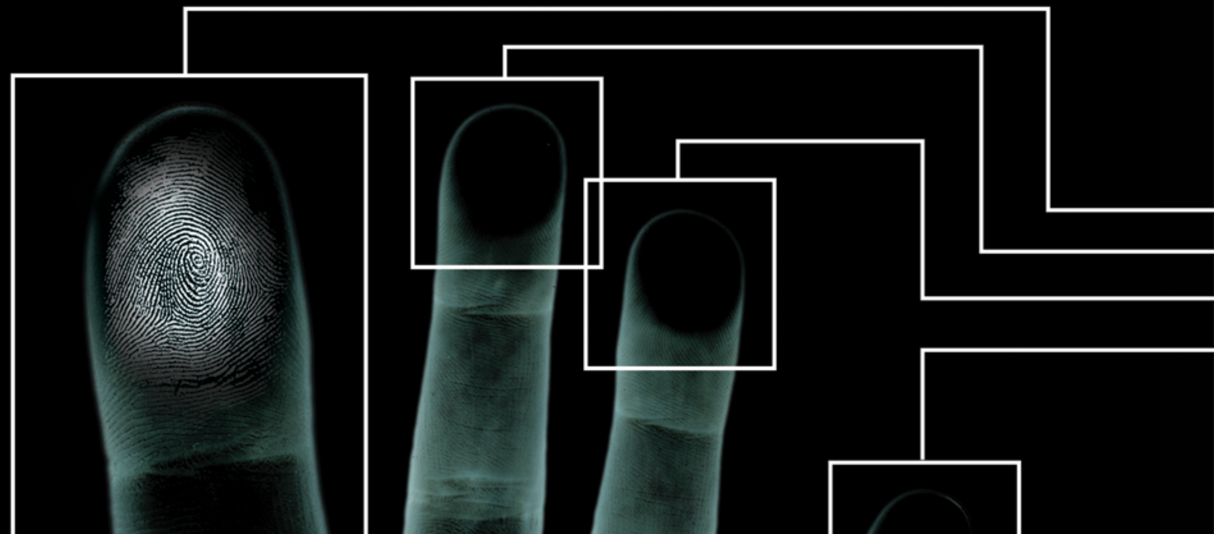
CHAPTER 9

EXAMINATION PROCESS

JOHN R. VANDERKOLK

CONTENTS



CHAPTER 9

EXAMINATION PROCESS

JOHN R. VANDERKOLK

9.1 Introduction

The purpose of an examination is to determine or exclude the *source* of a *print*.* This chapter will discuss a method used by examiners to determine a print's source by looking at and comparing the general ridge flow in two fingerprints, the sequences and configurations of ridge paths, and if needed, the sequences and configurations of morphological details of a particular ridge and nearby ridges. This chapter also addresses the philosophies of perception and decision-making that all fingerprint examiners need to understand before turning to the mechanics of a comparison.

Many authors (Seymour, 1913; Bridges, 1942; Osterburg; 1977; Stoney, 1985; Stoney and Thornton, 1986; and Hare, 2003) have sought to describe an examination method or thresholds of sufficiency for source determination [Olsen, 1983, pp 4–15; Stoney, 1985; 1986, pp 1187–1216; Hare, 2003, 700–706]. These explanations usually involve visual aids or physical tools that demonstrate a sequence or configuration of a number of points (e.g., details of ridge endings, bifurcations, and dots). Some of these involve the use of transparent grids, tracings, overlaid prints, pinholes through photographic enlargements of the specific points in the prints, or an enlarged chart documenting corresponding points. These efforts attempt to (and in some instances do) help to illustrate portions of the examination process.

The examination method of analysis, comparison, evaluation, followed by verification (ACE-V) is the established method for perceiving detail in two prints and making decisions. A thorough understanding of the sufficiency threshold within the method is essential. Merely arriving at a predetermined, fixed mathematical quantity of some details of a friction ridge impression (i.e., point counting) is a simplistic and limited explanation for why two prints originated from the same unique and persistent source or originated from different unique and persistent sources.

* For the purposes of this chapter, the term *print* refers to any recording of the features of friction ridge skin (i.e., unintentional recordings such as evidence prints and intentionally recorded impressions from any palmar and plantar surface). Unless indicated otherwise, *source* in this chapter will refer to a specific area of friction ridge skin. The source can be the palms or soles, the fingers or toes, specific areas of ridges, or a specific area of one ridge.

There is much more to prints than the arrangement of Galton points. The examiner must use knowledge and understanding gained from training and experience to make judgments about the features of the sources and details in prints to reach a conclusion about the origin of the print in question.

Cognitive science explains the processes of perception, decision-making, and development of expertise. Research in cognitive science is helping to explain how experienced examiners differ from novices [Palmer, 1999; Busey and Vanderkolk, 2005]. A philosophy of how examiners can determine or exclude a source of a print must be established for an examination method to be effective. Examiners draw from many philosophies to develop a particular examination method.

9.1.1 Philosophy of Uniqueness

Pattern formations in nature are never repeated in their morphological structures (or, as the saying goes, "nature never repeats itself") [Kirk, 1963; McRoberts, 1996]. This statement is supported and explained in part by biology, chemistry, and physics, and through practice and experience of observing natural patterns [Ball, 1999]. The morphogenesis of friction skin and the many developmental factors that influence the unique arrangement of friction ridges prior to birth provide the fundamental explanation of why volar skin is unique.

Basic print minutiae are defined and used in mathematical formulas for traditional classification, statistical modeling, and automated fingerprint identification systems (AFIS). These formulas consider some of the variations in friction ridge skin arrangements, but not all of the detail that is present. In spite of these limitations, no model and application has provided evidence that prints are *not* unique. Instead, the study of pattern formations in nature, and pattern formations in friction ridge skin in particular, have determined the formations in friction ridge skin to be unique. The friction ridge skin features of creases, furrows, scars, cuts, and natural imperfections are also unique.

9.1.2 Philosophy of Persistency

The morphological surface structure of friction ridge skin is persistent. Often, the friction ridge arrangement (ridge flow and minutiae) has been described as permanent. However, the cellular surface of the friction ridge skin is not permanent. Surface cells are replaced on a regular basis. The competing forces of regenerating skin cells and the effort of maintaining the form and function of the organ of skin produces a persistent, *not* permanent, naturally patterned surface with all of its minute and microscopic features. In other words, the process strives to reproduce, but cannot perfectly reproduce, the patterns of the preceding cells so that the arrangements of replacement cells can follow the form and function of the replaced cells. Microscopic variations do occur. Aging of skin is an example of persistency; although patterns in friction ridge skin are not perfectly permanent, they are remarkably persistent over time.

For friction ridge skin to be valuable for the examination of two prints, the unique features of ridges, creases, scars, and imperfections in the skin that had been recorded as details in two prints must be persistent between the two occurrences when each print was made. Persistency is all that is needed, not permanency.

9.1.3 Philosophy of Examination Logic

Deduction, induction, and abduction are three types of logic [Burch, 2001; McKasson and Richards, 1998, pp 73-110] an examiner can use to determine answers to questions in friction ridge examinations. A simple explanation of logic and inference could be found in the statements:

if A and B, therefore C

if B and C, therefore A

or

if A and C, therefore B

Replacing "A" with "Case", "B" with "Rule" and "C" with "Result", the examiner can explain which logic is used.

9.1.3.1 Deductive Logic. "Case and Rule, therefore Result" becomes "The two prints came from the same source and individualization is possible because the features of friction ridge skin are unique and persistent, therefore, the details in the two sufficient prints agree." Deductive logic starts with and infers the general and ends with the particular. Deductive logics infers that the particular of the details between two prints agree if the examiner knows the two sufficient prints did come from the same source, or a specific area of skin, and that friction ridge skin is unique and persistent. Deductive logic is used in training examiners. The trainer and trainees know the two prints came from the same source, the trainer and trainees know the rule of uniqueness and persistency of friction ridge skin, and so the trainer and trainees know the details in these two prints agree. Deductive logic helps the examiner understand tolerance for variations in appearance or distortion of two prints from the same source. With variations in appearances or distortions of the two prints, deductive logic is used during training exercises to learn agreement of details in sequences and configurations from the same source and to learn disagreement of details from different sources.

9.1.3.2 Inductive Logic. "Case and Result, therefore Rule" becomes "The two prints came from the same source and the details in the two sufficient prints agree, therefore, individualization is possible because the features of friction ridge skin are unique and persistent." Going from the particular to the general, or from results and case determination toward the rule, is an example of inductive logic. Determining that the details in two sufficient prints agree and making a conclusion that they originated from the same source supports the rule of friction ridge skin being unique and persistent. The determination that the details in two sufficient prints disagree and that they originated from different sources also supports the rule of friction ridge skin being unique and persistent. Studying all known sources is impossible. Examiners can thus never prove uniqueness of the source through inductive logic; it can only be inferred.

9.1.3.3 Abductive Logic. "Rule and Result, therefore Case" becomes "Individualization is possible because the features of friction ridge skin are unique and persistent and the details in the two sufficient prints agree, therefore, the two prints came from the same source." In actual case work, examiners start with the fundamental principles of friction ridge skin being unique and persistent, conduct an examination to determine agreement or disagreement of details in two sufficient prints, and make the determination whether the prints came from the same source. Starting with a rule, determining a result of comparison, and reaching a conclusion in a particular case is abductive logic. As one author explains:

> Notice how both deduction and induction are involved in abduction: induction helps to generate the formulation of the given and deduction helps to show a logical relation of the premises of the given. Further, when abductive logic generates a Case, deductive logic explains the logical relation of Rule and Result, and inductive logic provides a relation of the Case to the Rule. If, by the performance of this logic, the scientist can show a universal truth, the scientist claims an adductive logic. Abductive reasoning treats the particular; adductive treats the *universal*.
>
> Recall that "universal" does not mean "absolute." Universal refers to the breadth of the truth of the rule, its result and its case, as determined by the scientific community reviewing it: all who should know, agree. ("Absolute", on the other hand, refers to the quality of the truth of the rule and demands that the rule be unconditional, or "perfectly true".) Universal is a term that implies "everyone" when what we mean is "everyone who takes the same given," or for "the world" when what we mean is "the real world in which I and my colleagues operate." Universality involves subjective consensus: it is what "everyone knows" and accepts and is the basis for such hypotheses as "identity exists." It is our "given" by which we proceed to investigate the observations we are making. [McKasson and Richards, 1998, p 80]

If the rule of all pattern formations in nature being unique could definitely be demonstrated as false, or falsified, the rule would have to be altered. This falsification has never occurred. Based on observation, experimentation, and knowledge of pattern formations in nature (volar skin, other natural pattern formations, and their prints), the rule of law in forensic comparative sciences is: pattern formations in friction ridge skin cannot be replicated, and their prints can be individualized.

9.1.4 Philosophy of Belief

> The general context of belief is the collaboration of mankind in the advancement and the dissemination of knowledge. For if there is such a collaboration, then men not only contribute to a common fund of knowledge but also receive from it. But while they contribute in virtue of their own experience, understanding, and judgment, they receive not an immanently generated but a reliably communicated knowledge. That reception is belief, and our immediate concern is its general context. [Lonergan, 1992, p 725]
>
> Because collaboration is a fact, because it is inevitable, because it spreads into a highly differentiated network of interdependent specialties, the mentality of any individual becomes a composite

> product in which it is impossible to separate immanently generated knowledge and belief. [Lonergan, 1992, p 727]

One expert cannot generate all knowledge about everything that is used in examinations of prints. The expert must rely on valid collaboration and beliefs.

In order to know and have confidence in a conclusion, the examiner must be tolerant for variations in appearances of the two prints, because each independent deposition of a print does not produce a perfect replication of a previously deposited print. With each independent touching of a substrate (the surface being touched), there are always variations in appearances or distortions of the source friction ridge skin. The less clear a print, the more tolerant for variations the examiner must be. The clearer the print, the less tolerant for variations the examiner should be. The examiner must not stretch tolerance too far. Tolerance for variations in appearances, or distortions, must be within the limits of the substrate, the pliability of the skin, the effects of friction, and the motion of touching of friction ridge skin to the substrate. The examiner must study distorted friction ridge skin and its prints to understand tolerances for variations in appearances of prints.

Doubt must be overcome when determining actual agreement or disagreement between the details of the two prints. The examiner starts with no knowledge whether agreement or disagreement exists, begins doubting whether sufficient agreement or disagreement actually exists, continues the examination and works through doubt, and then makes a determination whether the details in the two prints actually agree or disagree. As the examiner works through doubt by asking and answering all relevant and appropriate questions [Lonergan, 1992, pp 296–300], predictions start to take place. The examiner predicts to find agreement or disagreement of details. Once reliable prediction [Wertheim, 2000, p 7] takes place by correctly predicting then validly determining the details, and all relevant questions have been asked and answered correctly based on ability, training, experience, understanding, and judgments, the examiner removes the irritation of doubt about actual agreement or disagreement of details and can make a determination whether the prints originated from the same source. The examiner must prevent prediction from becoming a bias that improperly influences the determination of agreement or disagreement. All relevant questions must have been asked and answered correctly for the prediction to be reliable. The examiner transitions through the examination by analyzing, comparing, and evaluating the details of the prints through critical and objective comparative measurements of the details of general ridge flow, specific ridge paths and ridge path lengths, the sequences and configurations of ridge paths and their terminations, and the sequences and configurations of edges or textures and pore positions along ridge paths.

The examiner makes a transition from insufficient knowledge, through doubt, to knowing and belief. The examiner bases this knowing on the previous training, experience, understanding, and judgments of self and a belief in the legitimacy of the training, experience, understanding, and judgments of the collaborated community of scientists. The examiner critically asks all relevant and appropriate questions about the subject (prints), correctly answers all the relevant questions about the subject, knows the determination, removes the irritation of doubt, and becomes fixated on belief [Peirce, 1877, 1–15]. Some of the relevant and appropriate questions involve the uniqueness and persistency of the friction ridge skin, the substrate, the matrix, distortion of the friction ridge skin, deposition pressure, deposition direction, development technique, clarity of details, quantity of details, sufficiency of sequence of details, threshold to determine sufficiency, and examination method. The scientific or examination method asks questions throughout the process to remove doubt from the examiner's conclusion. The examiner is seeking the truth or reality of the relationship between the two prints. By asking all relevant and appropriate questions; correctly answering all relevant questions based upon previous training, experience, understanding, and judgments of self and others within the collaboration of forensic scientists; and removing the irritation of doubt, the examiner knows what is believed as truth.

The collaboration of scientists and dissemination of knowledge is what science is about. The collaboration of scientists and dissemination of knowledge generate the relevant questions that need to be asked and determine the correctness of the answers. This process parallels the description of scientific method by making observations, forming hypotheses, asking questions, collecting data, testing data, reaching a conclusion, sharing the conclusion, and being able to replicate the conclusion.

If two examiners reach opposing conclusions of individualization and exclusion about the source of the same unknown print, one of the examiners has failed to ask and correctly answer relevant and appropriate questions about the prints. One of the examiners is wrong. As these rare dilemmas occur, part of the conflict resolution needs to determine whether all relevant and appropriate questions about the prints had been asked and correctly answered by the examiners. Humans can and do make mistakes. The resolution needs to confront the training, experience, understanding, judgments, and knowledge and beliefs of the examiners and their collaborators. Science must learn from mistaken beliefs through inquiry and collaboration of the scientists. Something has led the erroneous examiner to his or her mistaken belief. If the inquiry and collaboration fail to determine the cause for the mistaken belief, that belief will continue, for there is no reason to change. [Lonergan, 1992, pp 735–736]

9.2 Fundamentals of Comparison

Examiner understanding of friction ridge skin and the associated features of ridges, furrows, creases, scars, cuts, warts, wrinkles, blisters, and imperfections is needed before examination of prints takes place. In order to reach conclusions from the examination process, fundamental principles of the source, or skin, must be established. Uniqueness and persistency of skin are the fundamental principles [SWGFAST, 2002a, p 1; SWGFAST, 2004, p 1].

Every science has nomenclature that is needed for communication purposes. Adequately describing something that is unique is a difficult challenge. After all, unique implies nothing else is just like it. Labels are attached to the features of friction ridges and details of their prints for communication and classification purposes. Whorls, loops and arches, ending ridges, bifurcations, and dots are some of the generic labels used to generally describe the morphological structures of friction ridges and the details in prints. Examiners need to be attentive to the actual uniqueness of the features of the ridge and not allow the use of generalized descriptive labels to diminish the examiner's understanding of the actual value of the feature. If an examiner is looking for just ridge endings or bifurcations, the examiner might only see a ridge that ends or bifurcates. Conversely, if an examiner looks for the overall inherent morphology of the ridge, the shapes and dimensions of the ridge, where it starts, the path it takes, where it ends, the widths, the edges, the pore positions, and the morphology of the neighboring ridges, the examiner will become more perceptive of the details within the prints. Pattern formations in nature can never be completely described through the use of commonly labeled unique features [Grieve, 1990, p 110; Grieve, 1999; Vanderkolk, 1993].

Often, prints of the same source are recorded at two significantly different times, before and after trauma to the skin. As an example, scars might be present in a more recent print and not in a previous recording of the same source. By having a basic understanding of the biology, healing, and regeneration of skin, the examiner will understand the persistency issues related to the source that made the two prints. As long as there is sufficient persistency of any natural, traumatic, or random unique feature of the skin between the times of deposition of the two prints, the details of any unique and persistent features of the skin can be used in conjunction with the details of other unique and persistent features. There is no reason to ignore any of the details of any of the unique and persistent features in the source.

9.2.1 Variations in Appearances

Examiner understanding of variations in appearances among prints is needed before examination of a print takes place. Each independent print from the source will vary in appearance from every other independent print from the same source. Many factors influence the variations in appearances of prints.

The surface areas of the friction ridge skin that touch substrates influence the variations in appearances. The exact surface area of skin touching the first substrate will not be the exact surface area of skin that touches the second substrate. Each time the skin touches a substrate, the surface area will vary.

The manner in which friction ridge skin touches a substrate influences the variations in appearance. Each independent touching has different influences that cause variations in the appearances of the prints. Flat touching, rolling, sliding, or twisting will influence the skin's pliability, causing distortions. Studying the manners of touching and distortion will aid the examiner in examination of prints.

The substrates or surfaces being touched influence the variations in appearance. Each independent touching of differing substrates has different influences that cause variations. The cleanliness, texture, contour, or porous nature of the substrate will influence the prints.

The matrices, or residues, on the friction ridge skin when the skin touches a substrate influence the variations in appearance. Sweat, oil, and blood are common matrices that cause variations. The matrices on the substrate that is touched by friction ridge skin also influence the variations. Oils, dust, blood, or other residues are common matrices on substrates. The types and amounts of matrices and their interactions will influence variations with each touching of the substrate. The actual transfers of matrices between skin and substrate will vary because each independent touching has different influences that cause variations.

Variations in temperature, humidity, or weather before, during, and after independent touching of substrates influence the matrices upon a given substrate. These variations also influence the transfers of matrices between skin and substrate.

As skin is traumatized with imperfections and regenerates, variations in the morphology of the skin can occur. The healing process occurs over time. Realizing the persistency issues of healing and aging of various features is thus needed to understand variations.

Variations in different latent print processing or development techniques, and variations in the application of these techniques, will influence variations in appearances of an unknown or latent print. Heavy or light powdering, cyanoacrylate fuming, chemical processing, or fluorescent processing will cause variations in appearance.

The same is true for variations in different standard print capturing techniques, and variations in the application of these techniques. The components and amounts of inks, chemicals, powders, substrates, or electronics used to capture, record, or print known or standard prints influence variations in appearance.

The handling, packaging, or storing of an undeveloped or nonfixed print can further influence its appearance. The matrix might evaporate, rub off, get scratched, transfer to the package, or blend into the substrate. Surface contact, environment, temperature, humidity, and light all can influence the appearance of a captured print, just as they can with a latent print.

Additionally, the techniques used to view or enlarge prints will influence variations in appearance. Magnification, photographic equipment, computers, facsimile or copy machines, and other media used for printing, viewing, copying, and enlarging prints can cause variations.

The plethora of influences that occur during independent touching, processing, capturing, recording, storing, and viewing of unknown and known prints will cause each independent print to vary in appearance from every other recording. The examiner needs to realize this when examining prints. Each print will have various quality and quantity of details of recorded features. These variations do not necessarily preclude determination or exclusion of the source of the print. Rather, they are expected. Just as pattern formations in nature are unique, the prints made by each independent touching will produce a pattern that is just not like any other, as depicted in Figure 9–1. There is no such thing as a perfect or exact match between two independent prints or recordings from the same source. Each print is unique; yet, an examiner can often determine whether unique prints originated from the same unique source.

9.2.2 Levels of Detail in Prints

A way to describe features by using three levels of detail in prints was introduced by David Ashbaugh [Ashbaugh, 1999, pp 95–97, 136–144]. McKasson and Richards talk of levels as sets, subsets, and sub-subsets [McKasson and Richards, 1998, pp 94–100]. Levels of detail in prints are simple descriptions of the different types of information throughout the print. Depending on the clarity of the print, various levels may be detectable.

9.2.2.1 First Level Detail. First level detail of friction ridge features is the general overall direction of ridge flow in the print. First level detail is not limited to a defined classification pattern. Every impression that is determined to be a friction ridge print has a general direction of ridge flow, or first level detail. Impressions of fingers, phalanges, tips, sides, palms, or soles have first level detail. The perceived general direction of ridge flow is not considered to be unique. General direction is shared by many other sources. Figure 9–2 depicts three prints showing general direction of ridge flow.

9.2.2.2 Second Level Detail. Second level detail is the path of a specific ridge. The actual ridge path includes the starting position of the ridge, the path the ridge takes, the length of the ridge path, and where the ridge path stops. Second level detail is much more than the specific location of where a ridge terminates at a ridge ending or bifurcation, or its Galton points. Sequences and configurations with other ridge paths are part of second level detail.

FIGURE 9–1

Right thumbprint with differing factors demonstrated in inked impressions: (a) a typical impression, (b) more pressure exerted, causing a color reversal and recording a larger area; (c) an impression rolled from one side to the other; (d) an impression with some pressure toward the top of the finger and rolled forward to record more of the tip; (e) an impression with excessive pressure, resulting in a poorly recorded print.

The ridge path and its length with terminations are unique. The sequences and configurations of a series of ridge paths are also unique. Second level details in a print cannot exist without first level details. The general direction of ridge flow must exist for a specific ridge path to exist. Figure 9–3 depicts three prints with first and second levels of details.

9.2.2.3 Third Level Detail. Third level details are the shapes of the ridge structures. This level of detail encompasses the morphology (edges, textures, and pore positions) of the ridge. Fingerprint scientists Edmund Locard and Salil Chatterjee contributed to the field's awareness of the edges and pores of the ridge [Chatterjee, 1953, pp 166–169]. The features of third level details are unique in their shapes, sequences, and configurations. Clarity of the print might limit an examiner's ability to perceive the morphology, sequences, and configurations of third level details. Third level details cannot exist without first and second levels of detail. The general direction of ridge flow and a specific ridge path must exist for morphology or pore positions of a ridge to be visibly present as third level detail in a print. Figure 9–4 depicts three prints with first, second, and third levels of detail.

9.2.2.4 Levels of Detail of Other Features. First, second, and third levels of detail can also describe other features (e.g., creases, scars, incipient ridges, and other imperfections) from volar skin represented in a print. First level details describe the general directions and positions of the features. Figure 9–5 depicts the general direction of creases, scars, and imperfections.

Second level details of creases, scars, or imperfections are the actual paths of the specific features. The actual path includes the starting position of the detail, the path it takes, the length of the path, and where the path stops. A second level detail is much more than the location where a feature stops or bifurcates. Second level details of these features do not require the path termination to occur. A continuous path from one end of the print to the other end of the print is included within the definition of second level details. Second level details of other features cannot exist without first level details of the same features. Figure 9–6 depicts general direction and specific paths of creases, scars, and imperfections.

Third level details of creases, scars, or imperfections are the morphologies or shapes within their structures. This level of detail encompasses the morphological edges and textures along or upon the feature. Third level details of a crease, scar, or imperfection cannot exist without first and second levels of these details. Specific shapes and edges of creases, scars, and imperfections are depicted in Figure 9–7.

FIGURE 9–2

General ridge flow is visible.

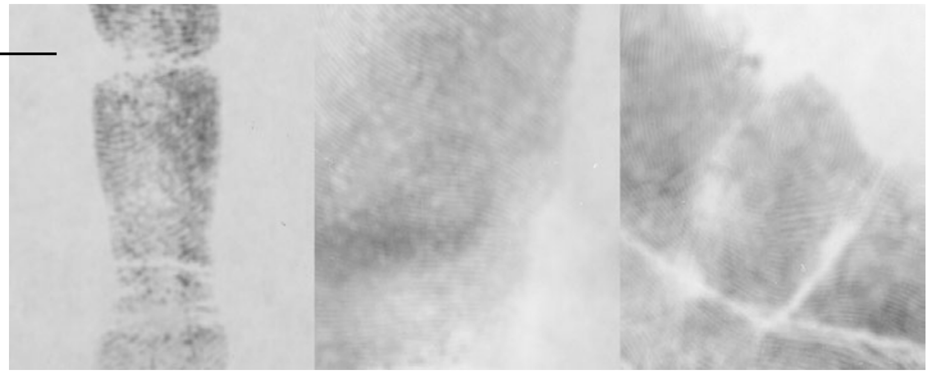


FIGURE 9–3

FIrst and second levels of detail.

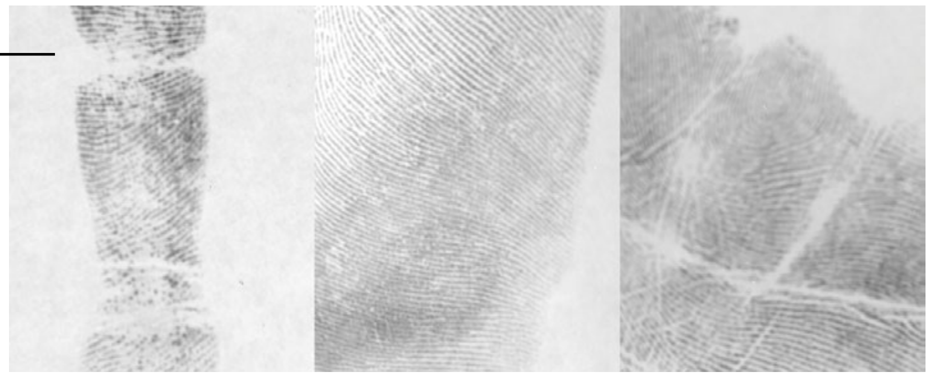


FIGURE 9–4

Prints with first, second, and third levels of detail.

An emphasis needs to be placed on persistency. No matter which unique feature is considered, persistency of the feature on the source must be sufficient between the two events of touching for details of the feature to be significant in an examination.

9.2.3 Ranges of Clarity

The ability to completely describe the clarity of a print is difficult, if not impossible, because there are ranges of clarity within each level of detail, and levels of detail are not equally clear throughout each level within a print. The ranges of clarity within each level of detail exist because the clarity within each level varies within each print [Vanderkolk, 2001]. Clear first level details have more significance than less clear first level details. Likewise, clear second level details have more significance than less clear second level details and clear third level details have more significance than less clear third level details. As clarity improves, the power or significance of the details within each level improves.

Ranges of clarity and their significance within each of the three levels of detail are depicted in Figure 9–8 [Vanderkolk, 2001]. The quality axis represents the clarity of details of the friction ridge features. Quality can approach perfectly clear recordings of the friction ridge features, but will never reach perfect clarity. The axis approaches, but does not reach, 100% recorded quality of the features of the source.

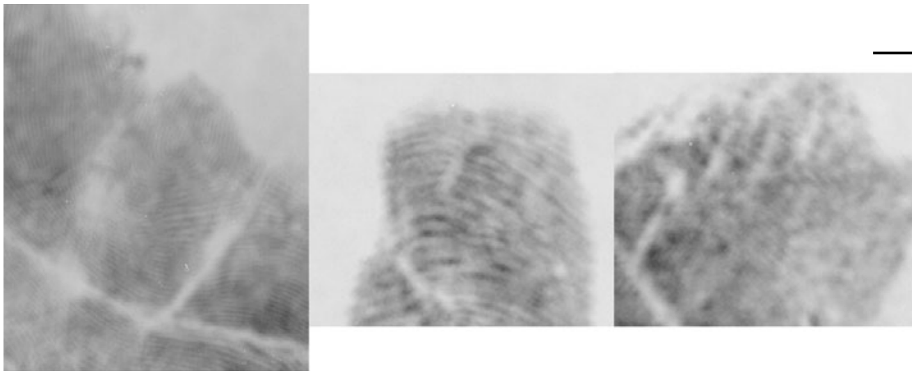


FIGURE 9–5

General direction of creases, scars, and imperfections.

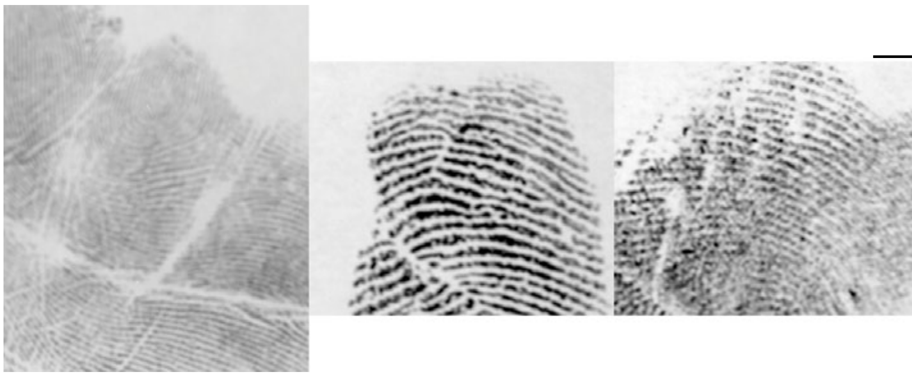


FIGURE 9–6

General direction and specific paths of creases, scars, and imperfections.

FIGURE 9–7

General direction, specific paths, and specific shapes and edges of creases, scars, and imperfections imperfections.

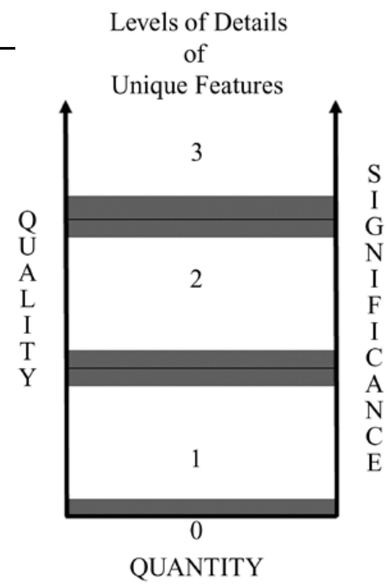
Quality is difficult to accurately quantify. That is why no numerical scale is placed on the quality axis. This scale simply depicts the relationship between quality and significance. As the quality of the print increases, the significance of the detail observed increases.

Quality also cannot exist without a quantity of details. Any figure depicting the quality aspect should also include a quantity of those details. As those details are observed and comparatively measured, the quantity of details increases across the horizontal axis and the quality of those same details are represented with the vertical axis. (For more on the relationship between quality and quantity, see section 9.4.)

The bottom of Figure 9–8 starts at 0. There is no image, no details, no significance. The diagram is separated into first, second, and third levels. An undefined width of quantity of details exists across the horizontal axis. Heights occur within each level, depicting the undefined increments that detail will have as the quality of the image increases. All first level details are not equally clear. All second level details are not equally clear. All third level details are not equally clear. The details within each level and among the levels have different significance or power, depending upon their clarities. As clarity increases, the significance of the details increases. As clarity decreases, the significance of the details decreases. Notice that there is no top to third

FIGURE 9–8

Ranges of clarity and their significance in the three levels of detail. *(Adapted from Vanderkolk, 2001, p 462.)*



level details. Again, the clarity of the image and third level details can approach, but never reach, perfect recording of the features of the skin.

An undefined breadth of gray area in Figure 9–8 separates each level. These gray areas represent expertise and doubt by the examiner. The black lines within the gray areas represent reality. The examiner cannot perfectly determine when the clarity of details transitions from one level to the next; doubt exists. The examiner must default to lower significance when in doubt. Just as importantly, the examiner must not give too much significance to details within a white level area. Too much significance must not be given to any particular detail [Grieve, 1988; Ashbaugh, 1999, pp 95–97, 143, 217–226; Vanderkolk, 1999; Vanderkolk, 2001].

As in ranges of clarity within levels of details of friction ridge features, there are ranges of clarity within first, second, and third levels of details of crease, scar, and imperfection features.

9.3 ACE-V Examination Method

The examination method of analysis, comparison, evaluation (ACE) and verification (V) has a history of progression [Huber, 1959 60; Huber, 1972; Cassidy, 1980; Tuthill, 1994; Ashbaugh, 1999; Vanderkolk, 2004]. ACE V is the examination method described in the Scientific Working Group for Friction Ridge Analysis, Study, and Technology (SWGFAST) documents [SWGFAST, 2002a, p 2]. Variations of the descriptions used elsewhere parallel the phases of ACE in other scientific applications [Palmer, 1999, pp 413–416] and ACE-V in other forensic disciplines [McKasson and Richards, 1998, pp 131–138]. ACE is a simple explanation of the phases involved in perception and decision-making. ACE gives the expert specific phases of examination that can be used to document the perception, information-gathering, comparison, and decision-making that takes place during an examination of prints. Scientific method is often described as observation, hypothesis formulation, experimentation, data analysis, and conclusion. ACE is one description of a method of comparing print details, forming a hypothesis about the source, experimenting to determine whether there is agreement or disagreement, analyzing the sufficiency of agreement or disagreement, rendering an evaluation, and retesting to determine whether the conclusion can be repeated.

Describing information-gathering and decision-making is difficult. ACE is a structured approach to gathering information about the details in prints. ACE is not a linear method in which analysis is conducted once, comparison is conducted once, and then a decision is made once in the evaluation. ACE can and does recur during information-gathering and decision-making. However, the three phases of ACE need to be discussed independently. The analysis and comparison must be conducted so that the comparative measurements and sequences can be accurately determined to reach a valid evaluation. The examiner must avoid allowing biases to influence each phase of the examination. Improper adjustments of determinations in the analysis and comparison phases because of biases do not validate a conclusion made in the evaluation. Thus, improper determinations can result from biases [Dror, 2005, pp 799–809; Dror, 2006, pp 74–78; Dror, 2006, pp 600–610; Byrd, 2005].

9.3.1 Analysis

Analysis is the assessment of a print as it appears on the substrate. The analysis of the print proceeds by systematically separating the impression into its various components. The substrate, matrix, development medium, deposition pressure, pressure and motion distortion, and development medium are analyzed to ascertain the variations in appearances and distortions. An analysis of clarity establishes the levels of detail that are available to compare and the examiner's tolerance for variations [Ashbaugh, 1999, pp 94]. The examiner makes a determination, based upon previous training, experience, understanding, and judgments, whether the print is sufficient for comparison with another print. If one of the prints is determined to be insufficient, the examination is concluded with a determination that the print is insufficient for comparison purposes. If the known print is insufficient, better known standards are needed for further comparison.

9.3.2 Comparison

The direct or side-by-side comparison of friction ridge details to determine whether the details in two prints are in agreement based upon similarity, sequence, and spatial relationship occurs in the comparison phase [Ashbaugh, 1999, pp 109–136, SWGFAST, 2002a, p 3]. The examiner makes comparative measurements of all types of details and their sequences and configurations. This comparative measurement is a mental assessment of details, not just a series of physical measurements using a fixed scale. The comparative assessments consider tolerance for variations in appearances caused by distortions. Because no print is ever perfectly replicated, mental comparative measurements must be within acceptable tolerance for variations. Comparative measurements of first, second, and third level details are made along with comparisons of the sequences and configurations of ridge paths. To repeat, comparative measurement involves mentally measuring the sequences and configurations of the elements of all levels and types of details of the first print with the same elements of the second print.

As stated earlier, because each independent touching of a substrate produces a unique print with a variation in appearance, comparative measurement tolerance must be considered during the comparison phase. The less clear or more distorted either print is, the more tolerant for variations the examiner must be. The clearer and less distorted either print is, the less tolerant for variations the examiner must be. Because the examiner is more tolerant for variations in poor-quality prints, the examiner will require more details when making an agreement or disagreement determination. Because the examiner is less tolerant for variations in good-quality prints, the examiner can make a determination using fewer details. And, also as previously stated, understanding the causes for distortion will support the explanations for variations in appearances. The examiner needs to study a variety of known distorted prints to understand acceptable tolerance for variations in appearances in prints.

Actual agreement or disagreement of similar details in sequences and configurations between two prints is the determination sought by the examiner during the comparison. Because the prints will vary in appearance, judgments must be made throughout the process. After determinations of actual agreement or disagreement of first, second, or third levels of details in the comparison phase, evaluation is the next step.

9.3.3 Evaluation

"Evaluation is the formulation of a conclusion based upon analysis and comparison of friction ridge skin" (prints) [SWGFAST, 2002a, p 3]. Whereas in the comparison phase, the examiner makes determinations of agreement or disagreement of individual details of the prints in question, in the evaluation phase the examiner makes the final determination as to whether a finding of individualization, or same source of origin, can be made.

During the evaluation, the examiner cannot determine two prints originated from the same source with agreement of only first level details. If the examiner determines sufficient agreement of first and second level details, or of first, second, and third levels of detail, after analysis and comparison, an evaluation of individualization is made. Figure 9–9 represents two prints with first, second, and third levels of agreement. (Not all details are marked in Figure 9–9.)

FIGURE 9–9

Two prints with first, second, and third levels of agreement.

If a determination is made that first, second, or third level details actually disagree, evaluation of the analysis and comparison results in an exclusion determination as depicted in Figures 9–10 to 9–12. It is important to note that excluding a finger as having made the unknown print is not the same as excluding a person as having made the unknown print. The examiner needs to indicate whether the source being excluded is a person, a hand or foot, a finger or toe, or ridges. Sufficiently complete and clear recordings of detail from the volar surfaces is needed to make any exclusion.

The inability to determine actual disagreement does not result in a determination of individualization. Instead, if after analysis and comparison no determination of sufficient agreement or disagreement of details can be made, an inconclusive determination is warranted [SWGFAST, 2002a, p 4]. The details might seem like they could agree or like they could disagree, but there is doubt. The examiner cannot determine whether the details agree or disagree, or perhaps cannot even determine whether the sequences and configurations of details are sufficient to decide. This could be due to insufficiency of the unknown print, insufficiency of the known print, or a combination of both. The examiner cannot determine which factor is insufficient, and must default to an inconclusive determination.

9.3.4 Recurring, Reversing, and Blending Application of ACE

The human mind is much too complex to only conduct one linear and single application of analysis, comparison, and evaluation during an examination. Figure 9–13 represents a model to help explain and illustrate the complexity of the variety of perceptual phases that occur and recur during an examination. The critical application of ACE is represented in the model by red area A, green area C, and blue area E.

There are no arrows in the model. The examination starts with analysis, then comparison, then evaluation. However, the examiner can change the phases with little effort. The phases of the examination often recur. The examiner often re-analyzes, re-compares, and re-evaluates during the examination. The recurring application of each phase is a natural occurrence.

The examiner can easily change directions in the examination. If unable to determine the significance of the examination with the details and information gathered in the current phase, the examiner can reverse the direction of application and return to a previous phase.

The actual phases of the examination cannot be completely isolated from the other phases. After analysis of the first print, the analysis of the second print starts. During this second analysis, the examiner begins to mentally compare the details in the first print to the details being determined in the second print. As this second analysis takes place, a mental comparison begins; the analysis and comparison phases seem to blend together. Even while analyzing and comparing the second print, an evaluation of the analysis and comparison phases starts to take place. The evaluation is blended into the analysis, which is blended with the comparison. This happens within all phases of the examination. The blending of phases is most apparent when quickly excluding a source as having made both prints when the first level details are extremely different. During the comparison, re-analyzing takes place. As critical comparative measurements are made, the detail is re-analyzed to verify the previous analysis. During the comparison, evaluations start to take place. During the evaluation, re-analyzing and re-comparing takes place. All these processes seem to occur at the same time in the mind of the examiner.

The examiner needs to critically examine the prints while in each phase and understand the recurring, reversing, and blending potential of each phase. Biases can potentially influence the perceptions taking place in each phase. The examiner must resist using what is determined to be present in one print as justification for finding that detail in

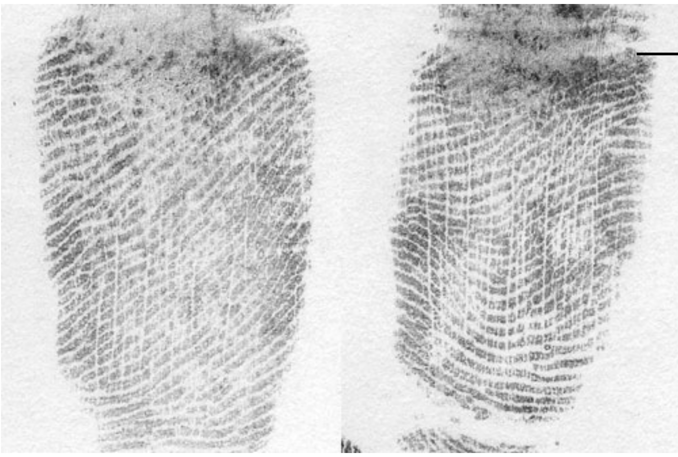


FIGURE 9–10

First level details not in agreement.

FIGURE 9–11

Second level detail not in agreement.

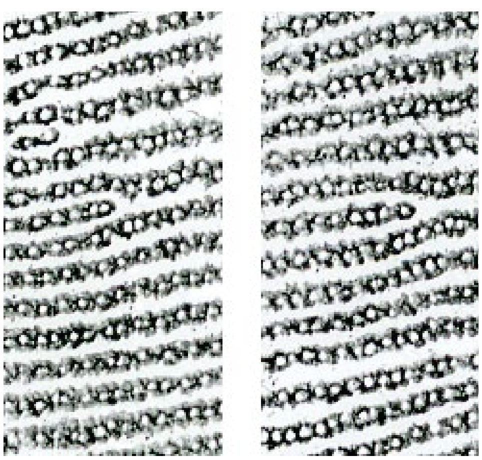


FIGURE 9–12

Third level detail not in agreement.

the other print. The analyses, comparisons, and evaluations must not be contaminated by the examiner's justification of details that do not exist. The details must be determined from proper analyses of the first print followed by proper analyses of the second print. As comparisons are taking place, the analyses will be reconsidered. As evaluations are taking place, the analyses and comparisons will be reconsidered. The examiner must consciously apply each independent phase of ACE. Critical perception needs to take place in the separate phases of ACE, and critical decisions must be made within each phase as well.

The examiner needs to critically attend to the prints during the examination. The actual examination is represented in the model by the three smaller circles with capital A, C, and E in the red, green, and blue parts of the circles. The colors of the circles represent the attention dedicated to

FIGURE 9–13

The recurring, reversible, and blending primary phases of ACE are represented by the small interlocking circles with the following colors: A = red; C = green; E = blue. The blending phases of A/C = yellow; C/E = blue/green; A/E = magenta; A/C/E = white.

The recurring, reversible, and blending complementary phases of ACE expertise are represented by the larger interlocking circles with the following colors: a = red; c = green; e = blue. The blending phases of a/c = yellow; c/e = blue/green; a/e = magenta; a/c/e = white.

The black dot in the center represents the subconscious processing of detail in which perception can occur. The gray (that encircles the ACE/ace circles) represents other expert knowledge, beliefs, biases, influences, and abilities. The white that encircles the gray represents the decision has been made.

(Reprinted from the *Journal of Forensic Identification,* 2004, *54* (1), p 49.)

the examination. The black dot in the middle of the model represents subconscious perception. The white center area represents a blended ACE that occurs very quickly. Yellow, cyan, and magenta also represent blended phases. Conscious, critical perception and decisions need to be made during the examination, represented by the red, green, and blue parts of the phases.

The examiner bases decisions made during the examination upon expertise or the knowledge and beliefs from previous training, experience, understanding, and judgments of his or her own and in collaboration with other scientists. This expertise is represented by the larger colored and overlapping circles labeled with lower case letters of a, c, and e that encircle the smaller current examination of colored circles. The current examination takes place within the larger expertise circles.

Each ACE examination is based on knowledge gained in previous ones. In the diagram, the current examination happens within the blended phases of previous analyses, comparisons, and evaluations. Also, each of the three phases of the current ACE examination is analyzed (a), compared (c), and evaluated (e) in consideration of previous examinations and training, experience, understanding, and judgments to determine the print's significance or sufficiency. That is why the model represents the current examination taking place within the white overlapping area of the larger expert phases of the model.

Numerous analyses, comparisons, and evaluations take place within the ACE phases. The first print (the unknown or latent print) is analyzed numerous times as needed. Then the second print (usually the known or standard print) is analyzed numerous times, as needed. Then, the first print is compared with the second print numerous times, as needed. Many comparative measurements take place to determine the agreement or disagreement of various levels of details. Many evaluations take place. Eventually, the final analysis and comparison lead to the final evaluation.

Many influences can affect the current ACE examination. Knowledge and beliefs of uniqueness, persistency, and impression evidence in other types of forensic comparative sciences can influence the examination. Biases, pressures, or expectations can influence the examination. The examiner needs to be aware of other influences and conduct the examination so that these influences do not negatively affect the examination. These other influences are represented by the gray that encircles the colored circles.

The white around the circles represents the decision made after critical analysis, comparison, and evaluation examination of the prints. After sufficient ACE examination within expertise and influences, the examiner makes a determination.

9.3.5 Verification

"Verification is the independent examination by another qualified examiner resulting in the same conclusion" [SWGFAST, 2002a, p 4]. In Figure 9–13, verification is represented by +V. Having a second examiner apply the ACE methodology between the unknown and known prints without indications of a previous conclusion by the original examiner is one method of applying verification. Reworking the case with indications of decisions made by the original examiner is another method of applying verification. Conducting an examination between two enlarged and charted prints provided by the original examiner is another method of applying verification. There are many methods of applying the verification phase of an examination beyond these examples. The method of verification must be selected so that the verifier is not improperly influenced by the original examiner's decisions or work products. The verifier must be able to reach an unbiased conclusion.

SWGFAST states verification is required for all individualizations. Verification is optional for exclusion or inconclusive determinations [SWGFAST, 2002a, p 4].

9.4 Decision Thresholds

Each print examined must have sufficient details or recording of the features of the skin to determine or exclude the source. Lack of clarity in the prints diminishes the examiner's ability to determine or exclude a source of the print. Because the prints have reduced quality of details, the prints must have sufficient quantity of details of these features to determine or exclude a source.

Decisions must be made within each phase of ACE. Whether to go forward, backward, or to stop in the examination must be decided. Selecting a threshold of sufficiency is the challenge. During the last 100 years, various models of sufficiency have been presented. Locard presented his tripartite rule in 1914; he indicated that more than 12 clear minutiae establishes certainty [Champod, 1995, p 136]. In 1924, the New Scotland Yard adopted a policy (with some exceptions) of requiring 16 points [Evett, 1996, pp 51–54]. At some time prior to 1958, the Federal Bureau of Investigation abandoned the practice of requiring a set number of points [Hoover, 1958]. During the 1970 conference of the International Association for Identification (IAI), a resolution was passed to form a committee for the purpose of determining "the minimum number of friction ridge characteristics which must be present in two impressions in order to establish positive identification" [McCann, 1971, p 10]. Three years later, that committee reported that "no valid basis exists at this time for requiring that a predetermined minimum number of friction ridge characteristics must be present in two impressions in order to establish positive identification" [McCann, 1973, p 14]. The standardization committee report has been reaffirmed and continues to date as the IAI position, and has been reaffirmed in various other forums [Grieve, 1995, pp 580–581; SWGFAST, 2004, p 1]. In North America, the prevailing threshold of sufficiency is the examiner's determination that sufficient quantity and quality of detail exists in the prints being compared.

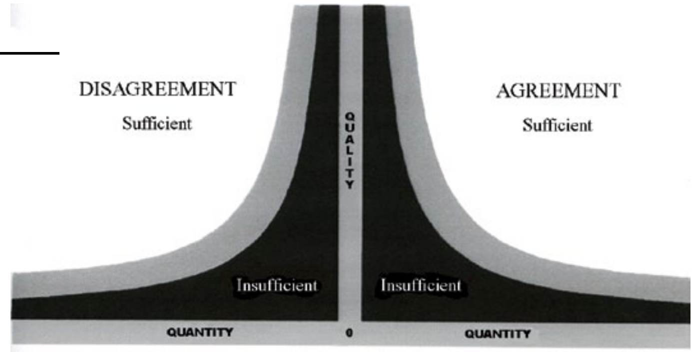
This is the quantitative–qualitative threshold (QQ), and can be explained simply as: For impressions from volar skin, as the quality of details in the prints increases, the requirement for quantity of details in the prints decreases. As the quantity of details in the prints increases, the requirement for quality of details decreases. So, for clearer prints, fewer details are needed and for less clear prints, more details are needed. This follows the law of uniqueness in pattern formations in nature. When challenged to predetermine how much is needed to individualize, it depends on how clear the prints are and how many details are present.

QQ represents the most natural threshold for recognition of details of unique features. Natural recognition relies upon how clear a print is and how many details are in the print. The QQ threshold can be used in all forensic comparative sciences that rely upon uniqueness and persistency in the source to make determinations. Artificial, predetermined quantities of limited and generically labeled details of unique features of the source are not adequate for

FIGURE 9–14

Quality-quantity curves.

(Adapted from the *Journal of Forensic Identification,* 2001, *51* (5), p 464.)



explaining agreement. Sufficiency for same source determinations depends on a quality/quantity relationship.

Figure 9–14 depicts the QQ threshold curves [Vanderkolk 1999, Vanderkolk 2001]. For any impression from volar skin, quality relies upon quantity just as quantity relies upon quality. Under the curve is insufficiency. Insufficiency is represented by black. Upon leaving the black and interfacing with the gray curve, sufficiency is reached. This sufficiency threshold is based on the value of 1. (X times Y = 1, or Q times Q = 1, is the curve.) One unit of uniqueness in agreement is the theoretical minimum needed to determine the prints had been made by the same unique and persistent source. One unit of uniqueness in disagreement is the minimum needed to determine the two prints had been made by different unique and persistent sources. This is why the threshold model is based on the value of quality times quantity equaling one. However, the examiner cannot determine the actual threshold of absolute minimum sufficiency of one unit of uniqueness. Therefore, the examiner must go beyond the theoretical minimum threshold of one, through the gray doubt area to the curves, and transition to knowing and believing the determination. An understanding of sufficiency becomes fixated beyond the gray doubt, in the white area.

Defining the physical attributes of one unit of uniqueness using common terms is difficult, if not impossible, because each unit of uniqueness is itself unique. Less clarity of many details increases the need to have more quantity of details to equal one unit. Sequences and alignments of details and features must be studied to develop expertise and understand uniqueness. The understanding of the physical attributes of uniqueness is based on previous training, experience, understanding, and judgments of the expert and the beliefs of the collaborating scientific community.

The gray quality and quantity axes intersect at zero. If the QQ curves were to intersect with either axis, there would be no print: A print with no quality of details could not exist. Neither could a print with no quantity of details. The QQ curves continue along both axes. The prints can approach perfect and complete recording of all the details of all the features of the skin, but will never reach perfection. Since nature is unique, there can never be a perfect and complete print, or replication of uniqueness. If complete replication of uniqueness would occur, uniqueness would cease.

The curves stop in the model because the examiner can only perceive details to a practical level. The curves actually continue. The quality axis approaches, but cannot reach, 100% clarity of the original source. The quantity axis approaches, but cannot reach, complete recording of all features within the recorded area of the skin. The model depicts reality and practicality at the same time.

The curve on the right side represents sufficiency of agreement of details for the evaluation phase. This curve also represents sufficiency of details in the analysis and comparison phases. The curve on the left side represents sufficiency of disagreement of details for the comparison and evaluation phases. These are two separate and distinct positive curves, mirror images of each other. The curves must be separate and distinct. Actual agreement and disagreement of unique details in two prints from unique and persistent source(s) cannot exist at the same time. Two prints from different unique and persistent sources cannot have two, four, six, or any number of details that actually match. (If an examiner states this is possible, the examiner is confused about uniqueness, confused about persistency, confused about actual agreement, confused about actual disagreement, or a combination of all of these.)

The ability to perceive agreement or disagreement is limited by a combination of the imperfectly recorded prints and human beings' perceptual abilities. If sufficiency does not exist for source determination or exclusion, the examiner cannot determine whether the details of unique features of the source(s) agree or disagree. Therefore, gray doubt exists between, or connects, the two insufficient areas under the QQ curves of agreement and disagreement. The examiner cannot determine whether the details of unique and persistent features of the skin actually agree or disagree. The examiner cannot determine the sufficiency of sequences and configurations of the details that are perceived.

The model also depicts the three decisions that can be reached after conducting analyses, comparisons, and evaluations:

- Agreement (white area): Sufficient details agree and support a determination that the prints came from the same source.
- Disagreement (white area): Sufficient details disagree and warrant a determination that the prints came from different sources.
- Inconclusive (gray and black areas): The examiner cannot determine whether the details actually agree or disagree, or cannot determine sufficiency of sequences and configurations.

The interface position between black and gray is fixed. The black area under each curve is also fixed. The black is insufficiency, less than the value of 1. The width of the gray varies. The upper limit of the gray can expand away from the black to represent less expertise or more doubt, or contract toward the black to represent more expertise or less doubt. Each examiner varies in their width of the gray. The width varies with expertise, training, experience, understanding, and judgments of their own and of others. The width of the gray also represents individual daily variations within the examiner.

The examiner must avoid examinations when unable to properly attend to the examination. The human factor must be considered when making determinations. The examiner must remember, "when in doubt, don't" and "do not be wrong". The gray also represents the interaction of the examiner with the method and threshold. The examiner is part of the method and makes the determinations using the QQ threshold as a model.

9.5 The Examination

An ACE examination starts with the analysis of the first print. The examiner then selects and stores some of the details of the first print as a target group in memory. The size or area of the print that contains the target group should not be too large because the examiner cannot perfectly store all the details of a large group in memory. These details are most likely some of the first level of general direction with, possibly, limited sequences and configurations of some second- and third-level details. Details of ridges, creases, scars, and imperfections can also be included within the first selected target group. Persistency of the features of the skin must be considered when selecting and then searching for a target. The examiner normally selects targets that are distinct and occur near the delta, core, or interfaces of details of ridges, creases, scars, and imperfections, because it should be easy to determine whether these exist in the second print.

Next, the analysis of the second set of prints starts. An example would be a tenprint card. Definitely different prints are quickly excluded based on very different first level direction of general ridge flow. This is an example of analysis, comparison, and evaluation blending. During the analysis of the second print, the target group of the first print's details is recalled as comparisons and evaluations start to take place. The first level ridge flow and sequences and configurations of the target group of details of the first print are searched in the second print. If a potential target group is not located in the second print, a second target group in the first print is then selected. This second target group is then searched in the second print. As always, the selection of a number of target groups of first, second, and, if needed, third levels of details of ridges, creases, scars, or imperfections is based on expertise of training, experience, understanding, and judgments of previous searching.

Once a similar target group is located in the second image, critical and recurring comparative measurements of sequences and configurations of first and second or third levels of details take place. If sufficiency is determined for actual agreement in the target and neighboring details, the examiner determines the two prints were produced by the same source.

If the target groups from the first image cannot be found in the second print, and the examiner determines the details of the persistent features actually cannot exist in

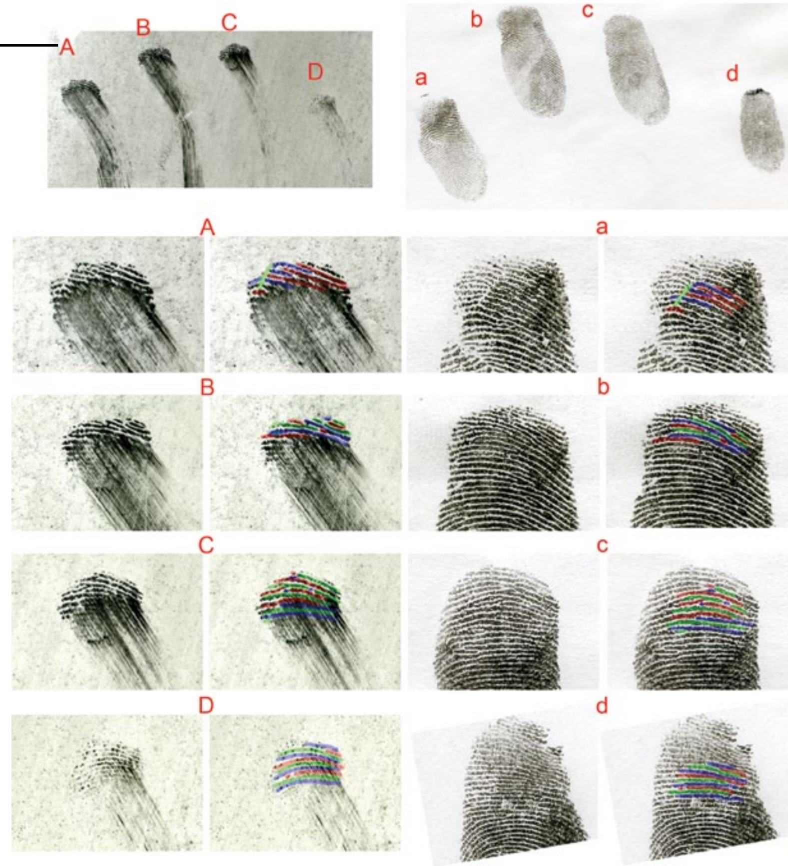


FIGURE 9–15

Each latent impression is marked with uppercase letters and its corresponding known print is marked with a corresponding lowercase letter. The first and third columns show the unannotated individual impressions. The second and fourth columns have colored markings to show the corresponding ridge flow and details.

the source of the second print, after recurring analyses and comparisons of various sufficient target groups, exclusion of the particular source is warranted.

If the target groups from the first print seem to be found in the second print, but the determination of agreement or disagreement of comparative measurements of all levels of available details throughout the prints cannot be determined between the two prints, or the target groups of the first print cannot be actually excluded from occurring in the features of the source of the second print, an inconclusive evaluation is warranted. If the examiner is unable to explain the variations of appearances, distortions, discrepancies, differences, agreement, or disagreement between the two prints, the inconclusive determination is similarly warranted.

9.6 Simultaneous, Adjacent, or Aggregate Prints

If a group of unknown prints are analyzed and determined to have been deposited within tolerance for simultaneity from one person—based on substrate, matrix, pressure, motion, and quality and quantity of levels of details in the prints—the prints can be analyzed, compared, and evaluated as an aggregate unit from one person. The individual prints within the aggregate are from individual areas or ridge sources, all from the one aggregate source of one person.

As in many aspects of forensic comparative science, challenges are made about aggregate prints. Just as with individual prints, the examiner needs to be able to defend the aggregate based on research, training, experience, understanding, and judgments. Whether the source can be determined depends on the quality and quantity of details and the examiner's expertise with aggregate prints [Ashbaugh, 1999, pp 134–135; FBI, pp 3–4; Cowger, pp 154–158; SWGFAST, 2002b; Black, 2006]. Figure 9–15 depicts the examination of details in an aggregate to reach a decision.

9.7 Summary

An expert conducts an examination based upon knowledge and beliefs from training, experience, understanding, and judgments. An acceptable explanation of a method to document expert perception is analysis, comparison, and evaluation, and the demonstration of repeatable determinations with verification.

Levels of clarity exist within all prints made by a unique and persistent source. A description of first, second, and third levels of detail of the features of the source is used to describe the clarity. Ranges of clarity exist within each of the three levels of details. Details in prints have various significances based on clarity.

Decisions are made throughout the perceptual process. A threshold, based on unique detail and expertise, is used to make decisions throughout the process. Quality of details of unique features of the source need a corresponding quantity of details to go beyond doubt to sufficiency in the QQ threshold. Likewise, quantity of details of unique features of the source need a corresponding quality of details to go beyond doubt in the QQ threshold.

The examination method needs the examiner to make decisions throughout the process. The examiner needs to ask and correctly answer all relevant questions to reach the proper conclusion in the examination. The examiner transitions from not knowing, through the irritation of doubt, to knowing and believing. The examiner does not simply make a leap of faith. What is needed is for scientists to collaborate more to better explain the foundations and processes examiners experience when making judgments throughout this process. There is more to print comparisons than counting to a predetermined threshold of a limited number of generically labeled parts within the wonderfully unique tapestries of skin and prints.

9.8 Reviewers

The reviewers critiquing this chapter were Debbie Benningfield, Herman Bergman, Patti Blume, Leonard G. Butt, Mike Campbell, Brent T. Cutro, Sr., Robert J. Garrett, Laura A. Hutchins, Alice Maceo, Charles Richardson, Jon T. Stimac, Kasey Wertheim, and Rodolfo R. Zamora.

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