Forensic Science International: Genetics 33 (2018) 84–97

Contents lists available at ScienceDirect

Forensic Science International: Genetics

journal homepage: www.elsevier.com/locate/fsigen

Research paper

Transfer and persistence of non-self DNA on hands over time: Using empirical data to evaluate DNA evidence given activity level propositions

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ARTICLE INFO

Keywords:
DNA transfer
Handshaking
Activity level propositions
Bayesian network

ABSTRACT

Questions relating to how DNA from an individual got to where it was recovered from and the activities associated with its pickup, retention and deposition are increasingly relevant to criminal investigations and judicial considerations. To address activity level propositions, investigators are typically required to assess the likelihood that DNA was transferred indirectly and not deposited through direct contact with an item or surface. By constructing a series of Bayesian networks, we demonstrate their use in assessing activity level propositions derived from a recent legal case involving the alleged secondary transfer of DNA to a surface following a handshaking event.

In the absence of data required to perform the assessment, a set of handshaking simulations were performed to obtain probabilities on the persistence of non-self DNA on the hands following a 40 min, 5 h or 8 h delay between the handshake and contact with the final surface (an axe handle). Variables such as time elapsed, and the activities performed and objects contacted between the handshake and contact with the axe handle, were also considered when assessing the DNA results.

DNA from a known contributor was transferred to the right hand of an opposing hand-shaker (as a depositor), and could be subsequently transferred to, and detected on, a surface contacted by the depositor 40 min to 5 h post-handshake. No non-self DNA from the known contributor was detected in deposits made 8 h post-handshake. DNA from the depositor was generally detected as the major or only contributor in the profiles generated. Contributions from the known contributor were minor, decreasing in presence and in the strength of support for inclusion as the time between the handshake and transfer event increased.

The construction of a series of Bayesian networks based on the case circumstances provided empirical estimations of the likelihood of direct or indirect deposition. The analyses and conclusions presented demonstrate both the complexity of activity level assessments concerning DNA evidence, and the power of Bayesian networks to visualise and explore the issues of interest for a given case.

1. Introduction

Over the last 15 years, there have been an increasing number of cases worldwide where DNA evidence has been questioned due to uncertainty about the activities that lead to its deposition, as in *R v Hillier* [1], *R v Weller* [2] and the case of the 'Death of Meredith Kercher' [3]. Several of these cases have been highlighted in the media, drawing significant attention to the methods applied to evaluate such evidence. While each case has different aspects that are unique to the scenario presented, the generic statements about the possibility of transfer do not adequately address the recurring questions being raised.

When considering propositions relating to activities of interest, termed activity level within the hierarchy of propositions [4,5], the DNA findings are evaluated in light of how they support the competing propositions from prosecution and defence. Such evaluations often require the analyst to assess the likelihood that DNA was transferred indirectly (secondary transfer or further), compared to the possibility that it was transferred through direct contact with an item or surface. Knowledge of the factors affecting DNA transfer, persistence, prevalence and recovery (DNA-TPPR) within the context of a case are of importance to enable an accurate and case-specific assessment of the likelihood of biological examination results given particular activities.

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https://doi.org/10.1016/j.fsigen.2017.11.017
Received 18 August 2017; Received in revised form 21 October 2017; Accepted 26 November 2017
Available online 28 November 2017
1872-4973/

To inform the courts properly, analysts must draw upon DNA-TPPR data from relevant in-house and/or published studies, or, in the absence of objective data, expert elicitation, where the expert (with or without assistance from multiple experts) provides an opinion based on their knowledge and experience [6]. The authors advocate the use of objective data over expert elicitation, though a statement of limitations should accompany the use of data from either method.

While extensive research has/is being undertaken to extend our knowledge on DNA-TPPR in various scenarios, i.e. [7–20], the number of factors influencing transfer events, and high degree of variability within and between these factors, complicate activity level assessments [21]. However, this should not deter forensic practitioners from proceeding with such evaluations [22,23].

Probabilistic methods have previously been demonstrated by others to be useful in addressing questions relating to activities [7,15]. Furthermore, as a graphical representation of Bayesian formulations, Bayesian networks (BNs) simplify working with complex statistical formulae and have been used to address questions at source [24–26] and activity level [27–29]. The ease with which Bayesian networks can be used to incorporate multiple variables make them ideal in complex cases, enabling the investigation of a diverse range of scenarios and factors. The use of empirical data to inform parameters decreases subjectivity, while the ability to graphically model case-specific scenarios with clearly defined relationships and assumptions among variables, provides transparency. Furthermore, the ability to analyse the impact of assumptions and the sensitivity of the likelihood ratio (*LR*) to changes in variables, can inform the need and relevance of data or specific variables [30].

Here we use aspects of the "Fitzgerald case" from South Australia [31,32] as a demonstration of how Bayesian networks can be used to evaluate DNA evidence when considering a pair of activity level propositions within the context of a case. This case was selected because of the numerous variables to be considered, the commonality of the factors and issues across cases, the various levels of uncertainty surrounding the activities involved and the fact that descriptions of activities deemed potentially relevant in the case were publically available. This case is primarily used as an example and it is not our intention to re-evaluate the evidence or the case specifically, but to simply demonstrate a conceptual framework for how certain aspects of cases like this might be evaluated in the future. As a result, there are many aspects of the case that are not mentioned or considered. Further, as the case was selected only as an exemplar of issues facing forensic biologists, the circumstances and variables have not been exactly replicated, but have been modelled within the research laboratory to provide indicative data in similar scenarios. As such, estimates of evidentiary weight should not be applied to the specific case utilised.

1.1. Case circumstances and forensic results

Here we provide a brief outline of the case circumstances. For further information see [31] and [32]. In the early hours of the morning, a large group (6+) of male offenders yielding weapons forced entry into a home that was being occupied by a number of individuals. Two of the occupants (D and K) were critically injured, with one (D) later dying in hospital. Sumner, who had been at the house visiting relatives prior to the attack, was charged with murder.

Along with other items, a didgeridoo found near the deceased was submitted for DNA testing. The didgeridoo, normally kept beside a washing machine in the laundry and used infrequently, was played by the deceased (D) just hours before the attack. There was no evidence as to how it came to be in the lounge or whether it was used in the attack.

A number of samples were collected (scrapings, swabs and tapelifts) from bloodlike stains (visual and presumptive tests) on the didgeridoo and DNA profiles generated. A sample obtained from one end of the didgeridoo, which consisted of two blood-like spots, gave a mixed DNA profile that could be explained by a minimum of two contributors. Following a database search, the major component within the profile linked to Fitzgerald with an *LR* of 200 million; an unknown source contributed to the minor component. Fitzgerald's contribution to this DNA profile was the only evidence linking him to the offence. Contributors to other profiles obtained from the didgeridoo consisted of the victims (D and K), frequently as major contributors, and unknown source/s as the minor component, although some profiles were too complex for interpretation or contained insufficient material to obtain a profile.

Fitzgerald claimed that he was not involved in the attack and had no association with the house or its occupants. He maintained that his DNA came to be on the didgeridoo through secondary transfer via Sumner, where earlier in the evening (~8 h prior to the attack) he shook hands with Sumner at a boxing tournament, once as Sumner arrived and once as Sumner departed. Sumner, who arrived at the house ~40 min after the boxing match, did not dispute the acquaintance with Fitzgerald or the handshakes at the boxing match. During his ~5 h visit to the house, Sumner became involved in several altercations before leaving. Sumner's presence during the attack several hours later was supported by witnesses and DNA evidence, though his DNA was not detected on the didgeridoo.

Despite Fitzgerald claiming he had no involvement in the offence and that his DNA had been secondarily transferred to the didgeridoo during the offence (8 h post-handshake), Fitzgerald was convicted of murder (along with Sumner) based on DNA evidence alone. An appeal some years later saw Fitzgerald acquitted, as the possibility of secondary transfer during Sumner's first visit to the house could not be ruled out [32].

1.2. Objectives

Both source and activity level propositions are of interest in this case as they were both raised at trial. In this paper, we aim to address questions at activity level. Hence, with matching DNA profiles we explicitly assume that a sample contains DNA of the person of interest (POI). Based on the timeline of events and points raised in the case, it was hypothesised that secondary transfer of Fitzgerald's DNA via Sumner could have occurred on Sumner's first visit to the house (between 40 min–5 h after the handshake with Fitzgerald), or on Sumner's second visit to the house during the attack (8 h post-handshake).

We designed a series of Bayesian networks to deal with specific aspects of this case. During the identification of relevant parameters, it became evident that there was a lack of data relating to the persistence of transferred DNA on hands over time. As a result, we performed a number of handshaking experiments based on the time intervals presented in the case, and collected the data required to calculate the probabilities for use in the Bayesian networks. To provide a broader application to the data collected, an axe handle was used as a substitute for a didgeridoo. In addition, data collected from the timeframes observed by Szkuta et al. [17], namely, immediate deposition post-handshake and 15 min, were also incorporated to broaden the application of the Bayesian networks beyond this case. Furthermore, we explore the impact of changes to the various parameter values on the *LR* by performing sensitivity analyses. Based on these objectives, the structure of this paper follows the case investigation process, where, generally, one would first design a model, identify relevant parameters, and then collect the data needed to inform those.

2. Bayesian network construction

The Bayesian network in Fig. 1 (BN1) considers the core case circumstances outlined earlier and was built using Hugin Expert Software