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Microscopical Discrimination of Twins' Head Hair

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ABSTRACT: Twin populations are ideal for studying human variation; a study of twins' hair, therefore, provided a better understanding of the value of hair comparisons. Duplicate head hair samples from 17 pairs of twins and one set of identical triplets were compared in a verified blind study. In addition to the direct comparison of all twins, random samples of two or three hairs were compared with randomly selected groups of known samples in a second blind study, to better simulate an ordinary forensic science case. Features commonly used by forensic hair examiners were adequate to distinguish hair samples from each twin from all other samples, illustrating the power of microscopical comparison when numerous questioned hairs are available in evidence. When two or three hairs were compared with randomly selected known samples, several were indistinguishable from hair samples other than the true source, proving once again that a human hair can never be associated with one person to the exclusion of all others.

KEYWORDS: criminalistics, hair, individuality, twins, exemplars

An experienced forensic hair examiner knows from practice that hair from two individuals selected at random can usually be differentiated easily. Except for identical twins, each of us has a unique genetic endowment, unprecedented and nonrecurrent, that has been nurtured by environment. Our hair should not be an exception. Theoretically hair is individual to each and every person. Why can it not therefore be individualized?

Unfortunately, the biological individuality of human hair is represented in a polygenic system. The variability of human hair is like an iceberg: only a small fraction is displayed as observable features, while the greater part is lying below the surface in the form of hidden genic differences. Consequently, the forensic hair examiner cannot detect the genic traits that might ultimately show a person's hair to be unique. This is the crux of the criminalist's problem in seeking to use hair as evidence. Otherwise, hair has many attributes that make it ideal as associative evidence.

The association of human hair is made more difficult because of intrapersonal variation. This variation is like the variation of anthropometric characteristics first described by Quetelet and Bertillon in the first half of the nineteenth century [*1*]. The amount and kind of variation differs from person to person and sometimes covers a rather wide range. Natural variation does not preclude the association of hair, because sometimes variation serves to personalize the hair specimen. When comparing several hairs from one source, it can sometimes be demonstrated that the questioned hair not only has the traits of the known hair, but that the variation in the questioned specimens matches the variation occurring in the exemplar.

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Francis Galton [2] first recognized the broad possibilities of twin studies. Galton deduced that a study of identical and fraternal twins could indicate the relative influences of heredity and environment.

Because twins provide examples of unduplicated physical similarity, twins have been used to validate the individuality and usefulness of some forensic science evidence, including fingerprints [3,4], lip prints [5], fingernails [6], handwriting [7], and voice prints [8].

With this background in the use of twins for forensic science research, we expected that a twin study could be a useful tool to appraise the value of the forensic hair comparison. Because a microscopical hair comparison is often quite subjective, a gestalt of education, training, and experience, the study should be conducted blind and verified by at least two examiners in order to ensure meaningful results.

Barnett and Ogle [9] criticized the research of Barry Gaudette of the Royal Canadian Mounted Police because his experimental design dealt solely with the ability to distinguish two hairs. The possible bias stems from the fact that there are always observable differences between any two hairs, even from the same individual. They felt a hair comparison involves two distinctly different tasks: (1) discriminating between two hairs and (2) correctly assigning an unknown hair to its true source.

To avoid this criticism, the experiment should be designed to require that the hair specimens be not only discriminated, but also properly matched with the correct exemplar. The researcher should not know in advance that any match between two hair specimens is erroneous. Ideally, the experimental design should mimic cases commonly examined in the crime laboratory, using a design like that of Straus [10].

Experimental Procedure

Material

Cut head hair samples were received from nine fraternal twin pairs, six identical twin pairs, one set of identical triplets, and two twin pairs of unknown zygosity (Table 1). All the twins were white. The age of the twins ranged from two to twenty-three years. Twelve of the eighteen sets were below the age of six. Eleven of the eighteen sets were blonds. The absence of roots because the hairs were cut and the predominence of blond hair made the comparisons unusually difficult. Most of the hairs were common featureless types (Table 2).

Each hair sample was assigned two random five-digit numbers [11]. Two representative samples of about twenty-five hairs were separated from the whole sample and mounted between glass slides, resulting in seventy-four mounted hair samples. These subsamples were identified only by a unique five-digit number. The original samples were secreted until the end of the project. The 74 specimens were shuffled and the subsequent examinations were made without knowledge of their true origin; that is, blind.

TABLE 1—*Number of twin pairs whose hair samples were examined.*

	Sex			
Zygosity	Male	Female	Both	Total
Identical	2[a]	5	...	7[a]
Fraternal	5	2	2	9
Unknown	2	0	...	2
Total	9[a]	7	2	18[a]

[a] Includes one set of identical triplets.

TABLE 2—*Traits of "common featureless" hairs.*

Blond
Cut (proximal and distal ends)
Unmedullated
Fine
Straight
Untreated
Diffuse liquid pigment
No cortical texture
Scales flattened and smooth

Methods

During the first phase, the duplicate subsamples from each twin were compared with all other samples. We attempted to match each sample with the correct duplicate without matching it with its twin. The comparisons were made visually and microscopically, with the hair specimens lying on differently colored backgrounds. Characteristics commonly used by the forensic hair examiner were used (Table 3).

The test of our discriminating ability would be to correctly assign the two duplicate samples as similar. If two twins were identical or indistinguishable, there would be four indistinguishable hair samples. If differences could truly be identified—that is, if twins could be distinguished—there would be two pairs of hair samples. If differences were imagined, the two pairs could be mixed, one pair containing hair from two individuals (probably twins). If the comparison criteria were exactly correct, and it is truly possible to distinguish between twins, the samples would be matched with the correct duplicates only, and not with any others. Each of us made the comparisons without collaboration, recording our results independently.

In the second part of our project, a simulated forensic science design was used to make the project more realistic. Two or three hairs were removed from seven randomly selected original specimen envelopes and mounted between glass slides. Known samples were selected from the 74 subsamples originally mounted for the first part of the project by using the random digit table. In this way, five to ten known samples were selected for comparison with each of the seven questioned samples (Table 4).

The experiment resembles many cases received in the crime laboratory where questioned hairs are recovered from the scene and compared with several known samples, usually including samples from the victim and suspect. As with actual cases, it was never really known whether the questioned hairs belong to the victim or suspect, or to any of the individuals who have been identified as possible sources and from whom exemplars have been received.

TABLE 3—*Characteristics used in comparisons.*

Color	Structure	Cuticular Traits	Acquired Characters
Hue	form	scales	treatment
Pigmentation	diameter	weathering	cleanliness
Variation	cross-sectional shape	sequence	abnormalities
Artificial coloration	cortical texture		artifacts
	medullation		
	shaft aberration		

TABLE 4—*Results of simulated forensic comparisons (second part of project).*

Questioned Specimen Number Q	Hair Color	Number of Known Specimens	Number of Matches[a] Examiner 1	Examiner 2	Comments
1	brown	10	1	0	hairs differ
2	blond	10	2	2	knowns contained duplicates
3	blond	5	0	0	...
4	brown	5	0	0	twin eliminated
5	brown	7	0	0	...
6	blond	7	1	0	indistinguishable in liquid media
7	blond	8	1	1	...

[a] All matches are incorrect (Type 2 errors). No Type 1 errors were made because none of the known pools contained the true source.

We then tried to determine whether the questioned hairs could have originated from any of the samples in the known pool. It was not known to us whether the true source or the twin's hair was included in the exemplars or whether both duplicates or the twin's duplicates were present.

Results

By visual and microscopical examination, we were able to distinguish correctly the groups of hairs of every individual in the study. The specimens were matched only with the correct duplicate samples and never with a twin. Whether the twins were identical or fraternal made no difference.

Some of the identical twins differed only with respect to color or hue, while others differed with respect to several traits. Our records showed that eleven pairs had more than one difference. The average number of recorded differences between identical and fraternal twins was approximately the same. There was a greater number of differences reported between twins with brown hair than twins with blond hair. Several of the twins differed with respect to treatment, including weathering and cleanliness.

In the second phase, each of seven questioned specimens was compared with several known control specimens. We did not know that because of the random selection of exemplers, in no experiment was the true source of the questioned hairs present in the known pool. In one of the simulated cases where the correct known sample was not present, a sample of the fraternal twin's hair was present in the known pool and was correctly eliminated. In other simulated cases, the questioned hairs were matched with control samples that were neither the true source nor the twin of the true source. In other words, on more than one occasion the questioned hairs were incorrectly indentified and indeed did match someone else's head hair (Table 4).

Discussion

No identical twins are ever exactly alike. As can be seen with head hair specimens, the term *identical* refers only to their genes, and not to their traits, which can develop quite differently under varied environmental conditions. Identical twins often look least alike at birth and in infancy but more alike later. Fraternal twins should look no more alike than other siblings, but often look most alike at birth and in infancy, while resemblances diminish as time goes on [*2*]. Regardless of the zygosity of the twins, all of the hair specimens could be discriminated.

These results are consistent with the work of Banerjee and Das Chaudhuri [*12*], who studied medullary structures alone. In 1969 they compared 25 pairs of twins (10 identical and 15 fraternal), using 25 hairs from each twin. Using the medullary ratio (the total number of medullated hairs divided by a total number of hairs examined), all the pairs differed. Das Chaudhuri expanded his twin study in 1976 [*13*] to include 48 pairs of twins and 100 hairs from each twin. Again he determined the medullary ratio. Of the 48 pairs examined, only 2 showed no intrapair differences.

The likely reason for the uniqueness is that everyone's hair has a range of characteristics over the scalp. This is what complicates hair comparisons. When several questioned hairs are available, this variation works to the benefit of the examiner by adding an extra dimension that strengthens the association. Strauss demonstrated that the distribution of traits in a sufficiently large sample of hair from one individual in her study showed a unique native range [*10*]. As with the identification of handwriting, "when the same distinctive personal writing characteristics are found in both the known and unknown writing in sufficient number that the likelihood of accidental coincidence is eliminated . . . then both must have been prepared by the same person" [*14*]. The verification of this principle may be impossible, but it provides a standard of comparison with the more usual type of forensic science case.

The availability of an adequate representative questioned sample is uncommon. One renowned exception is the case of *The Michigan Murders*, where Walter Holz had such a sample when he recovered 509 hairs from the victim's underpants and compared them with hundreds of hairs from the basement floor at the murder scene [*15*]. Based on our research and the others cited, Holz's conclusion that they all came from the same source seems justified.

The more common case involves one or maybe several questioned hairs that must be compared with known specimens from victim and suspect. The forensic hair examiner assumes that a single hair can never be positively identified with a single person to the exclusion of all others. The reasons for this limitation are known and reaffirmed here. There will always be hairs from one person that cannot be distinguished from another's hair. There will be cases, if the criminalist watches for them, where hair from different individuals will appear indistinguishable. Gaudette [*17*] reported on such a case in 1978. It was noted by Gaudette and should be reiterated here that the hairs most often causing confusion, as they did in our study, are common featureless types of hairs.

A simple model might illustrate the principles involved here. Any given specimen of hair may be represented as a collection of traits around a single point located in a multidimensional space. A number of similar specimens correspond to a number of intermingling points lying very close together within the multidimensional space [*18*]. Like the galaxies of our universe, the location and shape of a person's hair specimen in space is sometimes nebulous: the galaxies vary in shape and size; some of the galaxies have very close companions; and thousands of galactic clusters are known [*19*].

A single hair is like a small solar system, a cluster of planetary traits—one of many solar systems in the galaxy with only nominal identity with its galactic origin.

The point is that given the ability to determine the location and distribution in space of a sufficient number of stars, the galaxy can be identified and differentiated from all other known galaxies. But given only one or two stars, possibly somewhere in the space between two galaxies, it is impossible to determine to which galaxy the stars usually belong. It can only be determined that the stars could have originated from one galaxy, but not to the exclusion of all other similar companion galaxies.

Undoubtedly, if we could scrutinize the planetary nature of the solar system—that is, the number, size, and locations of the planets and possibly the features of each planet—we could positively identify its galactic origin. Unfortunately, we can only view the stars from afar. Possibly in the future, we will be able to better view and resolve the universe, identifying the unique aspects that would allow a more positive conclusion than we are now able to make. Is not the situation with human hair the same?

Although we have reaffirmed that hair cannot be positively identified, several investigators have demonstrated that given a limited number of questioned and known specimens, the questioned hairs usually can be matched correctly with the known specimens. We agree. Kirk's experiments using 20 students [*16*], the work of Gaudette [*17*], and, more recently, the work of Strauss [*10*] demonstrate the value of the forensic hair comparison. Two additional aspects of the forensic hair comparison have been illustrated also.

First, verification by a second examiner, as in our study, which is common in other forensic science disciplines, might measureably reduce Type 2 errors, as defined by Gaudette [*20*] (see Table 4). Second, it is important to obtain exemplars from all persons who may have discarded the questioned hair. Normally hair is received from both victim and suspect, but the importance of receiving exemplars from other family members, friends, employees, or others if it can be reasonably expected they may have had access and may have left the hair cannot be overemphasized. Irrespective of the probability of a Type 2 error, the hair may have been shed by the next-door neighbor. The obtaining of elimination samples from those other persons likely to have left the hair strengthens the case, because there is a very strong presumption that the unknown hair came from someone at the scene.[2] Without adequate exemplars, the evidence should not be used or the results should be disclaimed with an adequate and clear expression of the relative significance of the hair evidence.

Summary

1. Scalp hair samples from 17 pairs of twins and 1 set of identical triplets were used in a blind study to evaluate the significance of the forensic hair comparison.

2. With a sufficient quantity of hair, the hair from each twin could be discriminated by using common microscopical comparison characteristics.

3. In some experiments in which two or three questioned hairs were compared with several known samples, the hairs were matched with known samples that were not the true source of the questioned hair. The experiments illustrated the caution necessary in comparison of common featureless hairs. The probative value of single-hair comparisons is understandably much less than when several questioned hairs with varying traits are matched.

4. The forensic hair examiner should not underestimate the importance of receiving quality exemplars from all persons known to frequent the scene from which the questioned hair was obtained. A better understanding of the importance of exemplars and a better understanding of hair comparisons should lead to an increased use of this valuable evidence by police investigators, forensic science laboratories, and the courts.

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References

[*1*] Rhodes, H. T. F., *Alphonse Bertillon*, Abelard-Schuman, New York, 1956, p. 21.
[*2*] Scheinfeld, A., *Twins and Supertwins*, Lippincott, New York, 1967, pp. 260 and 151.
[*3*] Newman, H. H., "The Fingerprints of Twins," *Journal of Genetics*, Vol. 23, No. 3, 1930, pp. 415–446.
[*4*] Berry, J., "Identical Twins?," *Identification News*, Vol. 28, No. 3, March 1978, pp. 9.

[2]Personal communication from B. D. Gaudette, chief scientist, Hair and Fibre, Central Forensic Laboratory, Royal Canadian Mounted Police, Ottawa, Ontario, Canada, 1983.

[5] Tsuchihashi, Y., "Studies on Personal Identification by Means of Lip Prints," *Forensic Science*, Vol. 3, No. 3, June 1974, pp. 233-248.
[6] MacDonell, H. L. and Bialousz, L. F., "Personal Identification Using Human Fingernail Striation," *Identification News*, Vol. 22, No. 10, Oct. 1973, pp. 3-5.
[7] Gamble, D. J., "The Handwriting of Identical Twins," *Canadian Society of Forensic Sciences Journal*, Vol. 13, No. 1, Jan. 1980, pp. 11-30.
[8] Hennessy, J. J. and Romig, C. H. A., "A Review of the Experiments Involving Voiceprint Identification," *Journal of Forensic Sciences*, Vol. 16, No. 2, April 1971, pp. 183-198.
[9] Barnett, P. D. and Ogle, R. R., "Probabilities and Human Hair Comparison," *Journal of Forensic Sciences*, Vol. 27, No. 2, April 1982, pp. 272-278.
[10] Strauss, M. A. T., "Forensic Characterization of Human Hair I," *Microscope*, Vol. 31, No. 1, 1983, pp. 15-29.
[11] Beyer, W. H., Ed., "Table of Random Units," *Standard Mathematical Tables*, 24th ed., CRC Press, Cleveland, 1976, p. 499.
[12] Banerjee, A. R. and Das-Chaudhuri, A. B., "Genetics of Medullary Structure of Human Head Hair," *Man in India*, Vol. 49, No. 1, March 1969, pp. 30-40.
[13] Das-Chaudhuri, A. B., "Genetic Basis of Hair Medulla by Twin Study," *American Journal of Physical Anthropology*, Vol. 44, No. 1, Jan. 1976, pp. 51-54.
[14] Hilton, O., *Scientific Examination of Questioned Documents*, rev. ed., Elsevier North Holland, New York, 1982, p. 161.
[15] Keyes, E., *The Michigan Murders*, Reader's Digest Press, New York, 1976, p. 324.
[16] Kirk, P. L., "Human Hair Studies. I. General Considerations of Hair Individualization and Its Forensic Importance," *Journal of Criminal Law and Criminology*, Vol. 31, No. 3, Sept./Oct. 1940, pp. 486-496.
[17] Gaudette, B. D., "Some Further Thoughts on Probabilities and Human Hair Comparisons," *Journal of Forensic Sciences*, Vol. 23, No. 4, Oct. 1978, pp. 758-763.
[18] Oxnard, C., *Form and Pattern in Human Evolution*, University of Chicago Press, Chicago, 1973, p. 39.
[19] Pasachoff, J. M., *Contemporary Astronomy*, Saunders, Philadelphia, 1981, p. 479.
[20] Gaudette, B. D., "A Supplementary Discussion of Probabilities and Human Hair Comparisons," *Journal of Forensic Sciences*, Vol. 27, No. 2, April 1982, pp. 279-289.

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