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Investigation into the Detection of Drug Metabolites in Latent Fingerprints

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INVESTIGATION INTO THE DETECTION OF EXOGENOUS DRUG METABOLITES IN LATENT FINGERPRINTS

By

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For Mom and Dad

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Abstract

Fingerprinting has proved a useful mode of identification for thousands of years. Following numerous technological advancements, it has become a technique for categorizing and keeping track of people over large geographical spaces for almost half of a century. Those living in the beginnings of fingerprinting used them as a form of signature as it was something completely unique to each individual that could not be replicated. Although they are no longer used as the primary form of signature, it certainly remains a biomarker of identity. Over the past century the practice has been heavily refined in order to identify people from a wide variety of geographical areas with a centralized database referred to as AFIS. However, taking into account these improvements in technology, the invention of photography and a relatively newfound ability to preserve and relocate latent fingerprints, there must be more information that these accidental or intentional clues can provide in forensic or clinical settings. In this thesis paper, we look to expand the uses of latent fingerprints by determining whether exogenous drug metabolites can be detected from latent fingerprint samples. Our reasoning is that when a person has illicit or medicinal substances in their bloodstream, metabolites of these substances will be excreted during perspiration, which would then be left behind on any surface following physical contact. The proposed instrumentation to carry out this experiment include GC-MS, ESI-MS, and DART. Each of these methods use a different pathway of processing to analyze the makeup of an extremely small sample. We found these methods desirable due to the sample size they can accommodate, which provides a realistic standard for evidence collection in a forensic setting. We also

believe that two or more of these methods may be used in tandem in order to extract any and all evidence from the sample.

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List of Abbreviations

AFIS	Automated Fingerprint Identification System
ACE-V	Analysis, Comparison, Evaluation, Verification
DART	Direct Analysis in Real Time
GC-MS	Gas Chromatography-Mass Spectrometry
ESI	Electro-Spray Ionization
IAI	International Association for Identification
CLPE	Certified Latent Print Examiner
MeOH	Methanol
Mol	Moles
NPS	Novel Psychoactive Substance
BCE	Before the Common Era
SPE	Solid Phase Extraction

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1 Introduction/Background

1.1 The History of Fingerprinting

The fingerprints that a person is born with will persist with them until death, making it a reliable and consistent method of identification throughout a person's life. Although some genetic disorders, such as Trisomy 21 or Down Syndrome, can impact the pattern one's fingerprints may take, it does not impact the fact that each person's fingerprints are unique. Additionally, even identical twins do not have identical fingerprints. The papillary ridge patterns of identical twins are very similar, but they will never be identical.

Fingerprints have been studied as important identifiers throughout recorded and prerecorded history. Since fingerprints are an evolutionary development, with the function of aiding humans grip objects by creating strong friction between the object and the finger, people have always had them and became aware of them very early in history. All humans have these patterns on the pads of their fingertips, except for those with a very rare genetic mutation called adermatoglyphia, also known as 'immigration delay disease.' Through acquisition of archaeological evidence, experts can firmly say that throughout the prehistoric era, people understood that no two fingerprints were alike, an assertion that has been confirmed in the common era.

Around 1900 BCE, Babylon's writing system, cuneiform, was not suitable for personal signatures. One of the ways this gap was filled was through the use of fingerprints, which were used as personal seals to protect against forgery and falsification. These can still be found on clay tablets, the preferred medium for written

communication used at the time, as clay is a much more durable medium than paper or papyrus. These clay tablets may have been used for business transactions such as trade agreements or perhaps simply to indicate ownership, very similarly to how we utilize signatures in the modern era.

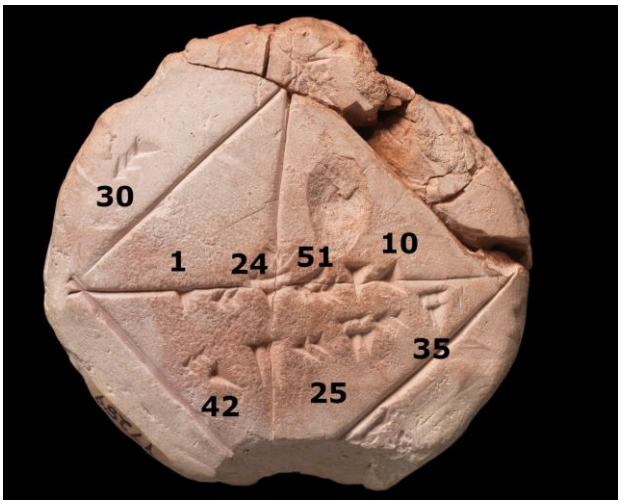

Figure 1 Labeled photograph of the Yale Babylonian Collection's Tablet. This was a mathematical tablet that was 'signed' with a fingerprint left by the person working on it.

Evidence suggests that law enforcement officials at the time of King Hammurabi about 150 years later took the fingerprints of those that they had arrested. In the Qin and Han Dynasties of ancient China (221 BCE - 220 CE) as well, seals using papillary ridge impressions were used as signatures and other methods of identification. More specifically, evidence suggests the Qin Dynasty used handprints as evidence in burglary investigations.

Figure 2 Clay Seal with Fingerprint from the Qin or Han Dynasty of Ancient China

About 1500 years later, in the Persian Empire, Khajeh Rashiduddin Fazlollah Hamadani's *Jaamehol-Tawarikh* presents the existence of a long-standing identification practice in the region using a person's fingerprints. Moving to the 17th century, Dr. Nehemiah Grew is the first European to publish observations regarding the skin of the finger pads. This is followed by Dr. Govard Bidloo's 1685 book *Anatomy of the Human Body* that includes details regarding the anatomy of the papillary ridge. This marked the beginning of a centuries-long interest in various uses of fingerprints.

This project is largely concerned with the forensic uses of fingerprints. The first recorded instance of fingerprints as evidence in the pursuit of justice occurred in Argentina in 1892, when Francisca Rojas' fingerprints were used to prove that she had killed her children only one year after fingerprints came into forensic use. Rojas was found wounded amidst the bodies of her children, and attempted to frame her neighbor. She claimed that she rejected his sexual advances, and he promptly became angry and threatened her. She alleged that she later saw him fleeing her house before walking in to find her children's bodies. However, this explanation did not account for Rojas' bodily wounds. Additionally, the neighbor was questioned and vehemently insisted that he had nothing to do with the crime. During evidence collection, Inspector Eduardo Alvarez

found a bloody fingerprint on the door of the bedroom, and sent it to Juan Vucetich, whom Alvarez knew was developing a fingerprint classification system for police use. The fingerprint was tested against those of both the neighbor and Rojas, and found to be a match for the latter. When confronted with this evidence, Rojas broke down and confessed to the crime. She had wounded herself and killed the children, her motive being a new suitor who was interested in a relationship with her but did not want the children. This investigation was a massive step towards the forensic use of fingerprinting.

Through the nineteenth century, Bertillonage, created and proposed by Alphonse Bertillon, was the standard method of identification of arrested persons. The system entailed identification through detailed record of anthropometric measurements. There were many limitations of this method. Mainly, it took an exceptionally long time to collect all of the information required by the system for adequate identification. Even then, the measurements were not guaranteed to be accurate or even enough to distinguish one person from another, as we will soon discuss in the William West-Will West case. Another limitation is that much of the data collected through Bertillonage could not be quantitatively connected to the scene of the crime. Some hair may have been left behind, the color and texture of which would have been recorded and may aid in investigation, but one cannot leave their height or eye color behind as evidence.

Around the same time as Bertillon's development of Bertillonage, Francis Galton also expressed interest in human anthropometry. However, his research took him down a different route. His attempts to determine mental characteristics from facial features eventually led him down the path of fingerprinting. In 1890, Galton published a paper that distinguished between the important fingerprint characteristics that could allow

comparison of humans. To this day, Galton is considered a pioneer in the field due to his desire to demonstrate how fingerprints could aid in the scientific identification of individuals. His early research contributed strides to the fingerprinting community.

The Henry System of Fingerprint Classification was created in 1897 by Azizul Haque and Hem Chandra Bose. This is a method of fingerprint indexing via physiological characteristics that replaced Bertillonage as the standard for categorization. Living in colonial India and knowing that native Indian citizens Haque and Bose had no chance of winning an appeal against him, their British supervisor, Inspector General Sir Edward Henry. took credit for their work while presenting it to his superiors. However, Henry backtracks a bit and begins to give Haque and Bose their deserved credit about twenty years following his assertion that he created the System of Fingerprint Classification. His timeline seemed to overlap with Haque's and Bose's promotion to Deputy Superintendents, a position making them more able to defend themselves against the blatant theft of intellectual property regardless of their imperial status. Additionally, someone asked Henry to recreate his method of devising the system, and he was unable to do so, which may have contributed to his admitting of the creators' due credit.

Fingerprints were accepted as evidence in British courts in 1901, ten years before they were accepted in US courts.

In 1902, the William West-Will West case changed the way that people were classified and identified using fingerprinting. Although the issue in the William West-Will West case was largely created by racism and incompetence, the method used to solve the case still aided in pushing the use of fingerprinting to the system we recognize today. Due to the perceived 'homogeneity' of people of color, the police documented

William West and Will West, both African American men, as a single person, despite a seven millimeters difference in height. This quickly became a problem, as it appeared that William West was in two places at one time, and at the same time found that they had an extra inmate. To rectify this, they used the aforementioned prehistoric knowledge that no two people could have the same fingerprint and recorded the two mens' fingerprints to distinguish between them. This story quickly made the rounds in the pro-fingerprinting circles of the early 20th century, where it lost much of the racist connotations but retained the progressive use of fingerprints. Despite this, United States courts did not accept fingerprints as a reliable way to identify people in criminal investigations until 1911.

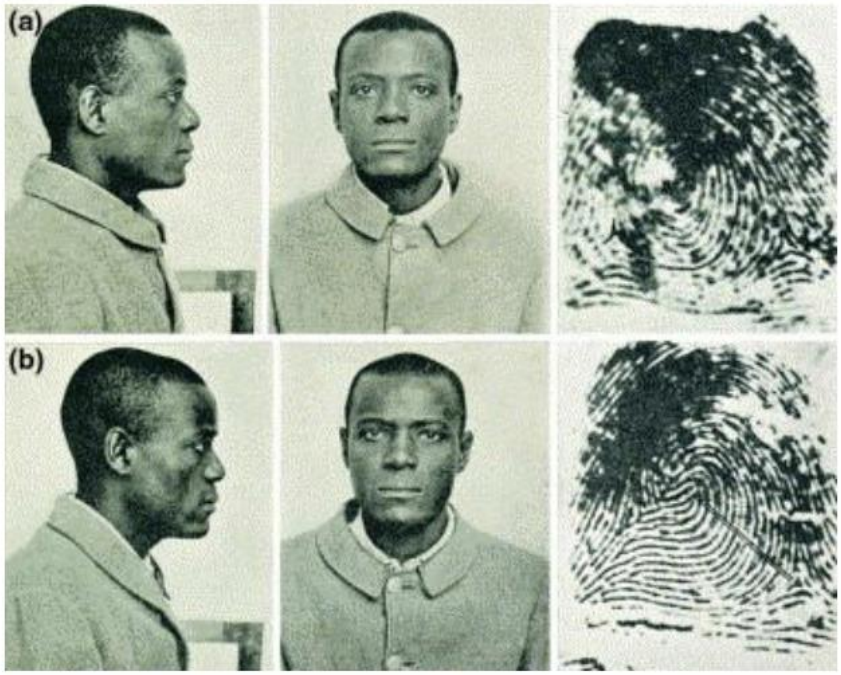

Figure 3 The mugshots of William West and Will West alongside their recorded fingerprints.

That very year, the Thomas Jennings case became the first trial where fingerprints were used as evidence to help reach a murder conviction. During an armed robbery gone

awry, Clarence Hiller was shot three times in his home. The alleged assailant, Thomas Jennings, was found half a mile away covered in blood with a revolver in his hand. In evidence collection, it was discovered that the assailant had left a fingerprint on a freshly painted railing within the house. The entire railing was collected as evidence and the fingerprint matched to that of Thomas Jennings. Members of the jury considered the fingerprints as crucial in their conviction. They were then considered substantial enough to warrant Jennings' execution the following year. The method of fingerprint collection and comparison used in 1911 remains similar to the techniques that are used in the modern justice system. Although it is an efficient method of identification, the fact that it has been the primary use for fingerprints for over a century renders it a bit outdated.

In the century following the Jennings case, the use of fingerprints became commonplace in forensic settings and in the justice system. The International Association for Identification (IAI) was established in 1915 as the first professional forensic organization. Following this, in 1977, the first certification program for professional forensic scientists was established by the IAI, the Certified Latent Print Examiner (CLPE) program. In 1980, the Automated Fingerprint Identification System (AFIS) was developed as the first centralized fingerprint database. Fingerprint analysis is now commonly used to verify the identities of those present at the scene of a crime in addition to tracking a person's arrest, parole, or other criminal records.

It is important to note that the history of fingerprinting is intertwined with a history of racism. Although we have been able to make great strides forward in this classification method, it was often at the cost of people of color.

1.2 Classification of Fingerprints

Latent fingerprints can be found on any solid surface, the human body included, and are formed when substances such as oils and sweat on the skin are deposited following physical contact. These fingerprints are more difficult to collect than their counterpart, visual patent fingerprints, since they are not readily visible and cannot simply be photographed. Assuming that a scene has not been disturbed or tampered with in any way, latent fingerprints can be lifted and analyzed in a laboratory. The purpose of this analysis is to identify the person that left them.

There are limitations of latent fingerprints and their consequent analysis. For example, there must be a known print for comparison. If the person does not belong to a database, there is no way to determine the owner without them being present, which can limit their use in forensic analysis in that they may be admissible in court following an arrest but they will not be of use in apprehending a suspect. This is a prevalent issue because AFIS is limited to criminals, suspected criminals, military and government personnel and a handful of others, leaving many others unidentified. Another major drawback of AFIS is the issue of interoperability between softwares. The distribution of AFIS to various vendors and software designers has led to multiple stand alone softwares that cannot be used interchangeably. This could lead to a situation in which the person's fingerprint is in a database, but it cannot be accessed due to the interoperability, or lack thereof, of all of the different databases.

Additionally, there is currently no way to determine the time that the print was deposited. This could lead to the arrest of an innocent person, or the finding of a fingerprint at a scene belonging to someone who was not there during the relevant time

period. Finally, it is impossible to determine age, sex, or race from a latent fingerprint. If the print is insufficient for comparison or the owner does not belong to any database, then current techniques of analysis render the fingerprint useless. Unless a suspect is apprehended, and their prints can be compared to a collected and complete fingerprint, there is little or no use for this particular evidence.

Patent fingerprints are readily visible to the naked eye, and can be photographed for analysis without further treatment.

1.3 The Collection of Fingerprints

The collection of latent fingerprints can be quite complicated. A common and simple method is dusting a smooth, nonporous surface with fingerprint powder, making any samples present visible for photography and lifting with an adhesive tape. While this method is popular and easy to perform, it is largely destructive. Fingerprint powders often contaminate evidence and prevent investigators from performing any other analysis that may reveal more fingerprints or other pertinent information that could aid in the investigation. Different methods, such as the use of a laser or LED device in conjunction with cyanoacrylate fuming, can allow investigators to visualize the fingerprints without destroying the sample.

Another limitation of the fingerprint powder method is that it is only available if the fingerprint has been left on a smooth, nonporous surface. A porous surface, such as paper, must be processed with chemicals such as ninhydrin to reveal a latent fingerprint. These chemicals cause the fingerprints to fluoresce or change colors in order to increase visibility and allow them to be photographed. On clothes, vacuum metal deposition using gold and zinc may be used. On rough or otherwise textured surfaces such as human skin

or curved surfaces, a liquid casting compound is used to lift a powdered fingerprint. The casting method is used to lift prints from ‘difficult’ surfaces, but it is more commonly used for bite and tool mark impression collection. However, all chemical processing is destructive and can prevent the investigator from further investigating the fingerprints in order to reveal any more available evidence. Any additional collection of evidence must be nondestructive and must be performed before any chemical treatment takes place.

1.4 Analysis of Fingerprints

After collection, processing usually follows the standard ACE-V method to obtain maximum information from the fingerprint. Analysis is the first step, in which a print is assessed to determine if it can be used for comparison with a database. If it cannot be compared, the processing ends. If it can be compared, the features that can be used, their tolerances, and any physical features that help indicate where to begin are marked. C stands for comparison, which is done by looking at the known fingerprints right next to the collected fingerprints. Evaluation follows, where it will be decided whether the collected print and the known print came from the same source, different sources, or if it cannot be determined. Verification is the final step, where another examiner independently repeats the process in order to confirm or refute the conclusions. This last step can aid in preventing false accusations or the use of subpar evidence in the conviction of a suspect.

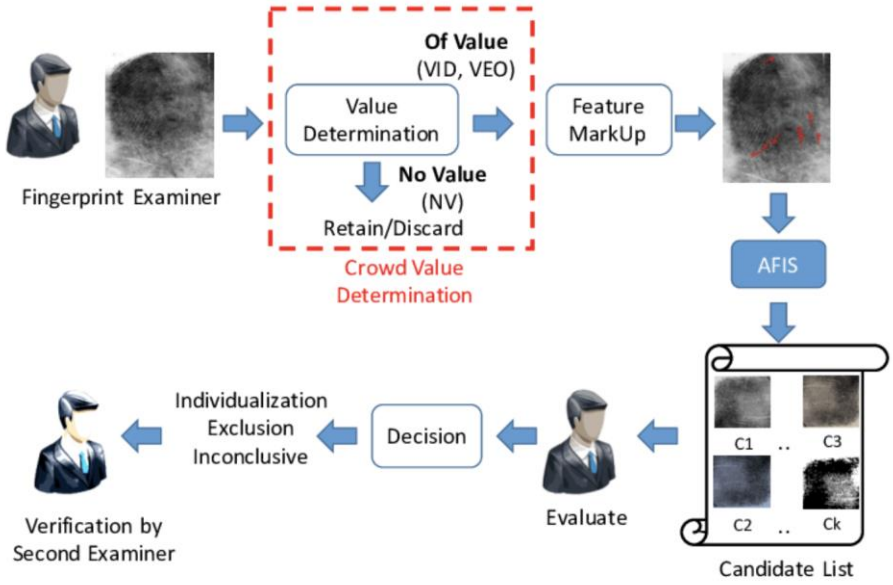

Figure 4 The ACE-V method of fingerprint analysis.

There are many points in this pipeline, as mentioned, where the analysis could be halted. Upon such an obstacle, the fingerprint would likely be marked as incomparable and become obsolete. The comparison step is a critical moment of truth for the analysis of the collected fingerprints. If the fingerprints are not available in AFIS, the analysis of the fingerprints must stop, as there is nothing to do in the current scope of analysis. Our goal is to prevent the loss of these fingerprints as valuable evidence.

The current method of fingerprint analysis does have its faults, but it also brings along with it many advantages. For example, fingerprint comparison of just a single finger is accurate more than 98% of the time. Especially in the absence of DNA evidence, fingerprints are crucial to conviction of criminals when they are found at the scene of interest.

2 Proposed Methods

2.1 GC-MS

Gas Chromatography-Mass Spectrometry is an analytical technique that combines the features of two distinct processes in order to identify the different components that constitute a sample. This method can be used to study samples in a solid, liquid, or gaseous state.

Gas Chromatography is an umbrella term used to describe a number of techniques that separate and analyze compounds. It is one of the few methods that does not interact with the mobile phase of an analyte, but is rather interested in the stationary phase. Different types of gas chromatography are useful for different analyses. Gas Chromatography-Mass Spectrometry in specific is the branch of gas chromatography useful for analyzing whole molecules.

Samples must be separated from any existing matrices before being introduced to the GC-MS equipment. The extraction processes differ between samples, determined by the matrix, the sample's purity, and required selectively of the analysis. These extraction processes may include headspace sampling, pyrolysis, or multiple forms of solid-phase extraction(SPE). SPE is most commonly used while dealing with biological samples, headspace sampling is mostly used for blood, cosmetics, or samples with high water content, and pyrolysis is used for samples whose additives have yet to be identified.

The process begins when a sample is vaporized into the gas phase and separated into various components by the stationary phase coated capillary column in the gas

chromatograph. The components are propelled by an inert carrier, meaning that it will not interfere with the reaction, and the time of elution (retention time) is determined by the individual components of the compounds. Upon departure from the gas chromatograph column, the components are ionized, meaning that they become gas phase ions suitable for analysis, and fragmented, or broken apart, by electron or chemical ionization sources. The fragments are then pushed through the instrument's mass analyzer, where they will be separated based on their mass-to-charge (m/z) ratios. The components can then be analyzed as fragmented ions shown as a function of their m/z ratios. The largest peaks indicate the most stable fragments of the molecule in question. These fragments can be used to trace the breakdown of the molecule and therefore positively identify the compound.

GC-MS brings with it significant advantages. As a hybrid method, it offers larger sample identification, high sensitivity, and an increased range of analyzable samples. Combining the abilities of gas chromatography and mass spectrometry has created a technique that has an exceptionally large range of applications. GC-MS is also fast, making it an efficient method of processing for a wide array of samples. Finally, it produces sharp and reproducible peaks, which makes it a reliable use of collected compounds.

However, limitations of GC-MS are that it is destructive and limited to thermally stable and volatile compounds. The destructive nature can be justified by the reliability of the results obtained, but the limitation of compounds significantly decreases the amount of compounds that can be detected with this equipment.

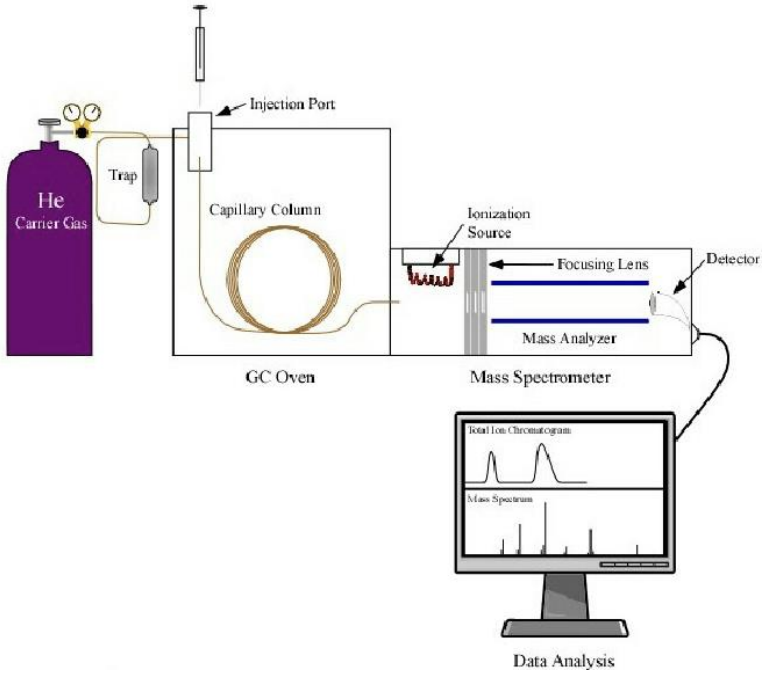

Figure 5 Schematic of Gas Chromatography Mass Spectrometry Equipment

2.2 ESI-MS

Electro-spray ionization-mass spectrometry is a desorption ionization method that begins with the spraying of a sample through a highly charged needle, called an ESI capillary. The resulting charged droplets are oxidized after entering a desolating capillary in order to cause solvent evaporation. Solvent evaporation leads to Coulomb repulsion between charges, and ultimately to the formation of individual gas phase analyte ions, which are then guided into a mass analyzer. The number of charges retained by an individual analyte depends on a multitude of factors such as size, structure, chemical composition, and instrument parameters. The retained charge can help us identify compounds.

ESI-MS is separate from GC-MS in that it accommodates samples that are nonvolatile or thermally fragile. It can also analyze organic samples that have non-

covalent interactions. Due to the sensitivity of the instrument, it is a reliable technique. However, it requires larger sample sizes than GC-MS or DART, and the range of sizes it can accommodate is relatively small. It also cannot analyze mixtures with great accuracy, which discourages use in drug detection where multiple compounds may be present. These drawbacks could potentially limit the practical use of ESI-MS.

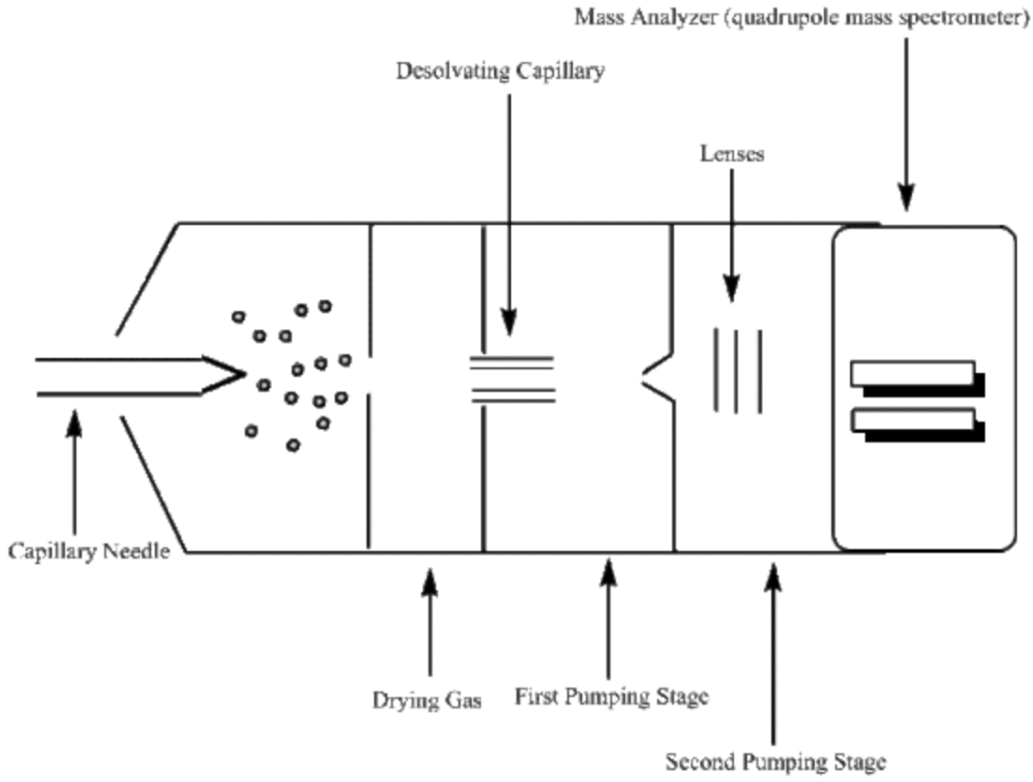

Figure 6 Schematic of Electro-spray Ionization Equipment

2.3 DART

Direct analysis in real time takes place at atmospheric pressure, which distinguishes it from other spectrometry techniques. The process begins by directly volatilizing analytes using a heated flow of gas containing metastable helium or nitrogen. Metastable means

that the element will remain at equilibrium if it does not experience anything more than minor disturbances. This takes place at the entrance of the mass spectrometer, out of which ionized particles will be released and transferred into the mass analyzer. If the process operates in the positive ion mode, the ionization of the analyte will happen either through penning ionization, a domination reaction mechanism using nitrogen or neon in the DART source, ammonium attachment, which can allow the operator to customize the experiment, or proton action. Negative ions can also be observed, as rapid switches between positive and negative modes are permitted by the polarity of the ion source. The spectra produced are relatively simple and fragment ions can be observed to identify the makeup of the compound. DART has already been pinpointed in the last decade as a technique of interest in analyzing drugs of abuse, as that is in fact the most popular use of this method of spectrometry. A major problem within the forensic system is the amount of novel psychoactive substances (NPSs) that are being seized by law enforcement. These drugs are new compounds made to mimic the effects of psychoactive drugs that are already circulating, for example, cannabinoids. The issues with these drugs is that their use is often linked to severe health reactions and that some are legal while others are not and the two are not easily distinguishable. DART is one of the only methods able to detect and even begin to analyze these compounds, making it all the more desirable for our purposes.

DART is a desirable method due to a multitude of additional factors. The method is nondestructive, stemming from its performance of non-contact detection of compounds on surfaces. This allows quick and efficient use in a forensic lab, and without the worry that after processing, the window of evidence collection will be closed. This

could allow detection of metabolites followed by the aforementioned identification techniques. Additionally, it is very sensitive, meaning it will be able to detect a compound even if it is present in a very small amount. However, the sensitivity of DART may also be viewed as a limitation, as it may become a barrier to providing accurate results.

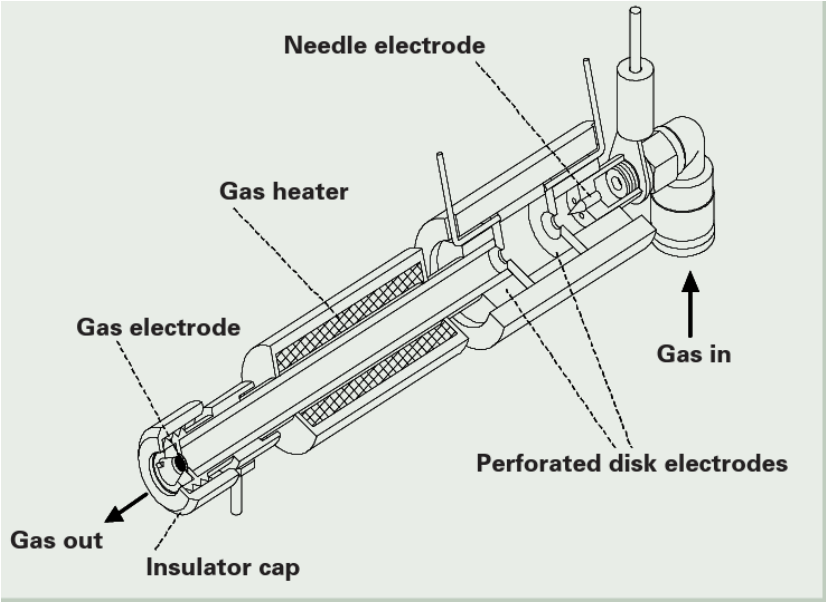

Figure 7 Schematic of Direct Analysis in Real Time Equipment

3 Purpose

The use of fingerprints as a means of identification can be found throughout recorded history, in addition to evidence of its use in prehistoric times. We now have the ability to access a database to match fingerprints collected at various locations to the person that was responsible for its deposition. However, the fingerprints recovered from scenes of interest are not always suitable for matching against this database. In that case, they may be discarded as useless evidence. If the fingerprint is incomplete, it may not yield much information, and thus it may not be used in the investigation. A final drawback to fingerprint comparison is the lack of interoperability between what has become multiple independent softwares. We aim to find a use for fingerprints found in a forensic setting that can be used in addition to identification databases or in a situation that renders identification impossible. The use of fingerprints for more than simply identification can aid in investigations by allowing a more efficient use of evidence and preventing inaccurate conclusions that can prevent perpetrators from being held accountable.

The rationale for this proposal is that when one has ingested a substance, metabolites can be found in their sweat. Previous studies have shown that sweat patches allow the accumulation of drug metabolites that the subject has injected. Since we know that metabolites are present in human sweat, and we know that mass spectrometry methods can accommodate an extremely small sample size, we are interested in combining these two ideas to find drug metabolites in samples from latent fingerprints.

Additionally, fingerprints are a noninvasive method of human data collection. Invasive measures include any number of procedures that enter the body or puncture the skin, whereas their noninvasive counterparts occur at the surface level. The more evidence that can be extracted from these noninvasive measures, the better. This both prevents invasion of personal space of people, both innocent and guilty parties, and allows evidence to be accessed more easily than a blood draw or a cheek swab. This would also decrease processing time, as the time to collect and analyze more invasive pathways of human based data can be quite long. The steps in these pathways include much more red tape than that of fingerprint collection, for the aforementioned reason of protecting the privacy and personal space of citizens. A warrant is required for collection of evidence involving people, barring a few specific instances. The police may take photographs, collect fingerprints, and a few other noninvasive procedures without presenting a warrant.

The purpose of this experiment is to determine an additional use for the fingerprints left behind at various scenes of interest. We explore the possibility of drug metabolites being lifted from these fingerprints through various spectrometry techniques. For example, a suspect may be taking a certain medication, but the fingerprints at the scene may not present metabolites of those drugs following laboratory analysis. This would allow an extra layer of identification, should the owner of the fingerprints not already be recorded in AFIS or other such databases or the latent print itself not be suitable for comparison. It would also add certainty even if they are found in a database, and the more sure a law enforcement official can be, the better. This can accelerate the apprehension of suspects, increase certainty when making arrests and prosecuting

criminals as well as decrease slanderous accusations due to false arrests. Our method would benefit society by helping catch criminals quickly and with certainty while preventing life altering false accusations. While an inaccurate accusation may be wiped from one's record, it could still impact their relationship with their community, a potentially negative outcome of investigations that must be avoided whenever possible. It is imperative that the method not only be accurate, but also timely and thorough. All of these criteria must be met in order for an analysis method to be adopted practically due to the sensitivity of the issues, both in the matter of time and subject. The room for error in a forensic setting must be kept as low as humanly possible, which must be considered when proposing new instrumentation and methods.

The proposed methods would also be performed in house, without outsourcing to different labs. Outsourcing due to lack of capacity or technology increases the time and cost of analysis. Preventing this will allow for more evidence to be acquired without sacrificing the speed and efficiency required in a time-sensitive field such as forensics as well as a more efficient use of taxpayer dollars. However, it is important to note that outsourcing is sometimes a result of court orders, which may not be avoided by new analytical techniques. We hope to present a multitude of possible techniques that can be applied to all collected fingerprints to expand evidence utilization.

4 Proposed Analysis

Should the proposed experimentation be performed, the researchers would be presented with a series of spectra for analysis. Below will be a presentation of a series of example spectra and a detailed process of analysis for each. The first is an example spectrum for cocaine, $C_{17}H_{24}NO_4$, which would likely be a drug often tested for in a forensic setting. The second example spectrum is for diacetylmorphine, $C_{21}H_{23}NO_5$. These two substances were chosen as they have already been investigated as potent in the sweat of those who have ingested them.

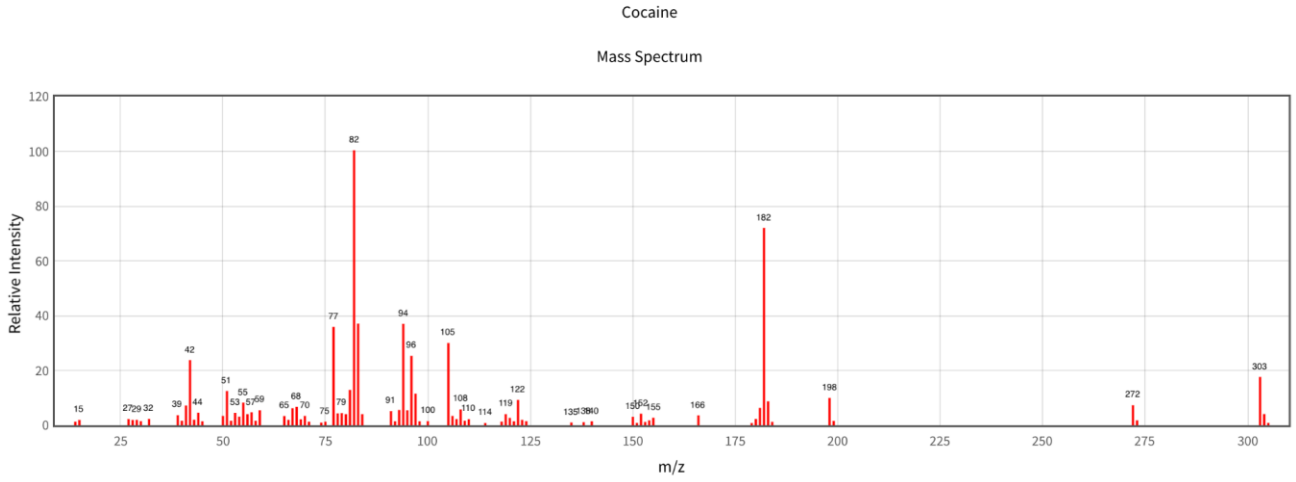

Figure 8 Example spectral results for $C_{17}H_{24}NO_4$ (Cocaine).

In these spectral results for cocaine, we can clearly see the fragmentation of the molecule. The parent peak, which represents the molecular weight of the complete molecule, can be found at 303 m/z on the far right, and from there we can trace the breakdown of the molecule to its most stable fragments. Upon the loss of a nitrogen and its attached methyl group, we come to the next most stable peak at 272 m/z. The benzene

ring is the next to go, bringing the molecular weight to 198 m/z. The additional loss of a methyl group produces one of the most stable peaks in the spectrum at 182 m/z. Both ester groups leave throughout the next few steps of fragmentations, leaving the most stable fragment produced in the spectrum at 82 m/z. The remainder of the fragmentation can be traced and attributed to the further loss of carbons and hydrogens until the molecule is completely broken apart.

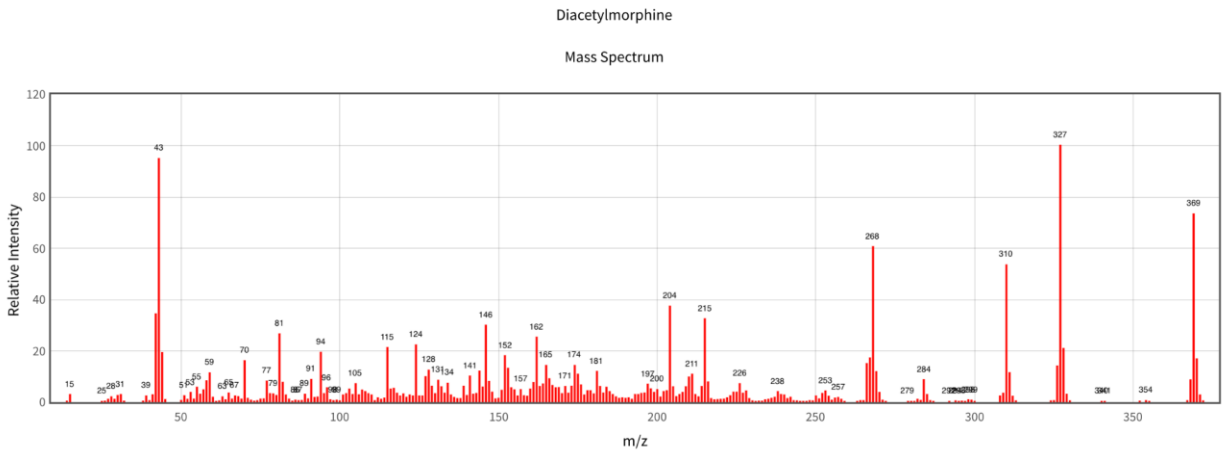

Figure 9 Example Spectral Results for $C_{21}H_{23}NO_5$ (Diacetylmorphine).

In the spectral results for diacetylmorphine, more commonly known as heroin, we are again able to trace the breakdown and identify landmarks of fragmentation. One of the first major fragmentations is the loss of an ester group, bringing the molecular weight from approximately 360 amu to 310 amu. The next is the loss of a nitrogen and two attached carbons, leaving the molecular weight at 268 amu Following the loss of the other ester group, the molecular weight sits at 209 amu, which is demonstrated by the peak at 204 m/z. The loss of additional carbons and hydrogens brings the molecular weight to 143 amu, represented by the peak at 146 m/z. The loss of the final additional oxygen is marked by the peak at 124 m/z. The remainder of the peaks can be explained by the further loss of hydrogen and carbon, including a very distinctive peak at 43 m/z.

5 Discussion

Through this experiment, we hope to make strides in the search for additional uses for collected latent fingerprints. From our presentation of the proposed analysis as well as previous studies, we are confident that this line of inquiry could produce valuable insight into future evidence processing. The methods proposed in this experiment will be employed in order to determine additional uses for valuable evidence.

A separate study on the buildup of drugs may need to be done in order to determine which are suitable for GC-MS analysis. As mentioned in the methods, GC-MS is only suitable for thermally stable and volatile compounds. Any illicit drugs or medications that are thermally fragile and/or nonvolatile would not be detected through GC-MS. An example of a nonvolatile substance would be alcohol, which would be useful if detected in a forensic setting. If no drugs are detected in the sample, investigators may conclude that the suspect was not under the influence. However, they may have been intoxicated due to alcohol, which could change the perspective needed to apprehend the suspect.

In a future where ESI-MS becomes an efficient method of analysis, it may be effectively used in tandem with GC-MS. A major drawback of GC-MS is the lack of accommodation of thermally fragile and nonvolatile compounds. ESI-MS does accommodate these, and thus fills a significant gap left by GC-MS. This spurs further interest in ESI-MS as a drug detection technique. However, the limitation that ESI-MS cannot reliably analyze mixed compounds as well as the small range of sample sizes it can accommodate may decrease the practical use of this analytical technique.

Moving forward, there are many opportunities to further this research and perform the proposed experiments. Additionally, there are a multitude of mass spectrometry techniques beyond those detailed in this paper that could prove useful for the detection of drug metabolites. Those that are nondestructive, such as DART, should be explored in great detail in order to avoid destruction of evidence when possible.

The use of DART in a forensic setting is already being explored as a highly desirable option. As mentioned previously, the issue of NPSs is especially prudent in the United States. While the legality of NPSs remains a gray area, they are still causing law enforcement and medical personnel a lot of trouble. The use of DART to detect and analyze a suspected NPS would have a wide array of benefits. It would allow a law enforcement officer to determine if the suspect has broken possession or substance use laws, and it may assist medical personnel in determining how to treat someone who has been using the substance. Another large reason that DART is a desirable method is due to its non-destructive nature. A sample can be tested for drug metabolites, and then continue to be analyzed following DART processing. Additionally, the sample does not have to be prepared in any particular way for DART to be able to analyze it. This makes it a quick and efficient method of analyzing evidence in house.

The use of latent fingerprints as evidence beyond identification would have a wide array of benefits both in forensics and within the criminal justice system. For example, if a crime has been committed and a latent print has been left behind, it will be lifted from the scene and taken to a lab for processing. If the fingerprint is incomplete, it could be rendered obsolete and not be used as evidence. However, if processing can be

used to detect medications or illicit drugs, these can be used to narrow a list of suspects and place them at the scene, and therefore to make more certain arrests.

As seen in the proposed analysis section above, the tracing of fragmentation of substances reveals landmark fragments that are telltale signs of specific drugs such as cocaine. In addition to being a cheaper option, this process being performed in house would allow the quick analysis of substances present in the samples.

Additionally, if an arrest needs to be made but there is insufficient evidence, the drug metabolites in latent fingerprints may be of use as well. If the suspect has been using illegal substances, the processing of their fingerprint would allow detection of those substances. Studies have already shown that cocaine and heroin, common and illegal drugs of abuse, are well detected in sweat. A fingerprint that has been sampled and tested for these drugs of abuse would implicate the suspect of a crime in addition to the primary crime being investigated. Therefore, an arrest could be made for substance abuse or possession while the justice system continues to gather the evidence needed for the crime in question. This could keep dangerous individuals from walking free due to a lack of evidence, and the countless cases where people who more than likely committed a crime walked free could be curbed. For example, cities with increased gang activity see both high rates of drug circulation and high rates of murder, and the two crimes are often intertwined. While it may be difficult to accrue evidence for murder, evidence of drug possession may be easier to come by. The perpetrators can be arrested for drug charges, while further evidence is collected for possible murder charges.

When a piece of evidence is recovered, it must be wrung out to reveal all of the information it has to offer. In many cases, the evidence is few and far between, and

investigators must extract as much information as possible with what little resources they have. Studies have found that less than thirty percent of cases have any forensic evidence. A significant reason for this is that there is often no forensic evidence to be collected. However, when forensic evidence is collected and requests for analysis are made, the majority of these cases involve requests for latent fingerprint analysis. Finally, when there is forensic evidence to be analyzed, the rate of case closure significantly increases. With this in mind, it is imperative to find more uses for fingerprints than those currently available. Fingerprints have been used for centuries as a method of identification, and although the technology and scope of identification methods has improved drastically, the use of fingerprints has not expanded a notable amount. As noted in the introduction, the standard fingerprint collection and analysis techniques have remained largely the same since the Thomas Jennings case rendered fingerprints admissible in court over one hundred years ago. We believe that through GC-MS, ESI-MS, and DART, another way to use these pieces of evidence, which are already critical to investigations but only conditionally, can be discovered. This method can provide a use for collected fingerprints that would have previously been discarded, decreasing the waste of evidence, and increasing the certainty of investigations.

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