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"Knuckles and Fingerprints: A Comparison and Case Study"

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Abstract

When a person flexes the hand to make a fist, the dorsalside skin near the knuckles tightens. When the fist is relaxed, the skin may fold, creating lines variously called wrinkles and creases.1 In a recent case, these lines were the evidence that was used to try to identify a defendant. The charges against the defendant, Devin Whitfield [1], included child pornography. Part of the evidence consisted of an image taken on a cell phone that included the dorsal side of knuckles. The prosecution called a qualified fingerprint analyst. In light of her expertise in fingerprint analysis, it is useful to review the similarities and differences between knuckle creases and fingerprints.

Disciplines

Legal Studies

Comments

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Commentary

Knuckles and Fingerprints: A Comparison and Case Study

Knuckle Wrinkles and Creases

When a person flexes the hand to make a fist, the dorsal-side skin near the knuckles tightens. When the fist is relaxed, the skin may fold, creating lines variously called wrinkles and creases.[1]

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The charges against the defendant, Devin Whitfield [1], included child pornography. Part of the evidence consisted of an image taken on a cell phone that included the dorsal side of knuckles. The prosecution called a qualified fingerprint analyst. In light of her expertise in fingerprint analysis, it is useful to review the similarities and differences between knuckle creases and fingerprints.

Embryology

Obviously, huge changes occur in the nine months between human egg fertilization and the birth of a child. Understanding the dynamics of development is difficult because the data consist of observations on abortees and stillborns, who are necessarily dead. As a consequence, the task is to infer dynamics from data static in age. Such data support documenting the sequence of events, but not the mechanisms driving those events. Furthermore, experiments on live human embryos are unethical. Hence, models of embryological development are conjectures, and evaluating them is problematic.

It is, however, well documented that friction ridges (fingerprints, palms, and the bottoms of feet) develop from volar pads,

[1] I am indebted to Michael W. Bowman, M.D. (Pittsburgh Hand and Foot Center) for explaining to me that knuckle creases, folds, and wrinkles are anatomically the same thing. This paper refers to them as wrinkles and creases.

which appear on the ventral side in both hands and feet some 10.5 to 16 weeks after fertilization [2]. Thus, the mechanisms of development are believed to be similar for the bottoms of the feet and the ventral side of hands. But volar pads are not observed on the dorsal side of the hand. A study of the fingerprints of twins showed that identical twins did have different fingerprints, but they were more similar to each other than those of fraternal twins [3]. Furthermore, the fingerprints of fraternal twins were more similar than were the fingerprints of random pairs of people. This supports the conclusion that fingerprints are influenced by both genetic and environmental factors.

With respect to knuckle ridges, a rare condition, called arthrogryposis congenita, gives a hint. Fried and Mundel [4] reported on a family in which a child was born who was unable to move his hand and lacked knuckle creases. This suggests that knuckle creases form by flexing the hand. There are other conditions that result in the inability to move one or more fingers, such as Dupuytren contracture, but I have not found reports about the dorsal knuckle creases of persons with this condition. However, it is reasonable to conclude that fingerprints and knuckle creases are biologically distinct.

Persistence

The persistence of fingerprints has been researched since Galton [5], who used fingerprints gathered by Herschel in India. The finding is that fingerprints, in general, do persist, "barring growth, disease or injury" [2]. This result was recently affirmed by Yoon and Jain [6].

Knuckle creases are regarded as an unwelcome (by some), but treatable, sign of aging. Roberts et al. [7] reviewed many treatments that are available to reduce or eliminate knuckle wrinkles and creases. The available methods include laser resurfacing [8], filler injections [9], fat grafting [10], and moisturizers [11].[2] Although the treatments vary in terms of cost, immediate effectiveness, long-term effectiveness, and side effects, there seems to be no question that knuckle wrinkles and creases are not persistent in the way fingerprints are. However, barring treatment, it is reasonable to conjecture that knuckle creases and wrinkles change slowly.

2 Dr. Bowman said, facetiously, that he suggests to patients wishing not to have knuckle creases that they put on a lot of weight.

Databases and Studies

There is a long history in the study of fingerprints. Galton [5] was the first comprehensive study. More recently, Ulery et al. [12] reported on a black-box study to identify the error rates in fingerprint analysis. A review by Thompson et al. [13] surveyed more than a hundred papers. Bécue et al. [14] reviewed almost 600 papers from the last three years. The largest database of fingerprints is operated by the FBI and is now called "Next Generation Identification" (NGI). The civil and criminal databases have well over 100 million Americans' fingerprints. The databases are accessed only by proprietary computer programs operated by various governmental entities. Neither the programs nor the databases are available for study by independent researchers.

The literature on knuckles divides into two groups. The most prolific are computer engineers studying what they call "biometrics", aimed at authenticating whether a person is who he or she says he or she is. The purpose of these computer programs is to check, for example, a person with employee credentials. With a database representing the knuckles of employees, the programs compare the knuckle offered to the image in the database. Reviews of this work can be found in Rani and Shanmugalakshmi [15] and Sahu and Rathore [16].

The forensic purpose is rather different. It seeks to distinguish a single person's knuckles from all others. This is a much more demanding requirement. The literature is sparse. Jungbluth [17] reported a case in which bruises on the back of a child were compared to the knuckles of three possible suspects, two of whom were eliminated. Harrison et al. [18] discussed a case revolving around a skin texture mark on the back of the hand, found on a discarded glove. Niemitz reported a study on creases used to identify ATM fraud [19, 20]. Although the details were not given, the paper reported odds of 1:10^10, apparently assuming independence among many characteristics. More distantly related, Mestrovic and Ozegic [21] and Singh et al. [22] addressed interdigital flexon creases. There are no known databases or other published studies concerning the forensic uses of knuckle prints.

Uniqueness

Because "uniqueness" is a somewhat loaded word in the fingerprint community, it is incumbent on me to be clear about what I mean by it. A general definition might be a state or condi-

tion wherein someone or something is unlike anything else in comparison. Unstated in this definition are the criteria being used and the set of things being compared. In the context of this paper, the criterion being referred to is the usual fingerprint analysis. I distinguish between three grades of uniqueness that differ according to the comparison set being referred to.

Grades of Uniqueness

Grade I addresses jointly the 10 fingers that almost everyone has. The uniqueness question is whether a given person's 10 fingers (together) are different from every other person's 10 fingers. This was the first large-scale forensic application of fingerprints, used to find out whether a person who had been arrested or convicted of a crime had also served time elsewhere, perhaps under a different name.

Grade II addresses the print of a single finger. The uniqueness question here is whether such a print is different from the print of every other single print of a finger. Most of the discussion of fingerprint uniqueness in the literature is about this grade.

By contrast, Grade III concerns a latent print in its relation to the prints of a person of interest (POI). The latent print may be partial or smudged. Presumably there are characteristics in common between the latent print and the POI's print. The uniqueness question here is the extent to which there are others who share the common characteristics found. Sometimes this inquiry can be limited geographically to the local area, the state, the nation, the hemisphere, or the world.

Fingerprints

Levels of detail of fingerprints are distinct from grades of uniqueness defined above. Grades of uniqueness refer to the set of items being compared, and not to the quality of the items themselves, which is what levels of detail describe. Traditionally, Level I refers to the general flow of fingerprint ridges, Level 2 to the minutiae or Galton points, and Level 3 to the finer detail of the ridges, such as the location of the pores.

Although people differ in their fingerprints more widely than they do in many other characteristics, that is not the same as uniqueness. Galton [5] devoted a chapter to describing an experiment that he claimed showed that there were 64 billion equally likely possible fingerprint configurations. Unfortunately, his experiment is not described in sufficient detail that it can be

replicated. Galton's experiment is attacked by Roxburgh [23] and defended by Stigler [24].

The International Association for Identification (IAI) is the sponsor of this journal. In 2007, it created a position statement entitled "IAI Position Concerning Latent Fingerprint Identification" [25]. The document declares, "The IAI fully supports the principle that finger, palm, and footprints (friction ridge detail) are unique to each and every individual. This principle has been well established through the biological sciences of anatomy, embryology and genetics." The problem is that it has not. Both the Thompson et al. [13] review of the literature and an article by Eldridge [26] found no articles in those biological sciences that support Grade 2 uniqueness of fingerprints[3].

The second justification put forward by the IAI in support of its position is, "As yet, no two fingerprints from different individuals have ever been found to be the same." [25] There are, according to the United Nations, about 7.7 billion people in the world (i.e., 7.7×10^9). Because roughly each person has 10 fingers, there are about 7.7×10^{10} fingers. With n fingers, there are $n \times (n\text{-}1)/2$ pairs of fingers to be compared (i.e., about $(n^2)/2$). Therefore, the number of comparisons required is $[(7.7 \times 10^{10})^2]2$, or about 3×10^{21}. This is a very big number. Galton's research was the first serious study of fingerprints, about 127 years ago. Since Galton's book was published, the number of seconds that have passed is $60 \times 60 \times 24 \times 365.25 \times 127$, or about 4×10^9 seconds. Therefore, the number of comparisons per second required to check uniqueness would be roughly $3 \times 10^{21}/4 \times 10^9 = 750 \times 10^9$, or 750 billion comparisons per second every second since 1892. These would have to be pairs of fingerprints not compared before in order to count. It is hard to believe that the number of fingerprint comparisons since 1892 comes to 750 billion, let alone 750 billion per second. Thus, the empirical evidence for uniqueness of fingerprints is very weak.

In summary, the Grade 2 uniqueness of fingerprints is an interesting conjecture, but is far from established science.

Knuckle Creases

Given that knuckle creases increase with age and can be treated if desired, it is not clear what one means by uniqueness of knuckle creases. However, it is reasonable to suppose, barring treatment of the kind mentioned previously, that in the short-term, knuckle

[3] Neither Thompson [13] nor Eldridge [26] used the phrase "Grade 2 uniquenss of fingerprints".

creases will not change drastically, and consequently might be sufficiently stable that one can inquire about uniqueness of them. I have not found literature addressing this question.

Forensic Expertise and Case Study

There is a vibrant community of specialists in fingerprint analysis, with meetings, publications, and proficiency examinations. The same cannot be said of knuckle print analysts. However, it is plausible that fingerprint expertise, with emphasis on detailed examination of tiny marks on skin, might transfer. There are no studies to buttress this conjecture, however.

In the Whitfield case, an examiner testified, "The print of the unknown on the cell phone is the same finger -- same knuckle as Devin Whitfield." [27] In a later deposition, she was asked, "How many people would you estimate in the Tampa area share the knuckle characteristics you found in the photographs?" Her response was, "It's hypothetical. I can't give you an answer on that. I would have no idea." [28]

In my rebuttal deposition, I stated "Well, if she has no idea, imagine - - pick a number, there are 50. On the same evidence she would identify each of those 50 people as being the person whose knuckles are in the photograph. That makes no sense. So her identification just doesn't jibe with the fact that she is unable to give any gauge on how many people share those characteristics, let alone that that set of people consists of only one person, namely the defendant. So my conclusion from that is that the identification, the source attribution, however you want to phrase it, match and so on, there's lots of different locutions that have been used for this over the years, but she doesn't have the information that would be necessary in order for her to come to that conclusion." [29] At the subsequent hearing, the prosecution announced that it was abandoning claims of identification. The case proceeded on other grounds.

Defensible Local Estimates of Frequencies (Grade III Uniqueness)

There are no defensible local estimates of how frequently a given set of knuckle ridges would be found. The situation is similar for fingerprints. Appeals to the literature regarding Grade 2 uniqueness do not address this issue. That literature addresses clean finger comparisons and not the often partial or

degraded latent prints. Thompson et al. [13] found, "The scientific literature does not, however, provide an adequate basis for assessing the rarity of any particular feature, or set of features, that might be found in a fingerprint. Examiners may well be able to exclude the preponderance of the human population as possible sources of a latent print, but there is no scientific basis for estimating the number of people who could not be excluded and there are no scientific criteria for determining when the pool of possible sources is limited to a single person." Hence, despite the enormous literature and huge databases, the rarity of a fingerprint is subject to the same challenge as is a knuckle crease identification.

At this time, it would seem that identification of other kinds of trace evidence is vulnerable to the kind of challenge made in the Whitfield case. Absent an estimate of the number of persons in some relevant geographical area who share the characteristics being relied upon, any number could be "identified" on the basis of the same evidence.

Estimating the Rarity of a Latent Fingerprint

It is possible that the rarity of a fingerprint could be estimated, although it would require substantial changes to current practices. Suppose that NGI included both Level 1 and Level 2 information (I believe it has Level 2, but possibly not Level 1, data). Also, suppose it has geographic data, which I believe to be the case.

A search of the database could then be made to determine the proportion, λ, of prints in the file that match the latent (a natural distribution to use is the Poisson distribution, the standard model for rare events). Adjustment has to be made for the incompleteness of the file. Suppose, compared to the census count of persons in the relevant geographic area, proportion p of them are represented in NGI. Then the estimated rate in the population would be $\lambda^* = \lambda/p$. Finally, according to the Poisson distribution, the probability of uniqueness would be $\exp(-\lambda^*)$. It is possible that currently used measures of similarity might be used to determine "match". However, these similarity measures are proprietary, so their usefulness for this purpose is unknowable.

Although a scheme along these lines may be feasible for latent prints, its extension to other kinds of trace evidence would be much more difficult, for two reasons. First, there are no exten-

sive databases for other kinds of trace evidence, such as fibers, paint, glass, and so forth. Second, for each of these other sources, there is not the equivalent of the census of population to guide an empirical estimate of the completeness of the database.

Conclusions

Table 1 pulls together the comparison between knuckle creases and fingerprints.

	Knuckles	Fingerprints
Embryology	From flexing	Develop from volar pads
Databases	None	Extensive
Studies	None	Many
Persistence	Absent treatment, develop over time	Well established
Uniqueness (Grade II)	Unknown	Debatable
Forensic Fxpertise	None	Many experts, meetings, proficiency exams
Defensible Local Estimates (Grade III)	None	None

Table 1

Comparison of knuckles and fingerprints.

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