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Tracking fingerprints in residential burglary investigations in Denmark

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Abstract
Denmark has the highest burglary rate per capita in Europe but burglary is one of its least solved crime types. Practitioners and scholars have made the case for the collection of fingerprint evidence for decades. Fingerprint evidence can lead to the identification of suspects and contribute to the case for prosecutions. In this study we explore how widely used this traditional investigative technique is in Danish burglaries and what differences there are in prosecution rates when fingerprints lead to the identification of suspects compared to when they do not. We analysed all residential burglaries in Denmark in 2019. Of almost 24,000 cases, fingerprints were obtained in just 708. When submitted for examination at the Danish National Forensic Services, only 530 prints passed the initial screening process containing the sufficient quality and details required to identify an individual. The likelihood of conviction was significantly increased if a suspect was identified through fingerprints, which begs the critical question of why fingerprint evidence is not collected more often by Danish Police. Our findings provide a new perspective for theoretical analyses of fingerprint evidence, emphasising the importance of organisational efficacy. There are also numerous practical implications, not just for Danish Police but for any law enforcement agency seeking to improve its burglary investigation outcomes. We discuss the potential implications for more forensic training, the time allocated to crime scene examination, and the priorities for future research in this area.

Keywords
crime detection, evidence based policing, fingerprints, forensics, residential burglary

Introduction
Denmark has the dubious distinction of being the European Union's (EU) leading nation for per capita burglary rates (Friis et al., 2019). Burglary is also of the crime types with the lowest clearance rate crime types in Denmark (Statistics Denmark, 2022). Between 2012 and 2019, burglaries in Denmark impacted 2.8 to 3.6% of its population (Pedersen et al.,

2021). Despite the profound effect of these crimes, only 6.3% were solved between 2014 and 2019 (Pedersen et al., 2021).

This situation calls for action, which inevitably leads to searches for alternative solutions such as prospective mapping (Johnson, 2004; Gerstner, 2018), non-prosecution for first-time offenders, and intensive tracking for prolific offenders (Sherman & Strang, 2017). There is also a need for scholars and practitioners alike to revisit well-established topics, such as the impact of forensic intelligence and evidence on the detection of burglaries (Baskin & Sommers, 2010; 2011). This article focuses on one aspect of this corpus: fingerprints.

Fingerprints have long stood as a cornerstone in the toolkit of the Danish Police since their adoption in 1904 (Larsen, 2021). However, recent debates on privacy and data retention have prompted a sweeping review of the Police's fingerprint records, eliminating illegally held prints. This purge raises questions about the influence of fingerprints in solving crime. One might reasonably ask to what extent fingerprints can still play an important role in this policing objective, particularly given the costs in personnel time, training, and equipment associated with their processing.

The issue of fingerprints transcends national borders, and there has been a lack of general agreement on their use since the early 2000s. This debate is encapsulated by American legal scholar Jennifer Mnookin's (2003) reference to Judge Louis Pollack's contradictory rulings on the admissibility of fingerprint evidence. Pollack ruled that fingerprints were not admissible as scientific evidence, only to change his mind weeks later. Mnookin herself represented some of the emerging scepticism around the use of fingerprints as evidence, yet the U.S. National Academy of Sciences' 2009 review called for bolstering forensic science, underscoring the subjective nature of the debate (Committee on Identifying the Needs of the Forensic Sciences Community, National Research Council, 2009). Similar debates have taken place in Europe and Australasia. In 2002, Scottish Justice Minister Jim Wallace labelled fingerprints as "not an exact science" (as cited in Cole, 2008) following a high-profile murder case in which fingerprint evidence was central and hotly disputed. Wallace's words were controversial and potentially challenged hundreds and thousands of previous convictions based on fingerprint evidence. Cole (2008) labelled this the "opinionization of fingerprint evidence".

In 2007, the U.K. Home Office identified inefficiencies in the fingerprint (and DNA) management processes, subsequently identified in replication in Australia (Brown et al., 2014). In Bruenisholz et al.'s (2019) study of Australian forensic processes between 2011 and 20, they found high variation in efficiency and effectiveness between jurisdictions. When it comes to increasing the efficiency of the fingerprint forensic process, three phases have come into focus: evidence submission, analysis of evidence, and identification. However, it turned out that if the focus on improvements had been made on one part of the process, it was not a given that the result would be the desired because of the complex connectivity of evidence; critical weaknesses at another may offset potential benefits from one stage. Despite the variation in evidence about use and effectiveness, fingerprints remain widely collected by law enforcement agencies attending crime scenes (James & Nordby, 2009; Hawthorne, 2009). Their historical effectiveness in court cannot justify further examining the scale of their use in burglary investigation in the search for solutions to current Danish predicaments in solving burglary crimes. To this end, our study seeks to unravel the effectiveness of fingerprint evidence in Denmark's take on residential burglary. We look at the following research questions:

1. What are the patterns of volumes in the submission of fingerprint evidence across all Danish Police jurisdictions between 2017 and 2021?
2. How did the number of prosecutions for residential burglary and percentage of fingerprint submissions resulting in a suspect being identified in 2019 compared to other major crime categories?
3. What was the probability of a fingerprint submission for a residential burglary in 2019 resulting in the identification of a suspect?
4. What was the probability of a conviction arising from identifying a suspect from a fingerprint submission for burglary in 2019?

The answers to these questions collectively enable us to make cautious inferences about the effectiveness of fingerprint evidence as a contributory factor in residential burglary justice strategies and contribute to contemporary knowledge. Our research is exploratory, with no specified hypothesis to test, but the outcomes of the analysis have a variety of implications for Danish Police and Government personnel working towards improving the rate of conviction for domestic burglary.

Methodology

About fingerprints

Regarding the fingerprint evidence process, there are manuals and guidelines at both international and national levels. There is a common internationally established standard (International Forensic Strategic Alliance, 2021) that describes the minimum requirements for the processing of serious crimes (e.g. homicides). For example, some of these criteria may not apply to less complex crimes such as house burglaries. For instance, under 'Controlling the Scene', establishing scene boundaries, scene guards and scene logs are not usually applicable to burglary scenes. However, some form of scene assessment, examination, recording, collection and management is part of the processing of every scene in order to locate something left behind by the offender at the crime scene. Issues to consider regarding fingerprints include, for example, any evidence that will assist in the elimination of a person(s) of interest or in establishing the identity of an offender(s) or the sequence of events of the crime, including its location and point of entry by an offender(s).

A fingerprint can be secured by using fingerprint powder and gelatine membranes. It may also be digitally secured without the use of powder. Powder enhances the prints, but with the right use of light source, it can be secured digitally with no need for powder to be applied. As with identification of deceased, the Police digitally secure the prints, often just using a mobile phone captured image. The gelatine membranes or photos are submitted to a laboratory for forensic examination. Examination is a complex process that consists of different phases: visualisation, imaging, and comparison. The findings are finalised in a report (European Network of Forensic Science Institutes, 2022) and the examiner can present the evidence orally or in writing to the court.

The dataset

Data for this study were collected for the period 2017 to 2021, with a focus on three residential burglary crime codes in the Danish Police case management system (POLSAS). Statistics Denmark uses the same data to calculate national burglaries and solved rate.

Commercial burglaries, rural locations and outbuildings were removed for precision as the nature of those locations is fundamentally different to residential properties and the object of our analysis is solely residential burglary. The most common burglary offences are residential (Friis et al., 2019) and the frequency of Danish burglaries provides a large sample for examination. We excluded 854 cases of rural burglary, of which only six had possible fingerprints submitted. This category does not just include burglary to farmhouses, but also, for example, burglary to machine halls, and theft of machinery and livestock. The same was applied to the categories relating to holiday homes, sheds, and similar property types, and review found that these accounted for <1% of the original dataset. Our analysis focuses primarily on the pre-COVID-19 period. From 2020 onwards, Danish residents were confined to their dwellings most of the day. This resulted in a significant reduction in residential burglaries (Danish Police, 2017–2021) and affects the validity of any analysis focusing on that period. The post-COVID years still have value and significance for comparison and are included in our overall description of burglary trends, but to examine the probability of conviction, we focus on 2019 on the basis that these cases had all had adequate time to proceed through the justice system.

Data sources

The primary database used by the Danish National Forensic Services (DNFS) was NSK Sag and covers the Kingdom of Denmark, which includes twelve self-governed police districts in Denmark and the self-governing entities of Greenland and the Faroe Islands. This case management system contains information about burglary cases forwarded for forensic assistance by the districts, and the data include variables on the assistance provided and all exhibits submitted to DNFS for further forensic examination and comparison. At the time of the research, the NSK Sag system was unlike other Danish Police case management systems in that access was limited to users employed by DNFS, ensuring data could not be amended, deleted, or tampered with by employees outside of the forensic services.

There are two types of prints submitted to the DNFS: (1) Ten-fingerprint registrations that refer to all fingerprints obtained by Police from, for example suspects, witnesses, asylum seekers and more. These are recorded on the Livescan system and uploaded to the Automatic Fingerprint Identification System (AFIS) database; (2) latent fingerprints that are obtained by police officers or forensic technicians at crime scenes and forwarded for examination by fingerprint experts. The focus of this research was the second group, since our focus was solely criminal investigations and suspects, but the first group is included in the analysis for question 1 for context.

Research setting

Several exclusions were made to ensure the validity and relevance of the analysis. The independent states Greenland and the Faroe Islands rarely make requests for assistance relating to residential burglaries, so data from both states were excluded. The following study is, therefore, based on the twelve police districts in Denmark.

Analytical procedure

Our analysis uses descriptive statistics to explore patterns in the numbers of burglaries, fingerprint submissions and convictions. We describe comparisons over the time period analysed and across crime categorisations. Our primary focus, however, is the calculation of conditional probability (see Bland & Ariel, 2015; Massey et al., 2019) of progression

from various steps of the 'fingerprint journey' using the basic principle of P(A|B). Seven steps were classified for this purpose:

A. Number of residential burglaries in 2019
B. Number of fingerprint submissions related to those residential burglaries
C. Number of submissions from which an individual could be identified
D. Number of individuals identified
E. Number of individuals identified who were suspects
F. Number of suspects who were prosecuted
G. Number of prosecutions resulting in a conviction

We also calculated similar steps for the number of cases with submissions to calculate the conditional probability of conviction. We compared those with and without individuals identified by fingerprints. Figure 1 outlines our approaches with (H) number of cases with fingerprint submissions related to those residential burglaries. Steps (K) to (M) are cases from which an individual could be identified, whereas step (k) to (m) is where it could not be.

Results

Fingerprint submissions over time

A review of comparable data from 20200 and 2021 confirmed the expectation that the number of burglaries decreased in 2020 compared to the previous year (Figure 2). A peak number of fingerprints was submitted in 2019, with 5,851 latent prints and 20,156 unique ten-print submissions. The registration of unique ten-prints in 2020 dropped to the same level as in 2017. An increase was observed in 2021, but not to the 2019 level. However, the number of latent fingerprints submitted between 2019 and 2021 was always above 5,000.

Burlgary prosecution rates

Figure 3 shows the proportion of prosecutions initiated over the five years that resulted in conviction or acquittal in the three residential burglary categories analysed. The picture is one of decline from 20177 to 2021 in successful prosecution rate.

Crime category comparison

There are several interesting elements to consider when comparing prosecution rates across different crime categories (Table 1). Most striking is the low level of prosecution for residential burglary. The rate of fingerprint submissions which result in an individual being positively identified was also much lower than all the other selected categories.

Figure 4 shows that this picture extends beyond 2019. It compares the mean 'hit' rate (where a person has been identified) for fingerprint submissions for residential burglary to the same rate for all crime categories in each of the five studied years. The mean hit rate across the crime categories improved from 37% in 2017 to 48% in 2021. However, the mean hit rate for fingerprints in residential burglaries remains roughly the same, with the lowest average in 2017 and 2020 and the highest at 13% in 2018, while it was 11% in 2019 and 2021.

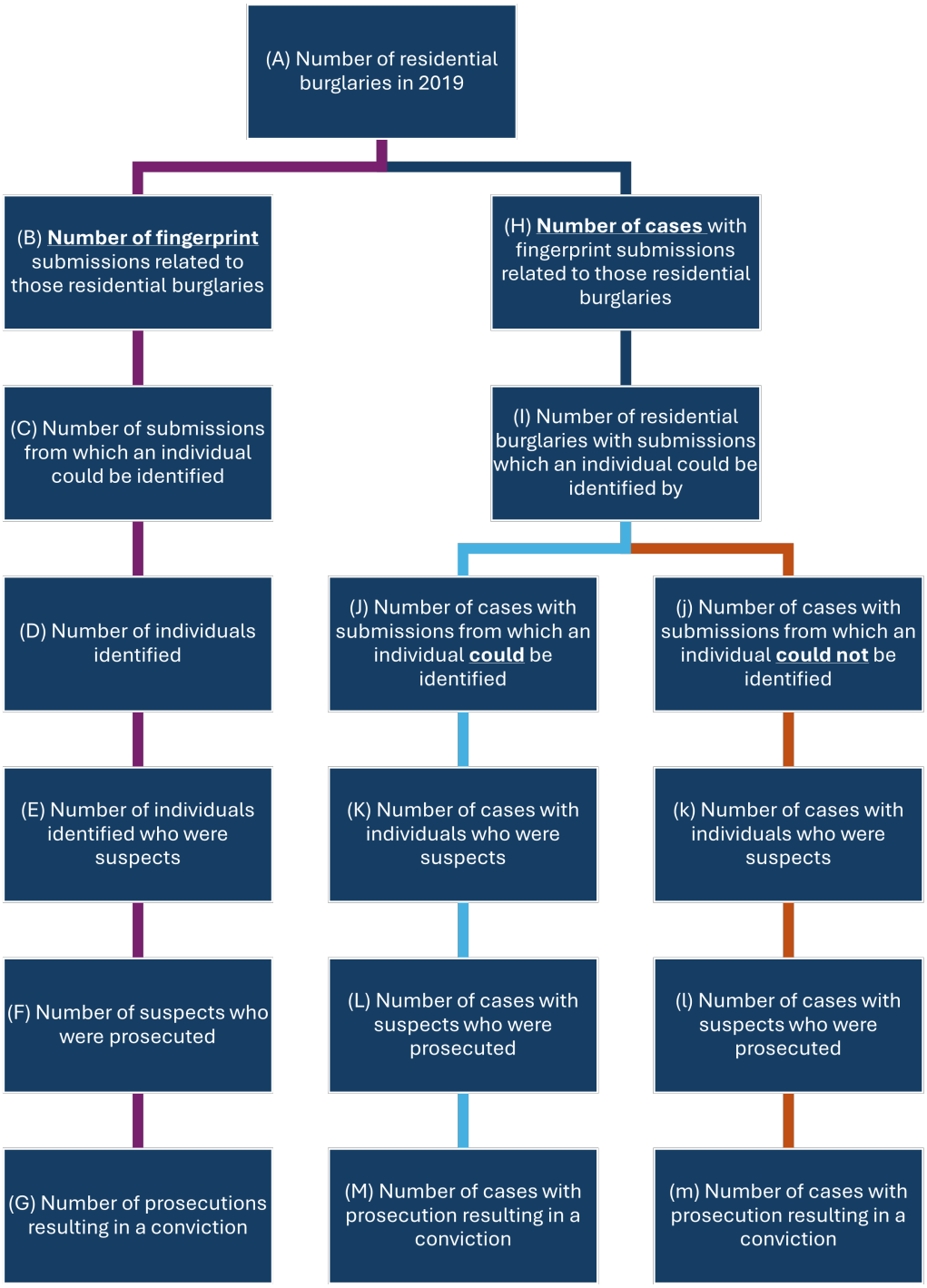

Figure 1. Tree diagram outlining calculations

Probability of identifying suspects and securing convictions from fingerprint evidence

Table 2 depicts each stage of the fingerprint journey. It shows that there were 23,953 recorded residential burglaries in 2019 and that just 1,479 fingerprint submissions were submitted to DNFS for examination from a residential burglary case. The numbers are not directly comparable because multiple fingerprint submissions could relate to the same burglary case. We can conclude that *at most* 6.1% of burglaries had a submission of fingerprints made, but the actual proportion was lower, as the next step demonstrates. Of

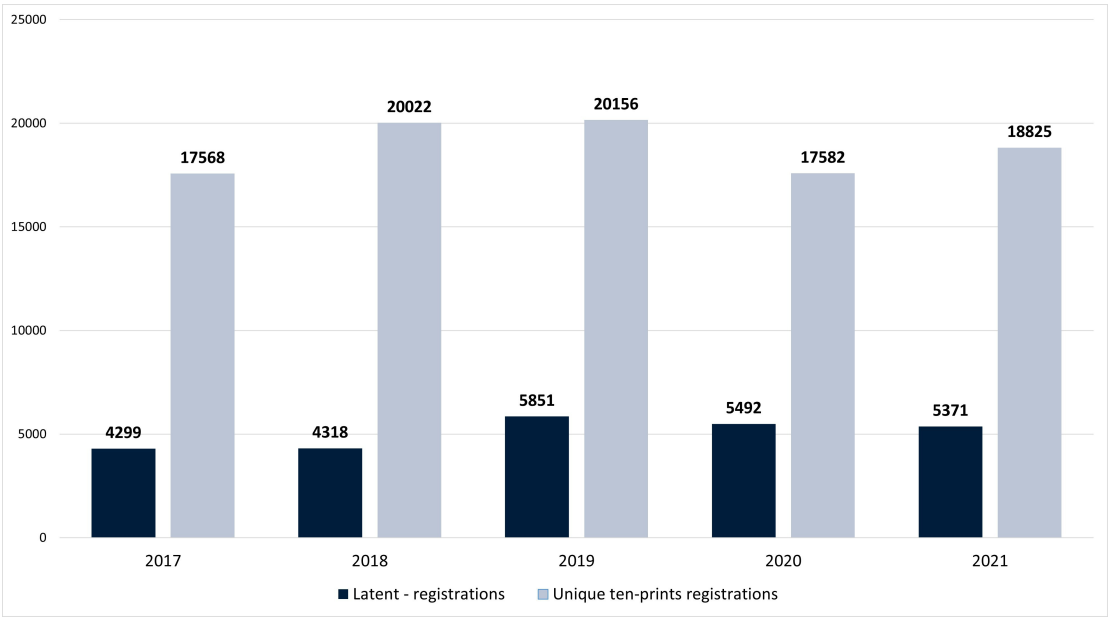

Figure 2. Ten-print registrations and latent fingerprint submissions received at DNFS

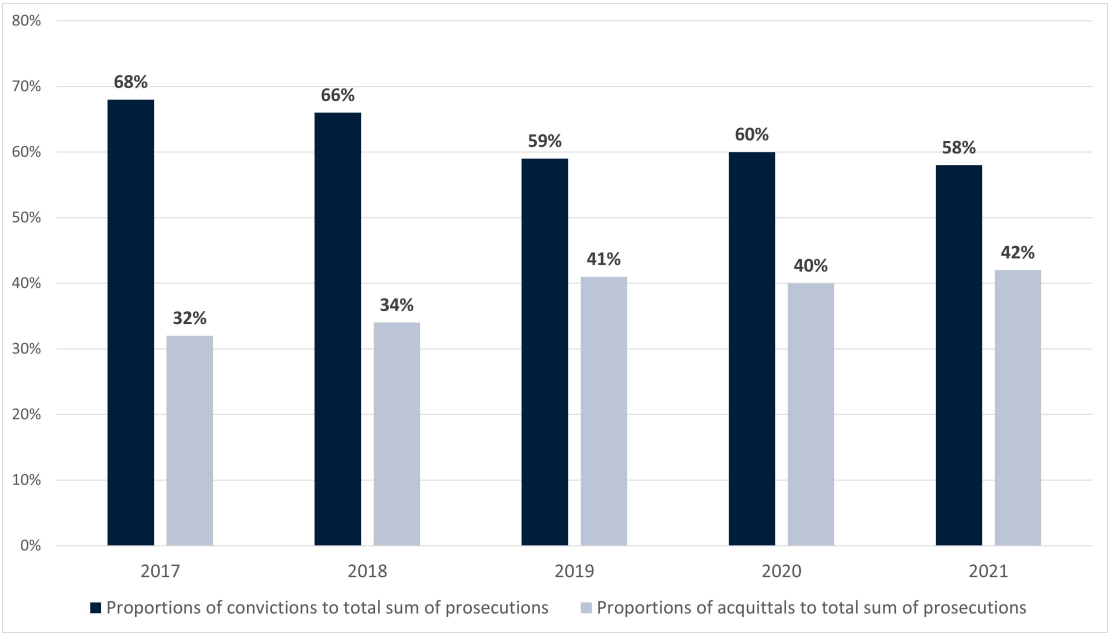

Figure 3. Convictions and acquittals over the five years in the three residential crime categories contained in the dataset

those 1,479 print submissions sent to DNFS, just 530 (36%) were of sufficient quality to be used for identification.

The 530 identifiable prints examined by the fingerprint section related to just 250 individual residential burglary cases (1% of the total for 2019). Of those 530 fingerprints searched within the AFIS databases for a match with a known person, 72 returned a match or 'hit'. These 72 'hits' related to 32 separate individuals. In some cases, the same offender was identified in multiple different prints from one crime scene or from different scenes. In official DNFS statistical reporting, all positive matches count as an identification, even if they identify the same person several times. Of the 32 named individuals only 22 were

Table 1. Comparison of case numbers, prosecution rates and positive identification of fingerprint submission rates across five crime categories in 2019

Crime category	Number of cases (2019)	% of cases prosecuted (2019)	% fingerprints submitted with positive identification (2019)
Residential burglary	24,816	5%	11%
Violence	16,474	64%	47%
Firearms	2,869	97%	64%
Rape	1,613	58%	27%
Homicide	49	147%[a]	58%

[a]*147% is a result due to cases from the previous year being registered with a delay.*

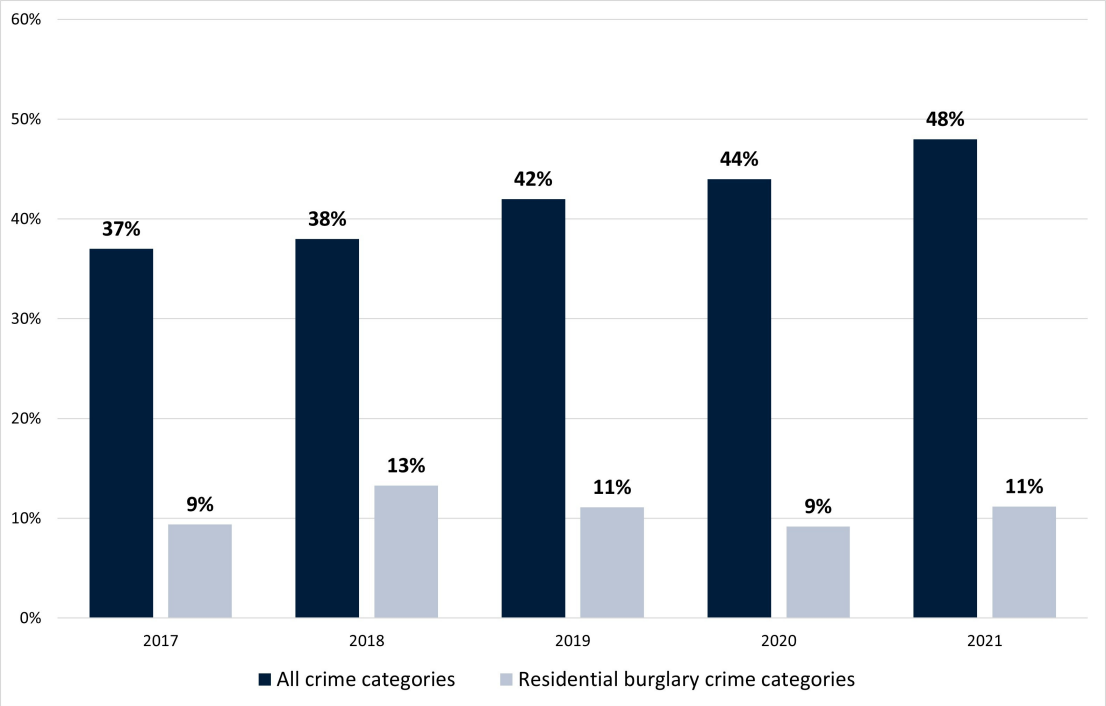

Figure 4. Average hit rate percentage across crime categories with one or several prints with an ID (per year and %)

Table 2. Conditional probabilities and the cumulative proportion of all submitted fingerprints represented at each stage

Stage	Count	Conditional probability	Cumulative
(A) Number of residential burglaries in 2019	23,953	N/A	100%
(B) Number of fingerprint submissions related to those residential burglaries	1,479	P(B|A) = 0.06	6%
(C) Number of submissions from which an individual could be identified	530	P(C|B) = 0.36	N/A
(D) Number of individuals identified	32	P(D|C) = 0.06	N/A
(E) Number of individuals identified who were suspects	22	P(E|D) = 0.68	N/A
(F) Number of suspects who were charged	16	P(F|E) = 0.73	N/A
(G) Number of charges resulting in prosecution	15	P(G|F) = 0.94	N/A

Table 3. The conditional probability and the cumulative proportion of all cases with a submitted fingerprint by which an individual could be identified (see Figure 1 for notation)

Stage	Count	Conditional probability	% of all	Stage	Count	Conditional probability	% of all
(A) Number of residential burglary cases in 2019	23,953	N/A	100%				
(H) Number of cases with fingerprint submissions	708	P(H|A) = 0.03	3%				
(I) Number of cases in which an individual could be identified	250	P(I|H) = 0.35	1%				
(J) Number of cases in which an individual was identified	24	P(J|I) = 0.10	0.1%	(j) Number of cases with submissions from which an individual was not identified	221	P(j|I) = 0.9	0.9%
(K) Number of cases in which individuals identified were suspects	21	P(K|J) = 0.88	0.09%	(k) Number of cases with individuals who were suspects	22	P(k|j) = 0.1	0.09%
(L) Number of cases with suspects who were prosecuted	17	P(L|K) = 0.81	0.07%	(l) Number of cases with suspects who were prosecuted	16	P(l|k) = 0.72	0.07%
(M) Number of cases with prosecution resulting in a conviction	12	P(M|L) = 0.71	0.05%	(m) Number of cases with prosecution resulting in a conviction	2	P(m|l) = 0.13	0.01%

suspects in the investigation. The remainder related to victims or witnesses. Of these 22, prosecutors charged 16 suspects and of those, 15 were convicted.

In probability terms we summarise these findings as follows. At most, 6% of residential burglaries had a related fingerprint submission, but the proportion of burglaries where there was a useable submission was just 1%. Within that small proportion of cases there was just a 6% chance of identifying an individual and 32% of the individuals identified were not suspects. When a suspect was identified there was a high probability they were charged and when charged it was probable they would be convicted. Overall, at most, 0.06% of residential burglaries in 2019 had a conviction in which fingerprint evidence was linked to the suspect.

Table 3 depicts each stage of the fingerprint case process and the associated conditional probabilities and percentage of all cases. It shows that of the 23,953 recorded residential burglaries in 2019, only 708 had fingerprints submitted to DNFS for examination. That means that fingerprints were submitted in only 3% of all residential burglaries. Of those,

only a third (n = 250) of the cases with submission had usable fingerprints. Just 24 of these produced a match to a known person, and 21 of these were matches to suspects. Of the cases, prosecutors charged 17 cases, and 12 resulted in a conviction. We can conclude that, at most, 0.05% of the total number of recorded residential burglaries had suspects identified by fingerprints and resulted in a conviction, although, as the table shows, the probability of conviction was higher when a fingerprint hit was present than when it was not. When a case with fingerprint evidence identifying the suspect was prosecuted there was a 0.71 probability of conviction, compared to 0.13 when there was none. Overall, when a suspect was identified by fingerprints at all, the probability of conviction was 0.5.

Discussion and conclusion

Our findings reveal a critical gap in the Danish criminal justice system's utilisation of fingerprint evidence in residential burglary investigations. Simply put, the role of fingerprint evidence in bringing burglars to justice appears marginal. If the picture from 2019 is not an isolated occurrence we would conclude that fingerprint evidence is rarely sought and collected. When it is collected, it is often unusable. When it is usable, it is rare for a suspect to be identified but when they are, there is a much higher probability of prosecution. These circumstances demand critical reflection.

There is little doubt that the technology has the potential to be influential in obtaining justice (Bond, 2007; Bond, 2009; Baskin & Sommers, 2011), but our results suggest that this potential is untapped. They suggest that there is little appetite, awareness or capability for gathering fingerprint evidence. They also suggest that when fingerprint evidence is collected, it is often not done so effectively. But they also show that it is extremely rare for suspects to be identified from useable prints. One thought could be that if only "0.06% of residential burglaries in 2019 had a conviction in which fingerprint evidence was linked to the suspect", then the collection of fingerprints is undoubtedly an ineffective way of solving burglary cases. However, let us play with the idea that of all the suggestions for improvement, only one is implemented. That is, to increase the number of fingerprints taken. Based on our research, this should directly affect to the very end – more convictions. Then, take the idea further, and one or more suggestions will be implemented. Now, we are faced with the fact that fingerprints have untapped potential. It remains true that we already know today what is required for a sound forensic end-to-end procedure, and therefore, it does not make sense to continue speculating on why the "hit rate" is so low. It is possible that the thousands of burglaries without fingerprint submissions had skewed our sample – perhaps there were thousands of useable prints at these scenes. It may also be that new restrictions in data retention have adversely affected 'hit' rates. We might also speculate that there is a vicious circle playing out in these statistics in that the low frequency of submissions in previous years perpetuates the low frequency of identifications in subsequent years. Offender awareness and false positives relating to victims and witnesses are uncontrollable factors, but our results also show there is considerable scope to improve the collection of prints and thus further explore what might be possible if standards and coverage were improved. There is existing evidence to suggest that training may help achieve this improvement (Antrobus & Pilotto, 2016). On a practical level, there is a clear need for law enforcement agencies to adopt more rigorous training protocols focused on the collection and preservation of fingerprint evidence. In Bruenisholz's research, it turned out that the reduction was primarily due to retraining the forensic practitioners with a focus on targeting better evidence, which subsequently

reduced the number of extraneous samples being submitted and decreased laboratory pressures, decreasing backlogs and increased turnaround times. In other words, it can be as simple as having current training frequently and continuously (Bruenisholz et al., 2019). Implementing standardised procedures across all jurisdictions will likely increase the probability of obtaining usable prints from crime scenes. The hit rates for other crime types indicate room for improvement, but the procedural context is important. Burglaries are not within the types of crimes that initiate an automatic request for forensic support from DNFS.

Perhaps burglary is just out of fashion and our results reflect a response to this? Previous research conducted in the United Kingdom showed that burglary and theft offences accounted for up to 50% of all crimes in England and Wales in the mid-1990s. However, by 2005, this percentage had dropped to less than 30% (Tilley et al., 2007). The drop was partly explained by a steady fall in burglary. In theory such reducing crime numbers should make it more feasible for high forensic coverage, but the reality is that even the present volume of burglary offences would require a massive increase of forensic experts able to attend all or the majority of relevant crime scenes. We might reasonably challenge whether even such an increase in coverage would make a significant difference, because residential burglary is a fundamentally different proposition for fingerprint collection. Apart from the difference in forensic training for attending officers, another contributing factor to the high hit rate regarding firearms (Table 1) may be the smooth surface of many firearms, which tends to increase the likelihood of discovering fingerprints. On the other hand, DNFS personnel and highly trained forensic technicians attend most of the crime scenes featured in Table 1 *apart* from burglary, so we cannot discount the possibility that higher hit rates would be achievable.

The variables at play in successful fingerprint collection are explored in another U.K. study, which identified three important predictors: fingerprint location, mobility, and police officer accreditation (Bond, 2009). The fingerprint location refers to the best prints, which are often obtained inside the crime scene. Mobility is fingerprints discovered on easily moveable objects and surfaces such as bottles, jars, cases, and similar. Finally, police officer accreditation, which the study found to be the most significant and the easiest to influence. Ensuring the attending officer had solid investigative skills and an understanding of how and where to develop fingerprints played a substantial role in obtaining identifiable prints.

Theoretically, this study contributes to the expanding body of knowledge on forensic science's role in criminal investigations (Baskin & Sommers, 2010; 2011; Horvath & Meesig, 1996; Peterson et al., 2012). It underscores the need for a more nuanced understanding of the complexities involved in fingerprint analysis, challenging the traditional perception of fingerprints as infallible evidence. Our findings suggest that future theoretical frameworks should incorporate the dynamic nature of forensic science, considering the impact of technological advancements and policy changes on the reliability of sample collection.

The problem our data show is that fingerprints are rarely submitted as traces, and this fact should serve to draw reflection from policymakers. It should be a much higher priority to prosecute burglars and therefore improve and simplify routines and guidelines.

We need to work on a broad front with increasing information sharing across the police districts within the forensic practitioners and support the development of new guidelines. The districts need to see and acknowledge the importance of increasing the number of fingerprints collected.

The findings within this thesis also show the urgent need for a national review of the forensic procedures within the residential burglary area and raise the question of whether this is just a small piece of the bigger picture. With awareness of the current state of affairs, actions should be taken to review and update current guidelines, re-adjust training requirements, and potentially rethink the forensic approach, for residential burglaries and other crime categories nationwide.

Our study opens several avenues for future research. There is a necessity to investigate the long-term effects of the recent elimination of unlawfully held fingerprints from police records. Comparative analyses with other countries employing different forensic techniques could provide valuable insights into the efficacy of various methodologies. Additionally, exploring alternative forms of evidence and their comparative reliability would offer a more comprehensive understanding of the forensic landscape. This research aligns with the global trend towards scrutinising and improving forensic science practices. As the field evolves, it is essential to continuously reassess and adapt methodologies to maintain the integrity of criminal investigations. Our findings highlight the importance of keeping pace with these developments, ensuring that law enforcement practices remain effective and efficient.

Our study has both internal and external validity limitations. The national nature of our sample is a strength – the inferences we draw apply to all twelve of Denmark's police districts. At the same time, generalisability across borders is finite due to the specific nature of Danish law and law enforcement procedure. Readers should also not ignore that our detailed sample was pre-COVID-19. Replications of this study should seek to bring the dataset up to date. Limitations notwithstanding though, our findings are stark. A Danish resident who reports a burglary at their home has little chance of seeing the offender brought to justice. However, fingerprint evidence still offers increased hope of that outcome. When fingerprints are found, prosecution is more likely.

Data availability statement

The data underpinning this study are not publicly available due to their sensitive nature. They are law enforcement records that contain personal and operationally confidential information. Access to these data is restricted by the relevant policing agency and cannot be shared to protect the privacy of individuals and the integrity of ongoing policing operations.

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