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A crisis for the future of forensic science: Lessons from the UK of the importance of epistemology for funding research and development

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ABSTRACT

This study presents analysis of forensic science research funded by UK Research and Innovation (UKRI) research councils (2009–2018), representing 150 projects with a cumulative value of £56.1 m (0.01% of the total UKRI budget over this time period). The findings indicate that dedicated forensic science funding represents only 46.0% of the projects included in the dataset. Research focussed on developing technological outputs represented 69.5% of the total funding (£37.2 m) in comparison to foundational research which represented 19.2% (£10.7 m). Traditional forensic science evidence types such as fingerprints and DNA received 1.3% and 5.1% of the total funding respectively, in comparison to digital and cyber projects which received 25.7%. These data offer insight into the scale of the funding crisis in forensic science in the UK, and the need to increase the resources available, to develop ways of articulating value and to ensure that both technological and foundational research are enabled.

1. Introduction

Forensic science is facing serious challenges globally. These challenges are multifaceted, systemic, and impact every part of the forensic science process (from crime scene to court). In terms of service provision there are well-documented cases of malpractice [1,2], quality system failures [3–5], and concerns about the reproducibility of conclusions reached from the analysis of specimens [6]. Added to this, crises have been consistently identified in the forensic science market [5,7–10], the justice system [11], and in the science underpinning forensic science and the research culture [12–14]. The report from the US President's Council of Advisors for Science and Technology [15] reiterated the issues in both the science and provision of forensic science that had been first articulated by the National Academy of Sciences in 2009 [16], demonstrating that insufficient progress had been made during the intervening years. Most recently, the House of Lords Science and Technology Committee [17] articulated the deep-seated and systemic issues that have persisted, and demonstrated in stark terms the scale of the crisis and the need for urgent reform across the board.

Forensic science is interdisciplinary and operates at the interface of science, policing, justice, government, and policy. Each of these domains is distinct but is critically interconnected [18] and, therefore, challenges or issues in one domain will impact on the others. In addition, where systemic issues persist, they are often root causes of many symptoms that are observed in the different domains across this interconnected forensic science ecosystem. The crises that have been identified across forensic science are arguably the result of core issues, and therefore, the only way to address the crises is to tackle the root causes [19,20]. A clear conclusion from the majority of the key policy reports [15,17,21–24] is that one of the root causes stems from a lack of resources, and particularly a dearth of financial funding over a sustained period. There are a lot of pressures on resources in such a complex ecosystem, and the need for appropriate funding for forensic services and ensuring a stabilised market have been well argued [7,9,10,17,25]. The importance of a sustainable system for forensic science services is clearly paramount for high quality provision of science services. However, another area that is core to thriving forensic science is the science itself as it forms the basis of the discipline. Research is therefore arguably the lifeblood of the science and a critical organ within the forensic science 'body'.

There are two critical factors that will impact the resources made available to forensic science research. First, what forensic science is broadly considered 'to be'. This is a contested factor in terms of whether forensic science is understood to be an applied patchwork of sciences, or a coherent single (yet interdisciplinary)

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discipline [26]. Second, what forensic science is considered 'to be for' [26]. There is a wide spectrum of purposes for forensic science ranging from the provision of a service to aid the investigation and detection of crime, to the foundational basis that derives theory to underpin the practice of the science at each stage of the forensic science process. Depending on the view taken as to what forensic science 'is' and what it is 'for' will impact what is ultimately valued, and therefore what type of research is funded, how it is funded, who will fund it, and over what time frame.

There have also been additional challenges in terms of the funding resources available. In the UK. For example, the transition to a fully marketized approach to the provision of forensic services has had an impact on the research landscape due to research outcomes potentially having commercial value and therefore restrictions on their dissemination. This has also become apparent in the US where certain software tools used in the interpretation of forensic materials, have proprietary knowledge that is the basis for the commercial value of the software, which has led to a lack of transparency in how those tools have been built and how they reach conclusions, introducing difficulties in reproducing results [27]. In addition, in the UK there has been a dramatic reduction in the size of the market (a conservative estimate is a reduction in spending on forensic science services of over 60% from £120 m to £55 m since 2008 [17]) and the increasing instability of the forensic science market [24] has dramatically reduced the capacity of the industry to support research activities [17] thereby increasing the reliance on national level funding bodies.

Research and development in forensic science has therefore suffered from the identity challenges of the discipline [26] as well as very restricted funding opportunities. As a result, some of the deep-seated challenges that research needs to address, such as how to harness the value and potential of digital evidence, pattern evidence, and achieving reproducible and reliable evaluative interpretation of forensic science evidence [22–24], have not been prioritised or enabled. In addition, to date, it has been difficult to establish exactly what is being funded in terms of the nature and scope of the research, to what level and over what timeframes, in addition to determining the impact of the research outcomes. This has made the scale of the issue difficult to communicate, demonstrate, and therefore prioritise in policy.

2. The UK perspective

2.1. The impact of a commoditised market

In a situation, such as England and Wales, where forensic science services operate within a competitive market, there is a focus on financial costs of services and turn-around times [17]. The police are judged on their detection rates and crime reduction targets, with measures of success regularly presented in the form of reduced spend by police forces on forensic services and reduced turn-around times [17,28]. In response to this, there have been a number of calls for caution as it has become clear that in the procurement of forensic services, financial cost is weighted as a greater consideration than quality [4,17] and as a result there has concern raised that there has been a reduction in the amount and/or type of forensic science analysis being carried out [3,29].

One result of this transition to a market economy is that the value of forensic science research and development outputs have (economic) value to the industry. As such the research councils have taken a similar approach to other disciplines with associated industries in terms of expecting investment from industry for relevant research and development. This is an approach that has had great success in other fields such as medicine and engineering. However, in forensic science, where the size of the market has been dramatically reduced and where the market has been demonstrated to be unstable and unsustainable, this approach has led to a further reduction in resources available for research [17].

Another outcome of a market economy is that the value of forensic science within the whole forensic science process becomes even more difficult to articulate [30]. For example, streamlined forensic reporting was introduced as a means of deriving a quicker initial result which may inform the investigation and enable investigators to curtail a particular avenue of inquiry saving time and resources. However, depending on the specific situation, a streamlined forensic report may not offer what is needed if that case results in a court hearing (a source level result may not answer the critical issue in the case) [31]. Similarly, due to the complexity of the ecosystem and fragmentated nature of the different domains in forensic science, the value of forensic science evidence that results in a guilty plea and saves police and court time is rarely articulated or considered when developing forensic science strategy.

In this complex ecosystem, it becomes critical to establish which identity of forensic science is being appropriated by each stakeholder and/or domain. For example, if forensic science is considered to be a patchwork of sciences, the responsibility for primary development rests with the 'parent science' and forensic science is reduced to solely exploring how to apply that science to a specific forensic science question, often related to the detection of materials or establishing the identity of individuals. If on the other hand, forensic science is considered to be a unified interdisciplinary discipline, the responsibility for developing the science lies within forensic science and will address questions of identification and detection (often through developing technological tools) and questions of evaluative interpretation (which often requires foundational research to develop robust theory and principles that can be applied to casework relevant scenarios).

2.2. Why is funding so critical?

The overall crisis, expressed in every sector of forensic science, is therefore wide-reaching, complex and not a challenge where there are clear, simple solutions. However, funding (and the lack thereof) within the system is clearly a significant driver and one of the root causes of many of these current challenges [17]. It can be acknowledged that funding alone will not address the root causes in their entirety, but it is a pervasive issue and one that is critical for addressing the crisis for three main reasons. First in terms of safeguarding the value and quality of science delivered through forensic services, second for ensuring equity in the criminal justice system, and third to guarantee the breadth of research required to underpin practice in the short, medium and long term.

The forensic science market in England and Wales is an example of how a relentless pursuit of 'value for money' can lead to a race to the bottom. Such a phenomenon has been identified in large scale grocery markets across the world [32] where cost becomes the only factor targeted to attract and retain a customer base. In this environment it becomes increasingly difficult for providers of services to win tenders unless they are the cheapest provider [24], and eventually the value is driven out of the market, instability is introduced, and the market can become unsustainable. In England and Wales, it is well recognised that providers of forensic services, whether independent or 'in house' within the police, are dedicated to quality and standards. However, ultimately if the procurer of these services puts cost as the main criteria in the procurement process, other factors, such as quality, will carry less weight.

Funding within the justice system has been the source of strong concern across the board [33] and equitable access to forensic science has emerged as a significant challenge when resources are stretched or reduced [17,25]. Successive cuts to legal aid in the UK

have led to an increase in self-representation in court [34], as well as increasing the hurdles to accessing independent forensic science expertise, a situation that disproportionately affects the defence [17].

When it comes to research, funding is clearly a highly significant factor in terms of what research happens. It has been recognised that a thriving research culture needs to be supported to enable research that develops both foundational theory to underpin evaluative interpretation of evidence, and technologies that can be deployed in a broad range of forensic science applications [17,24]. This research cannot take place without funding to support it that not only has short-term exploitable applications in view, but also medium and long term implications for laying the foundation for the developments and new approaches of the future.

2.3. Funding across the forensic science sector

Funding is not the only issue responsible for the crisis in forensic science. It cannot be separated from the need for effective accountability and responsibility and the stability and sustainability of the market [9]. However, it is clearly a critical foundational issue that impacts all the different stakeholders across the forensic science sector [17] and is essential for good governance, quality standards, robust science, and a well-equipped justice system.

It is beyond the scope of this paper to address the clear funding challenges being faced in the provision of forensic science services for the investigation of crime and the prosecution of crime in the courts. This is dealt with by the recent House of Lords Science and Technology committee report [17] where national level infrastructural changes and broad reform are recommended to address these issues in a holistic manner. However, it is clear that research has faced particular challenges in the UK within a context of forensic science not being included specifically in any research council remit [35], and the loss in 2012 of one of the major research labs that was part of the Forensic Science Service, which was not replaced. As a result, where funding has been available it has tended to be offered by the Home Office (most often through the Defence Science and Technology Laboratory) to address specific operational needs [17]. As such, the research commissioned has required high technological readiness levels within short timeframes to meet current needs. In this climate, foundational research that develops a body of theory has been neglected, arguably leaving the development of the science unsupported. As a result, the whole sector of forensic science is ill-equipped to address many of the clear challenges identified by many of the government reports [5,15,17,22–24,36] relating to the evaluative interpretation of forensic science evidence. To date it has been difficult to articulate the scale to which this has occurred due to a lack of data.

2.4. Funding for forensic science research in the UK

Therefore, in order to demonstrate the scale of the challenge, this paper sought to identify and present what forensic science research has been funded by the national level research councils within UK Research and Innovation (UKRI) in the UK between 2009 and 2018. Specifically, we sought to identify what type of research has been funded, by which research councils, to what degree (amount of funding and duration of funding) and, critically, to establish what has not been funded.

The key questions addressed were:

1. How much funding has been made available for forensic science research?
2. Of this funding how much was for 'direct forensic science research' (clear forensic science casework informed research questions, distinct forensic science research methods, and implementable outcomes), and how much was for indirect applications of novel science (based in other domains) to forensic science challenges?
3. How much research was devoted to developing technological tools and solutions with marketable deliverables in the form of high Technology Readiness Level (TRL) tools for application to the investigation of crimes, in contrast to foundational research (the development of empirical evidence bases to develop theory that underpins practice) that has medium to long term implications?

3. Methods

3.1. UKRI data set and coding

This study used the dataset created and provided by UKRI [37] to the House of Lords Science and Technology Committee during their inquiry into forensic science [17]. The data consisted of the abstract of every project funded by UKRI 2009–2018 and included the title, funding research council, amount of funding and duration of funding. This is clearly a limited dataset as it was not possible to consistently identify what was delivered from each funded project. However, it does represent the first dataset of its kind that enables an initial assessment of the projects that have been funded and the current situation within research council funding in the UK.

For this study, each abstract was categorised by research topic (such as 'analytical chemistry' or 'fingerprints' see Table 2) and by domain. Each project was categorised into one of five domains:

- 'forensic science', where the abstract clearly stated the forensic science context or application of the work.
- 'other domain with explicit forensic science application', where the work was being developed explicitly in another domain (such as 'analytical chemistry' but explicitly mentioned 'forensic science' as a potential application domain of the outputs.
- 'other domain with an implicit forensic science application', where the work was being developed explicitly in another domain (such as 'biology and biochemistry') with no mention of a forensic science application, but given the research question, and the outputs described it could be considered to have potential applications to forensic science.
- 'not forensic science research' where the work was being developed in another domain with no mention of a forensic science research question or application, and where the outputs described could not be considered to have potential applications to forensic science.
- 'no abstract' where no abstract was provided.

Within each of these domains, the type of research was classified as either 'technological (developing a detection tool or validating a detection method)' or 'foundational (developing theory)'. The coding was undertaken independently by two individuals to ensure consistency.

4. Results

4.1. The distribution of funding between research institutions and over time

Considering the whole dataset produced by UKRI, the distribution of funding over time (2009–2018) from all the UKRI

research councils is presented in Fig. 1. In total, £56.1 million was considered to have been allocated to forensic science research across the UKRI portfolio. This represents 0.01% of the total £60bn total budget over this time period (House of Lords 2019). Two trends are immediately apparent in Fig. 1. First, the largest share of funding (£28.6 million out of a total of £56.1 million) was allocated by the Engineering and Physical Sciences Research Council (EPSRC) with other research councils, such as the Medical Research Council (MRC) (£0.1 million), the Natural Environment Research Council (NERC) (£0.5 million) and the Science and Technology Facilities Council (STFC) (£1.0 million) making relatively small grants in comparison. Second, the highest levels of funding were allocated in 2014 (£9.0 million), 2015 (£13.3 million) and 2016 (£11.2 million). This is an interesting trend given that forensic science was removed from the research council remit in 2012 [35]. Since 2016, the levels of funding have been lower; £5.5 million were allocated in 2017, and £1.1 million in 2018, lower than the amount allocated in 2009 (£1.5 million).

4.2. The distribution of funding between research domains and research types

The funding allocation by domain (that is, whether the research was considered to be primarily forensic science research, whether it was research in another field that had explicitly or implicitly stated relevance to forensic science, or it was research with no relevance to forensic science), and by research type (foundational, or technological (usually with high technology readiness level (TRL) outcomes) is presented in Table 1 and Fig. 2. It is striking that only 46% of the projects (69 projects) included in the dataset related to clearly articulated forensic science research (Table 1). The majority of the funding was allocated to research in other fields (i.e. not specifically forensic science) with explicit or implicit forensic science applications mentioned in the abstract (£31.0 million, 55.3% of the total funding), rather than within the forensic science domain itself (which was allocated £17.2 million; 30.8% of the total funding, and less than 0.03% of the total UKRI budget over the time period

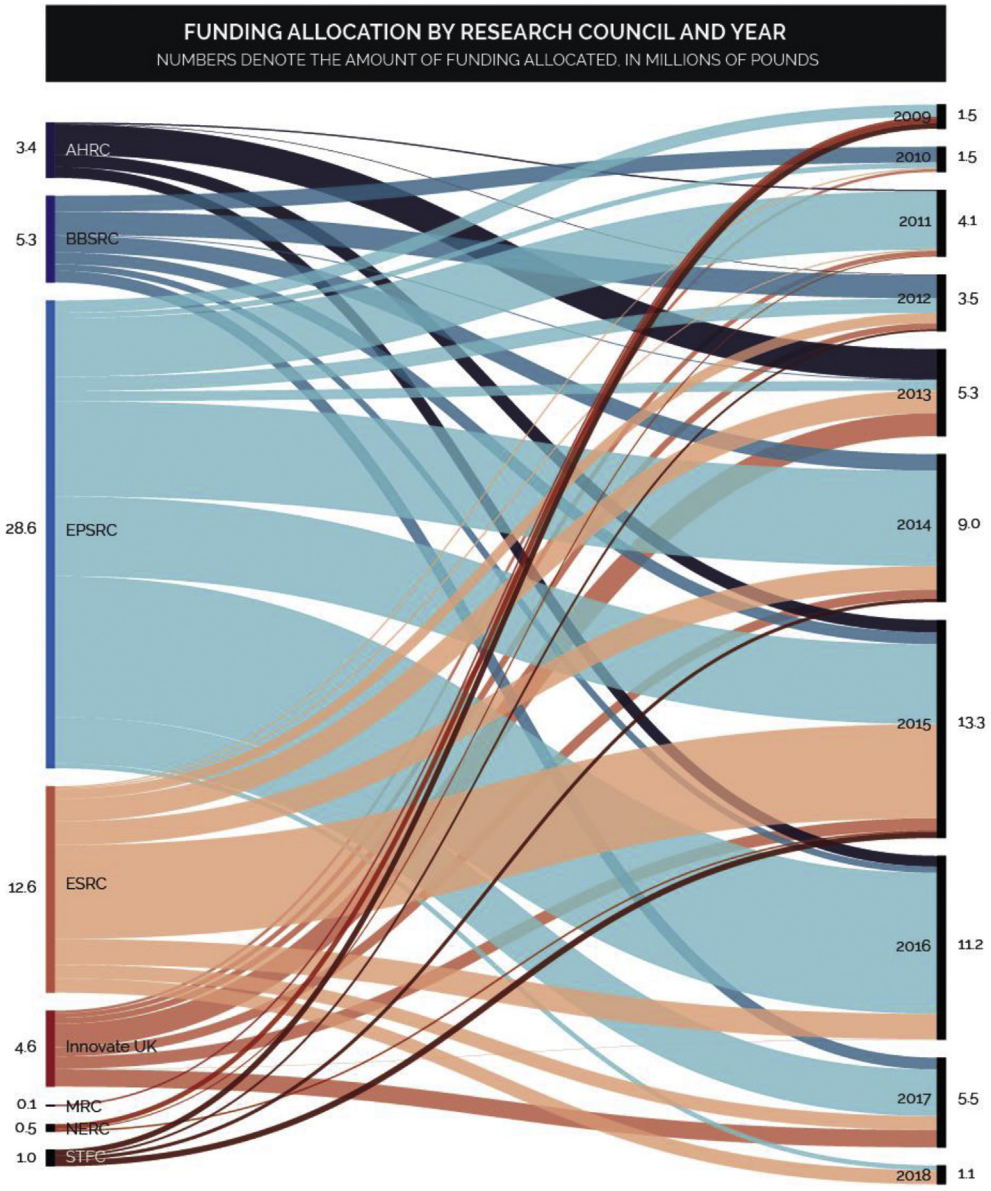

Fig. 1. Alluvial diagram providing an overview of the distribution of all funding by research council and year, between 2009 and 2018 (total funding £56.1 million).

Table 1
Amount of funding (£) and number of projects by domain and type of research.

Research Domain	Type of research	Number of projects		Monetary value of projects	
		Count (N)	Percentage (%)	Sum (£M)	Percentage of 56.09 M (%)
Forensic Science	Foundational	13	8.7	2.22	3.96
	Technological	56	37.3	15.03	26.79
Other domain - Explicit application	Foundational	8	5.3	2.61	4.66
	Technological	22	14.7	18.01	32.11
	Other	3	2.0	0.12	0.22
Other domain - Implicit application	Foundational	6	4.0	5.93	10.57
	Technological	13	8.7	4.19	7.48
	Other	1	0.7	0.13	0.23
Not forensic science research	Not relevant to forensic science	21	14.0	5.23	9.32
	Not research	3	2.0	2.43	4.34
No abstract	No abstract	4	2.7	0.18	0.32
Sum		150	100	56.09	100.00

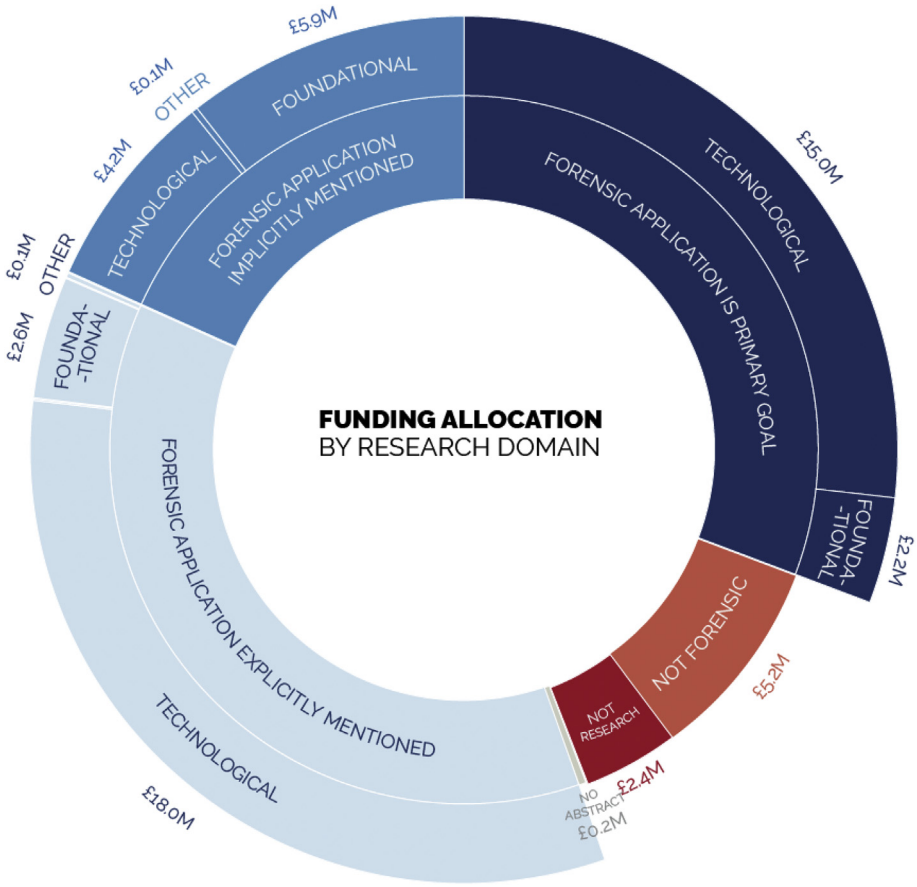

Fig. 2. Sunburst diagram depicting the allocation of funding by research domain and type, between 2009 and 2018.

(£6bn)). The majority of the directly forensic science research funding was awarded to projects that addressed a technological issue or challenge (£15.0 million, 26.8% of the total funding), and only a very small proportion of the funding (£2.2 million, 4% of the total funding, and less than 0.004% of the total UKRI budget over the time period (£6bn)) was allocated to foundational research where a forensic science application was the primary goal. A proportion of the funding was allocated to projects which were classified as either not research (£2.4 m) or not forensic science (£5.2 m). Both of these categories were larger than the amount of forensic science foundational research (£2.2 m). Across all categories, more funding was allocated to high TRL technological research projects rather than foundational research projects (Fig. 2).

4.3. The distribution of funding by research topic

Considering the whole dataset, the allocation of funding for research projects by topic is presented in Table 2, which depicts both the number and monetary value of projects funded with regard to forensic science topic, and Fig. 3, which displays the distribution of these topics between the Research Councils. The topics which received the most funding were (1) Digital and Cyber, where 33 projects received a total of £14.4 million between 2009 and 2018, accounting for 25.7% of the total funding, and (2) Analytical

Table 2
The distribution of funding (2009–2018) by research topic.

Research Topic	Number of projects	Funding (£M)	% of N	% of Funding
Digital and cyber	33	14.4	22.0	25.7
Analytical chemistry	22	11.9	14.7	21.2
Identification	13	10.1	8.7	17.9
Sensors and imaging	23	6.7	15.3	11.9
Policing/Criminal Justice	15	3.1	10.0	5.5
DNA and genetics	13	2.9	8.7	5.1
Language/linguistics/speech	9	2.1	6.0	3.7
Psychology	8	1.9	5.3	3.5
Miscellaneous	7	1.7	4.7	3.1
Fingerprints	2	0.7	1.3	1.3
Biology and biochemistry	1	0.4	0.7	0.7
No abstract	4	0.2	2.7	0.3

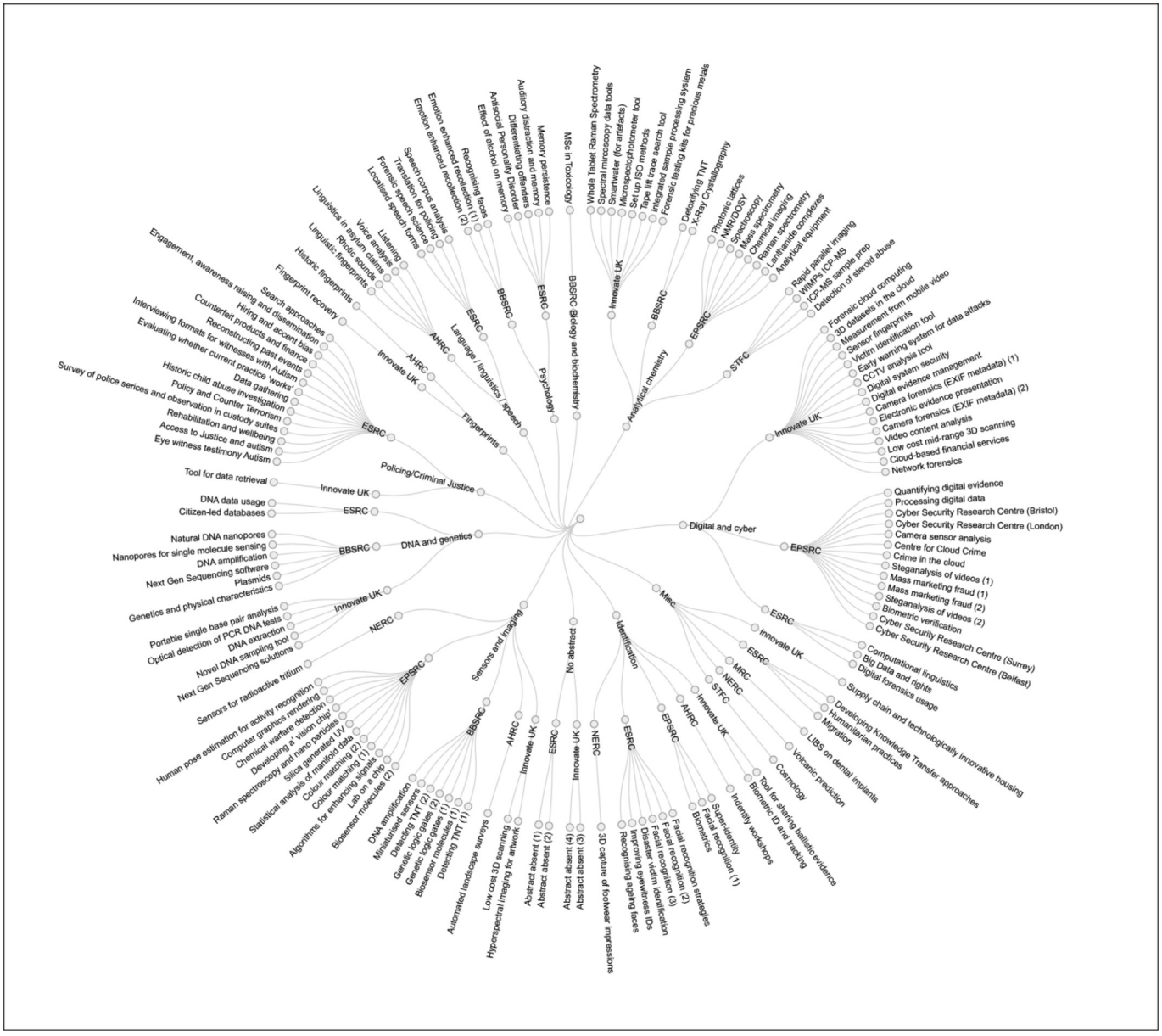

Fig. 3. A circular dendrogram depicting each project funded within the dataset by topic, and research council.

Chemistry, where 22 projects received a total of £11.9 million, accounting for 21.2% of the total funding. In the period covered by the dataset (2009–2018), only two projects on fingerprints were funded, accounting for 1.3% of the available funding (£0.7 million), while the topics of DNA and genetics received 5.1% of the total funding (£2.9 million).

5. Discussion and key findings

5.1. The distribution of funding between research institutions and over time

In Fig. 1, it can be seen that the total amount of funding allocated to forensic science research has been variable over the last ten years, and since 2015 has shown a trend of decline. The figure for 2015 (£13.3 million) is larger than those for 2016 (£11.2 million) and 2017 (£5.5 million), while the figure for 2018 (£1.1 million) represents the lowest figure seen in the ten years that the dataset covered. As stated in section 1, many have highlighted the issue of funding as a salient challenge facing the discipline and a potential impediment to research [17,38]. The analysis of this dataset suggests that the perceived decline of research council funding for forensic science research is both real and quantifiable.

5.2. The distribution of funding by research domain and research type

In Fig. 2, it can be seen that the majority of the research funded over the 10-year period was not in the forensic science domain, but in cognate disciplines where it was either implicitly or explicitly stated that the findings would have forensically-relevant applications. It was also observed that the majority of funding was allocated to technological (often high TRL) research, rather than foundational, theoretical research. Only 4% of the total funding budget was spent on foundational research within forensic science. While there is clearly value in pursuing interdisciplinary and/or technological research with short-term gains (indeed, both are necessary to underpin the discipline and secure the future capabilities of forensic science), this trend is problematic given that the current funding regime appears to be a zero-sum game. Foundational research that establishes theory and enables the evaluative interpretation of forensic science materials (physical and digital) is at present allocated a small minority of the funding despite it being repeatedly identified as a high priority for improving the quality of inferences made during forensic casework [5,14,22–24,36]. The impact of foundational research is often realised in the medium/long term, and it may not always generate economic value to be exploited in a market. However, this form of research critically provides answers to the activity-level and evaluative interpretation questions which are commonly at stake in the courtroom [39,40], thereby providing value in terms of 'societal good'.

In contrast, the US National Institute of Justice (NIJ) the US issued 23 dedicated forensic science calls over a 6 year period (2009–2014) and awarded a total of $116.7 m (c. £94.8 m) to 269 research projects with a further $11 m for federal projects (total $127.6 m) [41]. This represents a greater investment on average per year in comparison to the UK, especially given that the full amount funded by the NIJ was for dedicated forensic science research (equivalent research in the UK was categorised as 'forensic science' in the UKRI dataset). There was still a predominant focus on the development of new technologies in the US, however, it is particularly interesting that $23 m (18%) was awarded to foundational research (such as the examination of human factors in fingerprint analysis) in direct response to the National Academies Report [16], which broadly equates to the 'foundational forensic science' research in this study which received £2.2 m (4%).

5.3. The distribution of funding by research topic

The trend identified in the distribution of funding by research topic (Table 2) suggests that the largest proportion of the funding was awarded to projects in the field of 'Digital and Cyber' (which received 25.7% of the total funding), followed by projects in the field of 'Analytical Chemistry' (which received 21.2% of the total funding). Disciplines which might be viewed as 'more traditional' forensic science (such as fingerprint analysis, or the analysis of DNA and genetics) received a small proportion of the funding in comparison; 1.3% and 5.1% respectively.

It is interesting to note that in comparison, in the US the largest proportion of research funding was allocated to Forensic DNA research ($44.0 m equating to 37.7% of the budget) whilst Forensic Toxicology (broadly equating to 'analytical chemistry' in this study) was awarded a relatively low proportion $6.5 m 5.6%. In contrast to the UK, in the US only $2.8 m (2.4%) was allocated to 'digital forensics' (although this does not include cyber crime as this category did in the UK data) [41].

The distribution of funding by research topic in the UK can be taken as a positive trend, demonstrating that forensic science is evolving to encompass new disciplines of relevance to law enforcement (such as digital forensic science). However, it also clearly highlights the impact that the identity of forensic science can have on research priorities (see section 1) where the resources made available to forensic science are in part contingent upon the conception of what forensic science is considered 'to be', and what it is considered 'to be for'. This trend in funding, and the growth of 'Digital and Cyber' as a research area, suggests that, at least over the last ten years, that funding may have been predominantly allocated to areas of increasing or novel relevance for the detection of evidence as required by law enforcement, rather than having a broader portfolio that considers the requirements of every part of the forensic science system (thereby including both technological developments and foundational theory).

On the one hand, this can be seen as laudable flexibility, and the capacity to respond to the changing demands of law enforcement. However, the concern is that, given sparse funding and a dramatic reduction in spending on forensic science services [17], this expansion may have happened at the expense of other subdisciplines [5], and forensic science more holistically. There remain many research lacunae with respect to more traditional forensic techniques and fields; successive regulatory reports have suggested the need to not only perform validation studies of the methods, but also to construct empirical evidence bases to underpin inferences and evaluative interpretations [5,15,16,22–24,42].

Accordingly, in a sum-zero and dramatically-reduced funding environment, it is possible to suggest that there may be a compromise on the type of research being funded and then carried out. Without a re-evaluation of what forensic science is considered 'to be' and what it is 'for' it is unlikely to be possible to make the case to adequately fund both the future-facing, cutting-edge work on new subdisciplines that enhance our ability to detect and that harnesses the emerging technological capabilities, and also ensure that the very necessary validation and foundational, theoretical work which underpins the analysis of trace evidence (both physical and digital) also takes place. This state of affairs is problematic, and has significant implications for the development of forensic science going forward. Indeed, it is arguably one of the root causes of the severe crisis identified in forensic science overall [17] and the resulting call for urgent reform across the board. Increased funding that supports and enables both technological development as well as foundational research must be achieved to secure the future of

forensic science.

5.4. The need for a long-term outlook

A key trend which emerged from this data analysis was that the majority of funding was allocated to projects which were focussed on technological development to produce (often) high TRL solutions to current challenges in the short term, rather than foundational research that builds a body of theory upon which interpretation can be based (Fig. 2). Technological solutions to current challenges are important, but there needs to be additional investment in the medium to longer term – identifying new capabilities and developing the foundational research to pave the way for new developments in the future, and that underpin the evaluative interpretation of the forensic science evidence. In so doing, the longevity of forensic science is far more likely to be achieved. While reactive projects will, by definition, have engaged and clearly-defined stakeholders and end-users, the impact of theoretical research has the potential to be broad and significant.

In a fragmented field [17,21] short term solutions are highly valuable and it is possible to demonstrate the impact of those solutions with quantitative measures (such as an increased detection rate). Outputs that have a medium to longer term outcomes, are more likely to have their value distributed between different parts of the system (for example the police and the courts) and this makes it much more difficult to provide quantitative measures of their impact [26]. Considering ways to attach value to foundational research that incorporates the holistic needs of the entire discipline of forensic science over short, medium and long timeframes in both financial and 'contribution to societal good' terms, is a complex challenge, but an imperative next step as it has significant potential to redress the current imbalance, and ensure a strong foundation for forensic science.

5.5. A crisis of funding: treating the symptoms or the cause?

A key theme identified repeatedly throughout this study is that the present lack of funding available to forensic science acts as a barrier to research and development, and this lack of research and development acts as an impediment to the robustness and future development of the discipline [17,26]. Given that the lack of funding is problematic, it is possible to suggest that a solution would be an increase of funding. However, it is necessary to consider not only what level of increase in funding might address these problems holistically, but also the focus of the research that the funding enables.

It will be important to consider whether an increase in funding should be palliative (treating the symptoms of larger, systemic issues), curative (genuinely treating the problem of insufficient funds allocated to research), or preventative (curtailing potential future escalation of those problems). It is clearly too simplistic to suggest that the reduced levels of funding are the sole cause of the problems within forensic science as there are a number of systemic, wider issues around market stability and sustainability, and oversight and accountability which also need addressing [26]. However, it does appear to be fair to suggest that given the clear lack of funding across the board for specific forensic science research, and the disparity in that small proportion of the funding between research for technological innovation and foundational research, an increased (or even adequate) funding regime could have the potential to improve research and development and the provision of forensic science at a broad level. In asking whether increased funding might be palliative, curative, or preventative, given the complex ecosystem of forensic science, a mix of all three is likely to be the most necessary approach in the short term. However, in the medium to longer term, greater resources need to be devoted to curative and preventative approaches. Increased funding for research and development has the potential to treat the symptoms of sustained under-investment (i.e. the same priorities for research being identified in repeated, successive regulatory reports [5,22–24]); genuinely increase the quantity of high-quality, relevant, theoretical research required to draw robust inferences within forensic casework [12,14]; and have the potential to provide valuable insights which can contribute to broader agendas such as new means of detection, intelligence and prevention which can be addressed in the longer term.

6. Conclusion

The consideration of what forensic science 'is' and what it is 'for' is a foundational issue that has ramifications across the whole ecosystem of forensic science. We argue that taking a holistic view of forensic science as a coherent and interdisciplinary discipline is vital for a healthy and vibrant forensic science that can (1) meet the needs of each intersecting domain, (2) underpin forensic science that is robust and sustainable, and (3) ensure its development in the short, medium and long term, to deliver the innovation that is needed to address the challenges of the future.

It is clear that forensic science has suffered from a scarcity of resources. This is due, in part, to the disparate identity of forensic science to date, which has led to a discipline without a clearly articulated 'home', and the resultant lack of strategic oversight and accountability for the development and resourcing of the discipline. With a particular focus on financial funding for the science research that underpins forensic science (as a holistic endeavour to support the whole system from crime scene to court) this study has identified that:

- The amount of funding for specific and dedicated forensic science research is lower than has been previously stated, with only 69 projects out of a total of 150 and 46% of the total budget 2009–2018. This represents £17.2 m which is less than 0.03% of the total stated UKRI budget over this time period of £6bn. Whilst the 53 projects with explicit or implicit potential applications to forensic science may well offer value to addressing certain challenges in forensic science, they have been undertaken within other disciplinary frameworks and therefore, may not always have produced outcomes that are implementable within the forensic science system.
- The amount of funding for (broadly defined) forensic science research has seen a decrease since 2015 (when £13.3 million was awarded) to £11.2 million in 2016, £5.5 million in 2017 and £1.1 million in 2018.
- The focus of funded research has predominantly been on technological developments (91 projects, worth £37.2 million), with much less funding being allocated to foundational research (27 projects, worth £10.76 million).
- In more recent years there has been a modest increase in funding for novel technologies and evidence types (such as cybercrime and digital evidence (33 projects, worth £14.4 million)) and very small proportions of the budget have been allocated to more traditional evidence types such as fingerprints (2 projects, worth £0.7 million) and DNA and genetics (13 projects, equivalent to £2.9 million).
- There is potential for considering how research in forensic science can be addressing root causes rather than symptoms of the current crisis. There is a need to reduce the amount of resource going towards 'palliative' approaches, and to increase resources for curative and preventative approaches that in synergy have

great potential to contribute to the reforms that have been called for.

In order to address the challenges that have been articulated in many policy reports (including [5,7–10,15–17,21–25,28]), it is clear that funding is going to be a critical factor looking forward. However, it is not a case of simply increasing a budget (although it is clear an increased budget is needed). For forensic science to develop in a sustainable way, to ensure validity and efficacy, and safeguard robust science to underpin practice across the whole system there needs to be a broad acceptance of forensic science as a coherent discipline. Forensic science as a discipline with a clear and unified identity will be in a position, with adequate resources, to continue the development from its core foundation of distinct research methods, core principles and theories that underpin questions of source and identity as well as evaluative interpretation. It will facilitate the coherent and synergetic approach to physical and digital evidence and incorporate an understanding of the human actors within the entire forensic science endeavour from crime scene to court.

Both technological developments and foundational research within research and development need to be valued as integral parts to the healthy forensic science ecosystem. To achieve this, how value is articulated and evaluated will need to be addressed. At the moment, due to the multifaceted identity of forensic science, the value of forensic science is easier to articulate over short time frames and in situations where the value is not dispersed across the system (such as research developing technological solutions). In contrast, the findings demonstrate that there is a dearth of research addressing foundational issues and developing theory to support future innovation that provides value over longer time periods and across different domains (investigation and the courts). Addressing how to evaluate foundational research will be key to ensuring that forensic science research offers both technological and foundational developments.

There will also be a need for changes that address the root causes and offer reform to the current status quo [17]. The recommendations made by the House of Lords for addressing strategic oversight and accountability for forensic science, regulation of the market, and establishing a national institute for forensic science that will enable funding streams to address the full spectrum of forensic science research needed, aimed to address the root causes of the forensic science crisis and offer a 'blueprint for change'. From a research point of view, the findings from this study indicate that while more funding is certainly needed, a strategic approach must be developed to direct where additional funding is focussed. Having a coherent understanding of the identity of forensic science will increase the likelihood that funds are deployed in a way that addresses the root causes of the current challenges and anticipates the future needs of the whole system.

Declarations of interest

None.

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