Inter- and intra-individual variation in earprints

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SUMMARY

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When perpetrators of crimes listen at, for instance, a door or window before breaking and entering, oils and waxes on their ears leave prints that can be made visible using techniques similar to those used when lifting fingerprints. These prints appear characteristic for the ears that made them, and could therefore possibly be used as a tool for person identification.

In the FearID research project, funded under the 5th Framework Programme of the European Community, nine institutes from Italy, the Netherlands and the UK joined their research forces to investigate the potential of earprints for forensic investigations. Barge's Anthropologica of the Leiden University Medical Center was one of the research partners in this project. The work presented here was carried out in the context of the FearID research project.

The value of the external ear as a means of identification was recognized centuries ago. Prior to the use of fingerprints, the ear was studied and described as part of a procedure to establish the identity of criminals. Not only the ear itself showed potential for person identification, but also its prints. A great variety in the shapes, sizes and relative intensity of the various imprinted anatomical features may be observed in prints of different ears. However, not even two prints of the same ear are exactly alike. Differences in the way prints are left, or the material they are left on, may cause variation in prints by a single ear. The feasibility of earprint individualization, therefore, depends not only upon the amount of variation in prints of different ears (inter-individual), but also upon that which occurs in prints of a single ear (intra-individual).

To justify the claim that we can match an earprint uniquely to an ear, we must establish that the print resembles other prints from the same ear more than it resembles prints from another ear. We may attempt to do so by analysing multiple prints from a large sample of ears, comparing inter-individual variation with intra-individual variation over a suitable set of measurable features. An experimental feature set is suitable only if the inter-individual

variation is significantly greater than the intra-individual variation. The outcome of this analysis will be probabilistic. This means we may estimate the probability of encountering seemingly indistinguishable prints from different ears. To perform such an analysis, acquiring insight in the variability of the various features in multiple prints originating from the same ear is of paramount importance. When may discrepancies between prints still be considered potential intra-individual variation, and when should they be regarded as inter-individual variation?

In order to understand the limits of intra-individual variation, we also need to recognize the matters that cause it. It will allow us to make informed decisions regarding the circumstances under which earprints should be collected. A study of earprint variation that includes several prints from each ear – collected under varying conditions known to influence their appearance – will eventually enable us to determine the boundaries to 'natural' variation in prints by a single ear. Subsequently, we can compare the variation in prints from a single ear with that in prints of different ears.

Inter-individual variation in earprints may be studied by comparing prints of a great number of different people. In the course of realizing this thesis, we have studied prints of both ears of over 500 people. The FearID research team examined prints of over 1350 different people in total. To this purpose, these people listened a number of times at a surface. The resulting latent prints were dusted using fine aluminium powder, and preserved on Black Gel Lifters. We included three to five prints from each ear, thus also allowing a study of intra-individual variation.

In chapter 1 we provide an introduction to the various anatomical parts of the external ear, and their representations in the earprint.

In chapter 2 we provide the results of a literature study into the classification of earprint variation. Results from this literature study are combined with results from a preliminary study of earprints. An important conclusion from this study is that the imprints of morphological structures do not only differ in size due to variation in the force that is applied by the ear during listening. Features may change position in relation to each other as well. This decreases the reliability of a classification system that is based on recognizing patterns formed by calculated centroids, and of that making use of a polar axis in order to align prints.

In chapters 3 and 4 we investigate various sources of variation in the force that is applied by the ear to the listening surface, seeing that differences in applied force between two listening efforts may cause discrepancies between the resulting earprints. In chapter 3 we explore the effect of sound level and frequency of the target sound, and of the level of ambient noise. In chapter 4, we investigate whether presence or absence of a target sound affects applied force during listening.

Our results do not show a significant effect of the level of ambient noise on applied force. Listening to either sound or silence does also not appear to significantly affect applied force. The results for target-sound frequency are somewhat ambiguous. We do notice a significant effect from chances in the level of the target sound. When the sound level is reduced in between listening efforts, it evokes a reaction of listeners to increase applied force. In addition, we observe that listeners generally apply less force during their first listening effort. We assume that – unfamiliar with the procedure – subjects are more cautious during first listening efforts.

The two studies show that the inter-individual variation in applied force is far greater than the intra-individual variation. It is therefore advised that suspects should be actually listening at a surface when their earprints are enrolled. One may exploit the variables known to affect applied force in order to create conditions that increase the probability of obtaining (realistic) intra-individual variation in earprints. Asking the suspect to reproduce a provided sound may further be one way of insuring that there is no fraudulent attempt to create a non-functional (deviating) print.

In chapter 5 we attempt to determine the rate of growth of the external ear during adult life in order to evaluate the extent to which the anatomical features may vary with passing time. For this purpose, we perform a cross-sectional anthropometric study. We explore the effect of age on ear length, earlobe length and ear width. It was found that all three dimensions significantly increase with age. For males the annual increase in ear length, earlobe length and ear width is estimated at 0.178, 0.115 and 0.073 mm respectively. For females, this is 0.162, 0.100 and 0.073 mm. Estimated length and width increments of the external ear during the various stages of life appear to differ significantly between the sexes. The difference seems particularly obvious for width expansion, which appears to occur at a later age in females than in males.

Earlobe lengthening appears to exceed the lengthening of the remainder of the ear, and therefore the imprint of the lobe will probably be less stable over time. We do not observe an acceleration in earlobe lengthening after a certain age, as assumed in literature.

In chapter 6, we investigate whether the duration of listening affects the size and intensity of the imprinted surface. For this purpose we analyse print-mass, which is a characterization of the print that takes both the intensity and the size of imprinted areas into account. We conclude that how long a donor listens at a surface influences the appearance of the retrieved earprint, increased listening time resulting in an increase in print-mass.

In chapter 7 we investigate whether the amount of secretions present on the ear affects the earprint. The amount of these secretions may vary depending on outside temperature, and whether the ear was recently cleaned or not. More or less secretions available for printing may therefore influence the dimensions and/or intensity of the imprinted area. In turn, this might affect the area in which characteristics can be found, or the visibility of such details.

We compare print-mass retrieved from prints collected before and after the ear was cleaned. We do not find evidence for a significant change in the mass of prints created by cleaned ears. This, however, provides no guarantee that the imprinted details are of equal quality, and investigations into the stability of characteristic features (i.e., valuable for individualization) in prints of recently cleaned ears are ongoing.

One of the research goals the FearID team had set out to accomplish is the development of a computer programme that can – (semi) automatically and with an acceptable rate of false matching – group earprints that may have been left by a single ear. This software enables an earprint expert to quickly find similar prints in a database of digitised prints. In order to form an opinion on individualization, the expert will compare the print that was found at a crime scene with the prints on a list of most likely matches. The expert will not only compare similarities, but will also evaluate whether differences between prints are sufficiently small as to fall within the range of potential intra-individual variation. Knowledge on the extent of possible intra-individual variation is therefore of great importance. Rendering an accurate judgment on the extent of intra-individual variation involves the examination of multiple prints of a large number of individuals.

In chapter 8 we aim to provide insight into the level of detail to which prints may be compared. We show for five individuals (examples of) the variation that may occur between different prints of the same ear and speculate on the causes of this variation.

In chapter 9, realistic intra-individual variation in earprints is compared with a very small degree of inter-individual variation, i.e., that in prints of identical (monozygotic) twins. To our knowledge, our study is the first time that any method capable of fully automated earprint comparisons has been described.

We first provide an account of the corresponding characteristics and the differences that occur between prints of the individual members. We evaluate differences in both content (i.e., presence, shape and intensity of imprinted features) and geometry (i.e., position of imprinted features). Differences are visualized by way of digital overlays. Differences in geometry are further evaluated by performing a hierarchical cluster analysis using variables derived from the position of seemingly corresponding features.

As a next step, we explore a method to fully automatically analyse prints. In this approach, an algorithm is used to study the variation in earprints. The algorithm automatically detects and describes salient regions in an earprint. The appearance and constellation of the described regions in a given print is then compared with that in all other prints included in the study. The number of matching regions expresses the level of similarity between any two prints.

The results of this study may be analysed in terms of a hit-list, i.e., a list of prints ranked according to their degree of similarity to a given print. The method may therefore provide a tool for recovering matching earprints from a database. The number of similar regions found between two prints may further by used as an indicator of the evidential value of a print match: the higher the number of matching regions, the higher the evidential value of the match.

In chapter 10 we discuss the use of earprints in forensic investigations and as evidence in court. Theoretical and practical issues concerning the use of earprints are addressed. We further provide a summary of results from the previous chapters. Finally, we provide some recommendations for future earprint use. As statements on individualization cannot be made with certitude, we feel that experts should be trained to acknowledge this when expressing their opinions. Their opinions should further reflect the degree of similarity between print features in the context of their discriminating power. Forensic investigators as well as the judiciary should be aware of the consequences of a probabilistic view on individualization, and of the terminology involved. Ideally, opinions should be corroborated by objectively calculated match likelihoods, obtained from validated automatic classification systems and large representative samples. Finally, we encourage the application of a blind test in which candidates are subjected to a great variety of earprints, including prints offering low evidential value.