



# Mind-set – How bias leads to errors in friction ridge comparisons

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## ABSTRACT

Mind-set is a term used in the friction ridge discipline to describe a confirmation bias in which an examiner makes early decisions about their interpretation of a mark but fails to update or reconsider those decisions in light of additional information. This most often occurs during the analysis of a mark when an examiner makes decisions (such as orientation or anatomical source of a mark) to help expedite a manual search or set parameters for an automated search, but fails to re-evaluate these decisions if the initial screening of available exemplars does not yield a comparable area, potentially leading to a miss or an erroneous exclusion. Mind-set can also occur when an examiner believes a comparison may be an identification early in the comparison process and employs poor comparison habits to convince themselves it is true, often creating or adapting comparison notes after seeing the exemplar, straining logic to justify their decision, and potentially leading to an erroneous identification. A recent black box study on palmar comparison accuracy and reliability noted both behaviors in the annotations and notes provided by some study participants. Examples are provided in this paper to serve as a reminder to examiners to not allow mind-set to lead them into errors. Particularly given the high false negative error rates reported throughout the literature, examiners need to make re-considering their initial analysis before rendering an exclusion decision part of their comparison routine.

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## 1. Introduction

Failure by an examiner to adjust initial search parameters about a mark in light of new information or a failure to locate that mark during an initial search (whether manual or automated) is known as mind-set. Mind-set is a type of confirmation bias in that it creates an expectation in the mind of the examiner that can lead them to ignore or fail to consider other possibilities. When an examiner falls victim to such a mind-set or tunnel vision, he or she cannot even conceive that the mark could be oriented differently or located elsewhere. Examiners can be susceptible to mind-set both during the analysis and comparison phases of the comparison process and it can lead to false positive, false negative, and inconclusive errors, examples of all of which will be presented in this article.

Analysis is the first step of the friction ridge impression comparison process [1]. Analysis is used to determine:

1. what information is present on the mark (or the print);

2. whether there is enough reliable information to proceed to a comparison; and
3. how that information can be used heuristically in searching.

Two of the most important search parameters that can be derived from the analysis of a friction ridge impression are the distal orientation and the anatomical source. These two pieces of information, if known, help an examiner know where to search for an impression, which can save a great deal of time. Typically based on the flow of the friction ridges, an examiner will make an inference about the distal orientation of the mark and prioritize their search based on questions such as: how should the mark be positioned in regards to the tip of the hand? Shall the examiner consider a right or a left hand as a potential source first? Inferences are also made regarding anatomical source, referring to the area of friction skin considered, when the ridge flow will allow some informed judgement about questions such as: Is it a palmar impression, or a finger tip or phalange? If it is a palmar impression, is it the thenar, hypothenar, or interdigital area? All these decisions will condition the heuristics that an examiner will use in their search of the print(s) for a potential area of correspondence with the mark.

However, it should be kept in mind that all these decisions are susceptible to error and may need to be revisited. If the initial

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search does not yield a promising area for comparison, the search parameters should be loosened and a second, more thorough, search conducted based on broader sets of distal orientations or anatomical sources.

Mind-set can impact both identification and exclusion decisions during comparison and evaluation. If an examiner gets too locked into their first interpretation, it can narrow their search to the point where they reach an erroneous exclusion decision by failing to search in the correct area or orientation. Conversely, if an examiner falls into a mind-set that two impressions are likely from the same source early in a comparison, they can do remarkable mental gymnastics to talk themselves into an erroneous identification. This was noted in previous research [2] and will be illustrated again in this paper.

The authors recently conducted an NIJ-funded (award 2017-DN-BX-0171) study entitled “Testing the Accuracy and Reliability of Palmar Friction Ridge Comparisons: A Black Box Study” to establish a discipline wide error rate estimate for palmar comparisons. The full results of that study are presented in a separate publication [3], but here we focus solely on the issue of mind-set. Because this was a black box study, participants were not required either to provide written notes of their thought processes, or to annotate minutiae or other features relied upon in their decision-making. Nonetheless, many examiners chose to do both, and their notations

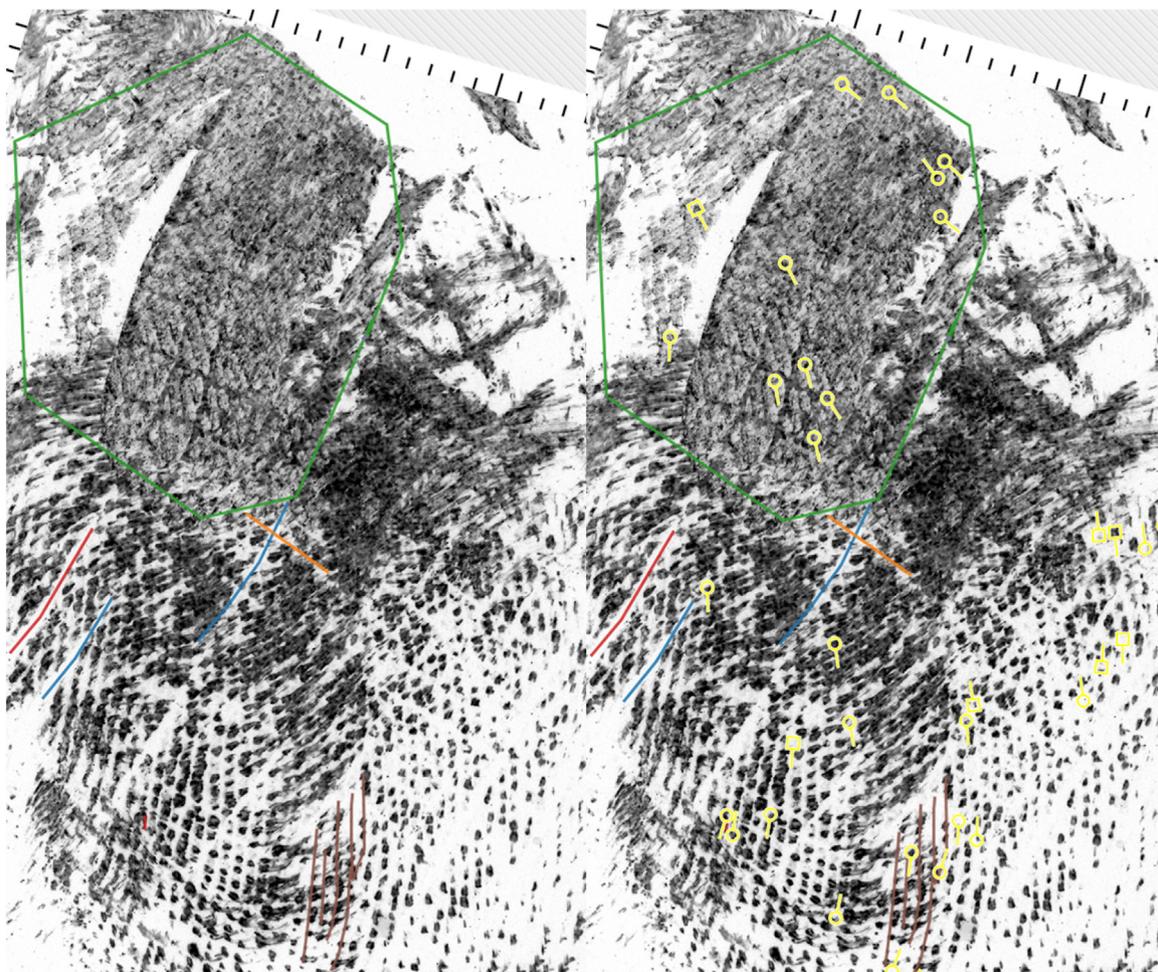
were often illuminating in understanding how errors occurred and often revealed a mind-set bias.

## 2. Erroneous identifications

In their 2013 final technical report to the NIJ describing their research findings, Neumann et al [2] (p. 83) describe the documentation habits of four study examiners who reached the same erroneous identification. One of those examiners (user-0481) displayed the worst habits of the group in that they completely re-annotated and paired all of the minutiae in support of their (erroneous) decision, as well as writing a gargantuan text paragraph to justify their decision that relied heavily on observations from the exemplar. It is a classic example of the lengths an examiner may go to in order to convince themselves of an outcome that fits the theory they have locked onto.

Unfortunately, some examples of similar behavior were observed in the current study. Two such examples are presented here. In both cases, the compared exemplar image is not provided due to a commitment to protecting the privacy of the owners of the exemplars, who were found through a database search. However, in both cases, the notes and annotations of the examiners are enough to understand the errors even without the exemplar images.

The first example comes from the notes of user-0257 in regard to case-0038. This different sources trial featured a mark that was



**Fig. 1.** Case-0038, a different sources trial. The mark is shown with user-0257's green line demarcating the area of identification. The image on the right includes user-0257's minutiae annotations, the image on the left does not. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

**Table 1**  
Results for case-0038, a different sources trial.

Conclusion	Number of users
No value	16
Inconclusive	3
Correct Exclusion	7
Erroneous ID	1
Did not complete case	2

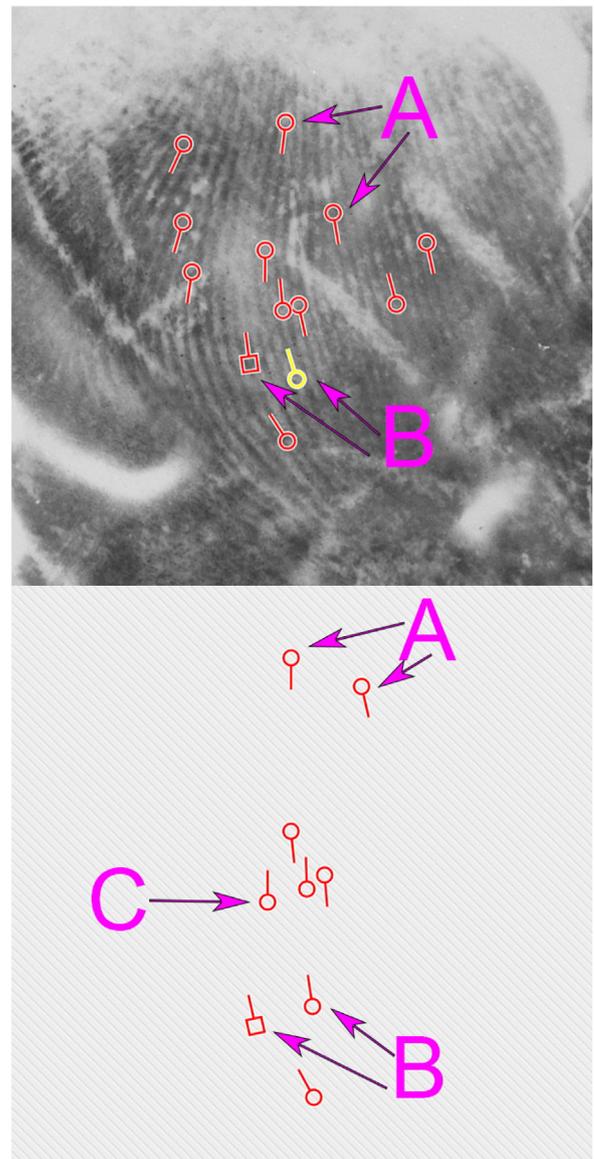
developed on a plastic bag using cyanocrylate fuming followed by a fluorescent dye (Rhodamine 6G). Fig. 1 presents user-0257's comparison notes without minutiae annotated on the left and with annotated minutiae on the right. The first thing to observe is that no minutiae were marked during analysis; all were added once comparison had begun and the exemplar was visible. The minutiae marker types used throughout this study are presented in Fig. 2.

The following free text comparison notes were provided by user-0257:

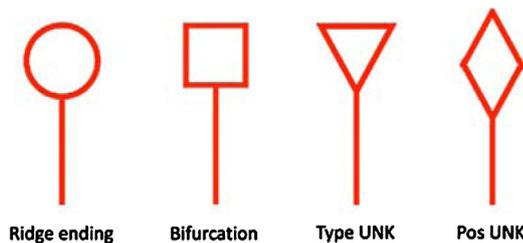
- identification only in green line area using vestige and ridge crease as red flag.
- unmatched minutiae outside green line.
- this latent palm composed of two different latent palms.

These notes, in conjunction with Fig. 1, illuminate the error, but also present a somewhat alarming picture of comparison practice and mind-set. The reader will note that the area outside the user's green line (while not pristine by any stretch of the imagination) is relatively clear compared to the area inside the green line. Yet user-0257 specifically tells us that they made the ID only to the area inside the green line, where the quality is very poor. A total of 29 examiners viewed this case, and with the exception of a single low-confidence minutia marked by user-0072 during analysis, none of the other examiners marked any minutiae within the area surrounded by the green line, either in analysis or comparison. User-0257 marked a total of 12 high-confidence minutiae in this area after seeing the exemplar. It is unclear what inspired user-0257 to feel that this comparison was from the same source in the first place, but once they formed that mind-set, it is clear that they would go to great lengths to support it. The full results of this comparison are displayed in Table 1.

The second example involves user-0045's interpretation of case-0107. This different sources trial featured a mark that was developed in powder on a glass bottle. Fig. 3 presents user-0045's comparison annotations of the mark on top and their comparison annotations of the exemplar on the bottom. As previously noted, the exemplar image is not provided due to privacy concerns, but



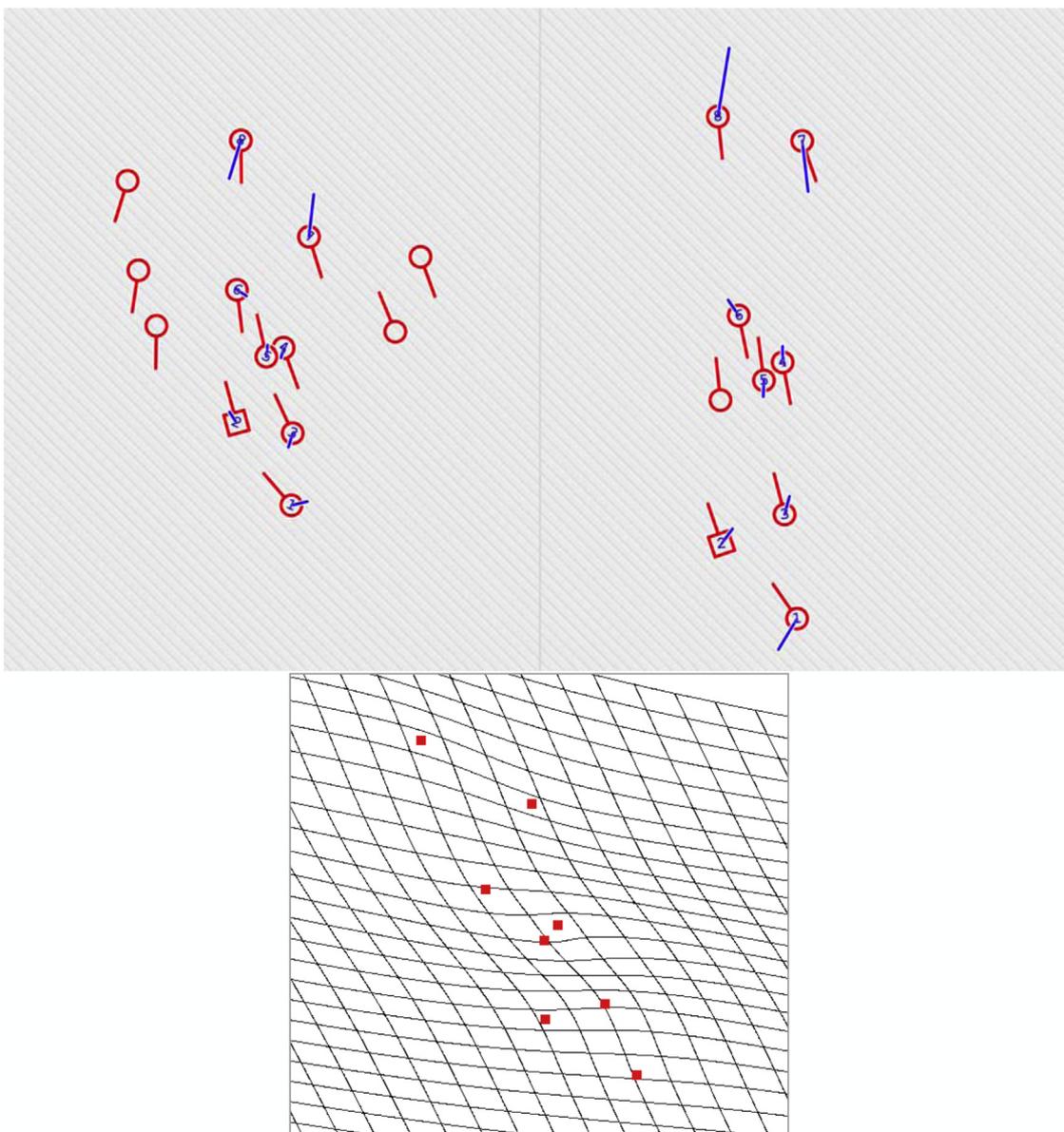
**Fig. 3.** Case-0107, a different sources trial. The annotated mark is presented on top and the annotations on the exemplar (without the exemplar image) are presented on the bottom. Discrepancies in the minutiae at the areas marked A, B, and C are described in the text. (For interpretation of the references to color in the text, the reader is referred to the web version of this article.)



**Fig. 2.** Four minutiae marker types were available to study participants. The ridge ending and bifurcation markers indicated certainty in minutia type and location, whereas the triangle and diamond markers indicated some uncertainty about the minutia's type or location.

the two images are aligned and at a 1:1 scale, so the relative positions of the annotations in each are preserved.

Based on the annotations from user-0045, a pairing of 8 minutiae can be postulated. If the mark and print originated from the same source, the amount of elastic distortion that would be required to align both sets of minutiae should be limited given the proximity of the minutiae and the area of palmar friction ridge skin considered. The amount of elastic distortion required to align the minutiae can be calculated using a thin plate splines (TPS) model [4]. Computed on the 8 paired minutiae, the TPS model gives all parameters allowing the elastic alignment from the set of minutiae on the mark to the set of minutiae on the print. Fig. 4 illustrates the elastic movements that would be required to align these 8 minutiae. On the top, we show the user's annotations with the 8 paired minutiae (on the left for the mark and on the right for the



**Fig. 4.** Case-0107. Top: pairing of 8 minutiae annotated by the user between the mark on the left and the print on the right. Bottom: representation of the elastic distortion required to align the minutiae. (For interpretation of the references to color in the text, the reader is referred to the web version of this article.)

print). The blue rods illustrate the distances and directions of movement that would be required for the proper alignment of the minutiae. The bottom image shows the global distortion map. Two sets of minutiae that superimpose perfectly will give a grid of perfect squares. That is not the case here, as evidenced by the distorted black grid. The wavy effects seen on the grid represent shearing stress and expansion and compression of the ridges. These effects would not be seen to this extent on paired sets of minutiae from friction ridge skin impressions coming from the same source.

User-0045's analysis notes are as follows and no free text comparison notes were made:

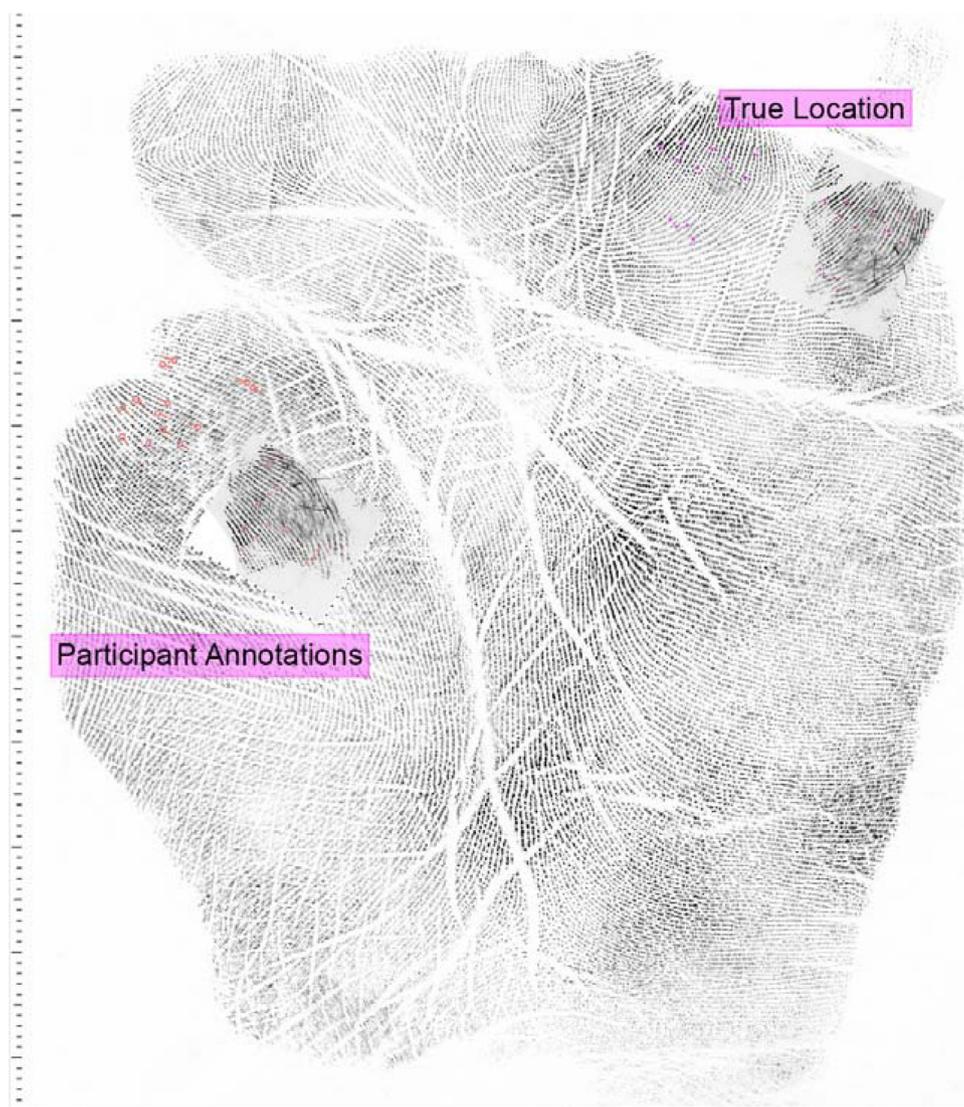
- *Possibly interdigital but I am not sure.*
- *relatively clear print.*

The user's belief that the print is relatively clear is supported both by the fact that all high-confidence minutiae markers were

**Table 2**  
Results for case-0107, a different sources trial.

Conclusion	Number of users
No value	1
Inconclusive	11
Correct exclusion	22
Erroneous ID	1
Did not complete case	1

chosen and the fact that user-0045 only adjusted the position of one minutia (the yellow one) after seeing the exemplar. However, the exemplar provided in this case was very clear throughout the image and still this user managed to convince themselves of an erroneous identification. Looking at Fig. 3, the reader should notice



**Fig. 5.** Case-0502, a same source trial. The unknown mark is superimposed on the exemplar twice. At the top right, the mark is placed next to the true location of its source. Some corresponding minutiae are marked in pink. At the left, user-0203's annotated mark is superimposed next to the annotated area of the exemplar in the orientation that matches the ridge flow. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)



**Fig. 6.** The mark that was presented in case-0502, shown in the orientation in which it was originally presented during the study trial (users were provided with a tool that allowed free rotation of this image during comparison).

both the number of non-paired minutiae and the places where the relative positions of putatively matched minutiae are well out of tolerance. To the left of the main vertical strip of minutiae, there are 3 minutiae annotated on the mark that are not annotated on the exemplar. This is because those 3 minutiae are not present in the exemplar. The same is true of the 2 minutiae to the right of the main vertical strip of minutiae that are similarly not annotated on the exemplar. It should also be noted that the two minutiae marked "A" in Fig. 3 are in very different relative positions to one another in the mark and in the exemplar and that they would have had to move quite a distance along ridges (as opposed to across them) to reach the closer position. However, it has been demonstrated that friction ridge skin compresses well across ridges under lateral pressure, but not well along ridges [5], making it unlikely that one of these two minutiae in the same local area could have travelled a great distance along a ridge while the other held still, in order to truly be in correspondence between the two impressions. The two minutiae marked "B" in Fig. 3 would have had to trade positions vertically (along ridges) in order to be in correspondence. Additionally, the minutia marked "C" on the exemplar in Fig. 3



**Fig. 7.** An example of how the substrate was held to create the mark presented in case-0502.

does not have a corresponding minutia annotated on the mark – the reader will note that there is clearly no minutia present in this position on the mark.

With all of these apparent differences between the two figures, it is astonishing that the examiner managed to convince themselves that these two impressions originated from the same source. The full results of this comparison are displayed in [Table 2](#).

These examples demonstrate that examiners need to be more alert to the dangers of mind-set while forming an opinion of identification. If one or the other of the images is highly degraded, or if the examiner just seems to be having to work too hard to make everything “fit,” it is imperative that they mentally check themselves and take an opportunity to consider whether they might be falling victim to mind-set and proceed with greater caution.

### 3. Erroneous exclusions

Previous error rate studies [6–8] have universally shown a much higher rate of erroneous exclusions than erroneous identifications, and our own palm data agree with this trend. Given that the average examiner is at a much higher risk of committing an erroneous exclusion than an erroneous identification, it is worth closely examining how mind-set can contribute to these errors in an attempt to minimize them.

Four examples in which the provided documentation allows us to understand how mind-set may have led to the error will be explored. In the case of erroneous exclusions, we are able to show both the marks and exemplars, because the donors of both have consented to their use in publications.

The first example we present involves user-0203's interpretation of case-0502. This same source trial featured a mark that was developed in cyanoacrylate fuming followed by a fluorescent dye (BY40) on the non-sticky side of tape. [Fig. 5](#) presents user-0203's comparison annotations of the mark superimposed on their comparison annotations on the exemplar, as well as showing the true location of the mark. [Fig. 6](#) provides the unannotated mark in the orientation in which it was initially presented during the study trial (participants were provided with a tool that allowed them to rotate the mark). [Fig. 7](#) shows the type of touch that was used to create the mark while [Fig. 8](#) shows the complete original mark, with the area that was cropped for the comparison trial highlighted in pink.

User-0203 did not provide any free text notes in either analysis or comparison, but it can be seen from their annotations on the mark and exemplar that they did use the rotation tool to consider different orientations, but only marked potentially corresponding minutiae in one area, which was not the correct area. The software used (PiAnoS) tracks the position of the search window over time within the large palm print. This allowed us to investigate the search strategies employed by this user. [Fig. 9](#) shows “hot spots” corresponding to the time spent by the user on different areas of the palmar surface. It shows that user-0203 spent only 3 seconds on the true location of the mark. Two other main areas were looked into for respectively 63 and 116 seconds, before locking on to the annotated area for 480 s. It is likely that once the user determined that the area where they were comparing minutiae was not in correspondence, they concluded that the pair must be from different sources, rather than considering that there might still be other areas of the exemplar that would provide closer (and correct) correspondence.

The full results of this comparison are displayed in [Table 3](#).

The second example involves user-0025's interpretation of case-0276. This same source trial featured a mark that was developed with 1,2-indanedione/Zn on graph paper. [Fig. 10](#) presents user-0025's comparison annotations of the mark superimposed on their comparison annotations on the exemplar, as well as showing the true location of the mark. [Fig. 11](#) provides the unannotated mark in the orientation that was initially presented during the study trial. [Fig. 12](#) shows the type of touch that was used to create the mark while [Fig. 13](#) shows the complete original mark, with the area that was cropped for the comparison trial highlighted in pink.

In this example, it is easier to more fully reconstruct the mind-set error, thanks to the free text notes provided by user-0025. Part of this user's analysis notes read:

- *parallel ridge flow, curved edge profile (bottom edge of palm?).*

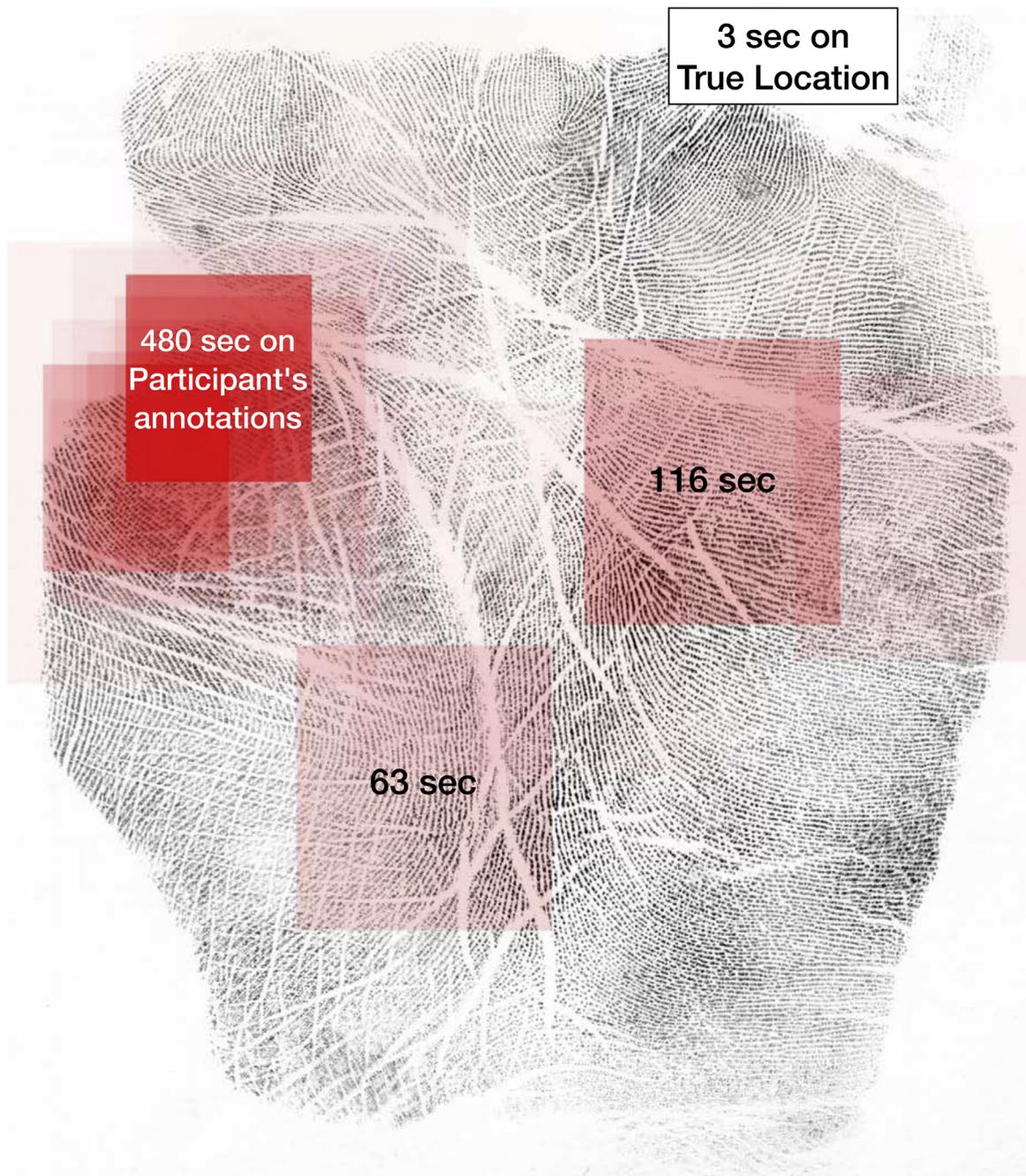
The entirety of the comparison notes were as follows:

- *curved area consistent with lower hypothenar.*
- *ridge flow, minutiae, and occasional features not in agreement.*
- *curved area and details in latent not observed in other areas of known palm.*

It is clear from these notes and the user's annotations that they formed an opinion during analysis that the mark was from the bottom edge of the palm, and that opinion was reinforced and went unchallenged during comparison. Note that user-0025's third comparison note explicitly states that they were looking for that curved area in other places and did not find it. Of course, the curved shape does not show up in the exemplar, due to the way the hand makes contact with the surface when recording exemplars, yet [Figs. 12 and 13](#) together show how this curved shape was created by the way the mark was laid down. Incorrect assumptions about how



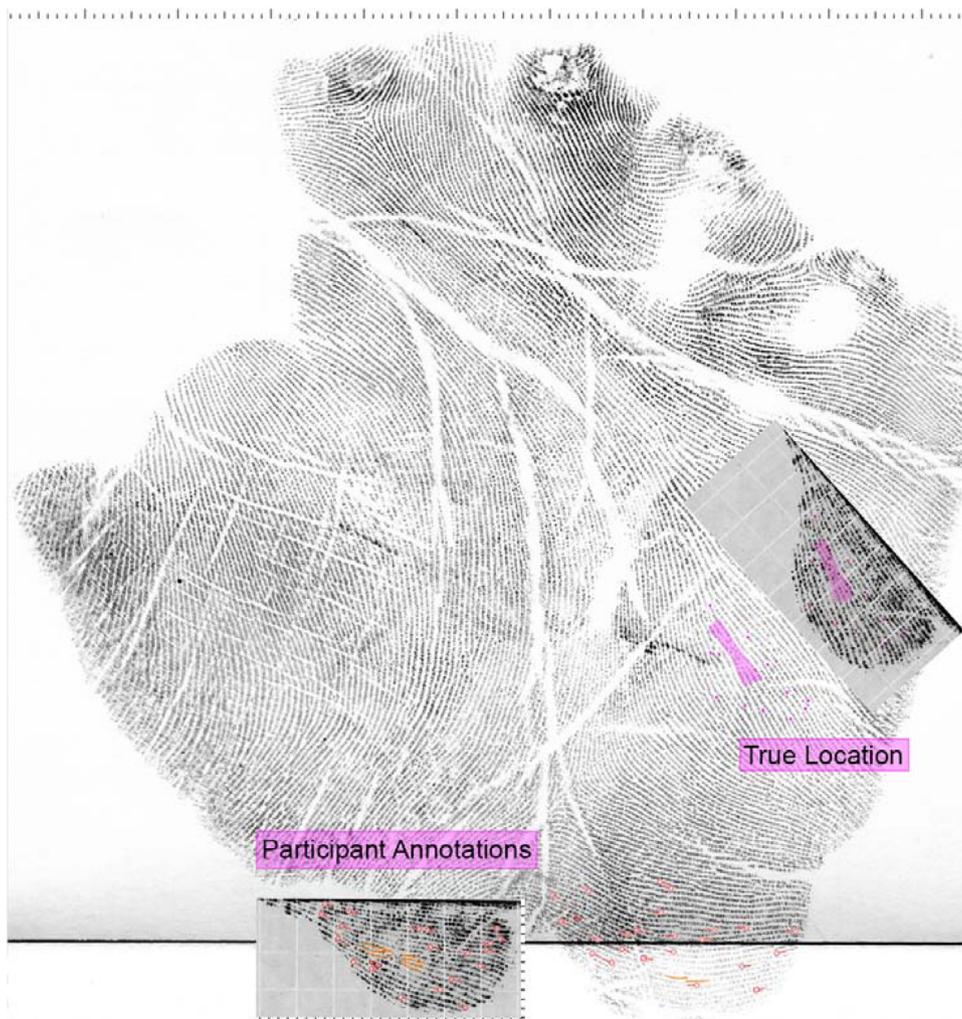
**Fig. 8.** The full, original mark that was used to create case-0502. The area highlighted by the pink box was cropped to become the unknown mark in case-0502. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)



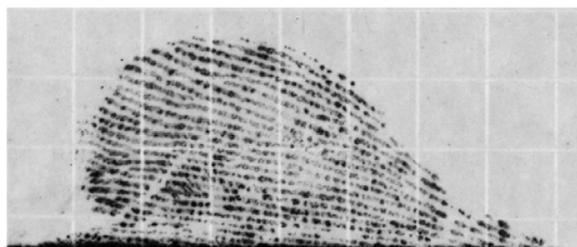
**Fig. 9.** Time (in seconds) spent by user-0203 on case-0502. The density of the red areas is proportional to the time spent by the participant in each area. The times spent in four zones are indicated. Only 3 s were spent on the area corresponding to the true location, whereas 480 s were used for the area with annotations. Respectively 63 and 116 s were dedicated to two other search areas. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

**Table 3**  
Results for case-0502, a same source trial.

Conclusion	Number of users
No value	0
Inconclusive	0
Erroneous exclusion	1
Correct ID	18
Did not complete case	1



**Fig. 10.** Case-0276, a same source trial. The unknown mark is superimposed on the exemplar twice. At the right, the mark is placed above the true location of its source. Some corresponding minutiae and the distinctive 'cat whiskers' formation are marked in pink. At the bottom, user-0025's annotated mark is shown superimposed next to the annotated area of the exemplar in the orientation that matches the ridge flow and the user's free text notes. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)



**Fig. 11.** The mark that was presented in case-0276, shown in the orientation in which it was originally presented during the study trial (users were provided with a tool that allowed free rotation of this image during comparison).

marks may show global curvature have led the examiner into tunnel vision, and ultimately, an error. Looking at the annotations made by the primary author in the true location, it can easily be seen that there are many minutiae in clear agreement between the two impressions.

Even more interestingly, user-0025 annotated in orange a formation that looks like cat whiskers. This highly diagnostic feature stood out to the user enough that they felt it was worth annotating but they did not find it at the bottom of the palm

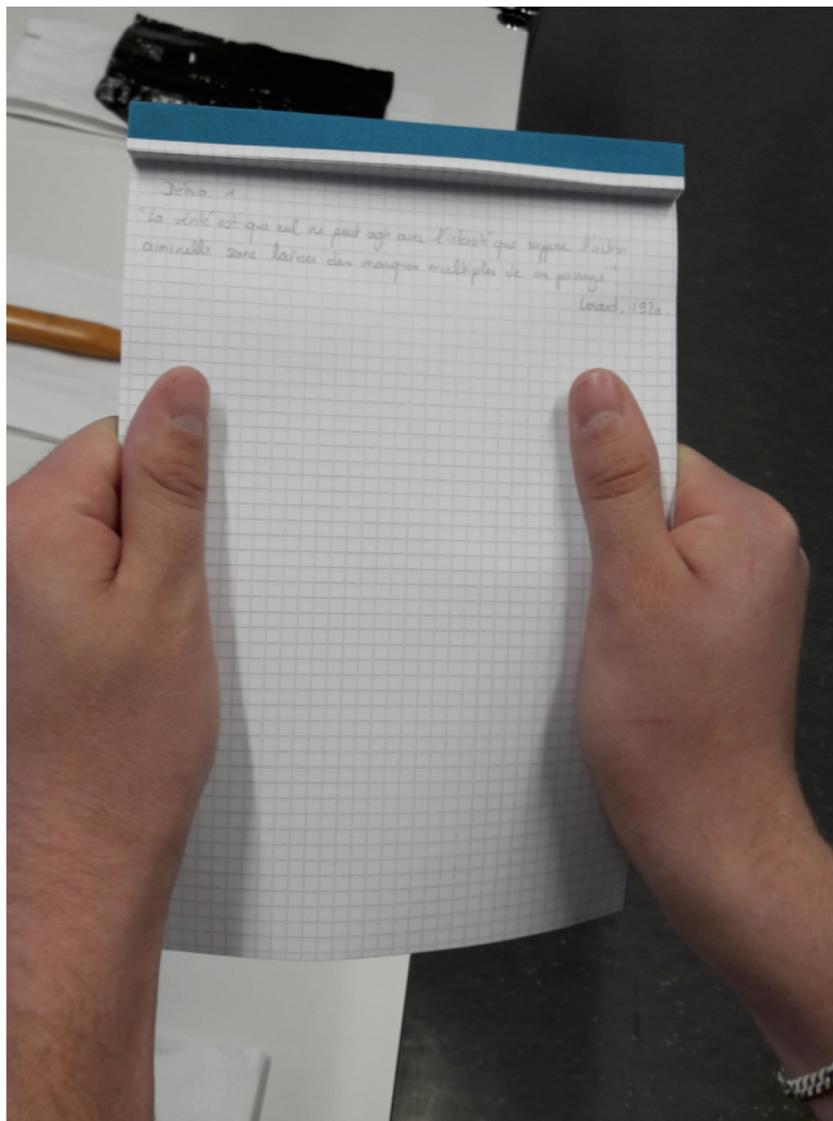


Fig. 12. An example of how the substrate was held to create the mark presented in case-0276.

where they were looking (because it was not there). However, if the reader will direct their attention to the true location of the mark, they will note that the cat whiskers are present in the exemplar, highlighted in pink. User-0025 correctly observed and annotated a very valuable piece of information but was so locked into their mind-set at the bottom of the palm that they failed to recognize it in its true location. The full results of this comparison are displayed in Table 4.

In addition to these two examples of erroneous exclusions impacted by mind-set during an in-depth comparison process, there were multiple examples of free text notes by users that made it quite clear that mind-set prevented them from doing any kind of meaningful comparison at all, which also led to erroneous exclusions.

In the first example, user-0212 states regarding case-0026, "Tenprint shows a right palm, latent is a left palm – immediate exclusion." However, the latent was a right palm; it simply had been presented nearly upside down. Perhaps the user would have

found this mark had their mind-set not prevented them from conducting a thorough comparison. Fig. 14 presents the mark and print from case-0026. While 14 users correctly identified this pairing, there were 3 erroneous exclusions in this case.

In a more puzzling example, user-0314 notes during analysis of case-0428 that "The latent appears good to great at first but finding L2D features seem more difficult upon closer inspection" then goes on to note during comparison "An absolute instantly visible 'NOT HIM'". Unfortunately, it was him (or her), and this was an erroneous exclusion. As the user did not provide additional notes, it is unclear what about this pairing seemed so absolutely and instantly visible to them as an excludable difference, particularly if they did not trust their L2D features. While the thenar area can be challenging and this mark did require rotation, both the mark and exemplar are clear and a good amount of area overlaps between the two. This pairing yielded 2 erroneous exclusions, 1 inconclusive, and 10 correct identifications. Fig. 15 presents the mark and print from case-0428.



**Fig. 13.** The full, original mark that was used to create case-0276. The area highlighted by the pink box was cropped to become the unknown mark in case-0276. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

**Table 4**  
Results for case-0276, a same source trial.

Conclusion	Number of users
No value	0
Inconclusive	4
Erroneous exclusion	4
Correct ID	25
Did not complete case	0

In an interesting twist on the erroneous exclusion, some users appeared to have committed erroneous exclusions in a conscious attempt to avoid an erroneous ID although this was not a forced-choice study and an inconclusive option was available. User-0208 noted in their case-0022 comparison notes that they reached their exclusion decision because they felt they were “*trying to force an identification*”. They had correctly oriented the mark and correctly annotated 8 minutiae in correspondence between the two (same source) impressions. If they were not comfortable with the risk of making an erroneous ID, one wonders why they did not just select inconclusive, rather than swinging entirely the other direction to commit an erroneous exclusion.

It is true that some agencies discourage or prohibit their examiners from using inconclusive in the situation where both impressions are of value, there is a potentially corresponding area, and no other exemplars are available. However, user-0208’s response to this question on the demographic and policy survey was “inconclusive determinations are freely accepted in this case” so that does not explain the observed behavior.

While the vast majority of the free text comments that were received exhibited clear reasoning or appropriate caution when the user was unsure about an attribute of one of the impressions, these examples highlight that many examiners are forming strong opinions about the impressions that are leading them into erroneous exclusion decisions. Given the high false negative rate reported in this, and other, studies, it is important for examiners to remember that if they fail to find their target during their first search, it is imperative to re-consider their analysis with an open mind before reaching an exclusion decision.

**4. Erroneous inconclusives**

Finally, we will explore examples of true “erroneous inconclusives.” In this particular set of examples, we can say that the inconclusive decision was incorrect for the reason given. In this study, any time an examiner selected inconclusive as their decision, they were prompted to give a reason for the inconclusive, from a drop-down list. One of the allowable options was “inconclusive due to no overlapping area”. However, each same source trial in this study was manually compared by the primary author (PI) prior to being included in the study to ensure that overlapping areas were available, otherwise the trial would not be “fair” as a same source trial. Thus, in same source trials where a participant chose inconclusive for the reason “inconclusive due to no overlapping area,” they were objectively incorrect. This is a mind-set error that is analogous to an erroneous exclusion in that the user’s incorrect determination of orientation, palm area, or failure to recognize target group led them to erroneously stop searching because they were locked in to believing the thing they sought was not present when it was. This error could also occur when the examiner actually did choose features that were not present in



**Fig. 14.** Case-0026, a same source trial. The mark is presented on the left in the same orientation in which it was presented during the study trial. The exemplar is presented on the right. The mark needs to be rotated approximately 130 degrees clockwise to be in the correct orientation. Four minutiae in correspondence are marked in pink to assist the reader. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

the exemplar but failed to select a second set of features to search when they did not locate the first.

In all, 1840 inconclusive decisions were reported in this study. Of these, 942 occurred in same source trials (where an overlapping area was present). However, in 123 (11.55%) of these same source inconclusive decisions, the “inconclusive due to no overlapping area” reason was selected. The breakdown of difficulty level (according to the designations set by the PI) in these 123 trials was as follows (Table 5):

It can be seen that the vast majority of these errors occurred in cases where it was anticipated that either no definitive conclusion would be reached (NV or Inconclusive) or that the comparison would be difficult (Hard or Very Hard). However, the 5 cases that were rated as “Easy” are a mystery. Review of the images from these 5 cases revealed that 2 required rotation, while the other 3 did not. The number of reported conclusions for each are given in Table 6:



**Fig. 15.** Case-0428, a same source trial. The mark is presented on the right in the same orientation in which it was presented during the study trial. The exemplar is presented on the left. The mark needs to be rotated approximately 130 degrees clockwise to be in the correct orientation. Four minutiae in correspondence are marked in pink on the right side of the thenar area to assist the reader. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

**Table 5**  
Breakdown of difficulty level (according to the designations set by the PI) for the trials reported 'inconclusive due to no overlapping area'.

Difficulty	n
No Value (PI anticipated the mark would not be compared)	7
Easy	5
Medium	18
Hard	71
Very Hard	17
Inconclusive (PI anticipated an inconclusive decision)	5
<b>Total</b>	<b>123</b>

**Table 6**  
Number of reported conclusions for the cases rated as 'Easy'.

Case number	Correct ID	Erroneous EXC	Inconclusive	Sum
case-0458	10	0	1	11
case-0260	18	1	1	20
case-0276 (rotation required)	25	4	4	33
case-0032 (rotation required)	33	5	2	40
case-0366	23	2	6	31

## 5. Conclusion

The analysis phase of comparison serves an important function in providing the examiner with information about the unknown mark that can greatly expedite their search, by narrowing the field to exemplars that match the putative orientation and anatomical source of the mark. However, when an examiner allows themselves to be locked into a mind-set where they do not consider that their initial interpretation could have been wrong, they expose themselves to a risk of erroneous exclusion. The heuristics applied by the examiner can be very efficient but come with a risk of tunnel vision. Similarly, mind-set can be a danger when an examiner sees some features that may be in agreement and falls into a mind-set that this comparison must be an identification, then sets about digging up justifications to support their belief, which can lead to an erroneous identification.

A recent black box study on palm comparison accuracy and reliability [3] found both of these behaviors amongst the notes and annotations provided by some of its participants. Examples of each were presented in this paper to serve as a cautionary tale and reminder to examiners to always stop and consider whether mind-set could have influenced their thought process and could be leading them to an erroneous conclusion prior to rendering their final decision.

As Findley [9] rightly pointed out (p.303): “Tunnel vision is a natural human tendency that has particularly pernicious effects in the criminal justice system”. Fingerprint examiners are not immune to this risk and have to develop procedures to mitigate it. Much has been written on the dangers posed by bias (in particular cognitive or contextual bias) in the fingerprint discipline and guidance and recommendations are provided to that effect (for example in the UK [10]). In this paper, we wanted to explore how misinterpreted information from the mark alone may generate mind-sets that impact the accuracy of friction ridge comparisons. We would not claim that the ways to mitigate that risk are obvious and fully effective, but we would like to suggest a few options:

- Introduce case documentation that allows for a full review of the features used and possibly the thought process of the examiner. In this paper we have used the documentation some examiners produced as a side effect of their participation in the black box study. Without it, there is no way to carry out a root cause analysis and propose corrective actions.
- Introduce a verification regime in which all conclusions issued by the fingerprint unit are verified.
- Introduce a blind verification regime in cases where it is known that there is a higher risk of erroneous decisions.
- Develop a workplace culture where challenging beliefs is promoted. The objective is to reduce a culture of *belief perseverance*.
- Develop a workplace culture where erroneous exclusions are not treated as inconsequential, but steps are taken to reduce their numbers in a non-punitive environment.
- Introduce a policy that includes criteria required to reach an exclusion, particularly requiring documentation of the distal orientation and anatomical source that were assumed in the decision.
- Introduce standardized training across the discipline on criteria necessary to reach each conclusion and on mitigation strategies for mind-set.

## Authors' contributions

**Heidi Eldridge:** Conceptualization, Methodology, Formal analysis, Investigation, Writing – Original Draft, Writing – Review & Editing, Visualization, Project administration, Funding acquisition.

**Marco DeDonno:** Software, Data Curation, Visualization.

**Christophe Champod:** Conceptualization, Methodology, Formal analysis, Investigation, Resources, Data Curation, Writing – Original Draft, Writing – Review & Editing, Visualization, Supervision, Project administration, Funding acquisition.

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## Conflict of interest

The authors declare no conflict of interest.

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