Fingerprint Patterns: Genetic or Random?

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Abstract: Fingerprints are used for identification in both legal and civil matters. Their use ranges from forensic evidence to identification for important documentation such as a driver's license. The patterns of friction ridge skin are varied throughout the population with a majority having loops and very few having arches. The aim of this study was to determine the predictability of pattern types and determine if they have genetic significance. The results from this experiment showed that overall pattern types are genetically inherited while distinctive minutiae are due to random environmental stimuli.

Keywords: identification, minutiae, genetic, friction ridge skin

Friction ridge skin is the composition of ridges and valleys in proximity to one another, creating distinct patterns at their interlocking and breakages on the finger (Llewelyn 2014). These develop within the 12th week in utero and finish developing within the 16th week. As humans age, additions or very slight changes to prints can occur in the form of scarring or wear over time. Fingerprint patterns are broken down into three groups based on their distinct appearances on the skin, which are commonly known as loops, whorls, and arches (Galton 1892). Although every print will be different, the pattern types are not evenly distributed throughout the population. Loops make up the largest group, about 60% of people will have them, whorls make up 35%, and arches are the least common with only 5% of the population (Surat 2020). Loop patterns have ridges that enter and exit on the same side of the finger. Arches are the simplest form; the ridges start on one side and exit on the opposite side. Whorls have at least one ridge that makes a complete circuit. To differentiate fingerprints further, minutiae patterns are analyzed on the prints. These are specific ridge patterns and breaks that are unique to an individual person. On one print, there can be 25-80 minutiae present, even get to upwards of 150 minutiae points present (Raja 2009). Minutiae are commonly broken down into 8 specific orientations in which prints form, the most common and simplest of which are the ridge endings and bifurcations, the point at which a single ridge will fork and branch into two (Thakkar). The minutiae are the individualizing factor of a print and the road map to correct legal and forensic identification of an unknown print.

Friction ridge skin patterns have been recorded as early as 300 B.C. in China as a means of identification. In Chinese and early European societies, the distinct ridges of a fingerprint were used in clay seals to prove the originality of official documents and individualize a particular person (Xiang-Xin and Chun-Ge 1988). In the ancient civilization of Babylonia, these identifiable ridges were used in business transactions and even as early criminal evidence. Starting with King Hammurabi in 1792-1750 B.C., law officers kept a record of every arrested criminal's fingerprints (Bose and Kabir 2016).

The aim of this experiment is to establish a relationship between fingerprints and their genetic variability by observing the ridge traits between related and nonrelated participants. The overall dictating patterns of the prints most likely will prove to be genetically passed down while the minutiae patterns are the individualizing characteristic between the prints.

Materials and Methods

Three families' right thumb fingerprints were assessed and the thumbs of three unrelated participants were compared in this study. The three families were made up of 2 or more children and their biological mother and father. Using a black ink pad (Lee Product Companies, Bloomington MN) each volunteer's right thumb was dipped thoroughly into the ink and gently pushed onto a blank index card (up & up, Minneapolis MN). After ensuring the clarity of the print, each was categorized into its respective pattern type within each grouping: loop, whorl, and arch. Identifying characteristics such as the presence of large or many creases were recorded and compared for potential genetic versus wear causes. The minutiae patterns of each were also observed using a chart provided by *Bayometric* (Thakkar) as a reference guide. In order to digitize each of the prints, each sample card was scanned via printer into a computer.

Results

Within each genetically related trial, the pattern types stayed the same within each family, while the unrelated group did not share the same characteristics. Table 1 shows the digitized photographs from the first genetically related trial. Within this group, the mother and father both have loop patterns, which are also seen among their three children whom each has loop patterns as well. The mother has distinct large creases protruding across the print. These creases are also seen in the first daughter's thumb, while they are less pronounced, there is a large quantity of them. Table 2 portrays the digitized photographs from the second genetically related trial. The mother and father have different pattern types, one being a loop and the other a whorl respectively. Their offspring have the same patterns; the oldest son's print is a whorl, like the father and the daughter's print is a loop, like the mother. Table 3 depicts the digitized photographs from the third genetically related trial. Similar to trial 2, the genetic parents have different pattern types. The father has a loop while the mother has a whorl. Their offspring contain the same overall categorization as well. The oldest daughter has a loop, like her father, while the two youngest share their mother's whorl. The

father also appears to have distinctive, heavy creasing; this trait is also shared by the two youngest daughters. Table 4 describes the control group of three unrelated participants chosen at random. Each participant has a different pattern type; one has a loop, one has a double-loop whorl, and the other has a plain whorl. Out of the 17 total fingerprints tested, 59% of them had loops as their overall pattern, 41% had whorls, and 0% had arches.

Family 1 Prints and Pattern Identification					
Print					
Relationship	Father	Mother	Daughter	Daughter	Daughter
Pattern	Loop	Loop	Loop	Loop	Loop

Table 1. The right thumbprints from family 1 with relationship and pattern type indicated.

Table 2. The right thumbprints from family 2 with relationship and pattern type indicated.

Family 2 Prints and Pattern Identification				
Print				
Relationship	Father	Mother	Son	Daughter
Pattern	Whorl	Loop	Whorl	Loop

Family 3 Prints and Pattern Identification					
Print					

Relationship	Father	Mother	Daughter	Daughter	Daughter
Pattern	Loop	Whorl	Loop	Whorl	Whorl

Table 3. The right thumbprints from family 3 with relationship and pattern type indicated.

Table 4. The right thumbprints from the control, unrelated group with relationship and pattern type indicated.

Control Group Prints and Pattern Identification			
Print			
Relationship	Unrelated	Unrelated	Unrelated
Pattern	Whorl	Whorl (double loop)	Loop

Discussion

Fingerprints contain some genetic significance, specifically when determining pattern type. As seen in this study, the overall shape of ridge patterns appears to be inherited since between all three trial groups, the offspring did not contain any patterns different from that of their parents. From this study alone, it is not feasible to assess the genetic sequencing or encoding of this trait, but it would work similarly to a genetic Punnett Square, meaning that the parents are the determining factor of the offspring. The control group only supported this more, the lack of relationships among the participants showed through since none of them share a pattern type or distinctive feature. Additionally, heavy creasing has been shown throughout the study to be somewhat genetically determined. However, scientifically, we cannot yet assess to what extent is genetic versus age and wear to the pads of the print (Laseinde 2012). In trial 3 specifically, the father's heavy creases are most likely genetic and the sole reason why the two youngest daughters have such significant creasing. Due to their young ages of 15 and 9, it is unlikely that they could be due to wear and old age.

Despite the pattern types being exclusively determined by the parents, among the offspring, each fingerprint is unique in shape, size, and ridges; the placement of the core of each pattern is not the same either. No two prints from this study have the same minutiae despite genetic relationship or the same pattern type. The minutiae on each are the only individualizing factor of the prints; while any print can be the same pattern or show evidence of creasing, the specific ridge breaks and formations differentiate all of them.

While this study and subsequent literature have shown there is the presence of a genetic factor in determining the pattern type of fingerprints, there is not enough data collected in this study to outweigh the statistical inconsistencies among the pattern types. Among the human population, there is a predisposition to have a loop pattern type since approximately 65% of the population will have loops. This statistic is even consistent within this study having 59% loops regardless of genetic relation. There appears to be a cooperative relationship to fingerprint patterns with hereditary and randomness playing a role in their determination.

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