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Abstract

This report provides supplemental information to NISTIR 8509 **Footwear and Tire Impression Examination: *A NIST Scientific Foundation Review*.** This report summarizes the concerns and critiques raised about footwear and tire impression examination by various groups including the National Research Council and the President's Council of Advisors on Science and Technology. Responses given by members of the footwear and tire impression examination community are also summarized.

Keywords

footwear; shoeprint; tire track; tire tread; forensic science; impression; pattern evidence; scientific foundation review.

Table of Contents

1. Introduction

There have been several published criticisms of footwear and tire impression examination by various groups including the National Research Council and the President's Council of Advisors on Science and Technology. This document summarizes specific concerns raised by these groups and responses to these critiques from members of the footwear and tire impression community.

2. Published Criticisms

2.1. National Research Council (NRC) 2009 Report

In 2009, the National Research Council (NRC), part of the National Academy of Sciences (NAS) published a report entitled *Strengthening Forensic Science in the United States: A Path Forward* (NRC 2009) that proposed 13 recommendations to improve the practice of forensic science, especially those areas involved in pattern analysis and feature comparison. The NRC report discusses footwear and tire impression examination on pages 145 through 150. Six articles were cited (Fawcett 1970, Cassidy 1980, Liukkonen, Majamaa, & Virtanen 1996, Majamaa & Ytti 1996, Bodziak 2000, Nause 2001) along with the International Association for Identification (IAI) Recommended Course of Study (IAI 2006) and the Scientific Working Group for Shoeprint and Tire Tread Evidence (SWGTREAD) guidance documents (OSAC 2023).

Regarding footwear and tire impression examination, the 2009 NRC Report found that the knowledge base underpinning footwear and tire impression analysis was incomplete in several areas. The NRC Report pointed to several key limitations of footwear and tire impression examination including:

- No established sufficiency criteria for the number of individual characteristics required to make a conclusion.
- Lack of research associating the number of matching characteristics with the probability that the impression was made by a common source.
- Lack of research on the variability of class or individual characteristics and the validity or reliability of methods to assess these characteristics.
- Lack of research on persistence of individual characteristics, the rarity of certain characteristic types, and appropriate statistical standards to apply to the significance of individual characteristics.
- Lack of proficiency tests that include ambiguous samples that would lead to an “inconclusive” conclusion.
- A course of study (IAI 2006) that does not require an understanding of the scientific basis of the examinations or recommend the use of the scientific method.

The report concluded that more research was required to identify critical needs in footwear and tire impression examination and to address the key limitations highlighted in the report.

2.2. PCAST 2016 Report

In 2016, the President’s Council of Advisors on Science and Technology (PCAST) published a report entitled *Forensic Science in Criminal Courts: Ensuring Scientific Validity of Feature Comparison Methods*. This report evaluated the scientific validity of seven of the most often used feature-comparison methods in the legal system including DNA (single source, simple mixed, and complex mixed samples), fingerprint, bitemark, firearms, footwear, and hair

analyses. For footwear impression examination, PCAST focused on the reliability of conclusions that an impression is likely to have come from a specific piece of footwear.

The report found that scientific evidence suggested that examiners could not associate shoeprints with particular shoes based on randomly acquired characteristics. As a result, the conclusions were left to the subjective judgment of the examiner and open to potential bias. PCAST also highlighted the lack of black box and white box studies to establish the validity and reliability of examiner identifications from footwear evidence. Therefore, the PCAST report concluded that the discipline of footwear analysis did not meet the scientific standards for foundational validity. While mentioned in examples of feature comparison methods, tire impression examination was not directly discussed by PCAST.

3. Responses to Criticism

3.1. Scientific Working Group for Shoeprint and Tire Tread Evidence (SWGTREAD) Input to the National Academy of Sciences (2007)

The Scientific Working Group for Shoeprint and Tire Tread Evidence (SWGTREAD) was created in 2004 by the FBI Laboratory to standardize and advance the forensic analysis of footwear and tire impression evidence. SWGTREAD published guidelines and best practices for the collection, preservation, and examination of footwear and tire impression evidence. SWGTREAD submitted a document to NAS in March of 2007 that specified the needs of the footwear and tire impression community. It included responses to NAS on eight (8) topics designed to identify current resources and future needs for the forensic science community. These topics were chosen by NAS to assist in their assessment of the forensic sciences that culminated in the 2009 NRC Report. Multiple disciplines within the forensic science community provided input on these topics and not all topics were relevant to all disciplines. The summarized responses from SWGTREAD below reflect this.

The eight topics from NAS and SWGTREAD responses were as follows:

1. Assess the present and future resource needs of the forensic science community to include state and local crime labs, medical examiners, and coroners.

   Response: SWGTREAD called for educating officers of the court on “proper” training and qualifications for expert testimony, increased funding for training resources and a National Training Academy for examiners and crime scene responders who use footwear and tire impression evidence, a searchable national database of shoe outsoles, studies on the frequency of particular shoe designs/sizes in the general population, and the frequency and relevance of individual characteristics in footwear and tires.

2. Make recommendations for maximizing the use of forensic technologies and techniques to solve crimes, investigate deaths, and protect the public.

   Response: SWGTREAD emphasized the need for funding research into fully automated pattern recognition software to aid in establishing a national database of footwear designs.

3. Identify potential scientific advances that may assist law enforcement in using forensic technologies and techniques to protect the public.

   Response: Not applicable

4. Make recommendations for programs that will increase the number of qualified forensic scientists and medical examiners available to work in public crime laboratories.

   Response: SWGTREAD highlighted the need for increased funding for footwear and tire impression positions in federal, state, and local laboratories and for continuing education for existing examiners.

5. Disseminate best practices and guidelines concerning the collection and analysis of forensic evidence to help ensure quality and consistency in use of forensic technologies to solve crimes, investigate deaths, and protect the public.

   Response: Best practices and guidelines in footwear and tire impression evidence were published by SWGTREAD. They recommended increased funding to disseminate these guidance documents to the forensic, law enforcement, and criminal justice communities.

6. Examine the role of the forensic science community in the homeland security mission.

   Response: See #1 and #2 above.

7. Examine the interoperability of Automated Fingerprint Identification Systems.

   Response: Not applicable

8. Examine additional issues pertaining to forensic sciences as determined by the Committee.

   Response: In the United States, footwear and tire impression evidence is underutilized in the criminal justice system due to a lack of understanding of its value and a lack of adequate training and resources for the collection and examination of evidence.

3.2. SWGTREAD 2009 Response to the National Research Council (NRC) Report

In response to the problems identified in the 2009 NRC report, SWGTREAD prepared an open letter and four supplemental documents detailing the then-current status of the discipline, clarifying perceived inaccuracies in the NRC Report, suggestions for advancement of the discipline, and a copy of the responses they provided to the NAS in March 2007 (see Section 3.1 above). When detailing the status of footwear and tire tread examination, SWGTREAD emphasized the prevalence of published research on the validation of examination methods and range of accepted conclusions, the training and certification resources available to practitioners, standards available through SWGTREAD, and the history of footwear evidence in the U.S. justice system (SWGTREAD 2009).

SWGTREAD identified seven statements in the NRC report as inaccurate and provided brief responses to them. Topics ranged from the subjectivity of examiner conclusions, current training materials, and inter-examiner consistency among others (SWGTREAD 2009). These comments reflected the criticisms listed in the NRC Report and listed in Section 2.1 of this document. Summaries of the NRC statements and SWGTREAD responses were as follows:

1. Identifications are based on subjective experiences of the examiners and on the number of individual characteristics shared with a known standard.

   Response: SWGTREAD claimed footwear conclusions are based on objective and verifiable features and experts can clearly communicate these features to officers of the court.

2. No threshold or sufficiency criteria for the number of identifying characteristics needed for identification.

   Response: Studies exist in footwear and tire tread examination that describe statistical approaches to individual characteristics used for identification. However, because of the qualitative and variable nature of this type of evidence, defining a threshold would not only be difficult but arbitrary and lack credibility.

3. Existing training programs neither require an understanding of the scientific basis of footwear and tire examination nor recommend the use of the scientific method. There is also no recommendation for proficiency testing or continuing education opportunities.

   Response: The training guide [IAI] does include discussion on the scientific basis of examinations. Continuing education opportunities as well as proficiency testing are out of the scope of the guide but are recommended in SWGTREAD guidance documents and through accreditation and certification programs.

4. Critique of footwear impression literature by [authors] Fawcett[1] and Bodziak[2] that attempts to assign probabilistic or statistical significance to footwear impression comparisons .

   Response: This is a misinterpretation of the references cited. Both authors emphasized that any use of statistics was for the purposes of example and not intended to represent actual results of the impression comparisons.

5. A European survey[3] concluded that different laboratories examining the same evidence reached considerably different conclusions.

   Response: The study cited in the comment was neither representative of a “normal” comparison process nor a validation of the process. This was an international study that included language differences in the wording of conclusions that could account for the variations reported.

6. Class characteristics can be identified and along with patterns of wear, specific individualization may be concluded.

   Response: Characteristics of wear are not utilized for identifications.

7. Critical research needs have not been identified nor have questions regarding the persistence and rarity of individual characteristics and the need for and application of statistical standards to determine the significance of individual characteristics.

   Response: SWGTREAD referenced the input provided in their 2007 letter to the NAS (see Section 3.1) and stated that no response was received by the NAS, NIJ, or other

[1] Fawcett AS (1970) The role of the footmark examiner. *Journal of Forensic Science Society* 10:227-244.
[2] Bodziak WJ (1999) *Footwaer Impression Evidence – Detection, Recovery, and Examination*. (CRC Press, Boca Raton, FL), 2nd Ed. Pp. 342-346.
[3] Majamaa H, Ytti A (1996) Survey of the conclusions drawn of similar footwear cases in various crime laboratories. *Forensic Science International* 82:109-120.

academic researchers to invitations by SWGTREAD to discuss the input or future research needs.

SWGTREAD also highlighted six recommendations to advance footwear and tire tread examination based on the criticisms from the NRC, including:

1. Mandate that minimum education and training requirements are met across the U.S. prior to the collection or examination of shoe and tire impression evidence.
2. Define and require materials and equipment that meet minimum performance standards.
3. Dedicate sufficient funds to the specific areas of training, materials and equipment, research and development, and for the establishment of career paths and other incentives to retain experienced personnel.
4. Mandate an acceptable level of forensic footwear and tire track training, experience and proficiency, and require certification (upon eligibility) to qualify as an expert in this discipline in a court of law.
5. Establish and mandate standards for procedures, terminology, or range of conclusions for the collection, examination, or testimony of footwear and tire track examiners.
6. Establish an oversight board or committee comprising certified, experienced, and qualified forensic footwear and tire tread examiners to design, administer, and enforce the aforementioned recommendations.

3.3. SWGTREAD 2011 Responses to the Subcommittee on Forensic Science

In response to the problems identified in the 2009 NRC report, the White House Office of Science and Technology Policy (OSTP) established the Subcommittee on Forensic Science (SoFS) under the National Science and Technology Council (NSTC). The goal was to identify challenges and ways to address the NRC report recommendations (Butler 2015).

SoFS established five interagency working groups. The Research, Development, Testing, and Evaluation Interagency Working Group (RDT&E IWG) asked forensic practitioners to provide examples of foundational literature that supported the methods used within their disciplines. Representatives of 10 forensic disciplines responded with annotated bibliographies (Butler 2015).

These annotated bibliographies have been archived on the NIST website[4]. They provide practitioner perspectives for a given discipline at the time provided and were given in response to specific questions raised by the RDT&E IWG. The bibliographies did not undergo further review or analysis when they were received by the RDT&E IWG and are not endorsed by the federal government. On November 16, 2011, SWGTREAD supplied a 37-page response to 15 questions on footwear and tire tread examination.

[4] See https://www.nist.gov/topics/forensic-science/working-groups/legacy-scientific-working-groups

The 15 questions from the SoFS RDT&E IWG were as follows:

1. What literature exists that addresses the number of characteristics/identifying marks required to render a conclusion?
2. What is the literature that discusses the use of statistics to support an examiner's conclusion?
3. What literature exists that measures the consistency of examiner conclusions, incorporating multiple examiners, with various training and experience, given the same sample set of known "matches" and known "non-matches" of varying quality?
4. What is the literature that addresses the effects of examiner experience/training/caseload in shoeprint/tire tread examinations?
5. What is the literature on the potential and actual cognitive bias in shoeprint and tire tread examinations?
6. What literature exists that investigates the effects of environmental conditions on shoeprint/tire treads? What is the literature that documents the formation of individual characteristics amongst a group of people wearing the same shoe for the same period of time?
7. What is the literature that investigates the transfer of identifying features from sole or tread to impression medium across differing substrates?
8. What is the literature that investigates the development of defects/individualizing characteristics on different sole or tread materials?
9. What literature exists that describes the automated systems in shoeprint/tire tread examinations? What literature exists that addresses the accuracy and validity of automated systems in shoeprint/tire tread examinations? What literature exists that addresses the effectiveness of human examiners and automated systems used in conjunction to render a conclusion in shoeprint/tire tread examinations?
10. What is the literature on error rates in shoeprint/tire tread examinations?
11. What is the literature that addresses the feasibility and reliability of partial print comparisons (i.e., situations where some of the sole pattern may be present with individual detail, but there is insufficient detail to compare class characteristics)?
12. What is the literature that describes the rarity of class characteristics and uniqueness of individual characteristics in shoeprints/tire treads? What published databases exist that describe the frequency statistics of various shoeprint tire tread patterns?
13. What is the literature on quantification; measurement precision and uncertainty in shoeprint/tire tread examinations? For example, are there studies that would help describe "small" and "large" scratches in terms of measurement uncertainty? For example is >1.0cm ± 0.1cm big and how jagged does a scratch need to be before it is unique?

14. What is the literature on population-based studies that describe variation (e.g., due to gender, pathologies, height/weight, running vs walking, stride, etc.)?
15. What new technologies and areas of research should be pursued with regard to shoeprint and tire tread examination and analysis and in what priority? (Note- this does not require a list of references, it is for informational purposes only.)

The SWGTREAD responded to these 15 questions raised by the SoFS RDT&E IWG with an annotated bibliography of 95 journal articles, 13 books/book chapters, and 4 conference presentations that reflect the state of the field at the time (SWGTREAD 2011). Most of the cited references are peer-reviewed journal articles from *Forensic Science International, Journal of Forensic Identification, Journal of Forensic Sciences*, and *Science & Justice* or edited volumes such as Cassidy (1980) and Bodziak (2000). Of the responses, three (#1, #4, #6) included an acknowledgment that there was little or no literature available to directly answer the questions asked. Two responses (#8 and #10) cited three or fewer references and one question (#15) was not answered in the response document. The note included with the question indicates that references were not required, so it was not included in the responses detailing the available literature.

3.4. OSAC Footwear and Tire Subcommittee Responses to PCAST's Request for Information (2015)

Established in 2014, the Organization of Scientific Area Committees (OSAC) for Forensic Science consists of 22 subcommittees made up of volunteer subject matter experts who develop standards and other guidance documents to strengthen forensic science methods and practices. OSAC also maintains the OSAC Registry which is a collection of published and proposed standards from OSAC and standards developing organizations (SDOs).

The OSAC Footwear & Tire Subcommittee focuses on standards and guidelines related to the detection, documentation, recovery, examination and comparison of footwear and tire evidence (OSAC 2023). Additional information on the guidance documents available from the subcommittee and other organizations are detailed in NISTIR 8509sup3 *Guidance Documents in Footwear and Tire Impression Examination*. In December 2015, the subcommittee submitted a 14-page response to 6 questions from the President's Council of Advisors on Science and Technology (PCAST) (OSAC 2015).

The six questions from PCAST were as follows:

1. What studies have been published in the past 5 years RE: FW/TT? What studies have been published in the past 5 years that support the foundational aspects of each of the pattern-based forensic science methods, including (but not limited to) FW/TT? What studies are needed to demonstrate the reliability and validity of these methods?
2. Have studies been conducted to establish baseline frequencies of characteristics or features used in these pattern-based matching techniques? If not, how might such studies be conducted? What publicly accessible databases exist that could support such

studies? What closed databases exist? Where such databases exist, how are they controlled and curated? If studies have not been conducted, what conclusions can and cannot be stated about the relationship between the crime scene evidence and a known suspect or tool (e.g., firearm)?

3. How is performance testing (testing designed to determine the frequency with which individual examiners obtain correct answers) currently used in forensic laboratories? Are performance tests conducted in a blind manner? How could well-designed performance testing be used more systematically for the above pattern-based techniques to establish baseline error rates for individual examiners? What are the opportunities and challenges for developing and employing blind performance testing? What studies have been published in this area?
4. What are the most promising new scientific techniques that are currently under development or could be developed in the next decade that would be most useful for forensic applications?
5. What standards of validity and reliability should new forensic methods be required to meet before they are introduced in court?
6. Are there scientific and technology disciplines other than the traditional forensic science disciplines that could usefully contribute to and/or enhance the scientific, technical, and/or societal aspects of forensic science? What mechanisms could be employed to encourage further collaboration between these disciplines and the forensic science community?

The OSAC Footwear and Tire Subcommittee responded to these questions with a discussion of the available resources and an annotated bibliography of 45 references, mostly peer-reviewed journal articles (40), conference presentations (4), and a book. The peer-reviewed articles came from journals such as *Forensic Science International, Journal of Forensic Identification, Journal of Forensic Sciences*, and *Science & Justice* and other journals with legal or computer science applications. Most of the responses fully addressed the questions posed by PCAST, however, two questions (#1 and #6) were not fully answered. Response #1 did not provide a response to the request for available literature on the reliability and validity of footwear and tire tread methods and response #6 included an incomplete answer regarding how to encourage collaboration between footwear and tire tread practitioners and the rest of the forensics science community (OSAC 2015).

3.5. IAI 2016 Response to the PCAST Report

The International Association for Identification released a response to the 2016 PCAST report. In this letter, then-IAI President Harold Ruslander summarized the criticisms of the friction ridge, footwear, and tire tread impressions from PCAST and provided a brief rebuttal. Regarding footwear examination, the IAI disagreed with PCAST's conclusion that this discipline did not meet reliability standards and stated that a complete assessment of the available literature was

not thorough. The IAI "...finds the report lacking in basis and in content, and improper in some of the statements that are made. There are significant research efforts that are not included in the report, including a black box study currently being conducted by West Virginia University and studies related to the evaluation of shoe damage" (IAI 2016).

Additionally, the IAI extended this lack of information to include the input provided to PCAST prior to the report from forensic science experts and IAI concluded that this input was not fully represented in the report; all published and in process research should have been included in PCAST's evaluation of the discipline: "Experts, including lAl members, provided information related to the methods, basis and research conducted in these fields that was not fully presented or addressed in the report" (IAI 2016). Furthermore, it was noted that while the PCAST report includes tire tread examination, it does not include a discussion or evaluation of the reliability of this type of evidence.

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