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The use of mantrailing dogs in police and judicial context, future directions, limits and possibilities – A law review

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ABSTRACT

The extraordinary capabilities of the canine nose are increasingly being used by law enforcement agencies in many countries to solve and reconstruct crimes. As a result, this type of forensic evidence can be and is still being challenged in the courts. So far, only a few publications have addressed the jurisprudence concerning mantrailing. We provide an overview of the jurisprudence in Germany and the USA, as well as insights from France. Relevant databases were searched, and 201 verdicts from Germany and 801 verdicts from the USA were analyzed. As a result, 16 published verdicts on the topic of mantrailing were found for Germany, and 44 verdicts since 2010 were found for the USA. The use of mantrailers and human scent discrimination dogs is employed in the investigative process in all three countries. The results derived from these methods are admissible as evidence in court, albeit not as sole evidence.

1. Introduction

The outstanding sensitivity of the canine nose has been well studied, e.g. Refs. [1–7]. Furthermore, a multitude of studies have investigated the cognitive abilities of dogs that suggest the potential for successful working dogs [8–11]. Additionally, it has been shown that dogs form expectations based on previous encounters with odor cues, associate a scent trail with an object, and use this information to locate hidden target objects [12–14]. The pervasive utilization of canines across a diverse spectrum of applications is therefore not surprising. For example, they support species conservation [15], can be used for medical diagnostic purposes [16–20] such as in connection with the COVID-19 pandemic [21–24], and appear to be more sensitive than real-time PCR [25]. However, the majority of professional use of dogs will be in connection with the use of service dogs by the military or authorities such as police or customs. Well known is the use of narcotics detection dogs to find drugs, for example at airports, train stations or in prisons. In addition, the extraordinary capabilities of the canine nose are increasingly used by law enforcement agencies in many countries to solve and reconstruct crimes. As a result, this type of forensic evidence can be, and is still being, challenged in the courts. Especially with regard to the use of so-called scent-discriminating dogs in the context of scent line-ups, and particularly with so-called man-trailing dogs but also other search dogs, their suitability and reliability are controversially discussed in both public media [26,27] and in scientific discourse [28–37]. This is not the place to delve into the theoretical foundations and explanations regarding scent differentiation and mantrailing, as well as the underlying behavioral aspects in dogs. We provide a detailed account of these elsewhere [38]. The focus of the following considerations is on whether the use of dogs as a possible investigative measure is subject to any criminal procedural limitations, and in particular, whether and under what conditions the results of such deployments can be attributed evidentiary value in court. In recent years, a large number of judicial decisions on this issue have been made in Germany. A cursory comparison of the systems of Germany, France, and the USA, as well as the respective case law, allows for an international perspective.

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2. Essentials of the criminal procedure law

Against the background of historical developments, different legal systems and legal traditions have emerged worldwide. In a rough distinction, one can differentiate between a "continental European" and "Anglo-American" legal tradition, among others. These are then divided into "civil law" (e.g. France and Germany) and "common law" (e.g. USA) [39]. Both systems have various peculiarities, which affect, among other things, criminal proceedings and criminal procedural law. These differences are to be presented here for better understanding.

The legal frameworks in France and Germany are encompassed within the realm of "Civil Law" systems. Legal principles governing the collection and evaluation of evidence, as developed by jurisprudence, find their foundation in the principle of investigation, the accusatorial doctrine, the doctrine of unconfined evidence, and the principle of unconstrained evidence assessment [40]. Procedural guidelines for law enforcement agencies and the police are comprehensively standardized within each respective country. In France, primary guidelines are derived from the *Code de procédure pénale* (CPP), while in Germany, they are governed by the *Strafprozessordnung* (StPO). Additionally, internal administrative regulations or decrees necessitate adherence. In Germany, these vary depending on the federal state. Nevertheless, it can be generally asserted that the utilization of service dogs for police operations is exclusively permissible upon successful completion of the mandated training and examination.

Both the hierarchical structure of governing bodies and investigative procedures demonstrate notable similarities. Owing to this hierarchical arrangement, central dependencies and corresponding powers of instruction are present within both public prosecutor's offices and the police. Particularly noteworthy is the directive authority, conferring the public prosecutor jurisdiction over investigative police officers, and the principle of official investigation (principe de légalité in France), which binds the police. The police (and the gendarmerie in France), as well as the public prosecutor's office, are explicitly bound by law to establish inculpatory and exculpatory circumstances (Article 14, 39-3 CCP or §§ 160, 163 StPO). In France, this duty extends to the examining magistrate during pre-trial investigation (Article 80, Paragraph 1, 81, Paragraph 1 CPP). In principle, the investigative authorities are vested with latitude in selecting their investigative methodologies (e. g. for Germany [41]) for collecting material elements that will serve as evidence (DNA samples, finger or palm prints, witness testimonies, video recordings …), which includes, for example, the use of mantrailing dogs or scent discrimination dogs. This may be undertaken as an independent police investigative measure or at the behest of the public prosecutor (or the examining magistrate in France). During the pre-trial investigation, material elements found during mantrailing are precisely documented in the official report by french officers of the judicial police (police or gendarmerie). This report is transmitted to the public prosecutor. If the dog's trail leads to a person, it does not constitute evidence in France, contrary to the data obtained during human scent line-ups identification tests (cf. § 5.). The trailing technique only enables the investigation to be directed towards the discovery of material elements that may constitute evidence. It is important to note that in some cases, positive mantrailing results may allow the public prosecutor to extend a suspect's custody during the investigation, enabling law enforcement agencies to collect additional evidence.

In contrast to the continental European legal systems of France and Germany, the legal framework in the United States falls under the purview of "common law" systems. A distinguishing feature is the preeminent significance accorded to case law. This governs aspects of criminal proceedings not explicitly addressed by constitutions or detailed legislative provisions, encompassing matters such as due process and evidence law, as well as issues related to the fair administration of criminal justice. The American criminal justice system is characterized by decentralization and the absence of a hierarchical structure. Consequently, intricate rules within criminal proceedings are dispersed between state and federal legal frameworks [39]. This results in the existence of 52 procedural codes, encompassing both federal jurisdictions and the District of Columbia. However, numerous state procedural codes are at least partially aligned with federal criminal procedure regulations, particularly the Federal Rules of Criminal Procedure (FRCP) and the Federal Rules of Evidence (FRE). Of commensurate significance are the safeguards enshrined within the amendments to the US Constitution. Furthermore, ethical obligations of both prosecution and defense are derived from model regulations established by the American Bar Association [42]. Unlike in France or Germany, each smaller political entity (municipality or district) within the US maintains its distinct district attorney's office, led by an individual not subject to a national hierarchy [43]. This implies a lack of legal or administrative oversight. Effective mechanisms for regulating their activities are notably absent in practice, thus affording them significant discretion in their duties [44]. Moreover, US prosecutors are not legally compelled to investigate exculpatory evidence. However, they are obligated to disclose such evidence if uncovered during the course of their investigation [43]. Similarly, law enforcement in the US follows a state and local organizational structure [44]. Police departments and district attorney's offices operate independently. The prerogative of the district attorney to dispense directives to the police is non-existent. The police, therefore, remain unaccountable to the district attorney and wield a comparable degree of authority. Correspondingly, there is no imperative incumbent upon the police to delve into exculpatory evidence inquiries. They retain sovereignty over their chosen investigatory methodologies, which includes the use of detection dogs (e. g. mantrailing and scent discrimination/line-up). Given the dearth of efficacious mechanisms to oversee individual police officers, the Supreme Court, alongside other American judicial tribunals, has meticulously demarcated the parameters governing police investigative activities. By extension, evidence obtained through impermissible methodologies has been expunged from admission in a multitude of cases since the 1960s [44].

When charges are filed by the prosecution, in both France and Germany, the comprehensive body of investigative documentation (including all gathered and documented exonerating and inculpating evidence) are to be presented to the court [45,46]. This naturally encompasses the outcomes of canine deployments. Notwithstanding, the mere incorporation of these outcomes within the investigative compendium does not ipso facto bestow probative status upon them within the contours of the ensuing criminal proceedings. The court is not circumscribed by the motions (viz. investigation findings) advanced by the prosecution (or the cognizant investigative officers); instead, it is vested with the autonomous responsibility of scrutinizing the factual matrix. The preeminent objective underpinning the trajectory of the criminal adjudication is the elicitation of veridical circumstances [45,47]. The trier of the fact retains unfettered discretion in the assessment of the probity of the proffered evidentiary matter [39,40] and is empowered to conduct supplementary evidentiary exploration and integration [42, 48]. This may encompass, for instance, results stemming from canine deployments (all instances in which law enforcement agencies use dogs for investigative purpose, i.e. human scent line-ups in France and Germany or mantrailing in Germany). Notwithstanding, circumscriptions and exemptions adhere to the principle of free consideration of evidence. The trial judge is enjoined to adhere to established scientific epistemology, the canons of logic, and axioms derived from quotidian experience. "Where a fact is irrefutably grounded in scientific understanding, the scope for judicial assessment and conviction formulation is obviated." [49,50]. During the trial, guided by the convictions accrued, the court pronounces its verdict and adjudicates the punitive quantum. The German legal architecture eschews the doctrine of stare decisis. Courts are ordinarily unshackled by the pronouncements of their judicial counterparts in their rendering of judgment. A singular exception inheres in the determinations of the Federal Constitutional Court. Nonetheless, a modicum of persuasive authority emanates from the echelons of jurisprudential hierarchy and the adjudications proffered

therein [51]. Should doubts persist following evidence evaluation, "if, subsequent to the consummation of evidence assessment, [the court] fails to unequivocally establish the existence of a fact …" [52], the doctrine of in dubio pro reo mandates a verdict favoring the accused.

In the United States, the prosecutor exercises discretion in selecting the cases to be adjudicated and the facts to be presented before the tribunal with the intention of securing a favorable adjudicatory outcome. In circumstances of ambivalence concerning the admissibility of evidence (such as the outcomes of mantrailing or scent line-up deployments), it is incumbent upon the prosecution to solicit the adjudicative perspective prior to the principal trial, in the absence of the jury's presence (refer to ABA Standard 3-6.5 (d)). Pending the resolution of the inquiry into admissibility, the prosecution is enjoined from introducing such evidentiary material. The court is not in possession of the exhaustive cache of investigative records germane to the case. Consequently, the adjudicating court and the jury are privy exclusively to the facts and evidence proffered by the contending parties. If the evidence is deemed admissible, the jury undertakes an appraisal of credibility and probative potency in consonance with the respective submissions. Judges in the US are fundamentally solicitous of refraining from exercising any influence upon the formation of juror judgment, with an inclination toward abstention from interposing inquiries or conducting independent investigations. Furthermore, the court would have to requisite to be apprised of the relevant evidence prior to initiating autonomous evidentiary proceedings. Nevertheless, the court retains the prerogative to solicit from the prosecution and defense supplemental presentations of evidence. The US criminal procedural rubric does not inculcate an obligation upon the judges to actively pursue the verity. Resultantly, owing to the intricate interplay of these circumstances, the US procedure may potentially occasion the exclusion of pivotal evidentiary material or contextual circumstances, culminating in a discernibly incomplete foundation for the ensuing judgment. The evidential edifice officially underpinning the judgment generally comprises the inculpatory evidence proffered by the prosecution to buttress the charges, as opposed to the outcomes of an exhaustive, impartial inquiry on the part of the court [42]. A quintessential tenet of American jurisprudence lies in the canon of case law. During the adjudicatory process, antecedent jurisprudential determinations wield a pivotal and binding influence concomitant with codified law.

Regardless of the respective legal system, it remains evident that the mere deployment of dogs (human scent line-ups or mantrailing) for investigative measures does not inherently render the results of these operations as evidence. This evaluative mantle, unequivocally, remains the exclusive province of the court. In light of these, at times divergent, foundational underpinnings, the inquiry naturally arises as to the manner in which the ramifications of canine deployments are subjected to a de facto evaluation within the precincts of the court. Consequent to this, the ensuing exposition duly expounds upon the contextual landscape, supplemented by pertinent judicial decisions.

3. The use of mantrailing and scent discrimination in law enforcement

Although a larger proportion of canine deployments in police operations likely involves drug detection dogs or explosive detection dogs, the scope of our inquiry centers on scent differentiation and mantrailing. It holds significance to demarcate between the tracking and trailing search methodologies. The former pertains to traditional scent tracking endeavors with canines, wherein orientation hinges predominantly upon ground disruption cues (e.g., vegetation displacement, modification of soil and vegetal composition) induced by foot impressions and to a lesser degree upon individual body scent left on the ground. Conversely, in trailing, the distinct scent path (also called "olfactory corridor" in France) of an individual is pursued [53,53,53]. "*Tracking Dog: In the strict sense of the term, the dog should indicate almost each of the subject's footsteps. (…) The basic orientation of the dog is to the footsteps. Trailing Dog: The dog is oriented to the rafts which have fallen to the ground along the person's route. The dog may well be working some distance from the actual footsteps*." [54]. This infers that the trajectory of the dog's search route (mantrailer) need not align precisely with the precise laid footprints; rather, it delineates the partial dispersion of an individual scent trail. Hence, the scent trail represented by the dog could potentially be several meters removed from the factual footprints. In both tracking and trailing, it is postulated that the dog inherently follows the chronological sequence of the scent trail [29].

The human scent identification line-up, developed originally by Schoon and De Bruin [55] and later refined [56,57], is a task in which trained police dogs are presented with scent collected from a crime scene ("evidence" scent) and are required to compare this sample to a selection of human scents ("comparison" scents, usually 5 or 6 in number) collected from persons not involved in the crime but also including a scent from a possible suspect ("target" scent). If the target scent matches the evidence scent, the dog shows a typical conditioned response (usually, sitting or lying down) at the target station. It should be noted that a secret patent was granted for similar methods in the former German Democratic Republic (GDR) as early as 1972, and it was afterwards also implemented in other countries of the so-called Eastern Bloc [58].

This behavior is obtained after an extended training procedure during which the dog acquired the principles of classical matching-to-sample, in which the conditioned response to a correspondence between target scent and sample is reinforced by food, whereas responses to any non-identical comparisons are not reinforced [59]. In France, we recently reported that the comparison between the body scent (direct sample) collected from a particular individual and a trace scent (indirect sample) collected at a different point in time (from some hours to several days between collections) from an object that has been in contact with the individual resulted in the identification of both scents as originating from the suspect with a very high level of sensitivity, well-trained dogs alerting to target odors in 70.2 $\pm$ 4% of cases and never alerting to non-target odors (based on a total of 18,127 trials; Marchal et al. [60]). This suggests that dogs are able to detect, memorize and identify a particularly human scent, so as to be able to retrieve it with a high accuracy. The excellent reliability and reproducibility of the method largely depend on rigor in dog training.

Mantrailing essentially relies to the capacity to discriminate and trail human scents as well. In this context, the objective involves locating the person to be searched or tracing their scent trail using a scent article. The canines are trained to initiate trailing upon encountering the congruent scent at the initial point; conversely, they refuse from trail initiation otherwise. For operational deployment within law enforcement agencies, the canine training regimen commonly commences during puppyhood and lasts for approximately two years. Throughout this process, the dog acquires the skill of recognizing and associating patterns. The congruence between the initial scent and the target individual is reinforced through interaction and food rewards, while responses to erroneous comparisons are left unreinforced [61]. Several studies [62–66] suggest that dogs are capable of recognizing, memorizing, identifying, and tracking the associated scent trail of a specific, achieving high accuracy (up to 92%) in locating the target individual. An exhaustive survey of the literature is offered elsewhere (Woidtke et al., in preparation).

Reliable data pertaining to mantrailing operations or scent discrimination within criminal proceedings present a somewhat limited availability. It can be stated that the internal security forces (Gendarmerie Nationale) in France and police in almost all states in Germany use mantrailing dogs. Within the period spanning 2011 to 2018, the state of Saxony singularly documented 2051 deployments [67]. Remarkably, the deployment of mantrailing dogs in France and Germany is often observed in cases involving severe criminal acts, such as homicides, arson, or instances of organized theft. The objective of such deployments, that usually take place rapidly after the crime, frequently revolves around establishing the presence of a suspect at a crime scene

or charting a trajectory of movement. In the wake of DNA evidentiary practices, the lineup methodology for scent discrimination was discontinued by the German police in 2012 but is still regularly used in France. Nonetheless, at present, scent discrimination dogs (experts in identifying the presence of a human scent on a particular scene) are only operative within the German police force of a single state, namely Schleswig-Holstein. These canine resources are predominantly deployed to cases involving grave offenses, including organized theft or homicide. In a previous paper, we provided a detailed overview of the utilization of scent discrimination dogs across eleven countries [32].

In a general context, canine deployments are initiated by either law enforcement agencies or prosecutorial bodies, occasionally in response to court requisition. Such a practice is employed by the police and prosecution to either augment existing insights or to develop new investigative leads. In addition to service dogs, dogs from private providers are also utilized but only in Germany. Nevertheless, it is often the case that the outcomes of these deployments bear limited significance or are entirely peripheral within the court proceedings. This trend emerges from the fact that findings resulting from canine deployments frequently assume a supplementary role, coexisting with other robust forms of evidence, such as DNA traces, intelligence gleaned from telephonic surveillance, or testimonies offered by witnesses. For example, out of approximately 100 instances of criminal prosecution deployments per annum in Saxony, the results of these operations were judicially used merely in 10 cases during 2017 [68]. Consequently, judicial engagement with the deployment of dogs and its potential probative value remains a rare occurrence within the fabric of decision-making processes. In France, mantrailing leading to a particular person is described in a technical report and recorded in the investigation files but has no probative value. It is arguable that research on the forensic reliability of procedures based on dog scent capability has not adequately supported its widespread use in law enforcement. Regarding human scent identification by dogs, the question of the exact sensitivity and specificity of dogs' line-up performance often arises.

4. Mantrailing in case law - Germany

Since around 2003, police forces in the German states have been using mantrailing dogs as investigative tool, which has subsequently led to the need for courts to address its use. Considering the fundamental guidelines of the German legal system regarding the presentation of investigation results in court, it would be expected that extensive jurisprudence on this topic has been published by now. However, courts are not obliged to provide their judgments to public databases. Therefore, a search was conducted in the relevant legal databases, Beck-Online and Juris (as of July 1, 2022). The search on Beck-Online, using the filter "jurisprudence" and the search term "search dog," yielded 61 entries, and the search term "sniffer dog" resulted in 33 entries. The majority of entries were not related to mantrailing. A further search with the term "mantrailing" or "person search dog" resulted in 12 entries, including two judgments by the highest German criminal court, the Federal Court of Justice - *Bundesgerichtshof* (BGH). The search on Juris, using the filter "jurisprudence" and the search term "sniffer dog," yielded 141 entries. The majority of entries listed judgments related to other sniffer dogs, such as drug detection dogs or cadaver dogs. Interestingly, the search term "search dog" only produced 31 results. A further search with the term "mantrailing" or "person search dog" resulted in 12 entries, including the two BGH judgments. Combining the results of both databases, only 16 of these judgments were found to be related to the use of mantrailing dogs in criminal proceedings, and only eight of the judgments provided a detailed examination of the topic of mantrailing. Additionally, the author is aware of five other judgments known to have extensively addressed the topic, but have not been published.

The ensuing assertions encapsulate the outcomes derived from the German jurisprudential landscape concerning the domain of mantrailing. The quoted excerpts from the judgments were freely translated into English. It should be noted that the higher court jurisprudence generally does not question that specially trained dogs are capable of finding things [69]. The first published decision by the BGH referring to mantrailing dates back to 2008 and describes the result of the search as "*unambiguous indications*." However, the lower court did not attach significant importance to the behavior of the dog for reasons related to the age of the dog, the experience of the dog handler, and the possible contamination of the scent samples [70]. The BGH explicitly commented on mantrailing in 2011, referring to the appeal of several accused's against an unpublished judgment of the LG Potsdam [71]. From the wording "*Given this situation, the results of 'mantrailing' experiments over around 20 pages, which are deemed unnecessary by the court (see UA p. 170), do not ultimately endanger the judgment's validity to any significant degree*," it can be concluded that the judgment of the LG Potsdam did not rely on the results obtained through the use of mantrailing dogs. Overall, it can be stated that mantrailing dogs are used by the police in a large number of criminal investigations. In addition to service dogs, dogs from private providers are also used. However, there are only a few known cases in which the court has actually dealt with the use of dogs and their potential evidentiary value in its reasoning for the judgment. This is because in many cases, the results obtained through the use of dogs are only supplementary to other conclusive evidence, such as DNA traces, knowledge gained from phone taps, or witness statements. It is noteworthy that mantrailing dogs are often used in cases of serious crimes, such as murder, arson, or organized theft. The objective of their use is often to prove the presence of the perpetrator(s) at the scene of the crime or to reconstruct a pattern of movement. The below listed judgments reveal under which circumstances the court has pronounced in favor or against probative value of the results obtained from using dogs.

In spite of certain judgments addressing aspects of mantrailing dog deployments (e.g., quantity of dogs employed, type of scent articles, handler's expertise, deployment outcomes) and regarding their utilization as a fitting and permissible method (LG Koblenz [72], recital 1512), not all cases provide explicit discourse concerning the evidentiary significance of the mantrailer dogs' work within their subsequent reasoning [73]. However, these aforementioned factors frequently contribute to the assessment of evidentiary value. For instance, in a specific case (LG Bamberg [74], as cited in Homburg [75]), an individual suffered grave injuries from an axe assault. DNA traces of the suspect were absent both at the crime scene and on the victim's attire. This marked the inception of deploying three mantrailing dogs. All three canines pursued a comparable route and concluded the search at the same location, suggesting that the offender had entered a vehicle there. The court interpreted the findings of the engaged person scent dogs as evidence indicating the presence of the victim's neighbor at the crime scene and their subsequent departure [75]. Conversely, in another instance (arson), the prosecuting authority terminated investigations based on § 170 II StPO (insufficient suspicion) [75], despite two dogs also tracking a trail along nearly identical paths and concluding the search at the same location during the investigation phase.

A judgment from the Regional Court of Nuremberg-Fürth in 2012 holds a prominent position. The court dealt with the question of under what circumstances the results of the use of mantrailing dogs can be considered as the sole evidence for the presence of suspects at the scene of a crime. The starting point for the decision was several burglaries in which the defendants broke into various buildings and subsequently stole valuables. All defendants claimed they were not involved in the burglaries in question. Except for the results of the deployed dogs, there was no other evidence that could support their guilt. Three police mantrailers were used 36 or 67 days after the crime, with items of clothing used as scent articles. The court concluded that "*… the use of mantrailing dogs … under the established conditions is not suitable to provide a* ***solely viable*** *basis for evidence*." [emphasized by the author] The "*established conditions*" included the lack of examination levels for individual dogs used, the unclear acquisition of scent articles, and the lack

of traceability of the dogs' work. The court dealt extensively with the special search method of "mantrailing" in its explanations and, for the first time, established criteria in the decision's headnotes that must be strictly adhered to for future deployments. The following minimum standards were formulated in the headnote:

"Results of mantrailing deployments (use of scent search dogs) can be used as the sole evidence for the presence of suspects at the crime scene only if the following conditions are met:

1. Only dogs that have completed the relevant police mantrailing examination level should be used.
2. The scent article used must be unambiguously assignable to a specific person. Therefore, only swabs taken directly from the body of the person in question should be used as scent articles. In addition, the acquisition of the scent article must be documented in a protocol.
3. Two search dogs must independently and without involvement of the other handler search the same trail. Only with an identical result is the necessary objectivity given.
4. *Each deployment must be completely filmed to enable subsequent tracing by the court and an expert witness."* [76].

In the present case, the dogs used did not meet these requirements, so the corresponding usability was not given. Nevertheless, the decision is groundbreaking under various aspects. Firstly, the court explicitly demands the use of dogs that have completed the relevant examination level, here with the Bavarian police. Furthermore, it can be deduced from this demand that only certified dogs should be used in the investigation process. In relation to the design of examination regulations for mantrailers, the Nuremberg judges issued a clear request to the police authorities of the states: "*The problem in this context is that even the strictest examination level PSH 3 in the present case does not even remotely correspond to the conditions of the deployments, particularly with regard to the age of the traces to be searched. It is therefore generally required that additional tests be created for law enforcement purposes that cover such deployments, …* " (LG Nürnberg-Fürth [76], recital 34).

Subsequently, the Federal Court of Justice (BGH) suggested in a decision that these minimum standards only apply in cases where they are to be used as the sole evidence of the presence of a suspect at the crime scene: "*The assessment of evidence is also not objectionable with regard to the results achieved through the use of the tracking dog 'Lucky.' The Senate can leave open whether it would follow the minimum standards established by the Nuremberg-Fürth Regional Court in its judgment of December 13, 2012 (13KLs 372Js 9454/12), which the appeal is based on. Because these refer to a situation that does not exist here, namely that it is the sole evidence of the presence of a suspect at the crime scene. Therefore, the Regional Court was entitled to attribute a certain indicative value to the knowledge obtained through 'Lucky' for the defendant's culpability, even if the use of the dog had not been carried out lege artis in all respects. The Regional Court was aware of the potential limited probative value of this evidence and only granted it 'subordinate importance for the assessment of evidence' (reasons for the decision, p. 41 et seq.)."* [77].

Although courts are generally not bound by the rulings of their peers, all subsequent judgments known in this context refer back to the precedent established by the Nuremberg-Fürth Regional Court. Notably, two courts, both in cases involving arson, accorded probative value to the outcomes of mantrailing dog deployments, considering them as evidence of the suspect's presence at the scene of the crime. This deployment was executed *"… in every respect lege artis …* "., encompassing the following key facets:

- the deployed canines were duly trained and certified,
- the collection of scent samples was meticulously documented through video recording to ensure their uncontaminated nature,
- an expert assessment of search quality was conducted based on the analysis of video footage,
- a trail was meticulously picked up and followed across a substantial distance,
- several negative controls were conducted, and
- plausible alternative sources of error were methodically eliminated [78,79].

The defense subsequently lodged an appeal against the first-mentioned judgment with the Federal Court of Justice (BGH), citing several issues, including the court's evaluation of evidence through substantial complaint. The Federal Prosecutor General's Office (GBA) opined: "*The Regional Court's deduction of the defendant's involvement in all instances from the totality of established evidence indications is unobjectionable.*" Additionally, the GBA asserted: "*The evaluation of evidence is likewise unobjectionable in regard to the outcomes derived from the utilization of so-called mantrailer dogs 'Hippie' and 'Hermine' (Reasons p. 11, 16–21) (*cf. *Senate, ruling of May 7, 2014 -5 StR 151/14 -)*" [80] (Office of the Federal Prosecutor General at the Federal Court of Justice, 2015, unpublished). The appeal was subsequently rejected on the grounds of being devoid of merit [81].

It seems that the Nuremberg-Fürth Regional Court has established a quasi-standard for assessing the outcomes of mantrailer deployments. Numerous other judgments, along with their individual deliberations, explicitly utilize these criteria. Consequently, it is recommended for investigative agencies to familiarize themselves with the directives outlined by the Nuremberg-Fürth Regional Court.

In cases where a substantial body of alternative evidence is at hand (such as crime scene DNA, video recordings, or other investigative outcomes), strategic considerations lead to a limited reliance on the outcomes of canine deployments. Nonetheless, these outcomes are also deemed supportive corroborative evidence. This is notably exemplified in cases of homicide, as exemplified by the Bielefeld Regional Court [82] asserting: "[The] *result of the mantrailer deployment alone would not suffice for conclusive proof of the defendant's presence at the crime scene at the time of the crime, but it* supports *and confirms the result of the DNA analysis*." [82] A similar stance is observed in a decision of the Hamburg Regional Court [83]: "*In the overall view, there is much to suggest that T followed the trail of the accused to the crime scene quite accurately. However, the chamber did not attribute significant or decisive probative value to this due to the uncertainties indicated in detail, but rather considered the result of the dog deployment as merely an additional corroborative evidence with, however, only minor probative value.*" [83]. This perspective was upheld by the Federal Court of Justice (BGH) during the appellate proceedings, as highlighted by the BGH's affirmation: "*In addition to the General Prosecutor's Office's written request, the Senate notes: 'Contrary to the petitioner's claim, the very meticulous assessment of evidence by the Regional Court does not exhibit any legal errors to the detriment of the accused. This also applies to the expert-assisted criminal chamber's assessment of the results achieved through the use of the scent dog 'Trude' as 'further corroborative evidence with, however, only minor probative value' (Reasons p. 39)"* [84].

The Regional Court Gera issued a comparable ruling in a case involving aggravated joint theft, articulating that: "In definitive terms, the court presently accords a significance akin to that of a 'bioindicator' to the utilization of person scent dog deployments in view of the myriad uncertainties and unresolved queries linked with the so-called 'Mantrailing.' Notwithstanding, the panel remains persuaded that the multitude of instances where the presence of scent traces from both defendants was ascertained at their respective crime scenes through appropriately executed and evaluated mantrailing dog deployments is not mere coincidence. Within the entirety of these instances, the panel regards this as an additional pointer to the defendants' culpability, further reinforcing the already-established conviction of the panel grounded in the abundance of other indicators, without necessitating the inclusion of this specific evidence to substantiate the panel's overarching conviction pertaining to the acts delineated under sections II. 1–21." [85,86].

However, a notable exception emerges in a specific judgment where

scant indications of the accused's involvement in an arson case were presented. During the trial, the accused refrained from commenting on the allegations. Nevertheless, he was discovered in immediate temporal and geographical proximity to the scene shortly after the fire outbreak. Further reinforcement was provided by findings from telecommunications monitoring that implicated the accused. In the course of the investigations, police mantrailing dogs were deployed. The court recognized the results of these mantrailer deployments as pivotal constituents of the overall evidence assessment. The tribunal affirmed: "*Furthermore, the ascertained involvement of the defendant finds reinforcement in the outcomes derived from the deployment of mantrailing dogs. Bolstered by the testimonies of the police canine handlers, who acted as witnesses, the partially reviewed video records of the mantrailing deployments, and the persuasive and lucid clarifications furnished by the experts, the tribunal is decidedly convinced that the dogs successfully discerned the scent trail of the defendant at each of the fire scenes.*" [87]. The judicial panel acknowledged the possibility of occasional canine errors leading to the pursuit of false trails during individual searches. However, the evidential significance attributed to the outcomes of the service dog deployment by the panel did not stem from isolated searches. Instead, it derived from the collective weight of eight service dog deployments, each involving a distinct set of eight dogs. Notably, in every instance, at least two dogs were deployed, and all managed to track a scent trail associated with the defendant at each respective location. The pivotal consideration influencing the chamber's assessment of the evidentiary value of the mantrailing dog deployments was the consistent success rate of the search results across trails of varying ages. This observation led the chamber to infer that the dogs possessed the ability to detect aged trails as well. Consequently, the chamber harbored no doubts regarding the dogs' capacity to detect the scent of the perpetrator, which corresponded to the defendant's scent, at the fire sites, even several months after the incidents. "*The chamber recognized that the service dog deployments took place between the end of April 2013 and mid-May 2013, while the fires occurred from mid-January 2013 until the end of April 2013. Moreover, in the context of the evaluated mantrailing dog deployment, the primary intent behind initiating the trail was to establish the defendant's presence at the fire sites, rather than establishing a specific distance covered by the trail.*" [87].

In cases where the temporal span of the trail extends across multiple days or even months, the diversity of evaluations arises due to the lack of research in this field. In the aforementioned cases, certain courts ascribed varying degrees of evidential weight to the outcomes of canine deployments, considering them indicative of the offender's presence at the crime scene. Notably, such assessments were applied to deployments involving trail ages of 11 days [83] 19 or 23 days [79], 8 weeks [88], up to two and a half months [89], up to 4 months [87] or up to 4.5 months [90]. In contrast, some courts withheld attributing any probative value to results of dog deployments pertaining to trail ages of up to 38 days [91] or up to 54 days LG Frankfurt [92]. In the latter ruling, the court did not harbor reservations regarding the acquisition, preservation, and utilization of scent samples, nor the operational procedures (qualification of the dog handler teams). However, the court remained skeptical of the mantrailing dogs' ability to reliably discern the defendant's scent traces at the crime scene and its vicinity 54 days post-incident. This skepticism primarily stemmed from the prolonged exposure of these traces to environmental conditions during the intervening period, and further accentuated by the dearth of pertinent scientific investigations within this realm. The ruling of the Heidelberg Regional Court follows a similar line of reasoning. Beyond mere doubts surrounding the capacity of mantrailing dogs to detect and track trails aged over a month, particularly across asphalted and volatile terrains, and in instances of a "vehicle trail" (where the sought individual moves with a vehicle) over substantial distances, the court further criticized the dog handlers' implementation as not being "*lege artis*." This encompassed aspects like the usage of inadequate scent samples, which raised concerns about potential contamination. Additionally, the court underscored a myriad of exculpatory investigative outcomes (e.g., absence of fingerprint traces, DNA traces misaligned with the defendant) [93]. The Bremen Regional Court scrutinized mantrailing deployments for their notably suboptimal execution based on the assessments of "*expert witnesses with pertinent expertise, […], who uniformly concurred, leading the chamber to find their conclusions persuasive and well-grounded, ultimately concluding that the results of the mantrailing deployments carried no evidentiary value due to their fundamentally flawed execution*" (LG Bremen [91], recital 190).

As is evident, the absence of scientific investigations did not invariably result in the court's dismissal of evidence. Especially when additional circumstances substantiate the outcomes of dog deployments, these are also factored into the assessment. However, a prerequisite for this is their *lege artis* execution.

5. Mantrailing during investigation and scent evidence cases in court - France

In France, there are two main internal security services: the police and the national gendarmerie. Although both institutions are placed under the authority of the same ministry since 2009 (Ministry of the internal affairs), the personal of the gendarmerie have military status, while the personal of the police service have civilian status as civil officers of the Ministry deployment. These two services are the main players in the fight against crime and the maintenance of law and order. Each force operates in a distinct geographical area. The national police force covers just 5% of the country, and is responsible for maintaining law and order in France's major cities, while the national gendarmerie cover 95% of the country, and are active in peri-urban and rural areas, i.e. medium-sized towns.

In the case of a serious offenses (homicide, rape, arson or organized robbery) or flagrant crime (which has just been committed; the suspect is found in possession of objects, or evidences related to the crime are found on him suggesting his or her involvement in the crime), the internal security forces secure the perimeter and call the criminal investigation services (CIS, police or national gendarmerie officers, art. 16, text 31, CPP, JORF March 15, 2023) who inform the public prosecutor before starting the investigation. The officers from the CIS are responsible for establishing criminal offenses, gathering evidence, tracking down and arresting offenders. They ensure the preservation of any evidence that may disappear and of anything that may help to establish the truth. They seize the weapons and instruments used to commit the crime or intended to commit it, as well as anything that appears to have been the direct or indirect evidence of the crime. They present the objects seized, for recognition, to the persons who appear to have participated in the crime, if they are present (art. 53, 54 CPP, JORF March 10, 2004).

After a crime has been reported, the preliminary investigation conducted by the CIS under the supervision of the public prosecutor may continue without interruption for a period of eight days. If the material evidence collected during the preliminary investigation is insufficient, the public prosecutor can extend the duration of the investigation. The CIS can proceed to external sampling collection (fingerprints, palm prints or photographs required to supply or that can be compared to police files according to the rules specific of each file; art. 55-1 of the CPP, JORF January 24, 2023) on any person likely to provide information on the facts in question or on any person legitimately suspected of having committed or attempted to commit the offense, in order to compare them with the traces collected on the crime scene or on the material evidence found on the crime scene. Depending on the nature of the offense and the type of evidence found at the scene, the CIS may request the assistance of a canine unit to carry out a tracking operation (mantrailing). This operation is led by the "Cynophile Investigation Group" (national gendarmerie or police).

Mantrailing technique has been officially used by gendarmerie forces as part of an investigation since the creation of the first national dog training center (CNICG) in Gramat in 1945 and by the police since the

creation of their first Police National center for dog training (CNFUC) in Cannes-Ecluse in 1953. The use of the police dogs for mantrailing stopped definitely in 2022.

The mantrailing operation must be carried out according to the following strict rules:

1) the deployed canines and their handlers are duly trained and certified by one of the two national training centers (CNICG for the gendarmerie or CNFUC for the police), and only dogs that have completed the relevant police mantrailing examination level are used.
2) the scent samples used during mantrailing are collected according to a specific procedure that has been developed and documented by the different national dog training centers (CNICG and CNFUC). These samples are taken from objects found at crime scene (trace scents) or directly taken from a specific person (body scent of the victim or the person suspected to have committed the crime). The acquisition of the scent article must be documented in a protocol.
3) The mantrailing results are documented in a technical report, detailing the entire procedure, from odor sampling to the end of the operation

All material elements collected during the mantrailing are included in the investigation file. This file is then forwarded to the public prosecutor. Just as in Germany, internal security forces (police and National Gendarmerie) have been using mantrailing dogs as investigative tool.

Contrary to what is afore-reported in the case of Germany, the results of a mantrailing are not considered as pivotal constituents of the overall evidence assessment. The use of dogs for mantrailing purposes is only considered as a "technical assistance" to provide additional investigative material elements characterizing the nature, the place, the course of events during the offense and the identity of he victim and/or the suspect. At the end of the investigation, the case files are forwarded to the judge before a trial is opened.

French courts are not obliged to provide their judgments to public databases. However, some famous cases have made the headlines.

For example, in May 2018, in Drôme Provençale (south of France), two people were found murdered in an isolated house. About 2 h after the murder, the criminal investigation service (CIS) began its investigation. The only evidence collected by the CIS is a witness who reported seeing an individual loitering 100 m from the house in the morning of the murder. The individual was found on the road, arrested and taken into custody by the public prosecutor. The CIS research section in charge of the investigation requested a mantrailing operation (by the National Gendarmerie) to try and find further evidence. To do this, scent samples were collected from the suspect. Three days after murder, the dog team (bloodhound breed and his handler) began the mantrailing. Arrived on the vicinity of the house where the bodies were found, the dog handler presented the scent sample to his dog and let him run around. The dog stopped at particular places: a broken window at the back of the house, the main door of the house and a barn attached to the house. Then, the dog guided his handler to the back of the garden and followed and trace till the road where the suspect was seen by the witness. The dog's behavior was documented in the investigative technical report forwarded to the public prosecutor who decided to extend the custody. During the investigation, clothes impregnated of the victim's blood were found in the garden where the dog stopped, and the murder weapon was found in the barn appointed by the dog. Analyses showed DNA of the suspect and the victims on the clothes and on the weapon. The suspect denied any involvement in the crime, but he was sentenced to life in prison at the end of the trial.

In another case, on the night of April 11, 2017, a young French army corporal disappears in Chambéry. Seven days after his disappearance, the CIS in charge of the investigation, requested a mantrailing operation (by the National Gendarmerie) to find him. To do this, trace scent samples were taken from the sheets of the bed occupied by the young man. Using videotapes recording from the town of Chambéry, the dog team (bloodhound with his handler) positioned themselves at the last spot where the cameras had spotted the young man before he disappeared. The dog clearly followed a trail from this location for a long distance before stopping at a particular parking lot. It was assumed that the young corporal disappeared from this parking lot. The dog's behavior was documented in the investigative technical report that was forwarded to the public prosecutor. Other video images showed that a car belonging to a person (that will be suspected of another crime several months later) was parked in the parking lot of the nightclub where the young man had been that night. By tracing the telephone numbers of the suspect and the missing man, the CIS was able to identify the presence of both men in the same place at the same time. The trace of the two telephone numbers showed that both phones moved very quickly at the same time from the parking area. The young corporal's bones were found in a forest a few months after his disappearance. At his trial, the suspect admitted the facts and was sentenced to 15 years' imprisonment for murder.

In order to have additional pieces of evidence during a judicial trial, magistrates in France can request a scent line-up identification task. The purpose of the task is to make a match between a trace scent collected from a crime-scene object ("evidence scent" or trace scent) and the body scent collected from a suspect or victim. This test, also called "human scent line-up identification" is a matching to sample task that takes place in a laboratory room with semi-controlled experimental conditions. During the task, the dog is asked to sample the trace scent and compare it to 5 body scents collected from different people including that of the suspect (or the victim). All scents were collected on cotton squares and placed in line-up jars. Positive identification (Hit) is noted in the official report when the dog lays down in front of the jar containing the body scent matching to the trace scent sample. In that case, the line-up was repeated by the dog and the trials are recorded by a video camera. In case of a non-match (Miss), the trial is considered negative. A Miss response means that the dog did not match the trace scent sample with the target (body scent of the suspect), but did not necessarily imply that the target scent was not present in the sample or that the suspect was not present at the crime scene. In order to be validated, the results of the tests (Hits and Misses) must be always confirmed with 100% consistency by one or several other dogs working on the same case (the same day or some days later). When the dogs completed all of the tests, the scent identification is officially validated and the report transmitted to the magistrates (prosecutor or judge) indicates whether an association has been made between the scent from the suspect and the collected evidence scent. The number of dogs assigned to the same judicial case is always ranged between 2 and 7 and the total number of line-ups per court case ranged between 14 and 40 and between 5 and 13 per dog, depending on the type of identification and the number of evidence scents. It is important to note that the success rates in identification are higher when the scent traces had been collected at the crime scene between within 24 h of the offense; when the interval is longer, the success rate decreases [53]. Interestingly, confronting the suspect with a positive identification often leads to confession.

Human odor identification in judicial cases are used from 2003 in France, by the dog department of the National service of the scientific police (SNPS, Ecully, France). Unlike the mantrailing technique, the procedures used for human scent line-up identification tests are subject to controlled procedures whose qualities are officially validated by the French Accreditation Committee (Comité Français d'Accréditation, COFRAC; french organization designated as the sole national service responsible for assessing the competence and impartiality of laboratories and certification or inspection services; Accreditation by COFRAC consists in verifying the competence and impartiality of analysis and certification services, JORF 2008). Human scent line-up tests may therefore be requested by the public prosecutor as part of a pre-trial investigation. They may also be requested by the investigative judge and be considered as a piece of evidence in a trial. These tests are

predominantly required in grave offense cases, including organized theft or homicide. From 2003 to 2016, positive identifications made by dogs of the French SNPS were considered as important pieces of evidence during the trial and helped to solve 162 criminal cases out of 522 (data from 2016 have not been communicated).

Some famous cases were judged in France with the help of the human scent line-up tests. For example:

In December 2007, two Spanish Civil Guards, wearing civilian clothes and carrying no weapons, were having lunch in a cafeteria in Capbreton. They were identified by three members of the Basque separatist organization ETA, who followed them to their car. The two civil guards were then shot in the head. One died instantly, while the second died a few days later. In the absence of direct witness testimony, useable DNA and papillary traces, human scent line-up identification played a central role in the results of the investigation. Odor samples taken from the ETA member's' car were used to identify the three suspects. The shooter was sentenced to life imprisonment and his accomplices to 28 and 15 years' in prison respectively.

5.1. Another example

On the night of March third in 2010, in the Bouches-du-Rhône region of France, a police crew decided to control a suspicious vehicle which, refusing to comply, sped away. At the end of the chase, the driver abandoned his vehicle. The passenger, who had remained in the car, took the driver's seat and reversed, seriously injuring one of the police officers. He then returned to the passenger's side, denying his involvement in the victim's injuries. The policeman, in cardiorespiratory arrest and suffering from numerous traumas that caused the loss of all movement as well as her speech. The case attracted considerable media attention, with the President of the Republic visiting the victim's bedside. Analysis of the scent traces found in the car proved that the suspect was indeed the last driver and identified him as the person responsible for the police officer's injuries. He was sentenced to 20 years' imprisonment.

5.2. And third

On February 22nd, 2007, a man took his rifle and shot another man twice. The judicial investigation struggles to find direct evidence of the killer's guilt and the suspect denied knowing the victim. The prosecutor decided to request a human scent identification test. The suspect was judged by the court on the basis of the results of two ballistic analyses, as well as the results of the identification test based on scent samples taken from the steering wheel and the driver's seat of the victim, attesting the suspect's presence in the victim's vehicle. The accused was sentenced to 10 years' imprisonment.

In this case, the lightness of the sentence imposed on the accused was due to the lack of direct evidence obtained during the investigation.

In a previous paper, we provided a detailed overview of the utilization of scent discrimination dogs across eleven countries [32].

6. Mantrailing in case law - USA

The use of findings from the deployment of tracking/trailing dogs in court has a long tradition in the USA. As early as the *Hodge v. State* case in 1893, the defendant's lawyer objected to the admissibility of the testimony regarding the tracking of the trail with a trained dog. The underlying crime was a homicide. Immediately after the crime, a dog was put on the trail of footprints that were found at the scene and followed them to the defendant's house. The appellate court ruled that: „*It is common knowledge that dogs may be trained to follow the tracks of a human being with considerable certainty and accuracy. The evidence in this case showed that a dog thus trained was within a very short time after the homicide put upon the tracks of the person toward whom all the circumstances strongly pointed as the guilty agent, and that the dog as if following these tracks or "trailing" went to the house of the defendant.[…] On this state of case, we are of the opinion that the fact that the dog, trained to track men as shown in the testimony was put on the tracks at the scene of the homicide and, "taking the trail" so to speak, went thence to defendant's house, where he, the defendant, is shown to have been that night after the killing, was competent to go to the jury for consideration by them, in connection with all the other evidence, as a circumstance tending to connect the defendant with the crime; and, of consequence that the court committed no error in refusing to exclude it.*" and thus recognized this evidence [94].

Based on this case law, two factions have emerged. The minority position, which generally opposes the admissibility of tracking evidence in the respective states, includes Illinois, Indiana, Iowa, Montana, and Nebraska. The *Brott v. State* case from 1903 is cited as the foundation for the minority position, which has a similar background to *Hodge v. State* from 1893. Bloodhounds were used to follow the trail of the defendant from the crime scene to his home after a burglary. The court initially involved saw it as evidence of guilt and convicted him. Additionally, there was a confession by the defendant regarding the crime. However, Brott was also convicted for other cases unrelated to the confession, and the only evidence was the work of the dogs. In the appeal, the state attorney general argued that the bloodhound has an exceptionally keen sense of smell, rarely or never errs when following a scent or distinguishing scents, and that knowledge of its exceptional abilities is so widespread that the courts can rely on it even without evidence. However, the appeals court made it clear that this belief is a fiction and strongly rejected the claim that there is any general knowledge of the bloodhound's ability to track that would justify accepting its conclusions as reliable under the circumstances presented in the available records (ibid p. 396). Furthermore, the court stated that the trailing took place more than 12 h after the crime and the trail had been exposed to the sun and crossed by others a hundred times in the meantime, which presented an exceptionally difficult situation for the dogs. The jury cannot evaluate whether the dog followed a strong or weak trail. The court also emphasized that the dog assumes a task that may exceed its abilities and that the performance of the dogs has limits. This must be taken into account in court. The court concluded that the work of the dogs is generally too unreliable to be accepted as evidence in civil or criminal cases. In conclusion, the court formulated the guiding principle that the behavior of bloodhounds, after being set on the trail of a fleeing criminal, cannot be used by the prosecution as evidence to prove that the trail of the defendant and the trail of the person who committed the investigated crime are identical [95]. In contrast, a few years prior in 1898, the principles were established on which the majority position (38 states and the District of Columbia) relies. These are:

- Use of a purebred dog of a breed that is characterized by a keen sense of scent and power of discrimination (e.g., Bloodhound, Foxhound, Pointer, and Setter) and has been demonstrated to possess this qualities.
- The dog must have been trained or tested for tracking humans.
- The dog was deployed from a location where it is established that the offender was present or circumstances indicate such [96].

Thereafter, scent tracking may be admissible as evidence to connect the offender with the crime or crime scene. However, in *Carter v. State* 1913, it was established that dog tracking evidence, while admissible, is insufficient for a conviction without supporting evidence [97]. These basic requirements were subsequently further developed differently in various states. The decision *Terrell v. State* from 1968 summarizes the previous decisions and lists additional features, including:

- The expertise and experience of the handler.
- The experience of the dog, its reliability, abilities, and training.
- The circumstances during the trailing (e.g., age of the trail, whether the trail was trampled, whether the dogs were disturbed during work).

If this adequate foundation is laid, the evidence can be used to identify the accused as the perpetrator or for other purposes, provided it is confirmed by additional evidence. Additionally, the purebred status of the dog is no longer required as a prerequisite in several decisions [98].

Through its long history, a variety of judgments have been issued. For a cursory overview, a search was conducted in the database of the Caselaw Access Project (CAP) of Harvard Law School (as of March 27, 2023). The database includes, according to its own information, all official, book-published state and federal United States case law — every volume or case designated as an official report of decisions by a court within the United States, which was published until 2020 [99]. An initial search using the keywords "detection dog evidence" yielded 11,149 entries. A subsequent query was narrowed down to cases where the terms "tracking" and "evidence" appeared together, as "tracking evidence." This refinement produced 801 entries. Reviewing these cases revealed that many were not relevant to mantrailing, in part because the search term "tracking evidence" produced a number of cases dealing with claims against railway companies, especially up to the 1970s or the admissibility of GPS tracking or cell-phone tracking in the 2000s. A search using the terms "bloodhound evidence" produced 737 entries, and was similarly refined to cases where the terms appeared together, as "bloodhound evidence." After excluding duplicates (2) and cases without relevance (1 with no relevance, 7 dealing with drug-sniffing dogs), 73 entries remained. Comparing these entries to the 55 cases not found in the "tracking evidence" search left 18 additional cases. An additional search using the condition that the terms "dog tracking evidence" must appear together yielded 94 entries, with only 11 of these overlapping with the "bloodhound evidence" search results. Combining the results from these searches led to a total of 156 cases spanning from 1904 to 2019. As a comprehensive overview of cases before 2010 already exists [100], this review focuses only on cases from 2010 onwards. Using the search methods described above, 44 relevant cases were identified, in addition to five known decisions. However, eight of these cases were not relevant to mantrailing (2 with no relevance, 1 dealing with arson detection dogs, 4 dealing with cadaver detection dogs, 2 dealing with drug-sniffing dogs), leaving 40 relevant cases. These cases were divided among the following jurisdictions (see Table 1).

In seven out of 40 judgements, the admissibility of scent evidence was not discussed. Eleven of the cases dealt with dog scent lineups, with nine of those involving the same dog handler. This is discussed in more detail below. Numerous cases mention the use of mantrailers in investigative measures, although they were not questioned by the defendant or the court (e.g., United States Court of Appeals for the Fourth Circuit [101], Connecticut Appellate Court [102]). Some cases are discussed below to illustrate the current case law context. It is notable that a large portion of the cases involve capital crimes such as murder, rape, or armed robbery, and in some instances, the death penalty was imposed. All cases involved appeals. From states holding the minority position, four verdicts have emerged in the research. Two of them are presented here to derive whether changes have occurred since 2010. One case occurred in Illinois. After an armed robbery and a severe sexual assault, a police dog was used to track the author, and it followed a trail from the crime scene to the location where the defendant was arrested. *In People v. Lacy*, 2011, the defendant challenged the ineffective defense with respect to canine tracking evidence. On the other hand, the prosecution argued that this was not raised in the direct appeal and thus was forfeited. Furthermore, the prosecution argued that the reliability and admissibility of canine tracking had significantly changed since the last time the Illinois Supreme Court addressed the issue. As it concerned ineffective assistance of counsel, the court commented that the defendant did not assert that the trial court admitted the dog evidence, but rather that the defense counsel failed to object to the testimony. Nevertheless, the court referred to the decision in *People v. Cruz*, which affirmed that *"bloodhound evidence is inadmissible to prove any fact in a criminal trial in Illinois*" [103]. However, it also noted that subsequent cases have decided that it is not erroneous for a court to allow tracking evidence to confirm other trial testimony (Illinois Appellate Court, 2011 [104], 407 III. App. 3d 466 and citation therein).

Table 1
Jurisdiction, states holding the minority position are grayed out.

Jurisdiction		Jurisdiction		Jurisdiction	
Alabama	1	Maine	2	North Carolina	2
California	1	Michigan	1	Texas	8
Connecticut	1	Mississippi	1	United States	9
Florida	1	Montana	1	Virginia	1
Illinois	1	New Hampshire	1	Washington	2
Indiana	2	New York	1	Wisconsin	2
Louisiana	2				

In the periphery of tracking evidence, the case of *Myers v. Superintendent, Ind. State Prison*, 2019 (Indiana) is addressed. Preceding this were cases previously documented in the mentioned research, including *Myers v. State*, 2015 [105,106]. In the current instance, the focus was also on the defense's ineffectiveness and the failure to object to the dog handler's testimony. Particularly notable is the fact that the bloodhound evidence served as the prosecution's strongest proof in undermining Myers' alibi. Consequently, a writ of habeas corpus was granted in Myers' favor. The judgment additionally emphasized that, despite the fact that the Indiana Supreme Court's relevant rulings on the fundamental inadmissibility of tracking evidence [107–109] were issued prior to the adoption of the Indiana Rules of Evidence in 1994, they did not alter the inadmissibility of Bloodhound evidence [110]. This illustrates the persistence of the minority position even after 2010.

In contrast, the cases that follow were addressed within jurisdictions adhering to the majority stance. In the majority of these instances, the scenario involves the immediate deployment of a scent dog at the crime scene subsequent to the commission of a criminal offense. The (trailing) dog is set on the trail with a scent article [111–115] or without a scent article (tracking dog), originating from the suspect, at the location where the offense occurred or where a suspicious individual was last sighted [116–121]. During the course of the trail pursued by the dog, items relevant to the offense or perpetrator (such as weapons or clothing) have been discovered [113,114,116–121]. In one instance, a suspect was apprehended [118]. In other cases, the dogs are utilized to establish a connection between the perpetrator and the crime scene [111,112,115], even in the absence of a definitive eyewitness identification of the suspect's presence at the crime scene. Furthermore, three cases exclusively involve cadaver dogs [122–124]. These instances are mentioned here since, in each case, the courts referred to previous judgments outlining the criteria for acknowledging dog-tracking evidence, reaffirmed or partially clarified them, and determined their applicability to cadaver dogs.

As previously noted, all the cases listed involve appeals. The appeals encompass applications for the complete exclusion of dog-tracking evidence, objections against courts admitting such evidence despite opposition, the inability to cross-examine the dog, the potential undue influence of jurors due to such evidence, or insufficient legal representation pertaining to this evidence. Consequently, subsequent exemplary case law will be presented addressing the aspects of the dog's reliability, the utilization of the dog after an extended period (aged trails), and the outcomes of the dog's deployment as the sole evidentiary factor.

6.1. Canine reliability

In the case of Tariq-Maidyun v. State, 2010 (Alabama), the defendant (though belatedly and thus not taken into account) raised an objection concerning the tracking capabilities of the deployed dog. Regardless of this, the appellate court addressed the use of the dog.

Most recently in 2003, the Court of Criminal Appeals of Alabama had ruled that dog-tracking evidence is admissible if the State establishes "*the training and reliability of the dog, the qualifications of the person*

running the dog, and the circumstances of the dog's tracking" (Alabama Court of Criminal Appeals [125], at 971) and subsequently reiterated this three basic requirements for admission of dog-tracking evidence (Alabama Court of Criminal Appeals [126], at 550 n. 6). In the present case, the dog had undergone a 12-week training program, encompassing tracking on fresh ground and object retrieval. The dog was trained for "patrol duty," which includes tracking work, building searches, area searches, and object searches. The dog handler had been working with the dog for four years. During the search, the dog was deployed at the location where the author was sighted. While the dog handler did not furnish information about the dog's past success rate, the court's decision suggests that this impacts the evidential weight rather than its admissibility. Ultimately, even if the defendant had timely objected, the outcome would not have differed [116]. Similarly, in Magee v. State, 2011 (Mississippi), regarding the dog handler's testimony about tracking, the court noted that the dog had been used in only ten investigations and lacked proof of purebred lineage. The court quoted a decision from Alabama: *"For dog-tracking evidence to be admissible, the State must establish the following: the training and reliability of the dog, the qualifications of the person handling the dog, and the circumstances surrounding the tracking by the dog"* quoting [125]. It was established that the dog had successfully completed a training and certification course. The dog undergoes official training for 8 h each month and additional 3-h sessions on days off. Neither the Mississippi Supreme Court nor the appellate court considers pedigree evidence necessary for the dog's qualification. However, concerning the weight of the evidence, the court did not focus on the dog's trail tracking but instead considered other case aspects such as the offense circumstances and DNA evidence [117]. It becomes evident that courts do not impose undue requirements on the deployed dogs. This is unsurprising. The centuries-old doctrine that only specific breed or purebred dogs can reliably perform tracking lacks scientific foundation. Furthermore, binding guidelines on training concepts or at least benchmarks specifying the duration and content of training required for a dog's eligibility in criminal proceedings are absent. This is aside from the experience and training of the dog handler.

6.2. Canine deployment after a prolonged period (aged trails)

Divergent from cases wherein dogs are promptly deployed post-crime, scenarios emerge where a certain period elapses before their involvement. This corresponds with the defense's contention that potential scent trails might become imperceptible to the dog over time, thus failing to meet one of the consolidated principles of the majority stance on admitting dog-tracking evidence concerning trailing circumstances (e.g., trail age), as encompassed in *Terrell v. State*, 1968 (Maryland) [98]. In one instance, a Bloodhound was engaged 44–48 h subsequent to the crime, casting doubt upon the reliability of this evidence. Adding to this, the appellant's prior presence in the area (months prior) suggests the dog might have picked up an older trail. The appellate court noted that despite the dog handler testifying that the dog could discern scents up to thirty days old, the dog was trained to track scents only aged up to 58 h. Apart from the dog's deficiency in training and capacity to follow a scent aged several months, it was indicated that the trail seamlessly connected significant zones of the crime scene, implying the dog had been following the appellant's scent from the inception of the crime. Moreover, the trail wasn't pursued with the intention of locating a suspect, a corpse, or a specific object at its termination; however, this doesn't alter the assessment. While the presence of the target person at the trail's end amplifies reliability, a parallel indicator of dependability exists here. The dog traced the scent from the point where a witness saw a man forcefully pushing a woman into the woods to the victim's body in the woods (where the appellant ultimately confessed to being at the time of the crime) and further to the location where the police apprehended the appellant. The dog's tracking was seamless, even leading to the discovery of missing evidence. Importantly, earlier jurisprudence [127] confirmed the admissibility of tracking evidence even when no person was found at the trail's end. The appeal was dismissed [114]. The case holds significance mainly due to the trail's age, exceeding two days. Moreover, the argument that the appellant was previously in the area could suggest that his scent was legitimately present at the location. Consequently, the court's rationale in this regard is noteworthy.

In *State v. Bucki*, 2020 (Wisconsin), canines were not employed until 14 days after the crime was committed. Participating experts expressed the absence of scientific consensus on questions such as the duration of human decay or human activity scent retention in an area (defense), but underscored the reliability of properly trained cadaver and tracking dogs (prosecution). The court engaged with precedent and determined that in numerous jurisdictions, the appropriate basis for canine tracking evidence - akin yet not identical to trailing dog evidence - necessitates proving that "*(1) the handler was qualified by training and experience to use the dog; (2) the dog was adequately trained to track humans; (3) the dog has been found to be reliable in the field; (4) the dog was placed on the track where the circumstances indicate the guilty party has been present; and (5) the trail has not become so stale or contaminated as to be beyond the dog's capability to follow*." Simultaneously, it rebuffed the demand for a categorical rule tying the admissibility of pertinent dog scent evidence to the presence of corroborative physical or forensic evidence validating the dog alerts [115]. Curiously, the judgment remained silent on the aging of the trail, despite the utilization of tracks 14 days old. Notable in this context is *People v. Jackson*, 2016 (California). Within its 93-page verdict, 33 pages delve into trailing evidence's admissibility. Trailing evidence has been admissible in California since 1978 [128]. To establish this, five criteria must be fulfilled: (1) whether "the dog's handler was qualified by training and experience to use the dog"; (2) whether "the dog was adequately trained in tracking humans"; (3) whether "the dog has been found to be reliable in tracking humans"; (4) whether the dog "was placed on the track where circumstances indicated the guilty party to have been"; and (5) whether "*the trail had not become stale or contaminated*". Additionally, it was stated that trailing evidence from dogs is insufficient to secure a conviction without direct or circumstantial corroboration [129]. However, in the present adjudication, the court arrived at an alternative ruling, elucidating that the fifth Malgren factor does not hold the status of an indispensable prerequisite for the admission of the evidence. "*Thus, the fifth Malgren factor is not an independent requirement; it is satisfied by evidence that establishes the other four factors. Again, to the extent that the People v. Malgren decision suggests otherwise, it is also disapproved on this point.* (ibid. 325)" [113].

Concerning the presence of physical or forensic evidence, State v. Cannon, 2021 (Tennessee) explicitly articulated: "After reviewing the law, we conclude that there should be no requirement of corroboration of the dog's alerts with chemical evidence. This holding comports with cases from other states. See e.g. , Lane, 862 N.W.2d at 457. With sufficient corroboration from other evidence aside from chemical evidence, as exists in this case, with an opportunity for cross-examination, and with a properly instructed jury, the dogs' alerts provide a valuable piece of circumstantial evidence." [124]. Against this contextual backdrop, the pronouncement in Castillo v. Commonwealth, 2019 (Virginia) holds import. This decision provides clarity with reference to Pelletier v. Commonwealth, 2004 [130], that a prior judicial precedent [131] did not "hold that dog tracking evidence must be explained scientifically before it can be admitted." [123]. These verdicts further underscore the absence of consensus among the cited experts regarding the persistence of the scent of human activity in a specific area. It emerges that the courts address these ambiguities by scrutinizing the contextual circumstances surrounding the investigation, encompassing aspects such as the presence of other investigative outcomes, the identification of items along the trail, or the dog's capacity to discern the location where the suspect ceased or was apprehended.

6.3. Results of canine deployment as sole evidence

From a legal standpoint, it is important to underscore instances where the outcomes of canine deployment serve as the sole evidentiary basis for connecting the defendant to a crime scene. An illustration of this can be found in the cases of *State v. Oliphant*, 2013 and 2014 (Louisiana). Following an armed robbery, two suspects were apprehended in their vehicle approximately 2 h after the crime occurred. These individuals were identified as the defendant and his brother. At the crime scene, two dogs were employed, using scent articles, notably a sock belonging to the defendant. Independently, these dogs tracked to the location where a witness observed the perpetrator entering the later-stopped vehicle. Both defendants received convictions during the initial trial. Following two unsuccessful appeals, a subsequent appeal was granted [132]. As early as 1921, the concept of "Bloodhound-testimony" was deemed admissible in Louisiana, although with a modest degree of probative weight, characterized as "„*but its weight is "merely as a circumstance tending to prove his guilt.*". However, this hinges upon establishing "*some proof of the reliability of the dogs, their acuteness of scent and power or sense of discrimination, and, in that respect, their reputation 'for trailing criminals, their pedigree, training, etc*." [133].

The court not only affirmed the underlying admissibility of such evidence but also, in reference to a Tennessee ruling [134], clarified that admissibility is contingent upon specific conditions being met, including purebred lineage, appropriate training, historical reliability, deployment on the trail, and within a reasonable timeframe after the crime. The essential criteria, particularly the absence of certification or records documenting the dogs' performance, were not fulfilled in this instance, leading to the inadmissibility of the evidence [111]. Given that the entirety of the case rested solely on the results derived from the deployment of the scent-tracking dogs (alongside unreliable DNA results and conflicting statements during the defendant's interrogation), the conviction was overturned, ultimately resulting in the defendant's exoneration. However, the prosecution chose to appeal this decision. The appellate court asserted that the collective body of evidence (inclusive of the canine work) suffices to sustain a conviction (ibid. p. 1259). Simultaneously, the court upheld the ruling deeming the Bloodhound evidence inadmissible in this specific case due to the total absence of verifiable information regarding the dog's training, experience, or capabilities. Notably, as the Bloodhound evidence was the sole proof connecting the defendant to the crime scene, a retrial was necessitated [112]. A similar scenario emerged in *State v. Battle*, 2017 (North Carolina), where the query arose regarding the sufficiency of evidence for inferring possession of a weapon based solely on the tracking of a scent trail by a canine from the weapon to an individual. Initially convicted in the trial court, the appellate court invoked its precedent, affirming the admissibility of tracking evidence when complementary evidence corroborates the outcomes of canine deployment. In the present case, however, the dog's tracking was the exclusive circumstance suggesting the defendant's possession of a weapon. Moreover, the dog followed the freshest scent trail, and no scent articles were employed. The demonstration that the dog trailed an unidentified scent does not legally substantiate a reasonable inference of the defendant's actual possession of a firearm. Consequently, the lower court's decision was overturned [118]. This precedent is also evident in *State v. Dupree*, 2020 (Michigan), wherein it is explicitly stated that "*tracking-dog evidence is not sufficient to* support *identification in a criminal trial by itself. Such evidence must be accompanied by other evidence, evidence that is not 'fragmentary or unsubstantial', but it need not be accompanied by direct evidence*." [121]. It is evident that despite some prior rulings where canine evidence in isolation led to convictions, the appellate courts have established rigorous criteria. Irrespective of extensive research into the capabilities of the canine olfactory system, the consensus remains that the human-canine partnership, as living entities, is not infallible to the extent of 100%. This viewpoint garners universal agreement.

At the outset, we have noted that the reliability of using dogs for human scent identification is often viewed critically and described in part as "junk science" [34,35,135]. The judgements presented above illuminate the requirements established for the potential probative significance of canine deployment outcomes. Clarifying the diverse viewpoints of the courts across different instances concerning the previously mentioned aspects is exemplified by the case involving the homicide of Murray Wayne Burr in August 2004. This led to numerous subsequent legal proceedings, which, among other matters, scrutinize the approach of a canine handler, Keith Pikett. The victim in the case was found stabbed to death in his home in 2004. In separate proceedings, Richard Winfrey Sr., his son Richard Winfrey Jr., and his daughter Megan Winfrey were charged. However, neither hair, blood, nor DNA samples from the crime scene matched them. During the investigation, scent lineups were conducted by the dog handler Keith Pikett using two or three Bloodhounds. For this purpose, a sample from the victim's clothing was used as a scent article. In contrast, 6 vessels with scent samples from six different female or male individuals, including the samples of the accused, were used. The procedure was recorded on video. All dogs showed an indication behavior for the samples of the accused. According to the dog handler, this indicated that the individuals had contact with the victim's clothing at the time of the murder. Megan and Richard Sr. were convicted, while Richard Jr. was acquitted. Richard Winfrey Sr. objected in his direct appeal that the evidence was legally and factually insufficient to justify a conviction for murder. However, the appellate court confirmed the conviction and concluded, among other things, that the evidence was legally and factually sufficient. It particularly found that the dog handler's statement regarding the dog scent lineup provided direct evidence that the appellant had direct contact with the victim's clothing, and therefore the jurors could reasonably conclude that the appellant was involved in the murder. The defendant filed a request for review of the court's exercise of discretion, which was granted, particularly because the appellate court relied on dog scent lineup evidence to support the legal admissibility of the evidence without considering the inherent limitations of such evidence. According to the reviewing court's assessment, this raises an important question regarding the administration of justice. Furthermore, the appellate court failed to properly evaluate the factual sufficiency of the evidence by engaging with the inherent limitations of dog-scent lineup evidence. The Court of Criminal Appeals of Texas found that scent lineup evidence is distinct from dog tracking evidence. Additionally, it ruled that scent discrimination lineups, when used as the sole or primary evidence, are legally insufficient to support a conviction. It further states that to the extent that lower-court opinions suggest otherwise, they are overturned, and it is explicitly stated that when incriminating evidence is obtained from a dog scent lineup, its role in the courtroom is merely supportive. "*To the extent that lower-court opinions suggest otherwise, we overrule them and expressly hold that when inculpatory evidence is obtained from a dog-scent lineup its role in the court room is merely supportive*" (ibid. p. 884). Against this background, the decision of the appellate court was overturned, and Richard Winfrey Sr. was acquitted [136].

As a result, the daughter, Megan Winfrey, also appealed her conviction. She argued that the evidence in her case was insufficient to support the jury's verdict. However, she did not object to the dog-scent lineup evidence during the trial. In this context, the appeals court saw no reason to review the admissibility of this evidence. Nevertheless, it stated that the dog-scent lineup evidence was not sufficient to establish the unequivocal guilt of the accused. Therefore, it was disregarded in the appeals hearing's evidence evaluation. Nonetheless, her conviction was upheld. This decision was not unanimous. One judge justified his dissenting opinion particularly due to the fact that the dog-scent lineup was the only evidence that connected the accused to the crime scene. In contrast, no other physical evidence indicated her presence at the crime scene, as mentioned above. Therefore, this judge did not see sufficient grounds for a conviction [137]. With particular reference to her father's acquittal, she directly appealed and argued that the evidence was legally and factually insufficient. As a result, she was also acquitted. In this case,

a judge had a dissenting opinion, who saw sufficient evidence for a conviction even without considering the scent evidence [138].

Following the verdict, Megan Winfrey filed a lawsuit against the investigators, including the dog handler Keith Pikett, claiming that her rights to due process were violated during the investigation. In particular, she alleged that Pikett knowingly used junk science, manipulated and falsified the results of his scent lineup, and used an inappropriately suggestive lineup procedure that led to Megan's mistaken identification. In the trial, another expert, Steven Nicely, testified that the scent lineup was flawed for the following reasons:

(a) newer scents are perceived as fresher compared to older scents;
(b) odor of people living in the same area are similar;
(c) dogs can become desensitized to scents if they are regularly exposed to them;
(d) Pikett's claim that his dogs are right 99% of the time is unreliable;
(e) Pikett may have influenced his dogs as he kept them on a short leash and could see inside the cans; and
(f) the dogs may have responded to conscious cues from Pikett.

In addition, Pikett's control samples were not suitable, as most of the control scent samples were older, from people who lived in the same location, and were stored near the dogs. Pikett kept the control scent samples for up to three years. The scent samples from the suspects were fresh. The court ruled that no claims could be derived from the complaints against the investigating officers. As for the complaint against Pikett, the court could not definitively decide whether conducting the lineup to gather evidence against Megan was reckless. Megan's complaint against Pikett was upheld [139]. Pikett subsequently sought summary judgment on the basis of qualified immunity. The district court denied Pikett's motion, and Pikett timely appealed. The plaintiff argued that the appellate court are not authorized to hear Pikett's appeal because his argument relates to factual disputes and not to the legal question of whether the district court made a legal error based on the findings and interpretation of facts in the light most favorable to Megan. The appellate court specifically examined whether it had jurisdiction over the appeal. In the appellate decision, the court referred to *Winfrey v. Pikett,* 2016 regarding the conduct of scent lineups, among other things, and found that no independent source had ever tested or certified Pikett and his dogs (ibid. p. 642). Regardless, it found that this court, as an appellate court, is not authorized to decide whether Pikett's version of the facts is correct. Accordingly, this preliminary injunction was denied [140]. The judgments and, in particular, the statements of the experts give rise to clear requirements that must be met for scent lineups to be admissible as evidence. However, this will not be discussed in detail here. Extensive discussions on the issue of scent lineups can be found elsewhere [32,141]. However, this scenario can serve as an exemplary illustration of the issue that arises when findings stemming from the deployments of canines are intended to be utilized as evidentiary support.

7. Discussion

The basis for employing results derived from canine deployments as evidentiary material lies in acknowledging the fact that each individual harbors a unique scent, a premise underpinning the deployment of mantrailers or scent discrimination dogs. To be more specific, the contention is that a particular trail (in this instance, the scent trail) emanates from a distinct source (here, the author), thereby allowing for the exclusion of all other potential sources. Nonetheless, this notion of singular distinctiveness is currently facing challenges [142]. "*To say that two things are identical is meaningless, and to say of a thing that it is identical to itself is to say nothing at all*" (Wittgenstein [143], 5.5303). If Wittgenstein qualifies as tautological, meaningless the notion of uniqueness as early as 1922, it was not until the 2000s that the latter was questioned in forensic science, to be described as a fallacy, a deception [144–146]. Inferring from two scent prints (controlled reproductions generated by the "unique" source at the best quality) necessarily calls for induction, which cannot ensure logically certain conclusions. Besides, the object of interest of the forensic scientist remains the trace, uncontrolled, imperfect specimen, often degraded, mixed, contaminated, polluted from such a putative source [147,148]. By affirming the identity of source, the forensic scientist expresses a personal opinion on the strength of an association (true and false positives observed) between this trace and a known scent print of the source, consisting in fact in the recognition of similar characteristics that are stronger than the dissimilarities observed. In short, the scientist compares the probability of the effects E (the similarities and dissimilarities of the trace with the olfactory imprint of comparison) under two alternative causes or hypotheses, those under which the suspect is at the origin of this trace (H_p) or not (H_d), denoted respectively $P(E|H_p)$ and $P(E|H_d)$. Note that H_d can also be more restrictive, for example the brother of the suspect or one of his acquaintances. We will not discuss this subtlety here. At the level of the identification of the source of a scent trace, it is easy to see that $P(E|H_p)$ corresponds to the sensitivity of the method or even of the handler-dog pair, and $P(E|H_d)$ to the false negative rate, opposite of selectivity. The ratio of these two probabilities $P(E|H_p)/P(E|H_d)$ is called the likelihood ratio (LR). It is recommended by the European Network of Forensic Science Institutes (ENFSI) or the Royal Statistical Society as the only solution for quantifying the probative value of an association [149–151], The Council of the Inns of Court (COIC) and The Royal Statistical Society [152].

The probability of causes interests the trier of fact (judge, jury, police officer, etc.). $P(H_p|E)$ corresponding to the probability that the suspect is at the origin of the trace knowing that an association has been asserted, we can expect this probability to be extremely high for such a decision to be taken, corresponding to the expression "beyond reasonable doubt" or "intimate conviction". Bayes' theorem helps to understand the contribution of the scent trace to the decision of identification [153,154].

$$\frac{P(H_p|E)}{P(H_d|E)} = \frac{P(E|H_p)}{P(E|H_d)} \frac{P(H_p)}{P(H_d)} \quad (1)$$

H_p and H_d being exhaustive, aka covering all the possible scenario explaining the trace, $P(H_p|E) + P(H_d|E) = P(H_p) + P(H_d) = 1$.

$P(H_p)/P(H_d)$ is called the prior odd or chance that the suspect is at the origin of the scent trace. $P(H_p|E)/P(H_d|E)$ is the posterior odd or chance that the suspect is the source of the scent trace. It follows that the identification decision reduced here to $P(H_p|E)$ necessarily depends on the prior $P(H_p)$, on the domain of the decision maker. At first glance, we can conventionally attribute to $P(H_p)$ the value 0.5 (i.e. $P(H_d) = 0.5$), expressing a prior equal indeterminacy between the hypothesis of the prosecution or the defense, aka a prior odd of 1 against 1, but this value remains a trier of fact choice, who can just as well decide that this prior is different. Note that the prior odd rating 1/1 also corresponds implicitly that only two individuals (the suspect and another person) are at the origin of the trace, which underlines the limits of an indeterminate prior between H_p and H_d: what are the alternative hypotheses of defense? For example, on the one side, if the investigation has reduced the suspect population to 10 equiprobable individuals including the suspect, shouldn't the prior rating express the prevalence, being 1 against 9? On the other side, wouldn't a transparent and reliable report of the whole process increase the trier if fact's prior over 1 against 1? Finally, would the trier of fact suspect a major bias in the process (as such as a Clever Hans one), he could even nullify its prior, implying a zero posterior probability whatever the outcomes, aka rejecting this evidence.

But let's come back on the weight of evidence itself. In this Bayesian model, a paper from Marchal et al. [60] makes it possible to perceive the LR ($P(E|H_p)/P(E|H_d)$), therefore the probative force of canine man trailing. On 12 validated German shepherds fit for legal purposes, they found a sensitivity of 85% and the absence of false positives on 18,127 tests. Such raw statistics would invite an infinite LR, i.e. an

individualization which would impose itself as a leap of faith [155]. Indeed, whatever the odd or the prior non-zero chance of H_p, the a posteriori odd of H_p (i.e. $P(H_p|E)/P(H_d|E)$) would then be infinite, which imposes $P(H_p|E) = 1$ and $P(H_d|E) = 0$. Therefore, whatever the priori knowledge on an investigation file, such as the fact that the suspect was unable to leave this scent trace, the decision would be to claim is the source of it! In fact, reading [60] invites to temper such an interpretation supported by the data they made available to researchers. It is first of all difficult to endorse their honest recognition that a thirteenth dog was also tested (Athos), but that, in an unexplained way, even not very credible for a national administration, "its records were accidently lost" (p. 6). Above all, before the validation of the 12 remaining dogs kept for the final tests, this paper recognizes 8 false positives, i.e. an LR of the order of 2000. However, these 8 false positives are qualified as high complexity (mixture of scent trace/print of the suspect), therefore potentially identifiable as difficult to interpret prior to tracking. This critical analysis argues that each tracking case must be analyzed in its context, evaluating the prior chance $P(H_p)/P(H_d)$ as a possible quantifier of such uncertainty or difficulty.

This recognized, it then becomes possible, even necessary, to interpret the absence of false positives on the 18,127 tests of the final experiment once these difficulties have been identified and dealt with, for example, by refusing the implementation of the tracking proof in such cases. The performance expected by such a rigorous selection process would then be close to that described by the authors of this study, with a Bayesian statistical approach assessing the expected uncertainty, i.e. the rate of false positives, currently zero [156,157].

The problem is then stated as follows: an association was found with a suspect (which happens in 85% of true cases in Marchal et al. [60]), and in 18,127 similar experimental circumstances where the suspect was excluded from the comparison scents, no association was found (i.e. a false positive rate θ close to 0). The researcher can then express his ignorance of θ by distributing its a priori occurrence P(θ) through a beta (1; 1). Marchal et al. [60] give the likelihood function in the form of a binomial with 18,127 trials without false positives, i.e. Bin(18,127; 0). The combination of these two distributions gives a beta P(θ|Bin(18,127; 0); beta(1; 1)), which is similar to the function P(θ|Bin(18,127; 0); beta (1; 1)) = 18,128 $(1 - \theta)^{18,127}$.

We therefore seek a lower bound θ_0 to θ, such that $P(\theta > \theta_0) = \varepsilon$ is as low as desired, or

$$\varepsilon = p(\theta > \theta_0) = 1 - p(\theta < \theta_0) = 1 - (n+1)\int_0^{\theta_0} (1-\theta)^n d\theta$$
$$= (1 - \theta_0)^{n+1} = (1 - \theta_0)^{18128}$$

For $\varepsilon = 0.05$, we obtain a maximum false positive rate of $\theta_0 = 5.5.10^{-5}$, and for $\varepsilon = 0.01$, $\theta_0 = 2.5.10^{-4}$. The respective LRs at 5% or 1% erroneous false positives are 15,400 and 3300 respectively, both of which can be described as very strong support for the H_p proposal [158–162]. In fact, the beta(1; 1) used as a prior to express our uncertainty on the false positive rate necessarily lowers the LRs calculated here: can we not reasonably assume that the false positive rate is not a priori distributed evenly between 0 and 1? Be that as it may, taking up our two previous priors, under the conditions specified by Marchal et al. [60], the Bayesian interpretation of the results gives the following table.

Prior prob.	Prior odd	LR	Posterior odd	Posterior prob.
0,5	1:1	3300–15,400	3300–15400:1	99,97–99,99%
0,1	1:9		3300–15400:9	99,72–99,94%

It is clear that there are remarkable performances in canine scent identification according to the conditions set out by Marchal et al. [60]. However, are such likelihood ratios exportable to all breeds of dogs, to all training methods, to all pairs trainer-dog? Do the conditions of execution of the mission support any of the priors proposed here? All these questions are in fact encapsulated in the I capital letter underneath, meaning background information, that should have appeared in equation (1), but was shortened for simplicity:

$$\frac{P(H_p|E,I)}{P(H_d|E,I)} = \frac{P(E|H_p,I)}{P(E|H_d,I)} \; \frac{P(H_p,I)}{P(H_d,I)}$$

Because of all these parameters to be assessed and validated, the decision of identification is first and foremost a personal decision of the trier of fact, considering much more factors than only the dog handler's report of a match. But once, accepted as a reliable process, the performance assessed through [60] allow him/her to allocate a very strong weight of evidence when a positive match has been transparently reported. In the context of these considerations, it becomes apparent that the possibility of false positives cannot be excluded. Within the context of the handler-canine partnership, beings who do not execute automated, flawless processes, this phenomenon is inherent and requires the attention of the courts. This necessitates an understanding of corresponding vulnerabilities. The notion of the (seeming) infallibility of the dog is widely propagated. This phenomenon also influences one's own evaluation as a potential juror in a criminal trial. Consequently, the propensity for returning a guilty verdict is heightened when one holds faith in the capabilities of detection dogs [163]. Recognizing this reality, the guidelines provided to jurors (Criminal Jury Instructions), particularly relevant to the American jury system, duly consider this aspect, exemplified by those of California: "*You have received evidence about the use of a tracking dog. You may not conclude that the defendant is the person who committed the crime based only on the fact that a dog indicated the defendant [or a location]. Before you may rely on dog tracking evidence, there must be: 1. Evidence of the dog's general reliability as a tracker; AND 2. Other evidence that the dog accurately followed a trail that led to the person who committed the crime. This other evidence does not need to independently link the defendant to the crime. In deciding the meaning and importance of the dog tracking evidence, consider the training, skill, and experience, if any, of the dog, its trainer, and its handler, together with everything else that you learned about the dog's work in this case.*"

"*The court has a sua sponte duty to instruct on tracking dogs whenever they are used to prove the identity of a defendant.*" [164].

The jurisprudence reveals that within the context of evidentiary significance, the courts demand additional insights to be garnered during the course of the search (e.g., discovery of objects on the trail, sighting of suspects at specific trail locations by witnesses, etc.). This approach can contribute to the mitigation of uncertainties. The minority-position states in the USA, which fundamentally preclude the suitability of trailing evidence, sidestep these limitations. From the aforementioned chronological overview, which is not intended to be exhaustive, it can be inferred that in jurisdictions allowing evidential admissibility, the courts' evaluation of the probative value of outcomes arising from the utilization of mantrailing dogs is contingent on the specifics of each individual case. This spectrum ranges from outright dismissal, through classification as weak circumstantial evidence, to providing corroborative indications of proof. In all three countries under examination, law enforcement agencies consider the deployment of dogs as a valuable tool, particularly in the investigation of capital offenses. The exposition of legal frameworks and subsequently the decisions of the courts have demonstrated that despite the disparities, the probative value of mantrailing evidence is consistently regarded. The criteria for the admissibility and assessment of evidence exhibit similarities. These criteria are influenced, on one hand, by legal statutes and especially by evaluation benchmarks established by the courts. These criteria encompass the training and operational experience of both the dog and its handler, or their certification. The breed of the dogs appears to play an insignificant role. In the scrutinized jurisdictions, both police and private handlers are employed. This variance entails distinct training methodologies, varying degrees of ongoing training intensity, and differing operational experiences. Therefore, it is recommended that dog

teams be required to demonstrate successful completion of an examination that mirrors the benchmarks of real deployment (e.g., trail age). In practice, only a minority of teams might achieve this. The potential for financial interests among private handlers cannot be disregarded. This can lead to extensive deployment scenarios even when they may not be optimal. Due to limited resources (personnel, time), this tendency is less likely among police handlers. Also, for these reasons, it is prudent for courts to critically assess the outcomes of dog deployments. An especially effective approach is the availability of video recordings of these deployments. Additionally, specific circumstances during the search should be taken into consideration. This relates, for example, to the quality or storage of scent articles. Ideally, these articles should originate directly from the suspect's body. If objects such as clothing are used, there's a risk of the extracted sample already being contaminated. Contamination of the scent article can also occur due to improper storage. The age of the trail being followed also has relevance. Furthermore, further insights related to the dog's work should be considered. For instance, caution should be exercised to prevent conveying case details to handlers in advance, which could subsequently influence the handler's unbiased search work due to the "Clever Hans effect." This phenomenon explains how animals can react to imperceptible human cues, such as slight muscle movements, facial expressions, and body language. Conversely, it's acknowledged that humans unconsciously emit subtle signals, without being cognizant of or able to manage them [165]. In scent dog handlers, the presumption of scent presence can lead to unintended cues, causing dogs to exhibit alert behavior regardless of a trail's presence. Additionally, the inadvertent influence of dog's search behavior by the handler can lead to a change in direction. This can result from the handler's misinterpretation of behavior or, conversely, from the (subconscious) intention of the handler regarding the assumed course of the trail, which subtly impacts the dog's search behavior through the handler's actions (tension on the leash, maintaining speed) [166,167].

Given the intricate nature of the subject matter, it becomes evident and, furthermore, prudent for the judiciary to augment the testimonies of handlers with the insights of experts possessing scientific proficiency in the field of mantrailing and/or scent discrimination. These experts can offer comprehensive perspectives on contemporary knowledge and explanatory methodologies pertaining to canine work. However, it should be acknowledged that certain inquiries presently lack definitive resolution or a consensus within the scientific community. For instance, uncertainties persist regarding the durability of scent trails or the specific constituents of scent trails utilized by dogs for individual trailing. Notably, the realm of mantrailing remains relatively underexplored. Some courts scrutinize outcomes stemming from deployments involving aged trails or what are termed vehicle-trails, raising skepticism primarily due to the absence of scientific insights. A thorough overview of the research landscape is presented elsewhere (Woidtke et al., in preparation). Crucial is the observation that the conclusions drawn from canine deployments find reinforcement through alternative indications or evidence. These may encompass discovered objects, testimonies from witnesses, or findings derived from technical surveillance (video, GPS, cell phone tracking). Noteworthy persuasive weight is achieved when dogs are engaged in searching for negative samples. In spite of the intricacy, none of the reviewed cases produced a determination that convictions were exclusively predicated on the outcomes of canine deployments, or if they were, such convictions were subsequently overturned (USA). The adjudicating judges are cognizant of the potential for errors in canine work.

8. Conclusion

The evidence has underscored the significant role of scent dogs in both investigative and subsequent judicial proceedings. Nevertheless, it is evident that a heightened awareness of the stringent admissibility requirements for trailing evidence can be beneficial for handlers and law enforcement officers. When evaluating the suitability of canine deployment results as evidence, the examined countries consider factors like the handler's qualifications, the dog's training and reliability, the appropriateness of the deployment location and timing, and the specific circumstances of the deployment. However, it's important to note the absence of definitive training and examination standards for both dogs and handlers. The criteria established by the American Academy of Forensic Sciences Academy Standards Board could serve as a useful model [168–170]. These standards incorporate insights from canine research, but no analogous framework is currently known for Germany. Valuable insights into the approach to scent dog deployment can be gleaned from case law. Prior to deployment, investigators, prosecutors, and judges should engage in discussions with handlers or other experts in the field to ascertain the feasibility of addressing the investigative query or scenario through the use of a mantrailer or scent discrimination dog. This assessment should encompass the potentials and limitations of canine deployment. Particularly when canine deployment results are presented as substantial court evidence, adhering to the aforementioned guidelines [76] can bolster the assessment of their evidentiary value. This includes measures like video documentation of canine deployments. The handler and dog should be filmed diagonally from an appropriate angle behind the team, capturing both the handler's interaction with the dog and the leash handling. Ideally, an individual unfamiliar with the case details should carry out this documentation, aligning with the "Clever Hans effect." During searches on public roads, personnel should be designated to control vehicular traffic, thereby preventing abrupt disruptions to the dog's search. These personnel should also remain unaware of the case particulars. Furthermore, they should be pre-instructed on how to respond to the dog's movements (e.g., dog reversing and approaching the safety post) during the search, so as not to impede the dog's work. Employing multiple dogs can heighten the probative value. It is prudent to utilize only well-documented and qualified dog teams for deployment tasks. The extensive realm of canine research is likely familiar to only a limited number of prosecutors, judges, or jurors. This familiarity gap can influence their decision-making [163]. It's crucial to acquaint this group more comprehensively with pertinent knowledge within the context of respective proceedings. The inclusion of relevant expertise during trials is paramount. On the other hand, gaps in knowledge regarding certain pivotal questions persist. For instance, the identification of chemical components constituting an individual's scent remains inconclusive [171]. Similarly, it remains uncertain which constituents dogs employ for scent detection [172], or how long scent trails endure in the environment and remain perceptible to dogs. These uncertainties contribute to the skepticism surrounding canine work outcomes. The necessity for research tailored to practical deployment scenarios in forensic canine applications is evident, extending to other application domains as well [173].

Case law has demonstrated that the courts acknowledge the inherent fallibility of the dog-handler dyad. The deliberations presented underscore the importance of integrating additional corroborative evidence in evaluating canine work outcomes. The analyzed jurisprudence reaffirms this aspect. Moreover, it showcases that administering justice does not necessitate the exclusion of canine work from investigative efforts and courtroom proceedings. Instead, it necessitates adherence to professional standards in training and deployment, anchored in scientific insights and practical studies.

CRediT authorship contribution statement

Leif Woidtke: Conceptualization, Writing – original draft, Writing – review & editing. **Frank Crispino:** Writing – original draft, Writing – review & editing. **Barbara Ferry:** Writing – original draft, Writing – review & editing. **Udo Gansloßer:** Conceptualization, Writing – original draft, Writing – review & editing. **Nina Marie Hohlfeld:** Writing – original draft, Writing – review & editing. **Tom Osterkamp:** Writing –

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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