Australian forensic textile damage examinations – Finding a way forward since PCAST

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ABSTRACT

Textile damage examinations are requested in a range of crime types such as assault, sexual assault and homicide. They typically involve the examination of clothing for damage such as cut, tear or thermal damage, often then followed by experimental scenario testing to help ascertain the cause of the damage. Understanding the underpinning science is central to the accurate interpretation of the complex mechanism of damage formation. In a stabbing incident for example, an understanding of the dynamic relationship between the knife blade, fabric and skin (or skin simulant) is critical.

Recent reports, including the President's Council of Advisors on Science and Technology (PCAST) report, have scrutinised forensic feature-based comparison techniques. Whilst textile damage was not a focus area, it can be considered a feature-based evidence class, and one which is currently largely reliant upon a practitioner's opinion, experience and professional judgement.

This paper will review the current state of textile damage examinations in Australia and survey research being conducted to address the issues raised in the context of the PCAST report. The central contribution of observational data to the evidence class of textile damage will also be explored, as well as some practical measures to counter the effects of cognitive bias.

1. A brief history

Court records exist in Australia indicating that textile evidence has been in existence since the last century, however it was not exploited to its full potential until the Chamberlain case in the early-1980's. An early example was the trial of R v Colin Campbell Ross, where in 1922 Ross was convicted for the murder of a young girl. The victim's torn clothing was recovered during the investigation however no formal examination of the clothing was conducted [1]. Ross was executed in 1922, however it was not until 2007 that the Governor of Victoria formally pardoned Ross after new evidence was presented showing that he was wrongfully convicted for this murder [2].

The Chamberlain case was the first formal record of textile damage examinations being conducted in Australia, where the interpretation of damage to an infant's clothing was critical to the conviction outcome [3]. More than 15 experts from a range of backgrounds gave evidence of the damage being created by scissors, by a knife or by canine teeth. Lindy Chamberlain claimed her baby daughter Azaria had been taken by a dingo, however Justice Morling found that "it cannot be concluded beyond reasonable doubt that the damage to the clothes was caused by scissors or a knife or that it was caused by the teeth of a canid' [3]. This high-profile case highlighted the lack of textile severance expertise within forensic laboratories at the time, as well as a deficiency in foundational research, with academic experts of the time offering robust opinions based on very limited trials.

A comprehensive body of research was conducted in the 1990's following the Chamberlain case, and in particular a research project sponsored by The National Institute of Forensic Science (NIFS) titled "Forensic Interpretation of Textile Severance Morphology". However, despite promising findings from the work conducted by Deborah Stuart and colleagues, unfortunately this work went largely unpublished [4]. Their research highlighted the importance of using a clear and systematic glossary of terms and definitions of the features to be assessed in textile severance morphology. It also demonstrated that damage varies in a complex way and understanding the influence of textile structure was paramount. Research was also conducted by the University of New South Wales which broadly looked at how fabric failed by observing the appearance of the damaged area. It included severance
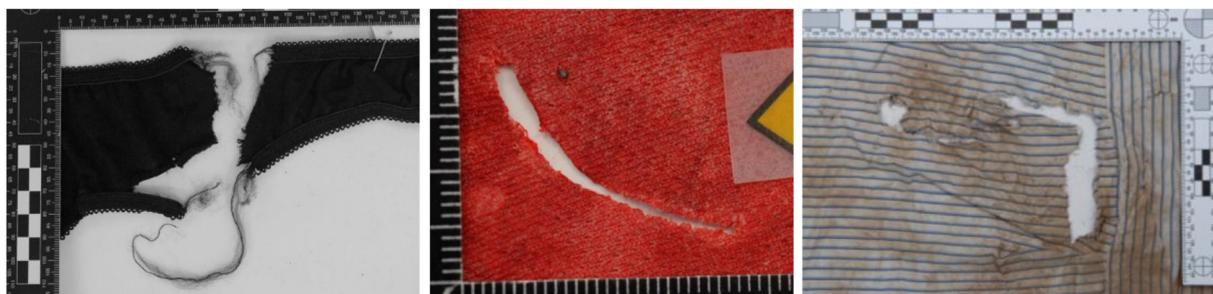
Fig. 1. Images depicting types of textile damage commonly encountered in forensic laboratories (tear, cut and abrasion damage).

morphology of stabbed fabrics [5], and also investigated the differences in fibre end morphology between ballistic impact and severances [6].

Requests for textile damage examinations have since risen significantly in forensic laboratories across Australia. In serious offences such as robbery, murder and attempted murder committed in Australia, knives are the most frequently used weapon [7]. Casework typically involves the examination of an item of clothing (or any textile) for damage such as cut, tear, heat and/or degradation damage (see Fig. 1). Examinations can however also include thermal damage from a bullet hole; puncture damage from a screwdriver; and abrasion damage on clothing from a hit and run victim. The most commonly encountered cases involve cut damage from bladed weapons such as knives, scissors, axes, and meat cleavers. Intelligence from the examination can often be provided in criminal investigations indicating a weapon likely to have caused the damage which can assist in locating a weapon during search warrants.

There has been a dedicated level of research into numerous facets of textile severance morphology, which will be further explored in this and future papers. The intention of much of this research has been to improve the standardisation and reliability of textile damage examinations and to attempt to address the issues raised recently regarding feature-based evidence types in the forensic sciences.

2. Standardised examination framework

Forensic practitioners follow a standardised and documented protocol, typically in accordance with a Quality System that has been accredited against a national or internationally recognised standard. Standardised and systematic recording of textile damage should be no different to any other evidence type and it is critical to ensure the examination framework is robust and reliable, from initial observations through to conclusions and including physical and microscopic examinations, simulation experiment assessments, and importantly the interpretation of the experimental results [8,9]. Australian Standard 5388 provides a guideline to cover processes from evidence recognition, recording and recovery, to analysis, interpretation and reporting.

Due to the diverse range of weapons and fabrics encountered it is difficult to develop a generalised description of the morphologies of stabbed fabrics [5]. Instead, a broad protocol based on relevant standards and principles that outlines the general process and considerations in an approach should be followed. This will include the process where observational data is recorded, how the interpretation of this data becomes a result, and how the significance of the findings is determined.

The mechanism which caused the textile damage of interest will mostly be unknown so there cannot be a procedure which will be fit-for-purpose for all cases. Comparisons are conducted on the basis that different actions and implements will impart damage to a textile in a characteristic and predictable manner, and that the damage will be created differently on textiles of different compositions and constructions.

Taupin (2010) stated that:

"*the examination of clothing will incorporate a number of different methods according to what evidence is found on the garment, but the initial procedure of examination should be the essentially the same.*"

Textile damage examinations are conducted as a step-wise process, where descriptions are first recorded, including observational data and measurements of the damage. An interpretation is then made of the qualitative and quantitative data, and an opinion formulated as to the significance of those findings. The importance of this step-wise approach was highlighted in the most comprehensive study conducted to date to evaluate the validity of damage examinations [10].

A preliminary examination of a garment or textile will include macroscopic features of the damage such as location, orientation, shape and type of damage. Next, the edge characteristics and the condition of the yarn and fibre ends will be examined microscopically. The advanced textile damage examiner will then interpret the damage observed [11–13], and provide an indication of:

- the mechanism by which the damage was created;
- the force that was used;
- the sequence that different areas of damage were created; and
- the type of implement which may have caused the damage.

If a weapon is submitted, it can be tested during manual simulation experiments to determine whether there are any significant differences between the evidential damage and the test damage. The forensic practitioner can access further information such as crime scene notes, witness statements, and medical reports, to design additional experiments which will help ascertain how the damage was created. Exposure to this information must be appropriately timed across the examination to avoid any biasing effects, which is discussed in more detail later in this paper.

For simulation experiments, the purpose of each experiment and the number and type of actions attempted should be clearly documented. Initially all testing should be conducted to *evaluate* the physical properties of the fabric and weapons. A range of questions can be explored in a stabbing simulation: Is that knife or weapon physically able to penetrate that fabric under controlled conditions? If so, are there any significant differences between the simulation damage and the evidential damage? Are they explainable differences? Further testing may then be required to *re-create* certain conditions, such as angled blade entry or a stab and drag action.

As previously discussed, examinations in Australia can be conducted with reference to the Australian Standard 5388; Part 3 of this Standard (Interpretation) lists qualifications, contemporary knowledge, training and experience as fundamental elements which contribute to the professional judgement of an examiners and their ability to evaluate and interpret forensic evidence [14]. The question can be asked though – what are *relevant* skills, qualifications and training required to conduct forensic textile damage examinations? Arguably one of the most important areas of foundational knowledge an examiner should have is in the field of textile science. There is no requirement that a qualified textile scientist conduct these examinations, however a targeted depth

of knowledge in the relevant topics is critical, so that the examiner can adopt and adapt the relevant principles of textile science to damage examination. This crucial knowledge can then be applied with knowledge of other factors that contribute to the formation of textile damage, including in the case of a stabbing, the type of fabric and substrate, the weapon, and the actions.

The examiner must have training to understand how textile properties will have an impact on the damage observed, as the critical components of a damage examination are the morphological features of the fabric, the yarns and the fibres. An understanding of how different features will present across different fabric constructions and compositions is paramount. For example, a torn elastane fibre will appear to have been cut as the tensile failure mechanism of such a fibre is a flat fracture plane [15] resulting a relatively flat fibre end. In contrast, a metallic polymeric feature fibre of a garment such as a scarf will have a very tapered and bearded end when torn. Other critical factors which contribute to the interpretation of damage are seam strength, the age of the fabric and the tension placed on it, as well as any principles of wear [11,12,16].

"*The morphological characteristics of damaged areas are usually better preserved and more definite in the edges of damaged non-wovens or woven fabrics than in those of knitted fabrics. The characteristics are mostly clearer in fabrics made from non-textured filament yarns than in fabrics made from textured or staple yarns*" [16].

Further,

"*the development of the morphological features in a damaged area is strongly influenced by the elasticity of the fabric, by the flexibility of the position of the yarns, by the construction of the yarns, and by the fibre material itself*" [16].

The requirement to use appropriate textile industry standards and reference materials has also been demonstrated. For example, industry research has shown that at least six laundering cycles are required to remove most manufacturing treatments and to improve the dimensional stability of the fabric [17–19]. Therefore if a new and unworn simulation garment is purchased then this regime should be adhered to using the relevant standards.

3. The impact of cognitive bias

Arguably one influence that textile damage examiners are susceptible to is bias, since interpretations and conclusions are typically largely based on the professional judgement and experience of the scientist. The role of human cognition in the forensic sciences has been recognised in the literature [20,21], and is increasingly being accepted by forensic laboratories. An awareness of the potential sources of bias and an understanding of how they can impact upon an examination will holistically give the examiner the knowledge and the ability to minimise the impact of cognitive bias. Dror in 2017 stated that '*with such an understanding we can develop and deploy different measures to combat biasing effects… [in order to] maximise the quality of forensic decision making.*'

The main sources of bias can be defined as originating from human nature, from the environment, culture and experience, or from case information [21]; practitioners will have an increasing ability across these groups respectively to counter the impact of the bias. Whilst certain elements of bias are inherent in human nature and are near impossible to alleviate, there are many steps that can be implemented to minimise the impact of other biases. Procedural changes can achieve much of the effect and by minimising exposure to task irrelevant information.

Confirmation bias can arise if the examiner is informed of the case circumstances, for example a night gown has been torn from a victim, then the examiner will subconsciously be looking for evidence to support that proposition. The examiner will tend to seek confirmation of the original theory or decision, and will naturally find difficulty in changing this original perception even if new facts are introduced.

However without knowledge of the case circumstances, the examiner will look for any type of damage on the garment, and will evaluate equally whether a yarn end has been cut or torn for example, without any preconceived idea about what *should* be found.

Similarly, expectation bias will arise where a person has performed a task with sufficient repetition to naturally expect a certain outcome. For example, in much of the casework encountered by the Australian Federal Police (AFP), there has been no evidence of compression damage where a victim has been assaulted by a baseball bat. The examiner will naturally not expect to find such damage in the next case received.

In an attempt to mitigate against cognitive bias, the AFP have implemented a step wise approach to the sequential unmasking of investigational information, where case information is removed from the initial examination request. The purpose of this preliminary examination is essentially to identify and document the type of damage present, and therefore in most circumstances minimal to no case information is required. If a case consultation is required at this initial stage, a triaging case officer can be utilised, whereby a second casework authorised practitioner can assist in triaging to facilitate withholding information from the primary examiner. It must be acknowledged that this is not always feasible in practice due to capacity and other constraints. There are also instances where this is not possible, for example if a preliminary examination is required at a scene and the garment is still being worn by a deceased victim.

Once the first stage of the examination is complete, a second request is submitted with information about the case context, including any witness statements or weapon seizures, to enable the appropriate simulation testing to be conducted. At this stage, case information is essential to the examination, and the role of the examiner is to determine the significance of the findings within the context of the case. This is essentially the sequence of events described in Part 3 of the Australian Standard 5388. This interpretation is particularly pertinent where there are two competing statements, or where certain case circumstances could account for differences observed in the evidential and simulation damage. Fig. 2 below illustrates one example where case circumstances critical to the interpretation were not communicated to the forensic examiner.

4. Is there a role for professional judgement?

The importance of forensic practitioners using sound scientific methodology has been discussed in the past, however more so than ever since the release of the widely known report '*Strengthening Forensic Science in the United States: A Path Forward*' [22]. Published by the US National Research Council in 2009 (and hereafter referred to as the NAS Report), this report cast a shadow across many forensic disciplines and was highly critical of the foundational science underpinning them. In addition, the recently released report by the President's Council of Advisors on Science and Technology (PCAST) [23] in 2016 has similarly undertaken a comprehensive review of feature-based comparative forensic methods. These reports have been fundamental in highlighting certain deficiencies in current practices, particularly for feature-based evidence types. Textile damage was not a focus area of either report, but can be considered a feature-based evidence class, and one which is by necessity largely reliant upon a practitioner's opinion, experience and professional judgement.

There have been differing opinions as to the relevance of the PCAST report to contemporary forensic practice in Australia [24–26]. To assess and improve the validity and reliability of textile damage interpretation, in our view it is important that periodic reviews are undertaken to ensure the provision of information to investigations and the judicial system is valid, relevant and reliable, including the issues raised in the NAS and PCAST reports.

The PCAST report highlighted the need to evaluate certain forensic methods to determine whether they have been scientifically established
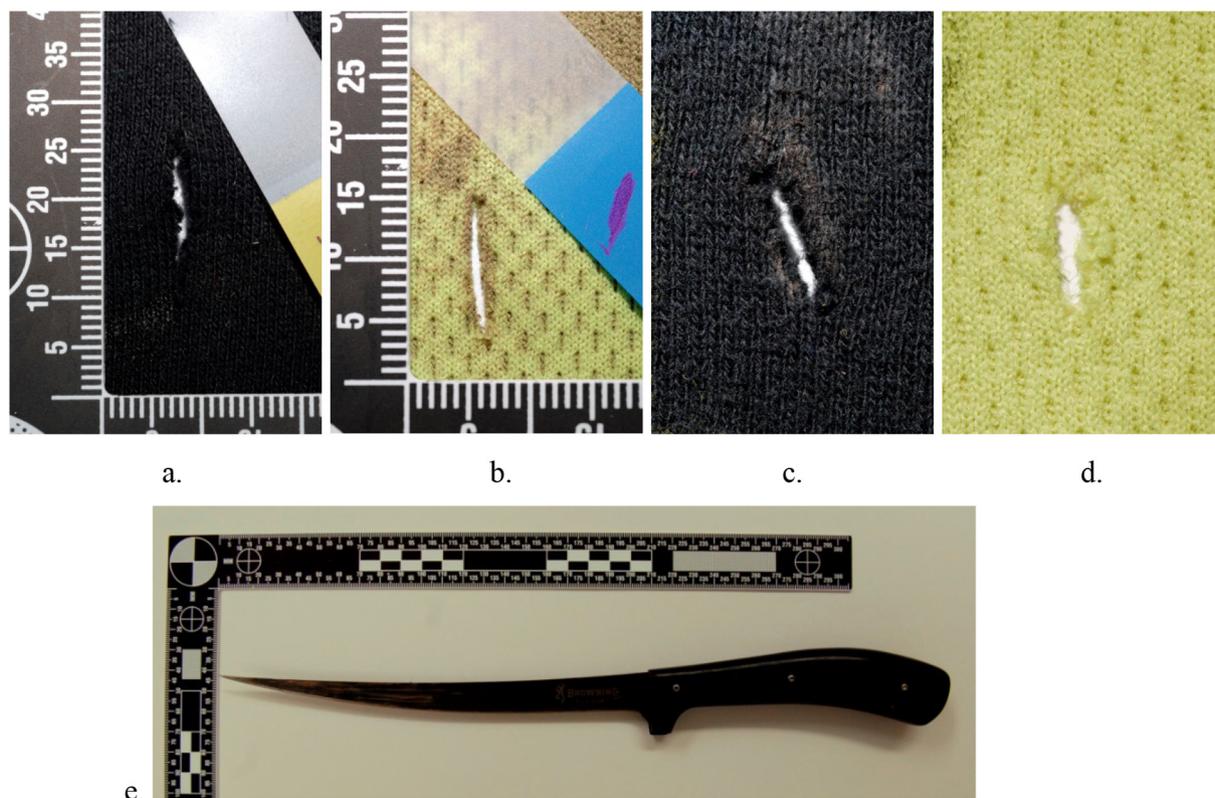
Fig. 2. Case Study 1 – A filleting knife (Fig. 2e) was submitted for simulation testing after a domestic, non-fatal stabbing. Damage analysis revealed stab-type cuts which extended through two upper garments (Fig. 2a and b). Simulation experiments were conducted where the knife was used in a stabbing action; simulation damage (Figs. 2c and d) was created that exhibited features that were not consistent with the evidentiary damage. On this basis, the examiner concluded that the knife could be excluded as having caused the evidential damage and a court statement was issued accordingly. The investigator queried the result and revealed that the knife was recovered from the ground, with the handle protruding from the surface. Upon further discussion, the forensic examiner was informed that witnesses had observed the suspect stabbing the knife into ground after the incident. Such an action could account for a change in the condition of the blade between the time of the alleged incident and when the knife was received in the laboratory, and account for the different textile damage features observed. A supplementary statement was then issued to provide an interpretation of the damage in the context of these case circumstances.

to be valid and reliable [23]. Specifically, its recommendations encouraged research and the development of objective methods in the forensic sciences. The PCAST report acknowledges two types of scientific validity, being *foundational validity* and *validity as applied* [23]. The report further describes (at p.5) that.

"*subjective methods require particularly careful scrutiny because their heavy reliance on human judgement means they are especially vulnerable to human error, inconsistency across examiners, and cognitive bias*".

A key question for textile damage as an evidence type is what is its underpinning and foundational science? We have argued that this foundation is in textile and fibre science. Hence, the *foundational validity* requirements need addressing in textile damage examinations, particularly relating to empirical testing. In order to comply with the *validity as applied* criteria, the PCAST report dictates that "*the forensic examiner must have been shown to be capable of reliably applying the method and must actually have done so*" (p.6 PCAST). Currently collaborative trials and proficiency testing are the key functions for determining the accuracy of the examiner. Further empirical testing is required for the examiner to properly understand the significance of their findings, and there are a lack of appropriate empirical studies to assess error rates. Work being undertaken in Australia to establish foundational validity and reliability of damage analysis is covered in more detail in the next section.

Among Australian casework authorised practitioners, there is agreement that to conduct a comprehensive examination, knowledge, training and experience are all essential. Experience and contemporary knowledge are independently recognised as being important foundations of an examiner in the Australian Standard 5388 Part 3 –

Interpretation [14]. Experience and professional judgement of the casework authorised examiner also plays a critical role in the discipline, which typically translates to the recording and interpretation of observational data. Exclusion of observational data from damage analysis would inhibit the examination from being conducted to completion, particularly in complex casework involving multiple garments, multiple weapons or where several types of damage are present, and therefore prevent the value of this evidence being utilised to its full potential. There is an inherent risk in relying only on data such as measurements of the damage or using a check box system noting the presence or absence of physical features, as this could result in false positives or false negatives. For example, if the same knife was used in a stabbing action on plain woven fabric (such as a business shirt) and on thick woollen jumper, the resultant stab cuts would have different dimensions. This is entirely a reflection of the physical properties of the fabric, rather than the knife, however an initial interpretation based only upon the length of the damage could suggest two different knives. A recent preliminary validation study was conducted where the performance of textile damage experts from one laboratory was evaluated in terms of their ability to classify damaged fabrics [10]. The complexity of the damage interpretation phase was highlighted in this work, and a well-considered classification system was therefore refined with step-wise approach to recording and interpreting the damage features.

Two case studies are presented below (Figs. 3–4) which demonstrate instances where the professional judgement of an examiner was critical to the case; they support the recently reported concept of the human examiner being the actual instrument of analysis [21]. In both cases, a knife or garment was changed by environmental exposure between

Fig. 3. Case Study 2 – Clothing was recovered in bush land that matched the description of a missing person. On first inspection, the clothing was described as having stab cuts (Fig. 3b). If using a damage classification system based on quantitative data alone, this damage would have been characterised as stab type damage due to the relative length and width of the damage, and appearance of yarn ends. In this case however, these features can also be explained by degraded condition of fabric due to environmental exposure and contact with limestone (calcium carbonate), where the fabric would essentially 'split' with manual handling.

creation of evidential damage and when received in laboratory for testing; here an understanding of which features of the damage could be attributed to the change in physical properties of the knife or textile (ie. *explainable* differences) was essential in contrast to which parts could not be accounted for (*unexplainable* differences).

Understanding the limitations of the damage examination process will ensure conclusions or findings are not overstated and that a particular weapon is not associated with a higher degree of certainty than what is justified. It is important to recognise that knives and other edged implements are mass manufactured items. Whilst there are preliminary findings to suggest that there is some variation among nominally identical knives, there is insufficient data to be relied upon at this stage [27]. Therefore, in most instances, on the basis of textile damage alone, a knife cannot be uniquely linked to, or identified to have been the cause of, evidential damage to the exclusion of all other weapons. Certain use or wear characteristics on a blade can however increase the likelihood of "matching" by imparting different characteristics on the

fabric. In judicial proceedings, however textile damage evidence is typically considered in conjunction with other disciplines such as fingerprints and DNA due to their ability to identify an individual, and it can therefore be considered associative evidence.

In certain cases, textile damage evidence has been pivotal to the case, particularly in the case of false allegations [28]. Figs. 5 and 6 below explain two case studies where the textile damage examination was the only evidence available to ascertain that allegations had been falsified, as there was no other strong evidence in the case. In both cases, the damage had the overall appearance of being consistent with the version of ev ents provided by the victim, however a careful examination of the damage revealed additional crucial details.

5. Textile damage examinations in an Australian context

The Textile Damage Working Group (TDWG) is comprised of practitioners from a number of forensic laboratories across Australia and

Fig. 4. Case Study 3 – A victim sustained over 60 stab wounds in a homicide where the damage analysis and pathologist report both indicated the use of two different sized knives. A warrant was conducted more than six months after the incident where two knives were recovered from a rural pond. The knives were missing their original handle scales. There was also evidence recovered from the same property that suggested the knives and other items were burned in a fire. The recovered knives were tested in simulation experiments, along with two replicate knives purchased new; Fig. 4a shows the pair of smaller knives. Differences were observed in physical features of the damage created by the recovered knives (Fig. 4b) and the new knives (Fig. 4c) including more distortion with slightly ruptured yarn ends. As these differences could be attributed to the knives being burnt and submerged, the knives could not be excluded as having caused the evidential damage.

Fig. 5. Case Study 4 – A night gown was received in a case whereby an elderly lady was allegedly assaulted, and her night gown torn off. Microscopic examination revealed the severance line in fact started with a cut at the neckline seam, and the tear was propagated from that point. Simulation testing further confirmed that it was virtually impossible to initiate the tear from the seam.

New Zealand, and has been instrumental in driving national initiatives to enhance the evidence class [29]. Together the group has implemented several initiatives to improve the foundational science underpinning the discipline and continues to work on developing further changes to holistically increase the level of standardisation in textile damage case work.

An early body of work undertaken was to establish the different levels of examination required in textile damage case work. The delineation of Level 1, Level 2 and Level 3 examiners was critical to establishing minimum training requirements for the discipline. A Level 1 examiner can undertake a preliminary examination where the type of damage is recorded, such as a cut or a tear. The more advanced Level 2 examiner can perform routine casework interpretations and simulation testing, as well as for complex damage cases such as those involving multiple garments or multiple weapons. A Level 3 examiner would be considered an industry expert in their relevant field and required only where a particularly challenging case may require additional expertise.

With the minimum training requirements defined for each level of authorisation, a national training package is being developed to ensure that each authorised member has the required knowledge of the science and standards underpinning the discipline. Included in the training package will be topics such as textile technology, skin simulants, weapon manufacture and blade characteristics, biomechanics and cognitive bias.

The group is also undertaking a review of current protocols to ensure uniform standards in methodology across laboratories associated with the TDWG. Initial work saw the creation of a glossary which enabled cross-jurisdictional technical reviews to be completed, and correspondingly an agreed classification scheme for damage. Guidelines for recording descriptions that are considered most subjective will also be broadly defined to assist the examiner, for example the description of the sharpness of a blade. This will directly inform work currently being completed to develop a standardised reporting framework to increase the consistency and reproducibility of the examinations. The two-step process described earlier in this paper not only minimises exposure to task irrelevant information, it also includes a step to ensure the examiner documents the features of the damage in writing before making a comparison to simulation damage. Further, it will enable inter-laboratory reviews to be undertaken, which will minimise the impact of bias as the technical reviewer will not have exposure to task irrelevant information. This approach will also progress the need to improve the documentation of which features, or combination of features, supports a reliable conclusion, as this is a gap in current protocols.

In its review of impression evidence such as shoes and tyres, the NAS report (at p. 150) summarised the importance of establishing *"the persistence of individual characteristics, the rarity of certain characteristic*

Fig. 6. Case Study 5 – A case was received where a female reported that she was sexually assaulted by a male colleague. Her jeggings were submitted and showed scissor cuts across the legs which were consistent with her version of events describing how the pants were removed. Further investigation revealed that part of the cut damage could only be created if the pants were not being worn, as the damage to both layers of leg fabric perfectly aligned. When confronted with evidence, the victim revealed that she falsified with damage to make her story more believable.

types, and the appropriate statistical standards to apply to the significance of individual characteristics". Correspondingly, a future paper will soon be available that addresses these issues with respect to the evaluation of physical blade characteristics and the impact they have on the creation of stab cuts to textiles.

Simulation experiments are currently performed manually which enables the evaluation of a diverse range of circumstances and conditions, providing an invaluable avenue of testing. There are however limited opportunities to incorporate standardisation into the experimental protocol, and there is potential for variation from each practitioner to be imparted on the process. In the instance of a stabbing assessment, experimental parameters such as the velocity of the action, and/or the force of impact are not strictly controlled during manual testing. Certain factors can also influence the way a person performs a stabbing action with a knife, including the shape of the handle [30], and the gender, weight and training or experience of the person [31–33]. To alleviate a number of these factors and to increase the level of standardisation in simulation testing, a custom-built stabbing machine was co-developed by the AFP and the University of Technology, Sydney (UTS) [34]. The use of an instrumented device to evaluate stabbing penetration events is well recorded [27,31,35–38], however this is the first such device to be implemented into operational protocols. Instrumented stabbing provides the examiner with a more reproducible and robust examination scheme by minimising the variation between experiments. This will be achieved by moving the simulation testing framework towards using controlled experimental parameters such as the angle and orientation of the blade, the depth of penetration and importantly the velocity or force of impact.

The reproducibility of the stabbing actions is a critical element which will improve the reliability of simulation testing, and which was further identified in the NAS report (at p.8):

"*A body of research is required to establish the limits and measures of performance and to address the impact of variability and potential bias. Such research is sorely needed, but it seems to be lacking in most of the forensic disciplines that rely on subjective assessments of matching characteristics.*".

Whist research is being undertaken to evaluate the reproducibility of human stabbing performance, it is envisaged that a combined implementation of instrumented and manual testing of weapons will provide a robust and reliable examination scheme. Here, the preliminary evaluative testing will be conducted under standardised conditions, and any additional manual testing can then be performed and tailored dependent on individual case circumstances.

A textile damage proficiency test was only first available from an externally accredited company in 2014. The TDWG therefore also facilitated the creation and distribution of collaborative trials, which along with internal proficiency tests, are essential for quality assurance conformance. Proficiency testing and ground truth testing were addressed in the PCAST report: "*Casework is not scientifically valid research, and experience alone cannot establish scientific validity. In particular, one cannot reliably estimate error rates from casework because one typically does not have independent knowledge of the 'ground truth' or 'right answer.'*" (p. 32–33)

One working group member has initiated the collation of targeted damage case studies from laboratories associated with the TDWG. The cases selected will have a reasonable certainty of how the damage was created, will be redacted and de-identified, and distributed to other laboratories for a damage assessment. The exact circumstances of a case will rarely be known, however, in many cases there is sufficient supporting evidence to believe with reasonable certainty that damage was created in a certain way. For example, a knife that can be linked to a garment through other evidence such as fibres and DNA, or where reliable witness testimony has indicated the mechanism in which damage was created. This compilation will facilitate a best-effort program for ground truth testing not ever used before by these laboratories. It will also be able to determine whether examiners from different laboratories are reproducibly reaching the same conclusion from a case.

6. Conclusions

Textile damage is a judgement-based examination, where the professional judgement of the forensic practitioner is crucial. It is acknowledged that gaps exist in the discipline, which continue to be addressed through systematic reviews. To see these examinations be excluded from current forensic practice on the basis of these issues would be a detriment to criminal investigations and to judicial enquiries, as the discipline has a strong and proven ability to answer the "how" questions in addition to the "what" questions. Textile damage examinations also have a unique potential to be able to unequivocally confirm or refute witness statements, which has been proven through numerous investigations in the past.

The authors and the Textile Damage Working Group (comprised of examiners from both Australian and New Zealand laboratories) recognise the need for in depth empirical studies to assess foundational validity, to estimate reliability and to demonstrate reproducibly of damage analysis. Current research being conducted by the authors, as well as initiatives of the TDWG acknowledge these issues and positive progress has already been made in order to address them. Work has been undertaken in Australia and New Zealand to formalise a national training structure and program, and to create a standardised reporting framework. Critical factors which lead to the final judgement or conclusion are now systematically recorded, and the terminology and references utilised have been standardised.

There are many factors that contribute to the formation of textile damage, including in the case of a stabbing, the type of fabric and tension placed on it, the substrate utilised, the knife blade profile, not to mention parameters such as velocity and angle of impact. It is paramount that the examiner understands this complex interaction as well as a comprehensive but targeted knowledge of textile science. A commitment from laboratory managers to provide or support opportunities for training and continuous professional development in these areas is critical to ensure there is a thorough awareness of the scientific principles underpinning the evidence class.

Forensic laboratories that conduct damage examinations should consider the implementation of procedural changes to ensure the examination framework is robust and reliable. Forensic practitioners should have an awareness of the types of cognitive bias and the impact they can have on their work. Laboratories and their personnel should where possible minimise the impact of certain cognitive biases, such as sequential unmasking, whereby task relevant information is only made available when required at particular stages across the course of an examination.

The NAS Report concluded that "*the most important part of our committee's report is its call for real science to support the forensic disciplines*" (p.7). Broader stakeholder engagement and ongoing collaborations have resulted in a more comprehensive approach to research in the discipline of textile damage. Future papers will each address certain aspects of foundational validity and reliability raised in the PCAST report. These will include a study of knife blade profiles which will provide an indication of the frequency of encountering certain damage characteristics, as well as standardising operational protocols by utilising a stabbing machine in casework examinations. As current practitioners and academic partners alike, we have a responsibility to ensure research and work to address the underpinning validity of textile damage examinations continues and to ensure improved approaches to textile damage examinations are properly applied.

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