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Citizen science at the roots and as the future of forensic genetic genealogy

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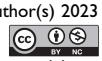
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Abstract

Forensic genetic genealogy is an emergent forensic technology that employs databases used by citizens to upload genetic data voluntarily to search for criminal suspects and/or unidentified individuals. Considering a wide view of the roots of forensic genetic genealogy, in this article, I draw on publicly available interviews with key stakeholders in the field, media articles, and companies' statements to analyze how this technology is both grounded and based upon citizen science. That is, a type of science to which citizens actively, voluntarily, and consentingly contribute in various forms. On the one hand, I show how the emergence of forensic genetic genealogy is mainly based upon the work of individuals with a personal interest in genetic genealogy, who are heavily invested in constructing their own and others' family trees. That is, citizens from various educational backgrounds and professional activities who became an untapped source of valuable expertise for forensic science because of their prolific experience in conducting genetic genealogy. On the other hand, I argue that the current situation of forensic genetic genealogy is also highly dependent on citizens' interest and willingness to upload genetic data into publicly accessible genealogy databases and voluntarily deciding to make them available to law enforcement searches. Perceiving citizen science as being at the roots and as the future of forensic genetic genealogy has important implications for the forensic epistemic culture and the protection of citizens' rights that must be considered in the development and implementation of such technology.

Keywords

Citizen science, forensic, genetic genealogy, DNA databases, expertise

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Introduction

On 28 April 1981, the body of a young woman who had been strangled and beaten was found alongside a road in Ohio, USA. Her case became known as Miami County Jane Doe, aka "Buckskin Girl", because of the buckskin poncho she was wearing. Her estimated age was between 18 and 27 years and she had died one or two days before being discovered.[1] At the time, police officers and other forensic experts recovered and preserved her clothing and other physical evidence, including a sample of her blood. Without viable leads, the investigation into the identity of Buckskin Girl gradually became a cold case for 36 years.

Over time, as several innovative forensic technologies became available, the case continued to be pursued, but despite such attempts, her identity remained unknown. A breakthrough in the case came on 10 April 2019, when it was announced that, together with the Miami County Sheriff's Office and the Miami County Coroner's Office, the DNA Doe Project was able to identify Buckskin Girl as Marcia L. King. The DNA Doe Project is a volunteer-based organization founded in 2017 to identify human remains and individuals using genetic genealogy.[2] A DNA profile obtained from the blood sample stored in 1981 "was processed using advanced DNA techniques and uploaded to a

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public genealogy database, GEDmatch".[3] The findings were confirmed by police officials. This became one of first announced cases to use genetic genealogy successfully to solve a "Jane Doe case", that is, an unknown cold case identification. Despite the identification of Buckskin Girl as Marcia L. King, the suspect who perpetrated the crime remains unidentified and criminal investigations are ongoing.

Two weeks after the announcing of the identification of Buckskin Girl, police officers in California stated they had arrested Joseph James DeAngelo, the so-called Golden State Killer, a prolific serial killer and rapist, using the same technique: genetic genealogy. Because of the high level of media attention, the Golden State Killer case became recognized as the birth of the nascent field of forensic genetic genealogy (Granja, 2021; Kennett, 2019; Murphy, 2018; Phillips, 2018). Since then, it is estimated that forensic genetic genealogy has been used in more than 500 cases (Glynn, 2022) within both civil and criminal investigations, not only in the USA, but also in Europe and Canada (Dowdeswell, 2022; Greytak et al., 2019). However, because it is not mandatory to report the use of forensic genealogy, numbers might be significantly higher (Glynn, 2022).

Taking a wide view of the roots of forensic genetic genealogy, in this article I draw on publicly available interviews with key stakeholders in the field, media articles, and company statements to analyze how this technology is both grounded in and based upon citizen science; a type of science to which citizens actively, voluntarily, and consentingly contribute in various forms (Irwin, 1995; Nielsen, 2012; Shirk et al., 2012; Vayena and Tasioulas, 2015; Vohland et al., 2021). On the one hand, I show how the emergence of forensic genetic genealogy is mainly based on the work of individuals with a personal interest in genetic genealogy who are heavily invested in constructing their own and others' family trees. That is, citizens from various educational backgrounds and professional activities who became an untapped source of valuable expertise for forensic science owing to their prolific experience in conducting genetic genealogy. On the other hand, I argue that the current situation in forensic genetic genealogy is highly dependent on citizens' interest and willingness to upload genetic data to publicly accessible genealogy databases and voluntarily deciding to make them available to law enforcement searches. Without such public engagement, the data sets needed to conduct forensic genetic genealogy would most probably cease to exist. Perceiving citizen science as being at the root and the future of forensic genetic genealogy has important implications for forensic epistemic culture that must be considered in the development and implementation of such technology, and that are considered in the concluding section of this article.

The challenges of forensic genetic genealogy

Forensic genetic genealogy has also been referred to using as "investigative genetic genealogy" (Ge and Budowle, 2020; Guerrini et al., 2021; Machado and Silva, 2022; McEwen et al., 2021; Samuel, 2021; Samuel and Kennett, 2020b) and "(long-range) familial searches in recreational DNA databases" (Granja, 2021; Murphy, 2018). In this article, I use the term forensic genetic genealogy (Ram et al., 2021; Wickenheiser, 2019), defined by Dowdeswell as:

> An interdisciplinary practice that combines genomics and computer database technologies, as well as traditional and genetic methods of genealogical research to identify unknown individuals by reconstructing their ancestral lineages and drawing out their family trees. (Dowdeswell, 2022, p. 2)

Academic debates about the "genetic genealogy revolution" (King and Jobling, 2009), made possible by the Y chromosome, have been held within the forensic genetics community for several years (Calafell and Larmuseau, 2017; Jobling and Tyler-Smith, 2017). However, the field took a on new significance in 2018, in the aftermath of the Golden State Killer case, as it became clear how genealogy could be a valuable resource for forensic science. Since then, debates around forensic genetic genealogy have proliferated in academic and non-academic forums, namely academic journals and media outlets with high levels of dissemination (for example, *New York Times*, *The Guardian*, CBS, BBC, etc.). Nonetheless, despite several attempts to create an ethical framework for forensic genetic genealogy (Machado and Silva, 2022; McEwen et al., 2021; Scudder et al., 2019; Wickenheiser, 2019), there remain ongoing and non-settled issues. Although the division between the challenges posed by forensic genetic genealogy is mainly analytical, because several issues entailed are highly interlinked and co-dependent, I divide them into three main categories: (a) ethical controversies and societal implications; (b) regulatory challenges; and (c) logistical issues. Understanding the challenges posed by forensic genetic genealogy is of paramount importance in understanding the role of citizen science because these challenges help us to consider and critically engage with the potential implications for the forensic epistemic culture of having citizens with very diverse educational training and professional skills actively involved with and contributing to this type of investigative work.

In terms of ethical controversies and societal implications, in addition to broader issues related to the function creep of recreational DNA databases, which are nowadays (also) used for law enforcement searches (Granja, 2021),

forensic genetic genealogy implies an enlargement of the type of information that can be retrieved from DNA. This is because the technology employed makes use of single nucleotide polymorphisms (SNP), which test far more markers than the short tandem repeats (STR) commonly used in forensic procedures and forensic DNA databases (Murphy, 2018). Forensic genetic genealogy also expands the populations involved in law enforcement searches. Unlike traditional familial searches used in forensic DNA databases, which are only able to identify close biological relatives, forensic genetic genealogy in recreational DNA databases enables the identification of distant biological relatives, such as fourth, fifth and more distant cousins; although it is increasingly difficult to validate the connections for these more distant relationships. In addition, recreational DNA databases mainly include economically privileged populations of European descent (Kennett, 2019; Machado and Silva, 2022; Murphy, 2018). This is in stark contrast to forensic DNA databases, which usually overrepresent underprivileged and racialized populations, because they tend to be more affected by actions of the criminal justice system (Skinner, 2013).

Forensic genetic genealogy also raises several issues associated with consent. First, because consent-related disclaimers are "usually unambiguous […and…] sometimes buried in terms of service or privacy policies that many individuals do not take care to read or fully understand" (Ram et al., 2018: 1079). Second, as outlined by Samuel and Kennett (2020a), although individuals who use genetic genealogy services recognize the importance of the need for consent, their views sometimes undervalue the fact that, by agreeing to make their DNA available for law enforcement searches, they might be also implicating their biological relatives who have not taken a DNA test and who have not consented to these methods being used. The focus on individual-based consent, therefore, narrows the discussion around the ethical controversies and societal implications of forensic genetic genealogy (Samuel, 2021; Samuel and Kennett, 2020a).

Another issue in the ethical controversies and societal implications raised by forensic genetic genealogy regards its impacts on public trust (Curtis et al., 2019). Early indications were that law enforcement access to genealogical databases to search for criminal suspects would receive high levels of support from the general public (Guerrini et al., 2018), as well from professional and public stakeholders (Samuel and Kennett, 2020b). However, there has been a significant decrease in the number of profiles available following a change in the terms and conditions of GEDmatch, which implied that each participant had to consent voluntarily to make their DNA profile available for law enforcement searches (Katsanis, 2020; Glynn, 2022). According to Glynn (2022), GEDmatch currently holds approximately 1.8 million kits, with more than 500,000 opted-in for law enforcement comparisons. However, there is no existing information about the sociodemographic factors that characterize individuals opting in for law enforcement searches.

In addition to ethical controversies and societal implications, forensic genetic genealogy also raises regulatory challenges. Companies involved with direct-to-consumer genetic testing have different policies and practices, ranging from stating that they will try to resist law enforcement inquiries to actively cooperating with law enforcement, with varying degrees of restrictions and cooperation in between these two poles (Skeva et al., 2020). Aiming to initiate a regulatory process for forensic genetic genealogy, in 2019 the US Department of Justice issued an interim policy to guide its use, indicating the types of crimes that could make use of this technology, disallowing surreptitious use of genealogy databases, and requiring that a search must be made on the national forensic DNA database before using forensic genetic genealogy in recreational DNA databases (United States Department of Justice, 2019). However, several loopholes continue to raise regulatory challenges, namely the fact that such an interim policy does not address the qualifications of the genealogists conducting the analysis (Kennett, 2019) and this policy only binds federal law enforcement personnel and state entities that receive federal funding to conduct forensic genetic genealogy, which excludes a significant portion of law enforcement in the United States (Ram et al., 2021). Aiming to address some of these issues, in May 2021, the State of Maryland enacted the first law in the world that regulates forensic genetic genealogy (Ram et al., 2021), although at the time of writing (February 2023) implementation has been stalled.[4]

Finally, forensic genetic genealogy involves complex logistical issues related to the fact that it is not a forensically validated technology and might entail high costs owing to the large sets of information it produces (Ge and Budowle, 2020). Being dependent on the complexity of the search required to identify an individual, the amount of work and resources put into each investigation are highly variable (Scudder et al., 2020).

Despite ongoing challenges and several controversies associated with forensic genetic genealogy, some countries (such as the USA and Canada) currently use this technology, some (such as Australia and Sweden) are running pilot projects (Tillmar et al., 2021) and others are discussing it, as is the case with the UK (Thomson et al., 2020). Nonetheless, the application of forensic genetic genealogy has mainly been focused in the USA, as shown in a study by Dowdeswell (2022) reviewing the 436 cases solved to 31 December 2020. According to the Dowdeswell, forensic genetic genealogy investigations fall into four broad

categories: criminal investigations (80%), investigations to identify unknown decedents (19%), and the identification of living individuals and victims of a mass disaster. Most cases involved a homicide and/or a sexual assault and were solved by Parabon NanoLabs, Barbara Rae-Venter, and the DNA Doe Project (Dowdeswell, 2022).

Citizen science

It was only in the 19th century that, owing to the institutionalization of science, specific boundaries between "scientists" and "non-scientists" started to be drawn, increasingly excluding the latter from scientific pursuits and achievements (Nielsen, 2012; Vayena and Tasioulas, 2015). More recently, the opposite trend has been taking place, with a substantial increase in citizens engaged in scientific endeavors, a phenomenon that has been recurrently called citizen science (Irwin, 1995; Vohland et al., 2021). This involvement might entail, but not be limited to, amateur experts, concerned community members, scientists trained in other fields, and/or students (Shirk et al., 2012). This, therefore, highlights the "participatory turn" that academic discussions on public engagement have been discussing (Jasanoff, 2003).

Although the term "citizen science" lacks a consensual definition (Guerrini et al., 2019; Vayena and Tasioulas, 2015), it broadly refers to active public involvement in scientific research development and enactment (Irwin, 2018). Despite being deeply associated with initiatives in ecology and the environmental sciences, citizen science has also become increasingly relevant in the field of human genomics (Guerrini et al., 2019) and current projects range across different disciplines and entail very different types of participation (Shirk et al., 2012). According to Vayena and Tasioulas (2015), two societal developments can help to explain the contemporary boom in citizen science. The first regards the potential offered by technological data-mining devices and the connection between individuals and platforms made possible by the internet. Online tools allow for the creation of communities in which individuals can learn from and support one another (Nielsen, 2012). The second element that can help to explain the increase in citizen science efforts regards increasing calls for public engagement in scientific advancement (Marris and Rose, 2010). In this sense,

> Today's citizen science movement is the product of this conjunction of unprecedented technological means at the disposal of the general public together with the heightened value accorded to individual participation in all the myriad facets of social life, including those formerly regarded as the exclusive domain of specialists. (Vayena and Tasioulas, 2015: 480)

Shirk and colleagues (2012) created a framework to situate the different initiatives that citizen science might entail. These include: (a) situations in which communities ask scientists to conduct research on a given topic and communicate the results—contractual projects; (b) projects designed by scientists to which the public contribute data—contributory projects; (c) schemes designed by scientists, but where members of the public contribute data but also engage with the project' design, data analysis and dissemination—collaborative projects; (d) endeavors designed by both scientists and members of the public and in which the latter are also involved in most or all aspects of the research process—co-created projects; and (e) arrangements where citizens initiate, design and conduct research independently, with varying degrees of expected recognition by institutionalized science and/or professionals—collegial contributions (Shirk et al., 2012: 28). Collegial contributions are a type of activity that has come to be known as participant-led research (Vayena and Tasioulas, 2013a), in contrast to conventional investigator-led research (Vayena and Tasioulas, 2013b). This latter model calls for a reconsideration of the boundaries of expertise as exclusive attributed to traditionally credentialed scientists (Shirk et al., 2012).

Citizen science initiatives are not a new phenomenon in the field of forensic genetics. There is a wide body of research detailing how in several Latin American countries, such as Argentina, Colombia, Peru, Chile, and Guatemala, work undertaken by the relatives of the disappeared has been of relevance in the creation and consolidation of a system that enables identification of the missing (Cruz-Santiago, 2020; Schwartz-Marin and Cruz-Santiago, 2016a, 2016b, 2018). Similarly, in Spain, relatives of individuals who disappeared during Franco's dictatorship also engaged in the identification of human remains (Ferrándiz, 2013) and in Srebrenica forensic specialists were deeply engaged with relatives of the missing (Haimes and Toom, 2014; Wagner, 2008). Based on the Mexico and Colombia context, Ernesto Schwartz-Marin and Arely Cruz-Santiago propose the term "forensic civism" to describe how through use of "forensic identification tools such as archaeology, anthropology or genetics, relatives and citizens have been able to again make death a public matter, thus effectively challenging the State as the legitimate governor of dead bodies or the disappeared" (Schwartz-Marin and Cruz-Santiago, 2016a: 70).

In this article, I argue that forensic genetic genealogy sheds light on a new configuration of citizen science within the field of forensic science. Instead of working to confront governmental officials and fight impunity and corruption (Schwartz-Marin and Cruz-Santiago, 2016a, 2016b, 2018), forensic genetic genealogy entails several types of participant-led contributions that work with and for

governmental officials, to ensure public safety by identifying crime suspects and/or victims. Forensic genetic genealogy thereby shows how what, in most cases, began as an amateur hobby has become a generative space for a new type of forensic work. However, unlike most citizen science projects and initiatives, which are based on research science, forensic science is regulated by different norms that constitute its particular epistemic culture due to its close relationship with the criminal justice system (Cole, 2013). This situation, therefore, poses particular challenges and unsolved ethical controversies that must be considered, both in terms of its implications for forensic science as a discipline and for the protection of citizens' rights.

Citizen science at the roots of forensic genetic genealogy: Collegial contributions and the changing role of expertise

Most accounts of forensic genetic genealogy begin with a brief introduction to the Golden State Killer criminal case that has become the landmark beginning of this technology, which, in turn, has been considered to "mark the start of a new era in forensic genetics" (Curtis et al., 2019: 1483) (see also Granja, 2021). Although there are other reported cases (Ram et al., 2018), they have not captured the public's attention and the political agenda similarly, nor increased the profile of forensic genetic genealogy techniques to the same extent. However, the roots of the vibrant field of forensic genetic genealogy are longer than the Golden State Killer criminal case and, in this section, I argue how it is deeply grounded on citizen science efforts.

Since completion of the Human Genome Project, a new type of industry has emerged capitalizing on genomic informative potential (Borry et al., 2010). Drawing on the cultural mystique of DNA (Nelkin and Lindee, 1995), genetics is increasingly perceived as being able to provide "clear-cut" information regarding identification and identity in several domains, such as forensic genetics (Lynch et al., 2008) ancestry testing (Abel and Schroeder, 2020; Nelson, 2016), and biomedical sciences (Guerrini et al., 2019). Based on the decreasing costs of genetic sequencing and genotyping, companies began to advertise and sell the possibility of conducting genetic tests with three main purposes: (a) knowing more about health and genetic susceptibilities to diseases (Borry et al., 2010); (b) discovering information about biogeographic ancestry (Horowitz et al., 2019; Nelson, 2016); and (c) conducting genealogical research. Some companies focus on one of these aims, whereas others target several (Horowitz et al., 2019). The common denominator of these companies marketing direct-to-consumer genetic testing is a service based on the voluntary collection and submission of a biological sample (usually saliva, from which DNA is then extracted) and the consequent analysis and communication of those personalized results to the consumer.

The wide availability of these services, coupled with decreasing prices, advancements in digital technologies, and the sharing potential of the internet, therefore offered a particular fruitful scenario for individuals interested in knowing more about their ancestry and families' histories. Consequently, by 2014, genealogy was one of the most popular hobbies in the United States (Rodriguez, 2014) and several genealogists were collaborating with academic researchers in publishing scientific breakthroughs (Azaiez et al., 2015; Mendez et al., 2013; Rocca et al., 2012; Zhang et al., 2016). Such popularity expanded the DNA ancestry testing industry (Abel and Schroeder, 2020) allowing for the construction of large-scale databases containing comprehensive genetic information on millions of individuals. Currently, Glynn (2022) estimates that the top four direct-to-consumer databases alone (AncestryDNA, 23andMe, MyHeritage DNA and FamilyTreeDNA) hold genetic information on over 41 million people worldwide.

Although the analysis of DNA by each company might be "enough" for individuals who aim to know more about their health-related genetic susceptibilities, the proliferation of companies offering direct-to-consumer genetic testing—each with its own DNA database—meant that individuals aiming to search for relatives and/or building a family tree faced a conundrum: they were unable to access information from possibly related individuals who had taken tests with other companies. Hence, in 2010, Curtis Rogers and John Olson created GEDmatch[5], an publicly accessible online database to which customers can upload DNA data generated from testing conducted by different companies in order to find genetic connections with others who have also uploaded their genomic data, aiming to enlarge the pool of potential matches.

Although GEDmatch was the first platform to allow cross-company comparisons, other databases (such as FamilyTreeDNA) soon began to accept uploads. As more data became available, genetic genealogy grew exponentially and resources teaching how to conduct it were abundant. For instance, the International Society of Genetic Genealogy (ISOGG) offered free educational resources and founded the ISOGG Y-SNP tree[6], and there was a boom of Facebook groups devoted to learning and discussing genetic genealogy, some of which have tens of thousands of members. Genetic genealogy thus became a particularly illustrative example of citizen science, as more and more citizens became directly engaged in not only finding their relatives, but also helping others to do so. This notion is reiterated by several genetic genealogy-based initiatives, such as DNA adoption, a non-profit organization, that states on its website: "We are a team of

unpaid volunteer genealogists, *citizen scientists*, geneticists, and all-around good folks helping those on a journey of discovery" (italics added).[7] Similarly, the DNA Doe Project, also a non-profit organization, is presented as "DNA Doe Project is an all-volunteer organization with over 60 experienced genetic genealogists giving their time and passion to our cause".[8] The notion of genetic genealogy as a citizen science effort is also echoed by other prominent stakeholders in the field, as is the case with CeCe Moore, currently chief genetic genealogist at Parabon NanoLabs[9], in her talk as keynote speaker at the International Symposium of Human Identification (ISHI), 2020, addressing the emergence and consolidation of genetic genealogy:

> How did we unlock this immense power of genetic genealogy that we are getting the benefit of today? Well, it came from *citizen scientists*. This was truly a grass rote effort from those that were deeply invested in trying to figure out how autosomal SNP testing could be used to unravel family mysteries. It was built through innovation and passion. It was a relatively small group of early adopters of this technology that volunteered tons of thousands of hours to get us to where we are today.[10] (italics added)

This idea of citizen science being at the root of genetic genealogy is also promoted by media outlets, as is the case with the CBS program *60 Minutes*, which described forensic genetic genealogy as "a mixture of high-tech DNA analysis, high speed computer technology, and old fashioned family genealogy pioneered by some quirky collaborators who got into it as a hobby".[11]

The emergence of genetic genealogy as a type of citizen science moved by "passion" and solidarity led to the establishment of a new field of expertise that remained relatively unregulated and open to all interested citizens, regardless of their particular aims. This remained the case even when genetic genealogy started to be used to advance missing person cases, a situation that mobilized the first contacts between genealogists and law enforcement agents in 2011. In this regard, the *New York Times* reports:

> In 2011, a physicist and former NASA contractor named Colleen Fitzpatrick worked with detectives in Washington State to help identify the killer of a high-school girl. Using Y-DNA testing[12], she concluded that the suspect was a descendant of Robert Fuller (…). The tip led police to the girl's neighbour, a family friend, who was totally innocent. (Khatchadourian, 2021)

Similarly, in 2014, detectives investigating the rape and murder of an 18-year-old woman named Angie Dodge, in Idaho Falls, obtained a warrant that compelled the genealogy company Ancestry[13] to allow access to the Sorenson database, which contained DNA data and genealogical information. Investigators intended to reveal the identity of a man who had submitted his Y-DNA profile to such a database, owing to its alleged genetic relationship with a profile extracted from semen found at the crime scene. The disclosure of such information led investigators to Michael Usry, who was then proved innocent through traditional forensic DNA profiling. The outcome of this case eventually led to closure of the Sorenson database. This was felt by the community to be a significant loss of an important and open-access genetic genealogy source.

Such cases, which reveal only what has been made public (and leave reasonable doubt about other cases that might be unknown to the wider public), therefore show how before coming into the public domain through "success cases", interest (and attempts) in using genetic genealogy in forensic investigations has been developing and tested for quite some time; sometimes marked by misleading information. In fact, it was such early attempts that eventually led to identification of the Golden State Killer.

Part of the path that eventually led identification of the Golden State Killer is made clear in the book *I Know Who You Are: How an Amateur DNA Sleuth Unmasked the Golden State Killer and Changed Crime Fighting Forever*, by Barbara Rae-Venter (2023), the genealogist who cracked the case. In the book, Rae-Venter explains how her first case using forensic genealogy, which started in March 2015 following a request for help by Deputy Peter Headley, was the identification of Lisa Jensen—a women who was abducted as a child and whose biological identity remained unknown until that point. Solving this case eventually led to Barbara Rae-Venter and Deputy Peter Headley finding out that the man who abducted Lisa was a prolific serial killer. The success of such identifications then led Paul Holes—the criminal investigator responsible for advancing the Golden State Killer case—to ask Rae-Venter to work on the case. When she started doing this type of work, Barbara Rae-Venter was a retired patent attorney who had been conducting genetic genealogy on a voluntary basis in an effort to assist a newfound cousin. As she writes in the book:

> In what began as a *postretirement hobby*, I was volunteering as a genetic genealogist—a "search angel" who uses DNA matches to build family trees and help solve unknown parentage issues. (Rae-Venter, 2023: 6, italics added)

Following the impact of the Golden State Killer case, several individuals who had been conducting genetic genealogy work as a hobby became an untapped source of expertise for criminal investigations. As noted by Colleen Fitzpatrick, who co-founded the DNA Doe Project and was already involved in civil identification

investigations: "The Golden State Killer case said we could go into homicides".[14] However, it was not only non-governmental associations that saw the Golden State Killer as a green light to move into criminal investigations. Major industry players already known in the forensic community for challenging discourses and practices around robust science, technology validation, and commerce (Granja and Machado, 2020; Wienroth, 2020) were also paying attention. As stated by Steve Armentrout, Parabon's CEO: "The wheels were already in motion. We sat back and watched the public response. It was overwhelmingly positive. This was like a starting gun to go ahead and move out".[15] This, therefore, marked the beginning of a booming forensic industry seeking to obtain profit from conducting forensic genetic genealogy within the framework of criminal investigations, with the number of companies offering such services growing daily.

Forensic genetic genealogy can, therefore, be framed as what Shirk et al. (2012) categorize as a collegial contribution, in which individuals initiate, design, and conduct research independently, with varying degrees of expected recognition by institutionalized science and/or professionals. The trajectory of forensic genetic genealogy shows a move from genealogy-as-hobby, in which the notion of affect plays a major role—because individuals usually work on cases related to their family history or other individuals with whom they have some type of relationship—to "collegial contribution" in which individuals pick up cases flagged by police forces that might not have any direct or indirect link to them.

Furthermore, the idea of forensic genetic genealogy as a collegial contribution also brings the issue of expertise to the forefront of the debate. Although science studies have shown that there is more to scientific and technical expertise than is encompassed in the work of formally accredited scientists and technologists (Collins and Evans, 2002), within forensic genetics a relatively stable distinction between experts and non-experts has been maintained over the years, constituting the foundation stones of the legitimization of forensic genetics. However, nowadays, with the advent and consolidation of forensic genetic genealogy, new players are coming into the field and redefining the limits of forensic expertise. Individuals who have been conducting genetic genealogy for years now represent "experience-based experts" (Collins and Evans, 2002) who are working full time as professional genetic genealogists either directly with law enforcement officials and/or through companies marketing forensic genetic genealogy. This, therefore, demonstrates how "the nature, relevance and limits of 'expert' identity are highly malleable and reactive to moves and counter-moves" (Lynch, 2007: 925).

Forensic genetic genealogy, therefore, represents a new wave of forensic science not only because it blurs the boundaries between forensic and non-forensic databases, but also because it creates a new set of expertise that is starting to be gradually incorporated into what Prainsack and Toom (2010) call "forensic technocracy". This implies that forensic science is in a "'liminal space' which are transitional and transformative states in which the values and norms of one stage have been left behind and the values and norms of the later stage have not yet been reached" (Derksen, 2010: 221). Within this liminal space, new norms, values, and consensus about the technology need to be created because genealogy "is on the verge of becoming a recognised profession and an academic discipline" (Durie, 2017: 1).

One of the most pre-eminent issues in this regard is the process of the accreditation and certification of forensic genetic genealogists. Owing to the particular characteristics of citizen science, there is no organization that provides accreditation in genetic genealogy. Consequently, forensic genetic genealogists are not necessarily subject to institutional or regulatory oversight. However, because they are increasingly dealing with data originating from several procedures of criminal investigations, the move from citizen science to the forensic epistemic culture (Cole, 2013) will probably involve being bound to processes of accreditation and certification. Up to this point, this process has remained relatively undeveloped because forensic genetic genealogy is addressed as an investigative lead, and therefore framed as the generation of intelligence, which remains "out" of the courts, whereas only the construction evidence is debated (in this regard see Wienroth, 2020; Granja and Machado, 2020). However, this understanding is being challenged and steps toward establishing certification in forensic genetic genealogy are currently being taken (Gurney et al., 2022).

Citizen science as the future of forensic genetic genealogy: The role of contributory projects

Another dimension of how forensic genetic genealogy is anchored in citizen science is related to how it broadly depends upon citizens' voluntary donation of genetic material to sustain and/or enlarge databases in which the search for criminal suspects is conducted. This is a totally different scenario from the notion of genealogy-as-hobby explored in the previous section. The donation of DNA is usually circumscribed to a particular moment in time, in which individuals who have previously resorted to direct-to-consumer genetic testing decide to make their DNA available to help "find criminals". It therefore contrasts with the use of forensic genetic genealogy as a collegial contribution, which entails medium- to long-term dedication and effort.

In the aftermath of the Golden State Killer, GEDmatch has been through several changes in the terms of service (Katsanis, 2020; Glynn, 2022), which currently suggest that citizens must consent to having their DNA profile compared with law enforcement searches. However, it is impossible to know whether existing users are actively opting out or whether they simply haven't overtly opted back in after modifications in the terms of service. So, despite recent changes, consent processes in both GEDmatch and Family Tree DNA continue to pose ethical issues. For example, in 2021, GEDmatch opted in their entire database to matching with unidentified human remains without informing users. In 2019, FamilyTreeDNA instituted a policy that automatically opts-in users from matching in law enforcement searches. However, considering the EU General Data Protection Regulation (GDPR), European users of FamilyTreeDNA have all been automatically opted out. Regardless of such ethical issues, stakeholders in the field are, aware that how their work is perceived by the public constitutes a major influence on the availability of genetic profiles for conducting searches. Such views are outlined by CeCe Moore and Barbara Rae-Venter, respectively:

> Investigative genetic genealogy is such a valuable tool that we must be sure to not let it slip from our fingers. This tool relies on public support and participation and so public perception is key. If public perception were to become negative people could remove their DNA files from the databases law enforcement is able to access or they could even stop testing with consumer genetics companies completely. That would be a huge tragedy. So, when using this tool, we have to think 'How would my actions be perceived by the public?' 'How might the media interpret my actions to the public?'.[16]

> [Forensic Genetic Genealogy] depends on what happens to the rules that we promulgate to protect how this work is being done and the people are careful with how they use it, so that we don't end up getting people upset so they say you can't do that anymore.[17]

To sustain large data sets, companies and organizations are therefore promoting the idea that, by making their DNA data available to law enforcement searches, citizens are actively collaborating and contributing to "a safer society". This reliance upon public contributions is also highly dependent upon media coverage of the use of forensic genetic genealogy in criminal cases. Consequently, one other way in which public participation is indirectly fostered is via the mediatization of criminal cases solved by forensic genetic genealogy through news and TV shows. Several representatives of Verogen, the company that acquired GEDmatch (and was later acquired by Qiagen) recognize how the database is influenced by this:

> When at The Genetic Detective and a whole bunch of other TV shows, news articles that have been coming out… Every time that happens, we've seen a bump in usage because there are a number of people who want to do their part in making society safer. Everyone wants to be a crime fighter, right? (Swathi Kuma, Director Product Management of Verogen)[18]

> The Genetic Detective series, that had a phenomenal impact on GEDmatch. The number of people signing up for law enforcement matching, uploading their profile, there was a huge increase. During that six-week period, we even had people calling us up [saying] "I don't care about genealogy, but I want you to have my profile, so that you can have it available for law enforcement matching, just let me know if that is possible". So, we know that created a certain amount of… There is a bunch of people out there that have this civic minded sense of duty to be able to help society in totality and that is where I think these shows, from a society perspective, they are very beneficial, because they drive their awareness of this situation. You have a number of serial killers out there. We need to get rid of these guys. (Brett Williams, CEO of Verogen)[19]

Forensic genetic genealogy is, therefore, creating a configuration, whereas citizens who did not take an active part in the search for criminal suspects now have this possibility open to them. Unlike forensic DNA databases, the size of which is mainly influenced by regulatory decisions (Santos et al., 2013), in the case of forensic genetic genealogy, the size of a database is mainly dependent upon the publics' willingness to actively contribute to law enforcement searches. Forensic genetic genealogy strongly benefits therefore, in the sense that the available data set grows, from "momentum" while criminal cases are under the media gaze. However, such appeal toward public involvement based on "public safety" tends to overshadow the significant business interests that are entailed in forensic genealogy, as more companies become specialized in conducting this type of analysis. By emotionally engaging with the public in criminal cases and promoting the voluntary donation of DNA to "solve crimes", companies are enlarging their highly profitable data sets in the relatively closed-circuit of forensic genetics in ways that transgress national boundaries and regulatory competences.

Another facet of this issue regards the increasing reliance on public donations to work on specific criminal cold cases. There are currently several websites aimed at encouraging such donations, such as DNASolves[20], Season of Justice[21], and Justice Drive[22], with several direct and indirect links to companies marketing forensic genetic genealogy and promoting crowdfunding. If this trend growths it might eventually suggest that cases are prioritized based

upon their potential to foster emotional attachment by the public, instead of investigative priorities, which holds relevant implications for the forensic epistemic culture.

Concluding remarks

Although the emergence of forensic genetic genealogy tends to be situated in the aftermath of the Golden State Killer case, in this article I attempt to show how a broader view of its roots and current configurations, based upon different types of citizen science initiatives, allows for a much more in-depth analysis of its current and future challenges. With the increasing attention, not only by police and judicial authorities but also by the civil society, on forensic genetic genealogy and the corresponding calls for more contributions to genealogy genetic databases (either by donating DNA or money), it is of paramount importance to critically consider the messages upheld by forensic genetic genealogy and explore what their consequences may be.

Being closely linked and dependent on the expertise of genealogists with variable educational backgrounds and professional activities, forensic genetic genealogy is now a "collegial contribution" (Shirk et al., 2012) increasingly entering the toolkit of forensic technocracy and challenging the limits of expertise within the forensic epistemic culture. This means that citizens highly interested and invested in genealogy, with varying degrees of expected recognition by institutionalized science and/or professionals, are increasingly collaborating with law enforcement, thereby creating a new type of expertise within forensic science that remains largely unregulated, unaccredited, and uncertified.

In addition being located at its emergence, citizen science is the basis of the future of forensic genetic genealogy in the form of a contributory project. In stark contrast to forensic DNA databases, which imply mandatory judicial police or judicial decisions, recreational DNA databases available for law enforcement are dependent upon citizens' willingness to contribute. To guarantee the viability of such databases, forensic genetic genealogy is being sustained by a public narrative that outlines its potential to identify and track violent offenders, while ensuring justice for victims. One of the main ways to promote this is to use the media spotlight to advance the promotion of forensic genetic genealogy.

Lessons learnt

The reframing of expertise analyzed in this article shows how genealogists with variable educational backgrounds and professional activities are increasingly taking a prominent role in the development and application of forensic genetic genealogy. It is, therefore, of paramount importance to formalize their involvement with the criminal justice system, creating safeguards that might involve accreditation and regulation procedures that limit who can play such a role. Furthermore, despite the fact that forensic genetic genealogy is an investigative rather than probative technique, such process must entail a reflection on the limits of expertise; that is, considering what counts as admissible expertise for pursuing criminal investigations because it directly impacts the chain of custody and eventual case prosecution.

Forensic genetic genealogy is mostly shielded from public criticism by the proclaimed aim of increasing public safety and ensuring healing for victims. However, the police use of recreational DNA databases constitutes an instance of function creep, with impacts on civil liberties that must be clearly communicated to all individuals making the decision to conduct genetic testing for recreational purposes and eventually making their genetic material available for law enforcement searches. In this sense, a sustained effort must be me made to create a more balanced narrative that shows the potential, but also the risks to civil liberties of using forensic genetic genealogy to find criminal offenders.

Finally, this technology is anchored in a highly profitable global market in which regulatory limitations are mostly absent. There is, therefore, an urgent need to reflect upon the role of companies making their DNA databases available for police searches, as well as companies selling such services to police forces without in-house capacity to conduct forensic genetic genealogy searches.

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Notes

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