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Article

Fingerprint patterns through genetics

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SUMMARY

Fingerprints are unique identifiers, but it is unclear how much similarity/variation closely-related family members exhibit. This study explores the link between fingerprints and genetics by analyzing familial fingerprints to show how the fingerprints between family members, and in particular siblings, could be very similar. The left and right thumb and ring fingerprints were taken from seven related individuals (immediate family and grandparents) and were classified to see which fingerprint feature was dominant and how it was inherited through the different generations of the individuals tested. Ridge features between the three siblings out of the seven individuals were measured and analyzed. The hypothesis was that the fingerprints between siblings would be very similar and the dominant fingerprint features within the family would be the same throughout the generations. The experimental data suggested that these same common patterns were passed down, helping to support this link. Also, the fingerprints between the siblings showed a trend of similarity, with only very small differences which makes these fingerprints unique. This work helps to support this fascinating link between fingerprints and genetics while providing a modern technological application.

INTRODUCTION

This study investigates if basic fingerprint patterns are inherited through genetics. Fingerprint patterns have multiple levels of classifications; in this work, we focus on level one and level two features, which identify basic fingerprint patterns without going into their individual complexity. Level one features include three main types of fingerprints: a loop, a whorl, and an arch. Of course, there are many variations of these patterns such as a double loop or a tented arch, which could be considered level two features (1). A loop is a pattern where the ridges enter from either side, re-curve, and pass out or tend to pass out the same side they entered (1). A whorl is where the ridges are usually circular, and the circles get smaller and smaller until they form a dot (1). The third type of pattern, the arch, is a pattern where the ridges enter from one side, make a rise in the center and exit generally on the opposite side (1). Since the DNA that a person inherits from their parents determines many characteristics and traits, such as whether someone is right- or left-handed or which color their eyes are, all biological siblings inherit a mixture of their parents' DNA and possess similar traits (2). The goal of this work was to examine if fingerprint patterns are also a genetically inherited trait, as well as how similar familial fingerprint patterns are. Fingerprints develop during gestation in the womb, and the environment of the womb can greatly influence specific ridge distances, making fingerprints unique (3).

MIT Technology Review gave a simple experiment that had aspects that were similar to this project in the way that they were able to take the fingerprints, using ink and tape. Some current research in this area is focused on new methods of being able to take fingerprints by forensic scientists to establish a link between biological evidence and a suspect in a criminal investigation. That method uses DNA samples to create different fingerprint fragments whose size and shape are compared between different individuals (4). Heng et al. conducted an experiment that studied the distribution of fingerprint patterns among Malaysian populations (5). The hypothesis of the experiment stated that it is impossible for two individuals to have identical prints, but highly similar fingerprints between closely related individuals are likely to exist (5). One of the groups that this study focused on was the distribution of fingerprint patterns between siblings within these populations. About 96 siblings were recruited from families around Kuala Lumpur and 96 public citizens were selected from around the same area, and the study revealed that siblings demonstrated greater similarity of all fingerprint patterns than non-siblings (5).

The purpose of the Heng et al. study was to examine the genetic link between fingerprint patterns utilizing examples from a family of individuals to understand how these prints are inherited and which fingerprint pattern is dominant. This work also compares the ridge features between siblings who developed in the same womb to investigate their similarity. Specific measurements of the ridge features of the center and outermost ridges from the siblings' fingerprints were taken, and those values were averaged to see if they fit within a boundary of being considered similar. Then, a statistical analysis was performed to show that the fingerprints of two people who developed in the same womb will be very similar. The testable question developed from the desire to find the link between fingerprints and apply the link to a modern purpose: can fingerprint patterns be inherited through genetics and how does that relate to how the fingerprint technology on

smartphones works? Here, we explore if fingerprint patterns could be inherited and, in doing so, compare, contrast, and classify the fingerprints within the family tested to see which pattern is dominant. Further, my fingerprints and my brothers' fingerprints were closely examined to see how the ridge features are different. Statistical analysis on the thumb and ring finger prints of seven family members was performed to evaluate whether the ridge features were significantly different. Only a few ridges were suggested to be significantly different, supporting that these small, subtle differences within the fingerprints of siblings are what allow the fingerprint technology on smartphones to work.

This question helped to influence the hypothesis that fingerprint patterns can be inherited through genetics; since a person inherits half of their DNA from each parent, those patterns should prevail among relatives' fingerprints (6). After comparing the ridge feature measurements for the left and right thumbs and ring fingers between siblings, I found the ridge features varied between my brothers and I, and in terms of magnified millimeters (mm) under a hover camera and a microscope, there were not significant differences between the ridge features on the same fingers since we developed in the same womb. This topic is meaningful to study because fingerprint identification is used in forensics to help find criminals and it is used to protect your phone. I wanted to learn about how these specific patterns are similar and different among family members which allows this technology to work. Scientists are still exploring how much of an individual's fingerprint is inherited through genetics. This study provides a new analysis technique (using the press-and-roll method) to find the small subtle differences in the fingerprints between family members and even between siblings who developed in the same womb by virtue of having a shared mother.

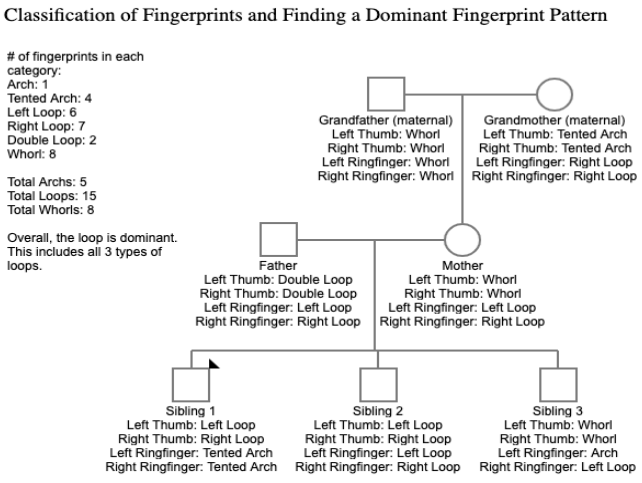

Figure 1: Classification of fingerprints and finding a dominant fingerprint pattern as a pedigree. Fingerprints were obtained from seven related individuals across three generations. Fingerprints were then classified using a microscope and a classifications guide. Using progenygenetics.com, classifications along with the individuals were put into the website to create a pedigree to better visualize how the individuals are related to each other as well as how the different fingerprint characteristics could have possibly been inherited.

RESULTS

Two experiments were performed where the fingerprints (obtained using the press and roll method) (4) of seven related individuals were documented and classified using the guidelines displayed in the introduction (4), to find the dominant fingerprint pattern and figure out if a trend suggests that it wasinherited through family lines. (**Figure 1**). The second experiment focused on the fingerprints of the three siblings, where the center and outermost ridges were measured for the left and right thumb and ring finger prints taken for each sibling, and then the measurements were averaged and analyzed for differences with student t-tests (**Table 1, Figures 1, 2**). **Figure 2** displays the actual ridge feature measurements as well as the average measurement for each finger tested for all three of the siblings. Nearly all of the error bars displayed in **Figure 2** overlap, showing that the fingerprint patterns between siblings are suggested to be statistically similar. Table 1 shows the student t-tests that were performed to show that the ridge feature measurements between siblings were statistically similar. Notably, the dominant fingerprint pattern in my family was a loop, and the student t-tests assessing the statistical similarities between ridge feature measurements between siblings showed that the fingerprints between my brothers and I were not statistically different. Most of the student t-tests produced a p-value that did not display a significant difference. These results support our hypothesis, suggesting that the loop is the pattern that is most likely to be inherited throughout my family lines. More specifically, the results suggest that the dominant fingerprint pattern in my family is the right loop. It is a trait commonly shared on the maternal and paternal sides of my family, as seen in **Figure 1**.

One surprising result from the student t-tests was that

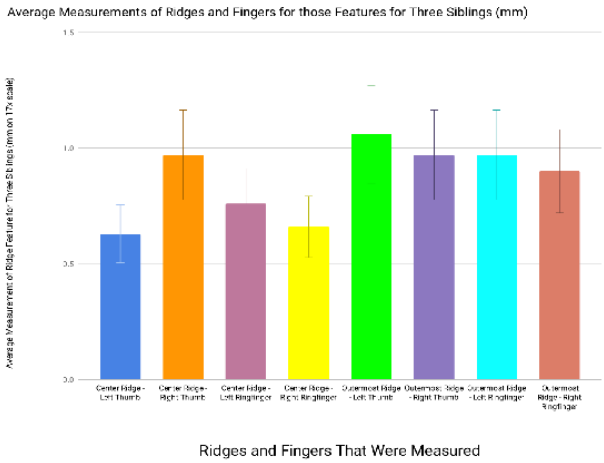

Figure 2: Graph comparing group averages for measurements per finger. Ridge features were measured in millimeters for three siblings. Average measurements for the ridge features are presented; error bars depict the standard deviation of the recorded measurements. Student t-tests were performed on the data, but very few significant differences were noted.

	Center Ridge Left Thumb vs. Central Ridge Right Thumb	Center Ridge Left Thumb vs. Central Ridge Left Ringfin-ger	Center Ridge Left Thumb vs. Central Ridge Right Ringfin-ger	**Center Ridge Left Thumb vs. Outer Ridge Left Thumb**	Center Ridge Left Thumb vs. Outer Ridge Right Thumb	Center Ridge Left Thumb vs. Outer Ridge Left Ringfin-ger	Center Ridge Left Thumb vs. Outer Ridge Right Ringfin-ger	Center Ridge Right Thumb vs. Center Ridge Left Ringfin-ger	**Center Ridge Right Tumb vs. Central Ridge Right Ringfin-ger**	Center Ridge Right Tumb vs. Outer Ridge Left Thumb
p-value	**0.04**	0.45	0.68	**0.01**	0.07	0.11	0.12	0.30	**0.03**	0.35
Statistically Significant	**Yes**	No	No	**Yes**	No	No	No	No	**Yes**	No
	Center Ridge Right Thumb vs. Central Ridge Right Thumb	Center Ridge Right Thumb vs. Central Ridge Left Ringfin-ger	Center Ridge Right Thumb vs. Central Ridge Right Ringfin-ger	Center Ridge Right Thumb vs. Outer Ridge Left Thumb	Center Ridge Right Thumb vs. Outer Ridge Right Thumb	Center Ridge Right Thumb vs. Outer Ridge Left Ringfin-ger	Center Ridge Right Thumb vs. Outer Ridge Right Ringfin-ger	Center Ridge Left Thumb vs. Center Ridge Left Ringfin-ger	**Center Ridge Left Tumb vs. Central Ridge Right Ringfin-ger**	Center Ridge Left Tumb vs. Outer Ridge Left Thumb
p-value	1.00	1.00	0.67	0.54	0.11	0.35	0.39	0.51	**0.01**	0.07
Statistically Significant	No	No	No	No	No	No	No	No	**Yes**	No
	Center Ridge Right Ringfin-ger vs. Outer-Ridge Left Ringfin-ger	Center Ridge Right Ringfin-ger vs. Outer-Ridge Ridge Ringfin-ger	Outer Ridge Left Thumb vs. Outer Ridge Right Thumb	Outer Ridge Left Thumb vs. Outer Ridge Left Ringfin-ger	Outer Ridge Left Thumb vs. Outer Ridge Right Ringfin-ger	Outer Ridge Right Thumb vs. Outer Ridge Left Ringfin-ger	Outer Ridge Right Thumb vs. Outer Ridge Right Ringfin-ger	Center Ridge Left Ringfin-ger vs. Outer Ridge Right Ringfin-ger		
p-value	0.11	0.12	0.47	0.54	0.24	1.00	0.71	0.74		
Statistically Significant	No	No	No	No	No	No	No	No		

Table 1: Statistical analysis of ridge feature measurements between siblings. Ridge features were measured for three siblings. Student t-tests were performed on the data and the p-values and significance (p-value < 0.05) are reported here. The four statistically significant relationships are emphasized in bold.

there were only four statistically significant comparisons: Center Ridge Left Thumb vs. Central Ridge Right Thumb, Center Ridge Left Thumb vs. Outer Ridge Left Thumb, Center Ridge Right Thumb vs. Central Ridge Right Ring Finger, and Center Ridge Right Ring Finger vs. Outer Ridge Left Thumb. These are very small differences which is why only four student t-tests showed a significant difference in ridge feature measurements.

DISCUSSION

Overall, the data collected did support the hypothesis that fingerprint patterns can be inherited through genetics. It also supported that the dominant fingerprint patterns in the data would be a loop and an arch. Those patterns are the dominant patterns from my left and right thumb and ring finger, and since a person inherits half of their DNA from each parent, those patterns would prevail among my relatives' fingerprints. Also, the ridge features did show some variation between my siblings and me, and in terms of magnified millimeters under a hover camera and a microscope, there were only small, subtle differences between ridges since which are suggested to be due to the fact that we developed in the same womb.

The dominant pattern within my family lines could have been passed down directly to my mother by her parents, and then again to my brothers and me. Consequently, basic

fingerprint patterns could be passed down through genetics. There are other factors that shape fingerprints, such as the environmental exposure during gestation, making every fingerprint unique, but these basic patterns are linked to a person's DNA and are passed along through family lines.

The main takeaway from our study is that this research suggests that basic fingerprint patterns can be inherited through genetics, which was shown by having the same common pattern passed down through members of the different generations in my family, and the analysis suggests that there are only very small differences in the fingerprints between siblings. Statistically, these differences are small and the fact that fingerprint recognition is able to pick-up on that is what allows that technology to work. Everyone has their own unique fingerprint, but that is a factor of every fingerprint linked through genetics (differential inheritance of parent's DNA) and environmental exposure during gestation. This is why the fingerprints between siblings were not exactly the same. The data suggests that if two people developed in the same womb, their fingerprints, could be very similar. Fingerprint recognition is impressive technology because it is able to recognize every individual user, even if they have a sibling with a very similar fingerprint. Since the ridge feature measurements between siblings showed only four statistically different tests, this shows how intricate fingerprint recognition technology is because the data suggests that these differences are rather subtle. These results are important because they help to begin to reveal this fascinating link between fingerprints and genetics, which not many people are aware of, and these ideas are fundamental to how big companies like Apple use fingerprint recognition for their iPhones.

At the conclusion of this study, some questions remain unanswered. I still want to know more about the specific algorithms used in fingerprint technology that allow this technology to recognize subtle differences, and I also want to see if there is an inheritance factor of fingerprint patterns within other families that would make that part of the data more significant. As for the fingerprint technology, very similar fingerprints can still be differentiated. I think that fingerprint technology is safe because fingerprints partially depend on the environment, causing a few significant differences in the fingerprints between siblings. Some limitations of this study include the fact that only one family of related individuals was tested. A family of unrelated individuals could be tested as well and the data could be compared. I could also possibly test the ridge features of other siblings and see if those fingerprints are statistically similar. There are multiple possibilities but, from the data that I have provided, fingerprints between siblings are statistically similar and there is an inheritance factor throughout the fingerprint patterns of family members.

MATERIALS AND METHODS

Generational Fingerprint Pedigree

Left and right thumb and ring finger fingerprint patterns from seven family members in three generations were collected and classified. The fingerprints were collected by gently rolling each subject's left and right thumb and ring fingers in ink, making sure to cover the whole fingerprint with ink and pressing and rolling onto a piece of labeled printer paper. The clearest prints from each of the four fingers for each subject were selected for analysis; each fingerprint pattern was placed under a microscope to observe the ridge features and classify the fingerprint. If multiple prints from the same finger were taken for clarity, the classification that was most present was deemed the dominant fingerprint pattern. This process was repeated for each of the four fingerprints for each of the seven subjects.

Magnifed Fingerprint Measurement and Analysis

A hover camera was used to zoom in on each fingerprint that was collected for each of the three brothers in the family. The ridges were extremely small, so a 1 mm sheet of paper was zoomed in until it was 17 mm, and the ridges were measured on this consistent 17 mm scale with a constant 1 mm error boundary for the fingerprints to be considered similar. Then, a millimeter ruler was used to measure the center and outermost ridge features of that fingerprint. This process was repeated for the fingerprint patterns of each of the four fingers for each brother. The results were averaged and student t-tests were used to compare ridge feature measurements between siblings to identify statistically significant differences (p-value < 0.05).

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