not change when the second half is added, whereas a process such as configural processing predicts that the value will be greater. **(c)** Data from experts and novices. The partial-image data are used to make a prediction for full-image performance in noise (labeled 'No configurality'). The experts exceed this prediction, whereas the novices do not. This suggests that when experts view fingerprints in noise, they extract more information from the full images than would be predicted based on partial-image performance. A subsequent EEG/ERP experiment found converging evidence for this result. Adapted, with permission, from Ref. [24].

Related studies from the perceptual-learning literature

Although there is no single training regime for latent-print examiners, they often apprentice for several years with a veteran examiner, and many police departments now require periodic proficiency tests. This training is expensive and often examiners must deal with poor-quality images. Dosher and Lu [27] addressed the question of whether novices should initially train using noisy images or clear images that are very low contrast. They used sine-wave Gabor patches, which locally seem to be much like fingerprint patches. They found that participants who trained with clear images could generalize their knowledge to noisy images, whereas participants who trained with noisy images could not generalize to clear, low-contrast images. They attributed this to two independent processes: external-noise filtering and improved stimulus enhancement. Low-noise stimuli enable both processes to improve [28,29]. Part of learning to process noisy images might be related to the process of learning what to look for in an image [30].

Research on cognitive factors

Once perceptual information has accumulated, the examiner must make a decision to exclude, individualize or declare insufficiency, which is not criterion free. Itiel Dror has addressed the influence of contextual factors on latent-print examinations extensively [31–33]. He and his colleagues asked latent-print examiners to perform latent-print examinations using the examiner's usual method. In some cases, they introduced contextual information, such as emotional pictures, supposed details about the facts of the case (i.e. the suspect had confessed) and the fact that the print in question was a known exclusion (the Mayfield print). What makes this research so compelling is that Dror used prints from files that represented previous decisions the examiners had made. The latent-print examiners were surprisingly vulnerable to this contextual information and, for difficult or ambiguous cases, they made decisions that were often inconsistent with previous decisions. When told that a print was the Mayfield print, only one out of five of the examiners remained consistent with their previous individualization [31]. This demonstrates how contextual information, perhaps unknowingly, can influence a skilled perceptual procedure.

Concluding remarks

The fundamental challenge of comparison judgments is that the conclusion that the two instances derive from the same source implies that the match that is observed is closer than any other possible match. This is impossible to verify because there are 6.5 billion people in the world, corresponding to 6.5 billion faces and 65 billion fingerprints. Nonetheless, probabilistic statements can still be made by eyewitnesses or fingerprint examiners, as well as relative statements such as 'This pair is closer in similarity than any other close non-match I have observed.' Observers in this situation struggle not only with the comparison but with an internal criterion that must be exceeded. Many of the errors that occur in eyewitness testimony and in the few fingerprint cases that have been studied are false positives on target-absent trials. Thus, pressure placed on observers might affect how they evaluate evidence relative to this criterion. In addition, observers often have difficulty monitoring their own abilities, which can lead to unconscious overconfidence [34].

The issues raised above suggest that cognitive scientists who work on perceptual and/or memory tasks, such as eyewitness testimony or latent-print evaluation, should consider carefully the cognitive and social aspects of the environment. Bias shifts could underlie performance changes, and recent work by Wenger [35,36] suggests that changes in bias might not result from what are traditionally thought of as cognitive processes, but might reside closer to the perceptual processing and might not be under strategic control.

Because the decision criteria can be altered by the testing conditions, care should be taken to consider possible demand characteristics of experiments. One exemplary instance is the work of Itiel Dror, who has partnered with police agencies around the world to gain access to prior files, enabling him to insert cases into the normal workflow of agencies without the knowledge of individual examiners (who have given prior consent). This presumably maintains the same level of decision criteria that would normally exist for cases.

Eyewitness-testimony research would benefit not only from the consideration of the lineup procedures, but also from a physical analysis of the available information. As the cases discussed here have demonstrated, the human visual system places limitations on what information is available, and a careful analysis of a particular situation demonstrates how an eyewitness might be overstating their abilities. In our view, the research on eyewitness testimony has focused on mock lineups using college students and it should instead take a more naturalistic view.

Acknowledgements

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