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HUMAN SCENT DETECTION: A REVIEW OF ITS DEVELOPMENTS AND FORENSIC APPLICATIONS

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Abstract: Human scent evidence can be of critical use in many cases where other types of evidence such as DNA, fingerprints, or fibers are not available. The use of canines within the area of law enforcement scent detection and forensic science often involves locating general human scent but is increasingly related to their ability to correctly match a human scent sample with its originating subject. Various challenges that have surfaced in courts of law across the United States relate to the validity and efficiency of this technique that employs biological detectors to alert to specific human scent. Additional concerns correspond to the actual human scent composition and its ability to transfer and be detected by the canine at different locations. There is little information as to the specific odor signatures the canine is alerting to when it makes a positive scent match with a subject. Until recently, studies of human odor have been focused mainly in the composition of human sweat or body malodors rather than the total volatile odor chemicals that emanate from humans. This article is a review covering the challenges and usefulness of scent-discriminating canine/handler teams and discusses various factors and theories of how human odor is produced, collected and used as a potential marker for individuality.

Key Words: human scent evidence, human odor, odor signatures, scent detection, scent-discriminating canine

Resumen: La evidencia del olor humano puede ser de uso crítico en muchos casos donde otros tipos de evidencia tales como el ADN, huellas dactilares, o fibras no están disponibles. El uso de perros en el área de detección de olor humano para usos policiales y en ciencias forenses está estrictamente relacionado con su habilidad de relacionar correctamente un olor humano con el olor que proviene del objeto de referencia. Varios desafíos que han aparecido en las cortes de justicia a través de los Estado Unidos, cuestionan la validez y la eficiencia de esta técnica que usa detectores biológicos para responder a un olor humano. El conocimiento tan limitado se origina de aspectos no definidos concernientes a la definición de la composición del olor humano y su transferiencia y detección en relación con el comportamiento de los perros en la escena de un crimen. Existe muy poca información en referencia a las huellas de olor que el perro identifica cuando hace una identificación positiva con el objeto de referencia. El origen del olor humano ha sido enfocado principalmente a la composición del sudor humano más que a una definición general del olor humano corporal. Este artículo servirá como una reseña para entender los retos y las utilidades de los equipos de perros adiestrados para discriminación olfatoria y para evaluar varios factores y teorias de cómo se produce y se colecta el olor humano y cómo el mismo es usado como un marcador individualizante.

Palabras clave: human scent evidence, human odor, odor signatures, scent detection, scent-discriminating canine.

HUMAN SCENT COMPONENTS

The use of human scent discriminating canines for the purposes of criminal investigations lies in the idea that human odor is a unique physical characteristic of every individual and that this odor is left at every location, object, or path which the subject has come in to contact with. The definition of human odor, however, cannot be limited to one factor and thus can be attributed to skin oils, sweat and volatile compounds emanating from the skin surface. In turn, some of these natural body processes can be affected by heredity, environment, and daily lifestyle activities which allow an individual to produce a characteristic odor (See Figure 1)[*1,2*]. The biological function of body odor production relies on the three types of secretory glands in the human skin. Two of these are normally called the "sweat glands" which are the eccrine and apocrine glands, with the third being the sebaceous glands. The aqueous portion of skin secretions originates mostly from the eccrine sweat glands which consist of entirely water along with dilute salts. The sebaceous glands are closely related with hair follicles and continuously secrete oils, or sebum. Sebaceous glands are found throughout the body, but have a higher concentration in the face and scalp. The apocrine gland is located primarily in the axillary and genital regions [*3*]. Much of the work performed for the elucidation of human odor composition has been focused in the axillary region of the human body which has helped to identify the chemical composition of sweat and has provided some insight into the understanding of this biological fluid. A number of studies have

demonstrated that the characteristic human axillary odors

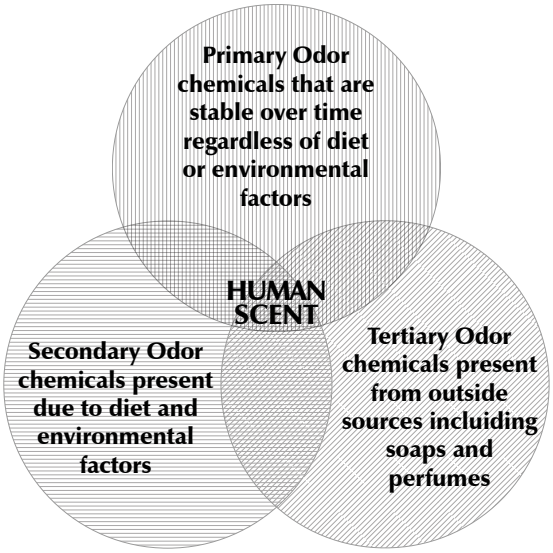

Figura 1: Human odor definition.

consist of C6 to C11 normal,

branched and unsaturated aliphatic acids, alcohol, carbonyls and some steroids as major contributors to underarm malodor, with a major contribution originating from (E)-3-methyl-2-hexenoic acid [*4, 5, 6*]. Human axillary compounds may not accurately reflect what a subject is leaving behind at a crime scene therefore the true composition of body odor may not be entirely covered simply by studying human sweat. Other research in the field has included analysis of human skin emanations by solid phase microextraction/ gas chromatography-mass spectrometry (SPME/ GC-MS). These studies have revealed key volatile organic compounds which may play a key role in determining the characteristic odor originating from an individual. A wide variety of compounds were found, the main of which included short chain aldehydes and long chain hydrocarbons [*7,8*]. Another result obtained was the notion that the levels of these common compounds varied among different individuals. Yet another study performed also highlighted the efficacy of SPME-GC/MS to study the chemical components of human odor. The results of this technique yielded the identification of functional groups such as aldehydes, alcohols, alkanes, and esters in individual armpit samples. The common compounds were shown to be present in a differing ratio pattern between the males and females in the study thus portraying qualitative similarities but with quantitative differences [*9*]. The skin in general has been described to be a continuous source of "rafts", which are dead skin cells, being deposited to the outside environment as a person touches objects in their surroundings. A common description of this raft theory basically adds to the human odor composition by the contribution of these rafts into the air currents after an individual comes into contact with a certain location or object of interest [*1*]. Regardless of the mechanism of human scent production, human scent is complex and may consist of many variables and components that constitute to an individual's body odor profile. In turn, these factors contribute to the reliability of the collected scent evidence and may be affected by collection procedures, dissipation of human odor, stability of human odor, contamination issues, storage protocols, canine training, and handler experience which ultimately dictate how effective this type of trace evidence can serve in a criminal investigation as can be seen from Figure 2. The challenge for human scent evidence in relation to canine olfaction is that it is unknown what compounds canines are using in the detection of human scent.

HUMAN SCENT AND THE LAW

For a scent identification to be admitted as evidence in a United States court of law it must satisfy standards for the court in question such as the Kelly rule, resulting from the People v. Kelly [*10*], which applies to new scientific techniques, especially in cases involving novel devices or processes. Different court jurisdictions have brought up different aspects and challenges in using this type of evidence including the reliability of the canine used and the subsequent acceptance of the scent identification as incriminating or exonerating evidence. In the US, the use of canines in a court of law has been debated since the beginning of the 20th century. In Hodge v. State [*11*], the state Supreme Court accepted testimony in regards to tracking dogs and the use of this type of evidence for jury consideration. Three years later in State v. Hall [*12*], canine evidence was once again admitted in court as long as there was enough information as to the training, breeding and handler experience with the case at hand. The challenges in court systems in the United States, however, did not settle and in 1903 some courts decided that this type of evidence contributed to too many errors rendering it as unsafe evidence [*13*]. The debate continues and 100 years later courts across the United States continue to discuss the merits and issues associated with canine evidence. Recent cases have addressed canine behaviour and their ability to discriminate between scents thus enforcing the idea that every individual has a unique odor. Now, there is the need for answers regarding the stability of human scent as well as its individuality and the adequacy of certification procedures [*14,15,16*].

In an effort to meet the general need of local, state and federal law enforcement agencies

for standardized practices, a scientific working group (SWG) has been created for detector dogs and orthogonal detectors analogous to those utilized in other technical areas to develop operational standards. The mission for the scientific working group for detector dogs and orthogonal detectors (SWGDOG) is basically to help disseminate ideas regarding methods, protocols and research while focusing on bringing together organizations and individuals actively involved in relevant disciplines. One of the current SWGDOG subcommittees is geared toward scent dogs covering areas such as scent identification, search and rescue, trailing and tracking dogs. Organizations such as SWGDOG are expected to

bring a number of benefits such as providing a forum full of resources for agencies interested in improving their detector dog certification programs [*17*].

SCENT DISCRIMINATING CANINES—OVERVIEW OF THEIR USE IN DIFFERENT COUNTRIES

One of the main uses of scent discriminating canines is for suspect discrimination procedures in practical police work. The first person to demonstrate suspect discrimination was Inspector Bussenius from Germany back in 1903; since then suspect discrimination has been an integral part of a detective's investigation. Traditionally, the use of a canine is to select the possible perpetrator of a crime from evidence collected at a crime scene by which the canine can establish if a relationship exists between both presented scents [*18*]. For example, scent discriminating canines can trace the location of a person or suspect of a crime by tracing the odor left on the point of interest whether this might be a building or simply the odor left on a car seat. Human scent evidence, however, as a tool in forensic applications and investigations has undergone developmental stages and remains a very young discipline. Different countries use different operational systems as it relates to actual scent identification protocols. European countries including the Netherlands, Belgium, Hungary, Denmark, Poland, and Germany have used scent evidence to a greater extent than the United States for investigating criminal cases in their justice systems. Each country has used this form of forensic evidence in different ways although the basic underlying principle is always the same - matching the odor of the perpetrator to the odor of the suspect of that crime. The general method can be separated by two systems as is seen in Europe, the tube retrieving system and the cloth responding system. Stainless steel bars or tubes are mainly used in Western European countries by where the suspect's odor is collected on the tube by direct holding of the bar for a specified amount of time. These metal tubes are either placed on a platform where they are secured into position or placed loosely on the ground. The canine is given a reference odor which may be an object collected from the crime scene to which they consequently search for the matching odor in the "line-up" of metal tubes. The canine then gives a characteristic response whether this be scratching, biting, pulling, barking, or jumping next to the selected bar. In Eastern European countries, scent evidence is presented to the canines by means of a "cloth responding" procedure. The pieces of cloth are used to collect the emanating odor handled by the suspect and from the scent samples from the crime. These cloths are then placed on glass jars, which are consequently placed in scent identification line-ups for the canine to perform a selection and matching of odors [*19*]. Although the use of human scent evidence has not been a traditional form of forensic tool in the Western Hemisphere, the United States and other Latin American countries have started to use and implement this valuable form of trace evidence in various criminal proceedings. Following a similar pattern of procedures as those seen in Western European countries, Cuba and Argentina are implementing human scent identification line-ups in their police work investigations. The development of human scent evidence in Cuba took off in the late 1980s when the government began constructing human scent line-up facilities. Initial experiments were conducted following the cloth responding system described above where cotton materials were being utilized for the collection of scent samples [*20*]. Argentina has recently added human scent evidence in their criminal investigations as well and has portrayed a level of training and method practices very similar to those employed in the Netherlands. Argentina only possesses one human scent identification team and is slowly building the method to parallel their European colleagues. Argentina has focused on working with the tube retrieving system and have begun working on the development of scent banks in the region by which they can use a perpetrator's odor years after in case other crimes are committed by the same person [*21*].

Even though European nations have a more extensive use of human scent evidence as a form of evidentiary material, the United States has also been developing the technique as an aid to criminal case work. The materials and the general method has included innovative ways for the collection of scent samples and has differed from the protocols established by the canine teams used in Europe. The use of scent discrimination canines in the United States follows the same assumptions that every individual carries a distinct odor that differentiates him/her from the population and thus serves as an identifier similar to DNA or fingerprints. However, the collection of human odor in some parts of the United States has employed the use of non-contact sampling including the use of the Scent Transfer Unit (STU-100). This device is essentially a portable vacuum designed to draw air through 5x9-inch sterile gauze pads and is currently being used by

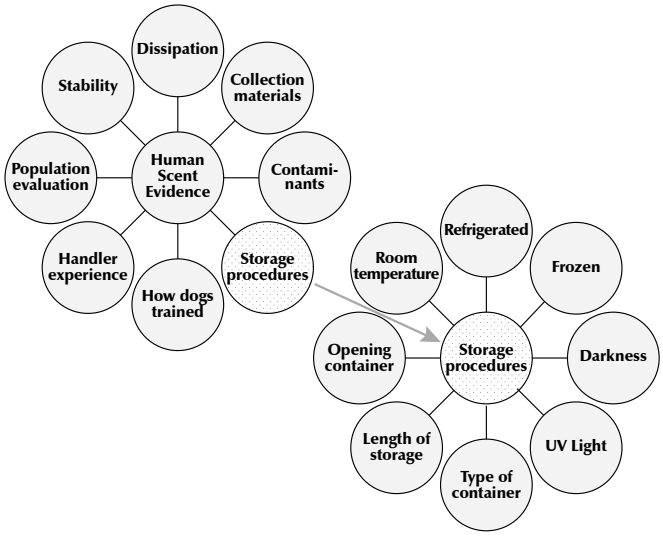

Figure 2: Variables that could possibly have an influence on human scent evidence.

law enforcement agencies as well as the Federal Bureau of Investigation. The Scent Transfer Unit allows the investigator to perform non-contact sampling and collection of human scent from objects without contaminating or altering the object of interest [*22*]. After making scent pads from the object or person of interest, the handler can then proceed to present these pads to the canine for location checking or suspect discrimination purposes as demonstrated in figure 3.

Figure 3: Use of the Scent Transfer Unit for Scent Discriminating Canines.

To date there has been limited scientific validation on the reliability of this device. A recent study determined the ability of the STU-100 to trap and release organic compounds at ambient temperatures under controlled laboratory conditions. The results demonstrate that at elevated temperatures human scent chemicals with high volatility are effectively being trapped and released [*23*]. Besides laboratory experiments, the device has been successfully demonstrated by the ability of the canine to use the scent pads created with this device to correctly match given targets. In a study performed by the Federal Bureau of Investigation (FBI) the use of human scent evidence to identify bomb makers and arsonists was examined utilizing the STU-100. The main purpose of the experimental procedure was to demonstrate the survivability of human scent after direct exposure to severe thermal and mechanical effects encountered in explosion and arson settings. Twelve test subjects were selected and allowed to handle materials used for the construction of four pipe bombs using two low-explosive powders and two high-explosive materials. Following the explosions, scent pads were collected from the pipe-bomb debris by placing the fragments on the STU-100. The study demonstrated the survivability of human scent which was still usable to the canine to make a positive scent match even after undergoing violent thermal conditions [*24*].

HUMAN SCENT DISCRIMINATION

The ability of canines to discriminate human scent has been investigated in a number of research studies over the past years. In a study conducted by Hepper, the role of genetic and environmental factors on the individual characteristics of human odor was evaluated [*25*]. The results portrayed that canines are indeed able to distinguish twins as long as there is a difference in genetic relatedness (mononozygotic or dizygotic) or a variation in environmental factors such as diet or housing which implies that the generation of human scent is affected by both internal and external characteristics of the individual. The ability of canines to match scent collected from different body parts has also been a point of interest for various research groups. Dutch police dogs were capable of matching hand scent to scent collected in the crook of the elbow and vice versa, as well as matching scent from the hand to that found in the subject's pants [*26*]. Also, experiments performed in the UK demonstrate that the canine is able to efficiently match objects containing scents of individual humans whom they do not know even when the objects have been in contact with different parts of the body and also collected with no precautions of possible environmental contamination [*27*]. An important factor of canine scent detection that has been tested is the amount of olfactory information these biological detectors require to determine the direction of an odor trail. One study provided the idea that footsteps alone are sufficient olfactory information for the determination of direction and that five sequential footsteps are required to enable the dogs to determine directionality [*28*]. The effect of both the age of the scent trace and the trail has also been documented in the literature. In one particular study, the scent transfer unit (STU-100) was used in order to transfer each person's unique scent to the gauze pads. Eight bloodhounds trained in human scent discrimination were used to follow and find the matching scent on different trails with varied environment conditions. The ability of the bloodhounds to locate a suspect on more than 48 hour old highly contaminated trails demonstrated the potential for expanded applications of human scent for criminal implications [*29*]. Another study in the Netherlands concluded that while the canines are able to perform faultlessly in matching odors collected on the same day, the results drop to a lower level and become more variable as the period is lengthened (2 weeks to 6 months). However, the results did not exhibit a systematic decrease in perfor-

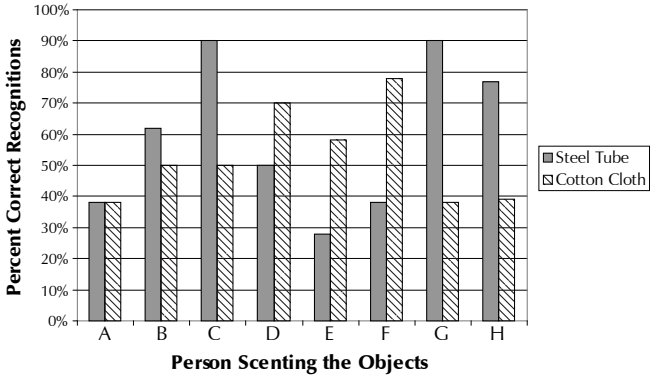

Figure 4: Canine percent correct recognitions on different material types. Data obtained from Ref.[30]

mance. As far as the materials implemented for scent collection and their relation to canine performance, to date, it has not been demonstrated that any particular material type is significantly better or worse when compared to the others. Figure 4 shows the similarity in results for two very different collection materials [*30*]. In the study performed by Schoon et al. the odors were collected on stainless steel metal tubes as well as cotton cloth with eight males contributing their target odors on the two kinds of materials. Only one canine was utilized to conduct the line-up with the collected sample odors placed in glass jars for identification purposes. The collection material, in which scent was collected, had very minimal effects on the canine performance thereby demonstrating their natural ability to discriminate even with large background and collection variables. A parallel comparison to instrumental analysis of human odor, however, shows that unlike canine detection, there is a significant difference in collected odor profile of the same individual subject was then given a 2″ x 2″ piece of pretreated material which was to be clasped for 10 minutes. The material with collected human scent was placed into a 10 mL glass vial and allowed to equilibrate with the headspace for 24 hours. The human scent sample was then extracted from the vial using Solid Phase Microextraction and then analyzed via Gas Chromatography/Mass Spectrometry. Initial results reveal how the odor profile ofthe same individual varies in both the amount of collected scent which is represented in nanogram amounts in Figure 5, with the highest mass of scent being collected with the cotton fabric as well as the compounds collected which are represented by a different shade in the odor chart. These results suggest that cotton gauze may be a better selection for the collection of a human scent sample in this limited study. In addition, Figure 6 which represents how the collected odor profile is more reproducible when the same material is used for the collection of human scent within a single subject by regular

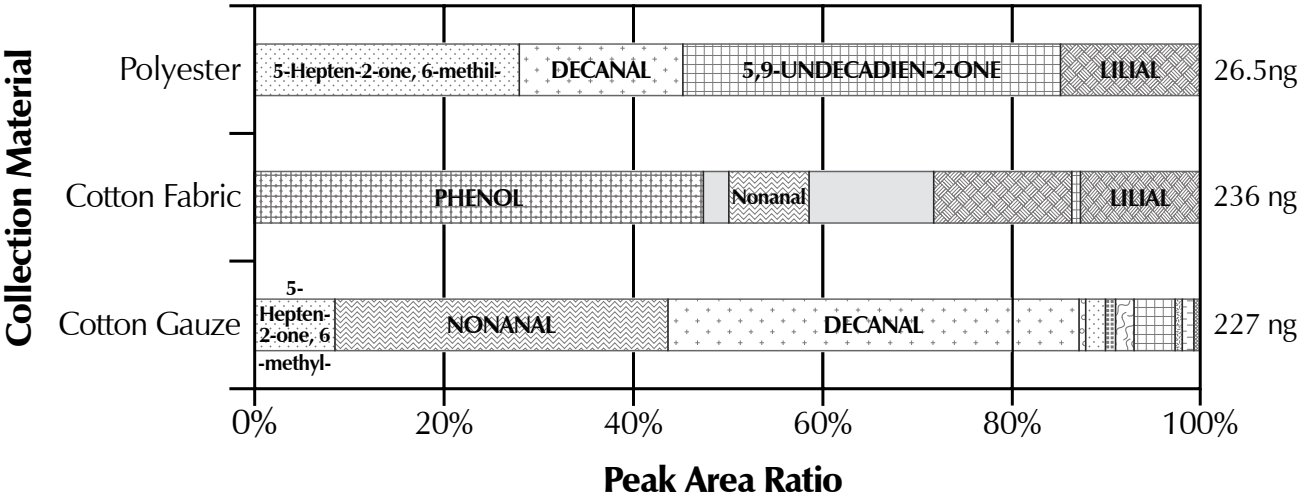

Figure 5: Hand Odor Chart of the Relative Peak Area Ratios of Human Compounds Extracted from a Single Individual with Varying Collection Materials

based on the material in which it is collected as shown in Figure 5. Materials such as pure cotton gauze, cotton fabric and polyester have been tested in preliminary experiments to determine and evaluate the differences between canine and instrumental detection.

EXPERIMENTAL FINDINGS

An example of recent research conducted at our laboratory has evaluated the effect of three sorbent materials (polyester fabric, cotton fabric, and cotton gauze) on the collection of human scent from an instrumental analysis approach [*31*]. The reproducibility of the collected human scent sample was evaluated, within the fabric type, during a four week period. The subject first washed the hands and forearms with natural oil soap for 30 seconds. Soaping was followed by 2 minutes of rinsing under warm water, 2 minutes of air drying, and 5 minutes of rubbing hands over forearms. The sampling at one week intervals for a period of approximately one month as was portrayed by initial samplings in the experiments performed. Thus, scent discriminating canines demonstrate an advantage over instrumental methods by being able to trail and perform recognitions regardless of the material where the scent is collected.

CONCLUSIONS

Despite potential problems with reliability in the use of canines for discrimination and matching of human scent evidence, scent discriminating canines can be extremely useful particularly where other forms of evidence are not readily available, provided that they have relevant and sufficient training and experience. When canines are employed the scent evidence is generally used in conjunction with other evidence or investigative techniques. Even if human scent evidence satisfies the corresponding criteria for admissibility

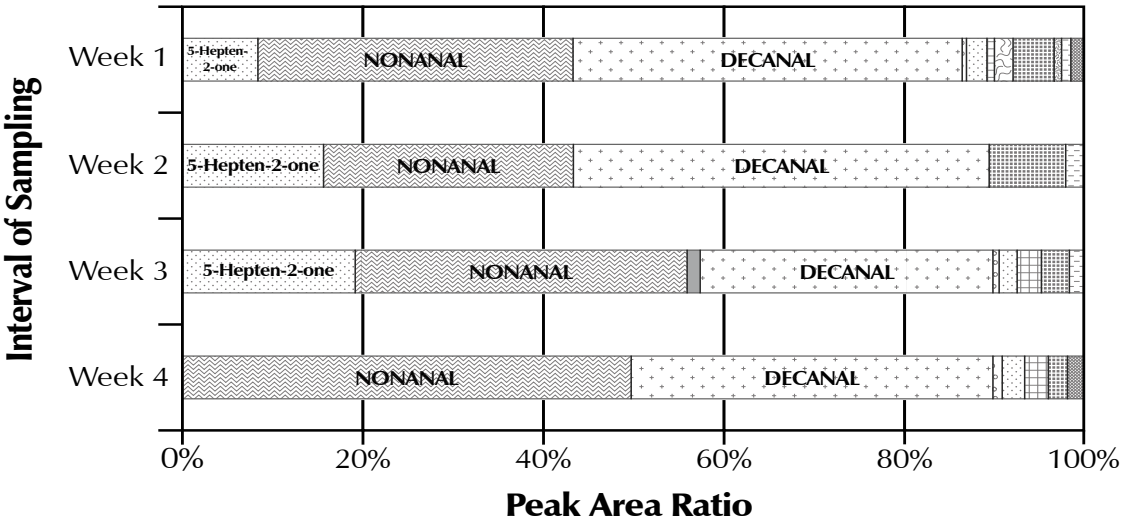

Figure 6: Hand Odor Chart of the Relative Peak Area Ratios of Human Compounds Extracted from a Single Individual using Cotton Gauze as Collection Medium

in the courts, evidence should be assessed on an individual basis given the variation in abilities between canine experience and training and the fact that no two cases are alike. It is also important to consider that although research has demonstrated the discrimination power of canines and their general accuracy and precision rates, the actual error rates are variable and come from a range of different disciplines. Therefore, many factors still need to be enhanced and developed in this area of research. Scent detection in general has many variables associated with it, and as opposed to a controlled laboratory setting, canines as biological detectors can influence the findings inadvertently if precautions are not taken as far as controls and contamination issues. The different systems and protocols used for the collection and preservation of human scent samples need to be standardized to a level where there is a general accordance of procedures that could validate the method in a court of law. Overall, even though the path to greater general acceptance has yet to be conducted, recent efforts for standardized practices such as SWGDOG should aid in the scientific establishment of scent discriminating canine teams and the use of human scent evidence in the forensic arena.

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