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Review Article

The Paradigm of Fingerprint Age Determination

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Abstract

Forensic sciences have gained wide public awareness in recent years owing to television programs and films that depict the exciting and high-tech glamour of technology available to practitioners in identifying and prosecuting criminals. The core of this discipline, however, is still the gathering and analysis of fingerprints, which remain the basic tool for identification of suspects at crime scenes. What is not widely known – and a fact that has far-reaching implications for forensic professionals, law enforcement, courts of law, and justice systems worldwide – is that no reliable method presently exists for determining the age of a latent fingerprint. That is, while fingerprints can be identified and associated with suspects potentially guilty perpetrators are released and innocent victims unnecessarily implicated because investigators lack a robust method of assessing the *time* the trace was deposited at a scene. We have compiled data showing the present socio-economic burden that criminal justice systems pose on government budgets, to conclude that dating crime evidence will be a useful measure to reduce the pressure on public expenditures, to increase the efficiency of criminal justice systems, and to collaterally improve public security and citizen's confidence in forensic sciences.

Keywords: Fingerprint; Age; Time; *in situ* testing

Introduction

The field of forensic science utilizes scientific principles for the analysis of crime scene evidence and the identification of donors. The main goal is to obtain and provide valid proof with maximum objectivity and reliability for the judicial process. On this ground, since the inception of fingerprint analysis in the 19th century, forensic scientists have focused on improving technical and methodological developments for the application and understanding of the characteristics of fingerprints as a tool for consistent human identification [1] [2].

Despite all the advances in the science of fingerprinting, errors in the identification of fingerprints are a subject of grave concern in countries worldwide. Although there are no official figures published, the release of guilty individuals and conviction of innocent persons based on wrongly interpreted evidence occurs (e.g. *Mayfield* case). Many of these errors in identification are caused by the examiner's subjective conclusions during the process of "matching" the unknown fingerprint at the scene to the alleged donor tenprint, rather than due to the absence of identification value of the trace itself. The United States National Academy of Sciences' National Research Council Report [3] noted: "*The simple reality is that the interpretation of forensic evidence is not always based on scientific studies to determine its validity*"; stressing the lack of strong scientific methods in some forensic disciplines that lead to biased, intentional or unintentional, incorrect attributions.

In addition, issues of reliability of fingerprints as a means for human identification frequently arise in court when the criminal trace cannot be directly correlated to the moment a crime was committed. In this context, the most common situation occurs when a suspect has legitimate access to a scene before or after the actual crime. The inability to date the moment the fingerprint was deposited often nullifies otherwise strong items of evidence or implicates innocent persons. Although safeguards have been put in place to minimize misattributions [2][4][5], including detailed protocols, quality assurance measures, proficiency tests, and specific training for fingerprint examiners, no scientific method or standard has been implemented to address chronological mismatches between a criminal event and the deposition of traces.

We anticipate and discuss in the present article that the next "natural" step forward in forensic science research, and fingerprinting, will be, and needs to be, the investigation of methods for dating criminal traces. The data gathered from different institutions are examples showing the convenience of increasing and diversifying government funding and human resources to this yet unsolved subject, which has relevant repercussions to criminal justice systems, public security and people's lives.

Methods

Several database tools were used in order to compile the data presented. National and international databases were searched, besides the traditional literature review included and referenced in the current report. In the absence of European figures on several matters that relate to the criminal justice system, some of the cost estimates summarized in the tables were extrapolated from US dollars to European euros from year 2010.

The Catalonia region information was gathered from the Government's "idescat" website, which includes numerous sources of statistical data that relate the public administration from 2012. Similarly, the annual report by the Ministry of Interior of Spain was used, as well as the website from the Spanish Statistical Office "INE" with information from 2012. For the European statistics, the Eurostat yearbook was utilized as reference document. Finally, the tables shown include data based on the British Home Office from year 2000.

Results and Discussion

Fingerprint evidence plays a central role in the European criminal justice systems in the resolution of crimes. According to a Eurostat report (Eurostat yearbook report 2011, the European Commission, ISSN 1681-4789. Accessed December 24, 2014), there were over 28 million serious criminal offences in the EU-27 in 2011, with an estimated 75 million direct victims (As mentioned on page 141 of the REGULATION (EU) _o .../2013 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of the Horizon 2020 - the Framework Programme for Research and Innovation (2014-2020). Overall, and depending on regional statistics and year, approximately 30 % of all criminal cases, not including misdemeanors, were solved based on any sort of criminal evidence. From these data, a realistic assumption is that fingerprints were recovered from approximately 30% of crimes (ANZPAA (Australian New Zealand Policing Advisory Agency) report "End-to-end forensic identification process project", in 2012; and personal communication from the Catalonia Police Force.), of which 25% would be positively matched to a donor. Altogether, a potential 2.1 million offenders are identified by fingerprints yearly in Europe (66,319 in Spain and 21,407 in Catalonia). The cost of obtaining identifications by fingerprints for law enforcement, from first activation of experts to the crime scene to the examination process and court reporting, is practically impossible to estimate. This is due to the absence of national and international records on the degree of complexity of each crime scene and the amount of hours and manpower employed for the examination process. However, based on the total number of court cases in Europe, we would assume that the cost of court prosecutions in which fingerprint evidence are involved would be 477 M€ per year.

It is difficult to estimate how many of the total inmate population of 637,929 imprisoned in the continent have been incarcerated based solely, or primarily, on fingerprint evidence. This is because the relevance (or "weight") of this type of evidence is unknown at the time of sentencing as each surrounding circumstance is unique. In addition, there is a total fragmentation or absence of official (public) data sources, and no international databases are currently available that could elucidate, to a certain degree, this matter. However, it is worth noting, based on US estimates, that the cost of maintaining the prison population is over 14 M€ per year. Table 1 and Table 2 illustrate the magnitude of the population impacted directly or indirectly by fingerprint evidence, from a regional to a continental scale.

The current economic situation has increased the pressure placed on law enforcement agencies and justice systems that are already operating with limited budgets, including pressure from taxpayers concerned with public expenditure. Accordingly, this is a key moment to propose new methods to increase the speed and reduce economic costs of producing scientific results without diminishing the reliability of criminal evidence. Given the significance of the figures above, it is critical that the methods of interpreting fingerprint evidence be as thorough as possible. As mentioned, the missing element in the current investigative protocols that could drastically reduce the costs of prosecutions is the determination of *time* [6]. Lacking this key element, the large amount of traces to be processed along with examination errors can have a negative effect across many dimensions, from unnecessary expenses for police and court systems, to unjust incarceration of individuals, wasted spending by cash-strapped regional and local governments, and more.

Table 1. Population data statistics in relation to the criminal justice system in Catalonia, Spain and EU-27

		Population Statistics on the Criminal Justice System										
		Forensic Science Laboratories (Law Enforcement)				Justice Department				Correctional Department		
	Population (millions)	Police officers (per 1000)	Serious crimes reported per year[4]	Serious crimes (per 1000)	Resolution of crimes per year (%)	Penal cases per year[4] (total)	Penal cases per year[4] (per 1000)	Convictions per year[4] (total)	Convictions per year (per 1000)	Prison population (total)	Prison population rate (per 1000)	Prison density per 100 places
Catalonia	7.554[1]	3.668[1*]	285,433[5]	37.78[5]	28.74[5]	61,729[1]	8.17	28,837[1]	3.81	10,062[1,7]	1.332[1]	94.3[6]
Spain	47.265[2]	3.624[2]	884,253[2]	18.71[2]	37.29[2]	300,142[2]	6.35	221,063[8]	4.67	58,556[2,7,10]	1.239[2]	153[6]
EU-27	502.520[3]	3.371[3*]	28,512,000[3*]	57.29[3*]	?	4,889,519[11]	9.73[11]	3,507,589[11]	6.98[11]	637,929[7,9]	1.260[9]	98.4[6*]

(1) Official statistics of Catalonia Government, 2012. http://www.idescat.cat (accessed 08-02-2014).

(1*) Includes Catalonia Police Force and Local Police of Catalonia.

(2) Anuario Estadístico del Ministerio del Interior, 2012, Spain. http://www.interior.gob.es/file/63/63661/63661.pdf (accessed 08-02-2014).

(3) Eurostat yearbook report 2011. ISSN 1681-4789.

(3*) Corresponds to 2008 figures.

(4) Includes homicide, violent crime, robbery, domestic burglary, theft of a motor vehicle and drug trafficking. Less serious crimes (misdemeanors) are generally excluded.

(5) Reported by the Catalonia Police (excluding Spanish National Police) in 2012. Report on "known criminal offences by the Catalonia Police in 2012". Catalonia Government.

(6) Council of Europe Annual Penal Statistics – SPACE I – 2009. Marcelo O F. Aebi and Natalia Delgrande. University of Lausanne, Switzerland.

(6*) It includes all continental European countries.

(7) It includes pre-trial detainees.

(8) Spanish Statistical Office, Spanish Government. www.ine.es (accessed 08-02-2014). Data for 2012.

(9) Eurostat, Trends in crime and criminal justice, 2010, by Steve CLARKE.

(10) Excluding Catalonia.

(11) International statistics on crime and justice. European Institute for crime prevention and control, affiliated with the United Nations. S. Harrendorf, M. Heiskanen, S. Malbydata. Data corresponds to all continental Europe in 2006.

(?) Data undisclosed.

Table 2. Impact of fingerprinting in the criminal justice system in Catalonia, Spain and EU-27; and potential savings that the estimation of the age of deposition could have on the system

	Estimated economic statistics on the Criminal Justice System						
	Forensic Science Laboratories (Law Enforcement)		Justice Department		Correctional Department		Public Administration
	Estimated offenders identified by fingerprints[1]	Potential fingerprint misattribution cases[2]	Costs of Penal trials[3,4] M €uros	Saving costs for Penal trials[5,6] M €uros	Costs of prison population per year[7] M €uros	Saving cost of prison services[5] M €uros	Total economic savings[5] M €uros
Catalonia	21,407	171	4,864	19.4	230	2.0	**22.7**
Spain	66,319	530	15,068	60.2	1,339	6.1	**70.4**
EU-27	2,100,000	16,800	477,147	1,908	14,590	192.1	**2,303.4**

(1) Official statistics of Catalonia Government, 2012; Anuario Estadístico del Ministerio del Interior, 2012, Spain; Eurostat yearbook report 2011. ISSN 1681-4789.

(2) Based on 0.8% rate of misattributions in proficiency tests (Cole, 2005).

(3) Based on Home Office Research Study 217. The economic and social costs of crime, 2000, by S. Brand and R. Price: GBP 186,641 (227,213€) per crime; including Police, prosecution, legal aid and non-legally-aided defense costs, magistrates, probation service, prison service, jury service, criminal injuries and compensation resources.

(4) Only considering trial cases where suspects may have been identified by fingerprints.

(5) Assuming a conservative 50% of cases where the new fingerprint dating technique would be used on false positives.

(6) Only taking into consideration potentially misattribution cases.

(7) Based on US estimates per inmate in 2010: USD 31,286 (22,871 €). VERA Institute of Justice, *The Price of Prisons, What Incarceration Costs Taxpayers*, 2012.

Eventually, *time* will become the center of criminal investigations beyond the identification of the criminal trace. In the context of this hypothesis, we would like to distinguish two concepts: *misattribution* and *misidentification*. The former denotes cases where a fingerprint is correctly associated to a suspect but is inconsistent with the timeframe of the crime. The latter refers to cases where an incorrect match is made between the trace and donor because not enough identifiers are present (i.e. poor quality and quantity of necessary detail), an error in interpretation has been made, or a clerical error has led to an improper identification. Despite standardization of the fingerprint identification process (The standard process includes: attendance to crime scene, evidence collection/transport, evidence submission and ACE-V process (analysis, comparison, evaluation and verification) in crime laboratories, errors still occur. For example, in a report [7] based on proficiency tests performed by Federal Bureau of Investigation (FBI) fingerprint examiners in the USA, it is estimated that a false positive (As S.A. Cole describes: In the context of fingerprint identification, a false positive would consist of reporting that an individual is the source of an impression when in fact he is not. On the other hand, a false negative would consist of reporting that an individual is not the source of an impression when in fact he is.) result is recorded by a forensic examiner on 0.8% of occasions. Although reliable data on false positive rates by country do not exist, based on the figures in Table 1, it could be extrapolated that in up to 16,800 cases examiners could have reported a false positive, which would in turn, result in a significant percentage of innocent citizens being incriminated and possibly incarcerated based on an "erroneous" fingerprint identification.

If the factor *time* were to be used in 50% of criminal cases where a suspect was identified by fingerprints, an estimated 1,050,000 criminal cases would benefit from these potential errors. Consequently, the number of court trials would decrease, with a corresponding impact on erroneous convictions and overall reduction of economic costs to public administrations (see Table 2). For example, in EU-27 the implementation of age estimation of fingerprints could represent an estimated 2.3 billion Euro savings to the overall EU Public administration. An additional benefit of the inclusion of the proposed aging factor is that it could be performed on-site, at no additional cost, unlike current expensive laboratory techniques that are not portable to the scene.

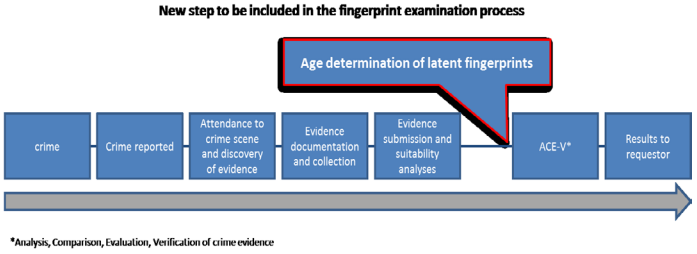
Although there are a few laboratories in the world investigating this unsolved *time* issue[8][9][10][11]each with substantially different approaches, currently there are no scientific methods or standards to estimate the age of fingerprints. There are two main reasons that account for this deficiency:

1. Scientific challenges: there are numerous variables, and interactions among them, that can affect the degradation process of fingerprints, which up to now have made age determination complex, challenging, and controversial. We could classify these as *intrinsic* (i.e. from the donor) and *extrinsic* (i.e. external to the donor) factors can affect the aging patterns and interpretation of the age of latent fingerprints, making aging studies very difficult to generalize. Many environmental conditions (e.g. temperature, humidity, and insolation) are known to cause a significant differentiating effect on the degradation and evolution of latent fingerprints [8][12][13]. The quality (chemical composition) of the donor´s sweat can be influenced by gender, age, health conditions, diet, and medication intake, even within the same individual at different times of the day and/or under specific psychological conditions [14]. Therefore, it is necessary to design a robust technique that can overcome some or most of the variability caused by these factors.

2. Financial resources: it has long been recognized [3] that trends in innovation and economic resources are more favorable to other branches of science, such as biology, physics or chemistry, while forensic science as a field of study has fallen behind, due in large part to fragmented institutional networks with limited funds for scientific research [15].

Despite the aforementioned difficulties, the inclusion of *time* in the examination process would include a very important new step in the current standardized protocols for crime scene analysis. We hypothesize that in addition to addressing the *what* and *how* aspects of evidence collection, the potential ability to add the *when* could strengthen the probative value of evidence in investigations worldwide (Figure 1), introducing a new foundational step in the standard identification pathway of fingerprints.

Figure 1. Fingerprint examination pathway with the new suggested step to be added in the future



In our perspective, fingerprint research conducted by De Alcaraz-Fossoul, J. et al. 2013 [8]; Barros, R.M. et al. 2013 [13]; Bailey, M. et al. 2013 [16]; Francese, S. et al. 2013 [9]; and Attard-Montalto, N. et al., 2014 [11]; are some excellent examples of studies that contribute to the inclusion of more science into fingerprinting. The singular scientific approach of every of the aforementioned investigators emphasizes the array of multiple directions for research in this field; from chemical profiling of the components of the print to visual imaging examinations.

Conclusion

The main goal of forensic science practitioners is to obtain valid evidence with maximum objectivity and reliability to pro-

vide for the judicial process. It is time to move beyond negative thoughts that fingerprint age determination is beyond the reach of the scientists, especially in the beginning of the 21st century.

We believe that the ability to estimate the time of deposition of fingerprints, or any type of evidence, will certainly help investigators in solving crimes and increase public security. We predict, for the specific field of fingerprinting, that the age estimation will have an impact in several aspects: 1) strengthen the probative value of latent fingerprints as criminal evidence by including a new step in the examination process; 2) speed-up and ease judicial processes that involve fingerprint evidence, which in turn will improve the quality of criminal justice system services to citizens (e.g. quicker exoneration of innocent suspects or the release of individuals wrongly incarcerated) ; 3) reduce the amount of evidence types necessary to secure or overturn a conviction; 4) decrease the annoyance to victims and all those indirectly involved by not requiring them to testify during a police investigation or in court; 5) reduce public administration expenditures that in turn will improve the efficiency and effectiveness of public resources devoted to criminal investigations. Most importantly, it will 6) minimize errors in the identification of suspects (Issues also noted by the Scottish Report "The Fingerprint Inquiry"; APS Group Scotland. 2011. ISBN: 978-0-85759-002-2.) [7][4][17] by placing them outside the timeframe the crime was committed.

It is well acknowledged that funding resources for research in the forensic sciences are very limited. We would like to emphasize that investing economic resources towards evaluating the age of crime evidence will have an enormous socio-economic impact. Forensic research should focus on resolving this matter because it is inevitable that there will be an increasing relevance of the factor *time* for the objective resolution of crimes and court proceedings. At the same time, the inclusion of this factor in the (fingerprint) examination process will reduce government expenditures and will dramatically increase the citizen's confidence in the criminal justice system. Therefore, efforts should be devoted in finding a global solution to this still unsolved matter.

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