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EEG Lie Detection Evidence and Potential Australian Jurors

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Abstract

Electroencephalogram (EEG) lie detection is a proposed method of determining criminal culpability, though it is currently unknown how this method will impact juror decisions. The present study investigated the persuasiveness of EEG lie detection with potential Australian jurors. Through a vignette-based experiment, participants ($N=421$) were required to make juror-based decisions (i.e. guilty, not guilty and unsure) on a 1989 U.S. trial involving the brutal murder of a young woman. Participants read about forensic evidence (blood, shoeprint and fibre analysis) presented at the 1989 trial that led to the suspect's conviction. Half of the participants also read about an EEG lie detection test conducted 11 years post-conviction that indicated the convicted man was innocent. Chi-square analysis showed the EEG information significantly affected determinations of guilt. Guilty verdicts were made by 41% of participants who did not read the EEG evidence. However, only 27% of participants who read the EEG evidence voted guilty. The implications of implementing EEG lie detection are discussed.

Keywords Lie detection · Electroencephalogram (EEG) · Brain fingerprinting · Jury decisions

The jury system in Australia, and many other countries, is founded on the notion that community members can evaluate and determine culpability in a manner representative of the broader population (Fricke 1997; Goodman-Delahunty et al. 2007; Kapardis 2003). Two underlying assumptions of a jury trial are that the trial process enables truth revelations and that everyday people can separate fact from fiction (Fisher 1997; Schauer 2010a, b). Unfortunately, as evidenced by wrongful convictions, trial processes are fallible, and jurors cannot always distinguish truth from untruth. Arguably, the worst possible trial outcome is a wrongful conviction, as an innocent person is punished for a crime they did not commit, and the guilty party is free to commit further crimes (Huff and Killias 2013; Wessells 2021). The U.S. National Registry of Exonerations (NRE) records exonerations, and since 1989, 3337 wrongly convicted people have been released from jail. Cumulatively, these people served over 29,500 years in prison for crimes they did not commit. In the USA, fallacious conviction rates vary from 0.5% (Diosa-Villa, 2015; Huff and Killias 2013) to 5% (Diosa-Villa et al. 2016). Whilst the prevalence of wrongful convictions in Australia is unclear, Australian rates are thought to be like the USA (Diosa-Villa 2015).

Decisions made in courtrooms can be life-altering and, in some countries, life-ending; thus, causes of incorrect convictions deserve attention (Denault et al. 2020; Gould 2007). Factors contributing to wrongful convictions are mistaken eyewitnesses (Gould 2007; Innocence Project 2021a, b; NRE 2021), police misconduct (Christianson 2004; Innocence Project 2021a, b; NRE 2021), informants lacking credibility (i.e. incarcerated criminals trading information for early release) (Innocence Project 2021a, b; Norris 2017; NRE 2021), false confessions (Gudjonsson 2003/ 2013; Kassin 2013; Innocence Project 2021a, b; NRE, 2021; Woody and Forrest 2020), law enforcers' use of erroneous lie detection methods (Denault et al. 2020) and fallible forensic science techniques (Garrett and Neufeld 2009; Innocence Project 2021a, b; President's Council of Advisors on Science and Technology (PCAST), 2016; NRE 2021). Fallible forensic science methods have contributed from 24% (NRE 2021) to 52% (Innocence Project 2021a, b) of wrongful convictions in the USA. Fallible forensic

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science is also implicated in wrongful convictions in the UK (Cordner and Woodford 2020; Field and Thomas 1994; Hoyle 2019) and Australia (Dioso-Villa et al. 2016). Despite past mistakes, forensic evidence is increasingly used in criminal trials (Garrett et al. 2021), leading to a body of research regarding how jurors weigh forensic science findings.

Forensic Science and Jury Decisions

Forensic science is defined "as the application of scientific or technical practices to the recognition, collection, analysis, and interpretation of evidence for criminal and civil law or regulatory issues" (PCAST 2016, p. 21). The scope of forensic science methods is broad (Smith et al. 2011), ranging from microscopic (e.g. textile fibre or hair sample) to large-scale (e.g. crime scene) analysis (Gallop and Stockdale 2004; PCAST 2016).

When forensic science evidence is presented at a trial, factors affecting jury decisions can involve the type of forensic evidence, how it is presented and impressions of the person giving the evidence, often termed 'the expert witness' (Howes 2014; Koehler et al. 2016; McCarthy Wilcox and NicDaeid 2018). Forensic expert testimony affected mock juror decisions in many studies (Koehler et al. 2016), whether this be laypeople eligible for jury service or actual jury members. For example, McCarthy Wilcox and NicDaeid (2018) questioned jurors from nine U.S. murder trials where forensic evidence had been utilised. Using a mixed survey method ($n = 29$) and interviews ($n = 22$), the researchers found that a range of factors influenced the expert's perceived credibility. The study found that jurors placed weight on the expert's educational attainment, personal presentation and confidence (McCarthy et al., 2018), indicating that the deliverer of the information, perhaps not the information itself, affects juror decisions.

Jury decisions have been shown to be influenced by how forensic science information is communicated (Howes 2014) and whether opposing expert testimony is presented (Eastwood and Caldwell 2015; Goodman-Delahunty and Wakabayashi 2012; Scobie et al. 2019). Additionally, the weight afforded to different forensic science methods varies, with DNA evidence being the most persuasive (Clancy and Bull 2015; Curley et al. 2020; Daftary-Kapur et al. 2010; Ritchie 2015). Studies also highlight the effect of providing information regarding the reliability or robustness of the evidence. For example, research with 541 American participants compared DNA and shoeprint evidence and differing strengths of the evidence explanations (Thompson and Newman 2015). Participants read a vignette describing a rape case and then read details regarding DNA or shoeprint forensic evidence against the accused. Participants were presented with weak forensic evidence and asked to provide their verdict and strength of belief in the suspect's guilt. Participants were then asked whether their opinions would alter if the evidence were strong and provided with information outlining more robust forensic evidence. The researchers found accuracy evaluations mattered, with only 3.6% of participants voting guilty in all conditions when the evidence's strength was low (i.e. inconclusive results). However, the type of forensic evidence also mattered, with participants significantly more likely to convict based on DNA evidence than shoeprint evidence (Thompson and Newman 2015). Studies comparing DNA evidence to other types of evidence, including eyewitness testimony, found DNA often 'trumps' other evidence (Daftary-Kapur et al. 2010; Maeder et al. 2017; Pozzulo et al. 2009). Daftary-Kapur et al. (2010, p. 142) stated, "a study of 200 sexual assault cases in Australia revealed that jurors were 33 times more likely to convict when DNA evidence was presented than similar cases in which no DNA evidence was introduced".

DNA evidence may be the most highly weighted forensic science method because, as noted by the report of PCAST (2016), it is the most well-supported forensic method. Crozier et al. (2020) showed the importance of forensic evidence efficacy information in a study with 1398 demographically representative U.S. participants. Participants were randomly allocated to one of eight groups. The participants read a crime vignette that included forensic bitemark or fingerprint evidence implicating the suspect, and different groups read different proficiency rates for the forensic method used. Participants informed about errors with the technique (i.e. low proficiency rate with blind testing) were significantly less likely to convict than participants told the method has high proficiency or those not informed of the proficiency rate. Consistent with the findings by Thompson and Newman (2015), the results suggest that informing people of error rates has the potential to affect juror decisions. However, unlike the study of Thompson and Newman (2015), Crozier and colleagues (2020) found that people have the tendency to assume that forensic methods presented in court are efficacious unless advised otherwise. As this study did not involve DNA evidence, it is possible that the findings may have been more pronounced had this been a variable.

Findings across research suggest that credible experts presenting scientifically robust forensic evidence affect juror decisions (Daftary-Kapur et al. 2010; McCarthy Wilcox and NicDaeid 2018; Thompson and Newman 2015). However, according to the report of PCAST (2016), most forensic science techniques lack empirical support, including some forms of DNA testing. Informing jurors about error rates and/or the fallibility of forensic techniques may mitigate incorrect incarcerations stemming from faulty forensic science. Another way of mitigating erroneous convictions is for courts to reject forensic evidence unless it is efficacious.

Whilst many current forensic methods are fallible, over the past two decades, there has been an expansion of neuroscientific research to understanding and explaining criminal behaviour (Freedman and Woods 2018; Jones et al. 2013), leading to a new field termed neurolaw (Gkotsi et al. 2015). Across these neuroscientific techniques, various examinations have taken place, including investigations into a perpetrator's mental capacity (e.g. neurobiological maturity of juveniles; Steinberg 2013), witness memories (Jones et al. 2013), victim's pain level (Reardon 2015) and the honesty of statements (Jones et al. 2013; McCabe et al. 2011). However, like many other forensic methods, independent efficacy studies with neuroscience methods are lacking. Concerningly, there has been a lack of regulation around forensic science, with methods and techniques often privatised, lax practices relating to conflicts of interest and research outcomes financially incentivised (PCAST, 2016). Although these issues have not been directly examined in relation to neuroscience, many forensic science methods have been identified as lacking validity when independently examined and tested (PCAST 2016).

In Australia, the law allows experts to provide evidence in cases whereby jurors are not expected to have sufficient knowledge in the area to form educated opinions (Roberts 2020). However, there is a risk that jurors may not understand a topic and be easily influenced by the statement and conclusions of jurors (Roberts 2020). Consequently, established scientific standards of forensic evidence are essential. Unfortunately, there have been several cases where forensic science evidence has been presented at trials, despite unknown error rates and a lack of supportive peer-reviewed research (Cordner et al. 2020). For example, bite mark analyses have been tendered as evidence in U.S. trials, yet bitemark analysis lacks scientific support (Cordner et al. 2020; PCAST, 2016). Edmond (2014, p. 136) observed that "Criminal courts routinely admit weak, speculative and unreliable expert evidence because lawyers and judges do not direct sustained attention to the reliability of forensic science and medicine evidence when considering admissibility". Although still a developing discipline, U.S. courts are increasingly presented with neuroscientific evidence (Aono et al. 2019), and the efficacy of Daubert (i.e. scientific standards required for court acceptance) has been questioned (Young and Goodman-Delahunty 2021). Due to this, it is prudent that forensic neuroscience methods are shown efficacious and error rates are established before court acceptance in Australia.

There is a long and controversial history of attempts to have lie detection approaches validated and supported in court. Whilst some aspects, such as the polygraph, have been considered admissible in the USA (National Research Council 2003), in Australia and other jurisdictions, these methods or approaches have failed to meet the legal standards for admissibility (Freckelton 2004). Recently, a body of research and interest has emerged on the use of brain imaging to identify and detect the lies told by offenders or those subject to a criminal investigation or court hearing (Afzali et al. 2022; Farwell and Richardson 2023; Wilcoxson et al. 2020). The use of this technology and process to examine lies has emerged over the last few decades, yet these approaches are claimed to lack the reliability and validity to be considered established forensic science (Meijer et al. 2016). One of the primary techniques that have been prominently publicised and promoted as having high accuracy rates in detecting lies is a methodology termed brain fingerprinting (Farwell 2012).

Brain Fingerprinting

Although brain fingerprinting is a relatively new forensic science method, the underlying technology is based on the P300 event-related potential phenomenon that has been studied for almost 60 years. An electroencephalograph (EEG) records brainwaves (Sur and Sinha 2009), and Sutton et al. (1965) discovered that a specific waveform termed the P300 appears shortly after (approximately 300-ms) perception of unexpected stimuli. Subsequent research suggests that this waveform reflects cognitive activity related to working memory and attentional processes (Rosenfeld 2020). P300s are created when people are shown, in rare format (Rosenfeld 2020), task relevant (Polich 2007) or personally meaningful information (e.g. one's birthdate) (Abootalebi et al. 2006; Rosenfeld et al. 2013, 2018).

The U.S. Central Intelligence Agency (CIA) funded over a million dollars for brain fingerprinting's inventor, Dr Farwell, to undertake brain fingerprinting research in the 1990s (United States General Accounting Office 2001). In completing this research, Farwell developed 'The brain fingerprinting method', utilising the Guilty Knowledge Test (GKT), or what is also known as the Concealed Information Test (CIT). This involves presenting suspects with information (in the form of word/s or pictures) relevant to a crime (e.g. murder weapon), some of which is probable but inaccurate, interspersed with information pertinent to the crime but known only to one who was present (i.e. facts not released to the public) (Farwell 2012).

According to Farewell (2012), brain fingerprinting involves three types of informational stimuli: probes, targets and irrelevants. Probes are crime-relevant information (e.g. specific gun used in a shooting crime) known only by one present. Targets are publicly known information, such as the place of the crime. Irrelevants are probable but incorrect specifics regarding the crime (e.g. different types of guns). The suspect wears an electroencephalogram (EEG) headband, and stimuli are presented on a computer screen. The suspect is told that the target information is relevant to the crime and asked to respond to this stimulus differently from other stimuli. For example, the response might be a mouse right-click after presentation of target stimuli but left-click for other stimuli. The suspect responds to multiple presentations, and brain wave responses to the different stimuli are averaged and compared. The target stimuli, which are relevant to the task and require a specific response, create a P300. The probe is also relevant for those who know the crime details, and a P300 is also produced. If P300s are recorded for probes and targets but not irrelevants, it is assumed that the suspect knows pertinent crime information. When neurological recordings for probes approximate irrelevant stimuli, it is determined that the suspect lacks knowledge of the relevant details, and indeterminate findings are also possible (Farwell 2012).

According to Farwell (2012), the methodology boasts an almost 100% accuracy rate at detecting memories of a crime whilst being resistant to countermeasures that a subject may engage in to 'cheat' the test. As Farwell stated,

The fundamental difference between an innocent person and a guilty person is that a guilty person has committed the crime, so the record is stored in his brain. Now we have a way to measure that scientifically. Brain fingerprinting is a scientific technique for determining whether certain information is stored in the brain or not by measuring brain waves, electrical brain activity (Gallagher, 2000, 0:35).

Guilt and deception are inferred from the brain fingerprinting results. For instance, if the suspect denies knowledge of crime details yet recognises salient information, they are likely lying about non-involvement. Alternately, if one does not recognise pertinent facts, it is assumed they were not present at the crime and, therefore, innocent. Brain fingerprinting differs in method from some other P300 GKT or CIT and includes additional analysis termed "a memory and encoding related multifaceted electroencephalographic response (MERMER)" (Farwell et al., 2012, p. 266). Farwell and colleagues claim brain fingerprinting is countermeasure (i.e. methods used to cheat the test) resistant and almost 100% accurate (Farwell 2012; Farwell and Richardson 2013; Farwell et al. 2013). Researcher's opinions on the utility of P300 CIT and brain fingerprinting for criminal investigations are strongly divided (Allen and Mertens 2009; Bergström et al. 2013; Farwell 2011, 2012; Farwell and Richardson 2013; Farwell et al. 2013, 2014; Littlefield 2009; Meixner et al. 2013; Mertens and Allen 2008; Rosenfeld et al. 2013; Sasaki et al. 2001; Wang et al. 2013; Wolpe et al. 2005). Some researchers have criticised many of the claims (Danaher 2015; Meixner 2018), particularly that of almost 100% accuracy with the method (Meijer et al. 2013). Some studies have also shown the use of countermeasures affected accurate P300 results (Bergström et al. 2013; Bowman et al. 2014; Derksen 2012; Math 2011). In response, Rosenfeld (2020) developed a more robust approach, factoring in the range of possible countermeasures that could influence results. The authors termed this method the Complex Trial Protocol. Thus, two P300 CIT methods claim to be countermeasure resistant.

In a review of P300 CIT research, Rosenfeld (2020) highlights caveats, such as a lack of ecologically valid studies and important considerations, such as an appreciation of the limitations of human memory. Understanding how memory functions are essential in forensic situations (Brainerd and Reyna 2019; Howe and Conway 2013; Schacter and Loftus 2013), particularly when brain fingerprinting assumes that a perpetrator will remember specific details. However, Rosenfeld (2020) suggested that P300 CIT research be expanded (e.g. real-world experiments) as this forensic method is valid and valuable.

Interestingly, Farwell has performed mock crime and real-world studies. In a study of Farwell and colleagues (2013), three separate lab-based studies which involved mock crimes with a total of 73 participants were conducted. They also present ten real-life studies, including minor crimes and occupation-specific knowledge for FBI, CIA and U.S. Navy personnel and criminal suspects. Some brain fingerprinting research has high ecological validity as Farwell et al. (2013) tested suspects of crimes, and these people were told that if they passed, it could be used as supporting evidence for them in court. Furthermore, in research where the stakes were not high, Farwell (2012) offered $100,000.00 to anyone who could beat the test to simulate a high-stake scenario. Further still, he taught the participants' countermeasures have been successfully applied in other P300 researches. In a review of brain fingerprinting studies, Farwell (2012, p. 149) stated, "In over 200 test cases by Farwell and colleagues, brain fingerprinting resulted in no false positives and no false negatives. Accuracy rate for determinations made was 100%; error rate was 0%". Therefore, brain fingerprinting seems a promising forensic method that may be more efficacious than many current forensic science techniques.

Historically, brain fingerprinting research was limited to its inventor and colleagues, and the MERMER analysis method is patented. However, in 2016, researchers in New Zealand, in collaboration with Farwell and N.Z. law enforcement, commenced studying brain fingerprinting (Palmer 2017). Afzali et al. (2022) conducted two brain fingerprinting studies: one tested for real-world incidents with female and male university students ($n = 28$, mean age 21.3) and the other for crime-relevant information with male parolees (excessive eye blinking led to study withdrawal for three parolees, with a final $n = 12$, mean age 47.5). The results of study 1 (university students) showed correct classifications for 27 participants and an incorrect classification (false positive) for one participant. Study 2 (parolees) resulted in eight correct classifications, one incorrect (false positive) and three indeterminate. The false positive participant was retested, resulting in the same inaccurate result. Afzali et al. (2022) showed that whilst brain fingerprinting may be a promising technique, it does not demonstrate 100% accuracy. This research highlights the importance of independent research and ecologically valid studies as the results from study 2 (likely recipients of the technology being criminals) are markedly different from study 1 (university students).

To date, most brain fingerprinting studies have been conducted by the developers, and there remains a lack of general acceptance within the scientific community. The development of scientific standards and acceptance of these methods within the forensic science community is a necessity for court acceptance in Australia and New Zealand (Dickson and McMahon 2005). According to Afzali et al. (2022), brain fingerprinting is a valuable forensic technique and may assist in the detection of deception if the present limitations and issues are able to be addressed. Independent testing of Rosenfeld's CTP method indicates this technique may also prove beneficial (Funicelli et al. 2021). Brain fingerprinting could potentially be a valuable criminal investigative tool in Australia (Williams 2016), and discussions about the applicability of P300 CIT for police investigations and the likelihood of court acceptance have occurred in other countries (Meixner 2018; Murphy and Rissman 2020).

Outside of Australia and New Zealand, attempts have been made to introduce brain fingerprinting evidence into courts. This has occurred in the USA (Farwell and Makeig 2005; Slaughter v State, 2005), whilst Japanese courts have admitted CIT evidence (Osugi 2011). However, there seems to be no research on the impact of brain fingerprinting evidence on potential jurors. An EBSCO host, PsycINFO, ProQuest, Scopus and Google Scholar search using the keywords P300, and concealed information test or guilty knowledge test and jury or jury decisions, revealed only one published study that included jury decisions and P300 CIT.

In this identified study, West et al. (2014) investigated the influence of P300 CIT evidence on juror decisions. Three hundred and ninety-nine racially diverse participants (244 identified as female and 143 males, mean age of 19.8) participated in a study regarding the influence of expert evidence, along with different types of evidence (behavioural versus neuroscientific), and the presentation of brain images (including P300 ERP), with mock jurors (West et al. 2014). Participants rated neuroscientific evidence more credible than behavioural evidence. However, the findings showed that behavioural and neuroscientific expert testimony significantly influenced guilt judgements (West et al. 2014). Interestingly, brain images did not significantly impact determinations, suggesting that the ERP P300 evidence may only be influential if an expert witness delivers it. However, although the neuroscience evidence was convincing, the impact of this on mock jurors was not statistically different.

A study assessing the effect of brain imaging lie detection findings from functional magnetic resonance imaging (fMRI) with potential jurors ($N=330$) showed that fMRI lie detection was more persuasive than the polygraph (McCabe et al. 2011). However, a dearth of research focuses on brain fingerprinting evidence's effects on jury decisions. Moreover, studies have not compared brain fingerprinting with other forensic evidence. Brain fingerprinting has been proposed for use in New Zealand and Australia, although it has not yet been utilised in court. The weight afforded to forensic evidence by jurors can be substantive (Garrett et al. 2021) and can determine the verdict (Koehler et al. 2016). Therefore, given questions about the reliability and validity of brain fingerprinting evidence, it is essential to understand how much jurors are influenced by this form of forensic evidence.

The current study assessed the influence of brain fingerprinting evidence on potential Australian jurors. The information for this study was sourced from court reports about a real U.S. murder case in 1989 (State v Harris). This case included blood, fibre and shoeprint forensic evidence, with the initial hearing resulting in the suspect being convicted of murder (https://law.justia.com). A decade after the conviction, the defence attorney, believing his client was innocent, organised a brain fingerprinting test, and according to the results, he was innocent (McKay 2002). The defence attempted to have this information presented at an appeal hearing; however, subsequent DNA tests (not available at the time of the trial) showed that the original ruling was correct, and that the right suspect had been convicted.

For the present study, this case was utilised due to the brain fingerprinting evidence contradicting the more established forensic methods submitted as evidence in the trial (blood, fibre and shoeprint evidence). This study's findings may reveal how potential jurors weigh neuroscientific evidence against more established forensic techniques other than DNA. This study assessed participants' perceptions of guilt with details from the initial trial and further information relating to the brain fingerprinting test.

Method

Participants

Participants were recruited via the Facebook pages of all CQUniversity campuses across Australia, and flyers were placed at one campus. After the survey was active for approximately 3 months, an online commercial panel provider was utilised to recruit an extra 270 participants. The total number of participants who completed the survey was 421; 55.1% identified as female, 44% as male and 0% as non-binary; 1% preferred not to say, and 3.9% did not respond to this question. The age ranges were 18–24 (12.4%), 25–44 (38.7%), 45–64 (32.8%) and 65 and over (16.2%), and 25.4% of participants were students. Participants were required to be 18 or older, and commercial panel participants' I.P. addresses must be from Australia. The CQUniversity Australia Human Research Ethics Committee approved this study.

Materials

This study was a Qualtrics online survey. Participants read a vignette that included details from court reports (https://law.justia.com) about a 1989 U.S. murder trial (State v Harris) (the names were either changed or omitted) (Appendix 1). The experimental condition contained the same vignette plus additional information from a CBS News report about a brain fingerprinting test conducted on the man convicted of the crime (McKay 2002). The probes used for the brain fingerprinting test were the initial attack location of the victim, the process of dragging her body through the underbrush and across the sand to the riverbank, and where her body was found (Appendix 2).

Procedure

The Qualtrics online survey commenced with demographic questions (age range, gender and student status). Participants were then randomly assigned to one of two possible conditions: control or experimental. Both conditions involved participants reading a vignette about the evidence presented at a murder trial in the USA, State v Harris (1989), (https://law.justia.com) (Appendix 1). The forensic evidence presented at the trial included shoeprint, fibre and blood samples, and the defendant was convicted. The participants in the experimental condition read the same vignette (Appendix 1) plus additional information about brain fingerprinting evidence used to appeal the conviction (Appendix 2). This information formed part of a CBS News article about brain fingerprinting (McKay 2002). The brain fingerprinting vignette contained a brief explanation of the procedure and an interview with Farwell, who stated that the brain fingerprinting test showed the convicted man was innocent. Error rates were not provided, but the news article contained supportive evidence in the form of this statement: 'This method was taken seriously enough by the CIA that they funded some of this research. The FBI also ran a successful experiment at the Quantico FBI Training Centre'. Appendix 2 shows this. In both conditions, after the information presentation, it was stated, 'Please try to imagine that you are a juror in this case. Based on this evidence, what would you vote?' The options were 'guilty, not guilty, or unsure'.

Results

A 2 (brain fingerprinting evidence, no brain fingerprinting evidence) × 3 (guilty, not guilty, unsure) chi-square test was performed to examine the relationship between brain fingerprinting evidence and no brain fingerprinting evidence and verdict. The relation between these variables was significant (X^2 (2, $N = 421$) = 14.25, $p < 0.001$). Visual inspection of the data showed little difference between the unsure verdicts for the experimental and control groups (Fig. 1). Thus, a 2 × 2 chi-square test was performed to examine the relationship between guilty and not guilty verdicts for those who read the brain fingerprinting evidence and those who did not. The relationship was significant (X^2 (1, $N = 265$) = 13.37, $p < 0.001$), indicating that the brain fingerprinting evidence significantly affected determinations of guilt. Guilty verdicts were made by 41% of participants who did not read the

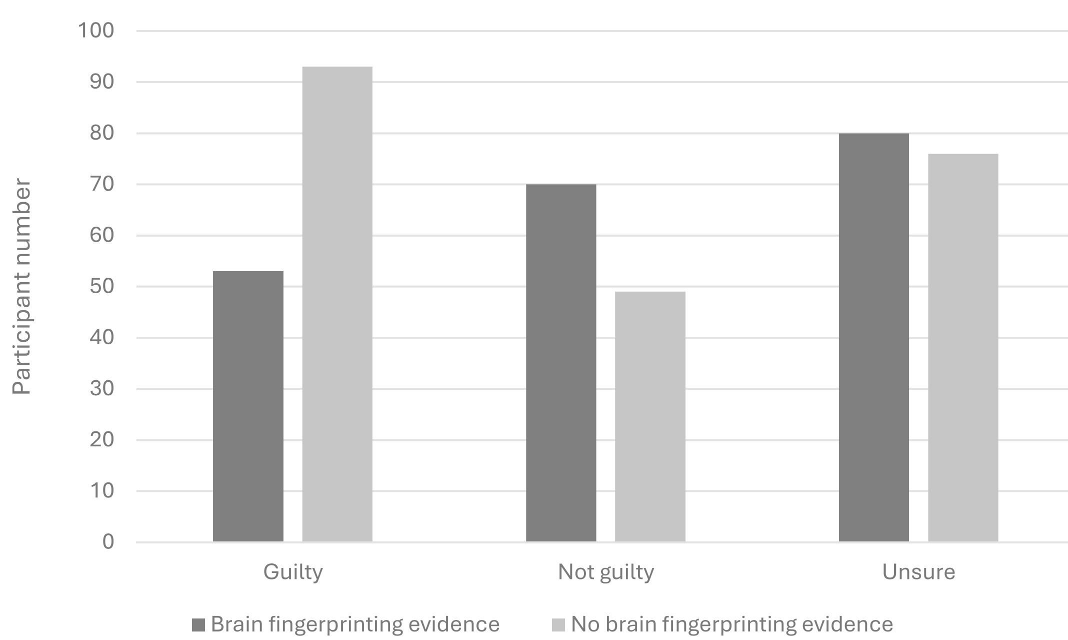

Fig. 1 Brain fingerprinting evidence and verdict

brain fingerprinting evidence. However, only 27% of participants who read the brain fingerprinting evidence voted guilty, showing that the introduction of brain fingerprinting evidence resulted in a significantly higher number of 'not guilty' endorsements. Interestingly, chi-square analyses showed no significant differences for verdict between males and females (X^2 (1, N = 413) = 2.99, p > 0.05) and across age ranges (X^2 (3, N = 421) = 6.80, p > 0.05), and no significant difference was found for verdict with students when compared to non-students (X^2 (1, N = 421) = 2.61, p > 0.05).

Discussion

This study investigated whether brain fingerprinting evidence would affect determinations of guilt in a murder case. Determinations of guilt did not significantly differ between males and females, between students and non-students or across age ranges. The conditions employed across the vignette indicated that the offender was either innocent based on brain fingerprinting evidence or guilty due to other forensic evidence (blood, fibre and shoeprint analysis). Consequently, when subjects were presented with brain fingerprinting evidence, they were significantly less likely to return a guilty verdict than the control group. Given the brain fingerprinting evidence contradicted the other forensic evidence, the results suggest a preferential effect for brain fingerprinting and highlight the potential prejudicial effect that this evidence may have on jurors.

In the present study, statements from the neuroscientist who invented brain fingerprinting were included in the information provided to participants (i.e. the neuroscientist stated that the brain fingerprinting findings show the suspect was not present at the crime; McKay 2002). This information could be considered a form of expert testimony. Expert testimony, presentation style, the credibility of the presenter and the weight afforded to different forensic methods have previously been shown to affect determinations of guilt (Howes 2014; Koehler et al. 2016; McCarthy Wilcox and NicDaeid 2018), and West et al. (2014) found that participants perceived neuroscience as credible. Therefore, the credibility of the science type (neuroscience) and the statements from the scientist who performed the brain fingerprinting test (expert testimony) may have affected the verdicts given by participants in this study.

The methodology employed in this study highlighted both positive and negative aspects of forensic science. The initial trial for the case utilised forensic evidence, including blood (blood type matching victim found on suspect's shoe), shoeprint (print found at the scene matched suspect's shoes) and fibre (fibres matching victim's clothing found in suspect's car) analyses to convict the suspect. Therefore, forensic science techniques likely helped convict a murderer. The brain fingerprinting findings, in this case, highlight problems with implementing forensic methods without a large body of independent efficacy research, established error rates and adherence to court admissibility standards. It has been claimed that brain fingerprinting has shown a 0% error rate (Farwell 2012). However, the case used for this study reveals that brain fingerprinting results can be incorrect. Brain fingerprinting and other P300 methods may prove helpful for future investigations if the methods can demonstrate reliability and validity and meet the evidence admissibility standards for the court. However, it will be essential to establish accurate error rates, or miscarriages of justice may occur. The results of this study indicate that had the appeal of this case occurred in the absence of the DNA test, a murderer may have been set free.

Neurolaw is a new and expanding field, with neuroscientific evidence increasingly presented to courts in Europe (Gkotsi et al. 2015) and the USA (Gazzaniga 2011; Farahany 2015). Neuroscience methods claim to determine the previously indeterminable, such as pain level (Reardon 2015) and neurobiological capacity (Steinberg 2013). Forensic techniques require a large body of independent scientific support and established error rates before they should be admitted to courts; however, this has failed to occur with many techniques (PCAST, 2016). The court case used in this study showed that brain fingerprinting is not as infallible as claimed. Consequently, as with all forensic science methods, independent scientific support is needed before evidence is presented to courts: brain fingerprinting is no different.

Support seems to be accumulating for the utility of brain fingerprinting and other P300 CIT in forensic investigations; however, as noted by Rosenfeld (2020) and Afzali et al. (2022), limitations of the technique need resolving or acknowledging. Although Farwell (2012) and Farwell et al. (2014) have performed studies with higher ecological validity than many others, independent replication has been lacking (Rosenfeld 2020). Little attention seems to be paid to memory processes and the difficulty of deciding what the guilty party is likely to remember. The reason the brain fingerprinting results were inaccurate in the case employed in the current study may be due to the many issues that emerge with memory and recall (i.e. the location of the body was not remembered by the perpetrator). The case used for this study highlights the importance of understanding memory for a crime. Furthermore, research has not established how drug, alcohol or personality disorders, such as psychopathy, may affect brain fingerprinting tests.

A limitation of this study is that brain fingerprinting and other forensic evidence were provided without the benefit of cross-examination arguments that can be heard by juries and affect juror determinations (Eastwood and Caldwell 2015; Goodman-Delahunty and Wakabayashi 2012). Furthermore, error rates and efficacy information that can affect verdicts

(Crozier et al. 2020; Thompson and Newman 2015) were not provided. DNA, the most persuasive of forensic evidence (Daftary-Kapur et al. 2010), was also not included in this study as the purpose was to uncover if the brain fingerprinting evidence carried more weight than the forensic science methods used in the initial trial (blood, shoeprint and fibre analysis). Future research could investigate the persuasiveness of brain fingerprinting evidence compared to DNA evidence.

In the initial stages of planning the research, the authors sought to obtain the brain fingerprinting report prepared for the defence. However, as this was unavailable, the CBS News report that discussed the findings was utilised instead. The use of the CBS material could have affected results in two ways: participants may have been more convinced of brain fingerprinting efficacy if they had read the official report as it would have been direct testimony from an expert witness (i.e. the inventor of brain fingerprinting) instead of the third-party report provided by journalists (who may not be perceived as credible). Alternately, the CBS reporting of the test was brief and non-technical, clearly outlining the method and the outcomes of application (innocence).

A further possible limitation of the research may also have related to the perceived credibility of the CIA and FBI, who investigated the utility of brain fingerprinting, as noted in the CBS report. As the study did not examine the preconceptions of the participants, it is possible that these may have influenced their responses to the brain fingerprinting evidence. Similarly, this effect could also have occurred in relation to participant's pre-existing views on forensic science. Although interestingly, studies with Australian jurors (Holmgren and Fordham 2011) and Australian forensic science students (Weaver et al. 2012) have found that the CSI effect (the assumption, derived from television shows such as CSI, that forensic science evidence is both accurate and available for most cases; Homgren and Fordham 2011) is not evidenced in samples of Australians. Whilst these findings are preliminary, it would be valuable for future research to explore the role of preconceptions in jury decision-making, along with whether areas of study or criminal justice field influences opinions on scientific evidence.

Conclusion

Mistakes in the criminal justice system can have grave consequences, such as wrongful convictions (Denault et al. 2020). The tragedy of wrongful convictions is multi-layered and arguably the broad failure of the criminal justice system (Huff and Killias 2013; Wessells 2021). Government reports on forensic science techniques (PCAST 2016) show that many methods lack empirical support, and U.S. exoneration statistics suggest that many inaccurate convictions result from fallible forensic science (Innocence Project 2021a, b). Given the lack of evidence supporting many forensic science techniques, any method capable of leading to incorrect convictions should be subject to rigorous testing before implementation. There has been some support for using brain fingerprinting in New Zealand (Palmer 2017) and Australia (Williams 2016). However, whilst some promising findings are observed in controlled laboratory settings, research with the likely recipients of this technology (criminals) (Afzali et al. 2022) highlights possible issues with real-world implementation. The implications of using this approach under real-world circumstances and with varied offending presentations are significant. Even if high accuracy rates are found, mistakes and errors will likely occur without replicable and consistent outcomes. This risks people being wrongfully accused, charged or ultimately wrongfully convicted. This study's results suggest that brain fingerprinting evidence affects determinations of guilt with potential Australian jurors and may outweigh some other forms of physical forensic evidence. Thus, highlighting the importance of ensuring forensic methods is scientifically sound before implementation.

Appendix 1

On December 31, the body of 21-year-old Kylie was discovered by two men looking for a fishing spot on the east bank of the Missouri River. The police officer who was called to the scene observed a shoeprint in the sand approximately 10 to 15 ft from the body. The officer also discovered a scarf of blue-grey colour near the crime scene.

The State Medical Examiner performed an autopsy on the body on January 1. He concluded that death resulted from ten stab wounds to the chest inflicted by an instrument with one blunt edge and one sharp edge. He further established that the victim had suffered a skull fracture, and neck contusions consistent with manual throttling. He estimated the time of death at some time during the evening of December 30.

Evidence presented at the trial included two statements given to the police by the man accused of the crime, David. The first statement was given to a police officer on January 4. At this time, David stated that he had known Kylie for 2 years and had last spoken to her in a telephone conversation sometime between December 28 and December 31. He told the officer that he had not seen Kylie in person since Christmas. The officer interviewed David again on January 6. At this time, David indicated that he had spoken with the victim by telephone on December 29 between 5 and 6 p.m. He said he had worked at the Burger King restaurant on the nights of December 29, 30 and 31 from 9 p.m. until 2 a.m. He again stated that he had not seen the victim personally since sometime prior to Christmas.

Three witnesses testified that they saw David with the victim on the evening of December 30. An inmate at the county jail, during the time that David was detained there awaiting trial, testified that David told him that he had killed Kylie. This inmate also testified that David had talked of taking a gold neck chain which the victim had been wearing.

Physical evidence obtained from David's residence pursuant to two search warrants included deck shoes with a shoeprint pattern similar to the one found at the scene of the crime and a gold neck chain (found in the personal effects of David). This neck chain was identified by the victim's father as being similar to a chain worn by his daughter.

Vacuum sweepings from David's Mustang automobile produced fibres of the same diameter and colour as those taken from the scarf found near the crime scene. The fibres were also chemically the same as those in the scarf. Other scientific evidence offered by the State included an analysis indicating human blood was present on defendant's deck shoes which was identified as group O PGM type 1 + 2 +. The victim's blood was also determined to be group O PGM type 1 + 2 +. Ten percent of the population has this type of blood.

David had several alibi witnesses to account for his whereabouts on the evening of December 30. Among these was the assistant manager of the Burger King restaurant where David was employed. That witness testified that David had worked at the Burger King from 9 p.m. on December 30, until 1:30 a.m. on the following day.

David states that he is innocent, and his lawyer argues that the police have set him up.

Appendix 2

A Harvard educated neuroscientist becomes involved in the case as he has invented new technology that will revolutionise crimefighting by telling investigators what is inside someone's head. It is based on the widely accepted theory that when people are presented with familiar information, like words or images, their brains unconsciously emit special electrical signals called brain waves. The method is called brain fingerprinting.

Here is how it works; there are three steps:

1. Step 1: The suspect is connected to an electroencephalogram (EEG) which is a machine that records brain waves.
2. Step 2: A computer in front of the suspect flashes photos or words/phrases describing important details of the crime scene, such as the murder weapon. One of the photos or words/phrases is correct, and the others are likely but incorrect. The correct picture or phrase is called a probe. For example, if the murder weapon was a gun (probe), suspects could be shown a gun along with different types of weapons such as a knife, sword, rope or piece of wood. Alternately, suspects could be shown the words gun then knife then sword, etc.
3. Step 3: Analyse results. Because brain waves are involuntary, it is impossible to conceal the truth: "The perpetrator, having committed the crime, has those details stored in his brain. The innocent suspect does not" states the neuroscientist. "If a person recognises the probe, their brain will generate a particular kind of brain wave. If a person does not recognise the probes, the brain's response is noticeably different".

Many scientists have recorded these kinds of brain waves in the lab, but this was the first to try to apply this science to real-world criminal cases. This method was taken seriously enough by the CIA that they funded some of this research. The FBI also ran a successful experiment at the Quantico FBI Training Centre.

The Brain Fingerprinting Test for David's Case.

The neuroscientist first examined the case file, and visits the crime scene, searching for potential memory probes.

The neuroscientist decided that the murderer would have to remember the place where Kylie was initially attacked, the place where her body was found and the process of dragging her body through the underbrush, across the sand to the riverbank.

Phrases with these details were used to test David. The phrases describe how Kylie's body was dragged through bushes, dragged across sand and left half submerged in the water.

The neuroscientist measures the brain waves of David to see if he recognises details of the murder. The results are immediately clear: David does not recognise the crime scene. "This is very solid evidence that what you said is accurate", states the neuroscientist to David. "That you were not there because you do not know these things".

A scientific report was prepared and presented to the court.

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Data Availability The data that support the findings of this study are available from the corresponding author, Rebecca Wilcoxson, upon reasonable request.

Declarations

Ethical Approval and Consent to Participate This project was approved by the CQUniversity Human Research Ethics Committee, approval number 0000022777. All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards. This article does not contain any studies with animals performed by any of the authors. Informed consent was obtained from all individual participants included in the study.

Competing Interest The authors declare no competing interests.

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