GAP INDIAN JOURNAL
OF FORENSICS AND BEHAVIOURAL SCIENCES
(ISSN – 2582-8177)
Globally peer-reviewed and open access journal.

PARAPHERNALIA IN THE FIELD OF NEURO-FORENSIC PSYCHOLOGY

Reena Paul Thengilan

PhD Scholar, National Forensic Sciences University
Gandhinagar, Gujarat, India
reena.phdbs21@nfsu.ac.in

Abstract

Neuropsychology provides the rationale behind human behaviour by delving into the neural processes. Forensic psychology is the application of psychological principles to the field of law and the judicial system. Besides understanding the chronological order of events related to a crime, forensic investigation moreover involves understanding the underpinning of every event, action and behaviour. The application of neuropsychological principles to the domain of forensic psychological investigative methods not only provides intuitive apprehension of the nature of crime but also aids in overcoming the bias caused by multifactorial approaches of investigation such as psychometric testing. A plethora of researches stipulate the application of various tools and instruments in neuroscience that aid in forensic investigation. The goal of this paper is to provide an overview of the contemporary methodologies such as EEG, BEOS employed in forensic investigation specifically emphasizing on the ground breaking and cutting-edge technology of eye-tracking. This paper provides an introduction to the studies that have initiated the first move towards employing the gaze-based biometrics and thoroughly exploiting its potential thus, greasing the wheels for the use of eye-tracking as a forensic investigative tool. This paper concludes with the challenges involved in using the contemporary methodologies in the domain of forensic investigation.

Keywords: *Forensic psychology, Eye-tracking, investigation, neuroscience*

1. INTRODUCTION

Forensic psychology is a remarkably novel and an emerging domain of forensic science, still in the process of moving forward leaps and bounds. Numerous psychological factors influence and play an important role in criminal behaviour. Interruptions, blocks and other issues in the thought process result in committing a crime which include motives such as greed, jealousy, vengeance, rage, ego (Bartol & Bartol, 2008). This makes it imperative to scrutinize the different facets of an individual i.e. social, biological, and psychological aspects that underpins the intellectual abilities and behaviour. Within the sphere of forensic psychology, it is commensurable to seek answers and evidences from the physical and the mental source i.e., the body and the brain respectively. The main objective of this approach is to uncover the neurobiological processes underpinning behaviour, emotions and thoughts that may have influenced the criminal act. This valuable information can prove to be highly beneficial in the evaluation and rehabilitation of criminal offenders as well as aid in the decision-making process of prosecution.

One of the studies that was conducted to explore the utility of the above-mentioned approach was based on deception done by Kozel et. al. (2005). The main goal was to figure out whether the methodologies based on neurobiological principles will furnish information that will complement what is acquired by employing the conventional psychological methods. This study examined the neurobiological mechanisms involved while impersonating a mock crime scene. The volunteers participating in this study were briefed about a task according to which they had to filch a watch and plant it in a locker along with other possessions. As per the research procedure, in a scenario where the volunteers were able to fool and mislead an investigator, they would be rewarded with plus $50. Next in line was the functional part of the study wherein the volunteers were made to sit in an fMRI scanner and presented with photographs of the mock crime scene. They were posed with certain questions. The analysis of the results obtained from the fMRI revealed that the anterior cingulate, orbitofrontal cortex, and dorsolateral prefrontal cortex exhibited increased neural activity during the process of questioning. This clearly pointed towards the participation and association of these areas in the act of deception.

GAP INDIAN JOURNAL
OF FORENSICS AND BEHAVIOURAL SCIENCES
(ISSN – 2582-8177)
Globally peer-reviewed and open access journal.

Neuropsychology, simply encompasses research and decoding of the association between brain and behaviour. The traditional view of neuropsychology propounds that it solely incorporates evaluation of brain disorders and injuries. However, it is important to change the frame of reference and understand how the principles, concepts, techniques of neuropsychology can be turned to account in the forensic domain.In numerous cases, the court calls for the expertise of a neuropsychologist in order to envisage the technique and approach for investigation of mental health and neuropsychological issues in relevance to a particular criminal investigation. Neuroscientific evidence, that is scientifically validated is accepted by the court under special provisions. Such evidences at times do play a crucial role in the legal decision-making process.

As the field of forensic science is gaining its ground in India, it is of utmost importance to explore how neurobiological evidences in collaboration with physical evidences proves to be effective in understanding and investigating a crime. Several methodologies in neuro-electrophysiology have established their base and are known to provide deep insights into the activities of the brain and its processes such as Electroencephalography – Event-related potential (EEG-ERP), fMRI, eye-tracking etc. However, the basic concepts, principles and mechanisms involved in these methodologies can furnish us with highly valuable knowledge of facts and evidence pertinent to the behaviour of criminals. Neuro-electrophysiology methodologies will harmonize with the conventional methods such as interviews, self-report tests etc.

Techniques such as electroencephalography (EEG), functional magnetic resonance imaging fMRI), and positron emission tomography (PET), Brain Electrical Oscillation Signature Profiling (BEOS) produce indicators that reflect brain activity in specific structures of the brain and are characteristic of specific behaviours which could potentially be linked with certain crimes (Beech, Carter, Mann, & Rotshtein, 2018; Butz & Kutter, 2017; Grimshaw, this issue).

Numerous researches, articles published in academic journals, science and technology magazines etc. have evidenced an unexpected upsurge of interest and vigour in the last few decades towards the instrumentation in neuroscience and their practical application in forensic investigation and the legal system. An in-depth, 36-chapter handbook has been published by Beech and his colleagues that distinctively is associated with forensic psychology. It encompasses an extensive spectrum of content and material related to the neuroscience of deception and neuroimaging approaches to guide treatment (Beech et al., 2018).

This paper further explores the need for building an interface between the two disciplines of forensic psychology and neuropsychology. The recent trending and cutting-edge technology yet to be unveiled and unravelled in the field of forensic psychology is eye-tracking, a gaze based technology.

Next, section will consist of the discussion of the different instruments in neuroscience that are relevant in investigating a crime from the perspective of comprehending their use with the help of researches and case-studies. A special emphasis is made on the initiation to use the Eye tracking technology for forensic investigations beginning with respective researches. These studies hint upon the shortcoming of exploring this technology in the Indian context.

2. PARAPHERNALIA INTERLINKING NEUROSCIENCE AND FORENSIC PSYCHOLOGY

This paper is crafted in an orderly manner as follows. Firstly, every instrument will briefly be discussed with an introduction, conceptual understanding and few researches and applications.

2.1 Electroencephalography (EEG)

Electroencephalography is the measurement of the electrical activity of the brain. It is the voltage difference between different parts of the brain that is measured rather than the electrical current. A cluster of active neurons produce electrical currents sufficiently large to be measured by the electrodes placed on the scalp. The first recording of the electrical activity of the human brain was carried out by the German neuropsychiatrist Hans Berger. He figured out that the human brain generated rhythmic electrical oscillations which could be recorded from the scalp of humans with unblemished skulls (Berger, 1929). He entitled this methodology as electroencephalography (EEG) and the signal records were termed as an electroencephalogram. It took several years for Berger's discovery to be accepted hands down by the scientific society. After a long period of cynicism and disbelief, several researchers and scientists acknowledged and appreciated this breakthrough discovery making EEG a mainstream technique with a remarkable prognostic benefit. It proved to be a critical milestone in

the progress of neuroscience research and clinical diagnosis eg: seizures, sleep disorders, behavioural issues etc.

2.1.1 A Study on the Feasibility of Using EEG Signals for Authentication Purpose

Several research studies have been conducted to understand and explore the potential of EEG in biometric identification by employment of machine learning. This is a completely different domain than the conventional use of EEG in the clinical field. The process of an EEG recording is completely non-invasive with an option of the device being portable which is an added advantage making it practical for use in Brain Computer Interface (BCI). BCI furnishes the connection between an individual and a computer without physical contact. Moreover, EEG has been employed in the forensic discipline to unveil the hidden information and identification of deception.

2.1.2 EEG-based authentication (Biometrics)

The pattern of the brain waves are individualized which makes the EEG signals practically conducive to be employed in the domain of biometrics. Machine learning is a part of the large realm of computer science, artificial intelligence, and pattern recognition and is widely employed in the processing of EEG signals. It has also found its utilization in the area of EEG-based identification of an individual.

An EEG-based individual identification system consists of two main stages: training and testing, each of which consist of two main components i.e., screening and choosing features and their categorization. The process begins with procurement of the biometric information of an individual from the brainwaves. Following this is the training phase, during which the pre-processing of the EEG signals is executed to decrease noise along with an extraction of features carried out by implementing a specific feature selection algorithm. Next in turn is constructing a framework of the brainwave patterns characteristic to the individual with the help of the procured feature vectors. During the testing stage, the above-mentioned specific feature selection algorithm performs certain operations on the EEG signals. The features thus generated are then matched with the framework build in the training stage.

Authentication is the verification and validation of the identity of an individual in the real-time environment and is the cornerstone of every security mechanism. A biometric authentication is solely based on the biological characteristics that are unique to every individual, for instance, fingerprints, iris scans, voice recognition etc.
EEG is proving to be a successful mechanism for authentication due to the following benefits: Confidentiality due to its association with mental tasks, challenging to impersonate, the heist idea is out of question, brainwave signals and patterns are produced by every living person.
Any EEG-based authentication system will have two steps: enrolment and verification. During the enrolment step, an individual will be assigned some simple tasks to be performed such as visualization of the movement of a finger or a hand and the EEG will be recorded. Since authentication is a separate concept than recognition, the visualization activities given should not be witnesses by any third party as they are a segment of the credential evidence. The level of security of a specific system determines the number of tasks to be included for authentication. Once the information is collected, the EEG signals recorded for each task go through pre-processing, feature-extraction, framework generation prudently preserved in a database. During the process of verification, for obtaining access, an individual will be required to produce EEG signals by repetition of the activities done in the enrolment stage. The EEG data obtained is then processed and the features acquired are matched with the information of the individual available in the database. Depending on the level of security, the match may be single i.e. one or two tasks are required for verification or multi-match i.e. several tasks are to be performed for authentication.

Research conducted on individual recognition till now have evidenced that stable and replicable brainwave patterns are possible through motor imagination (Nguyen, P., Tran, D., Huang, X., Sharma, D, 2012). The password for such systems consists of the unique EEG patterns and the secret activity performed. This concept is congruent to the one in voice-based authentication wherein voice is the key component for identification however, only precise vocabulary is employed for example: uttering specific words in a particular order.

Authentication system based on EEG is practical and enviable. More researches are in the pipeline that plan to explore the EEG-based authentication system on different populations with a comparison between different persons performing the same activity and an individual performing different activities. EEG is now no longer

viewed as an instrument used extensively in medical and research field rather its features and advantages are now explored applying it in every domain such as forensic investigation, security systems etc.

2.2 Brain Electrical Signature Oscillation Profiling (BEOSP or BEOS)

Another landmark instrument that has forged ahead in the sphere of detecting deception is Brain Electrical Signature Oscillation Profiling (BEOSP or BEOS). It varies from the conventional lie detection tests. This innovative instrument has a unique approach of procuring information straight from an individual's memory without any intimidation and compulsion to react or provide answers to the statements, technically referred to as probes, set forth. The most challenging aspect of any investigation is the uncovering of a criminal act and extraction of truth from the individuals involved. This is because the people involved will always attempt to conceal the truth and incriminate others. Polygraph test identifies whether the information given by an individual is false and thus, partially assists in the investigation of crime.

2.2.1 Principle of BEOS (Remembrance v/s Knowing)

The principle of BEOS is the differentiation between remembrance and knowing. It measures the different constituents of the electrical oscillations produced by the brain during the process of remembrance of autobiographical episodes which eventualizes solely when an individual experienced an event or action by virtue of active involvement in the said event/action.

We often redeem memories for two reasons: either for perceiving humans, elements or materials in the external world or to stir up some autobiographical memories that are formed by the diverse experiences of an individual. A P300 event related potential (ERP) follows the recognition of a stimulus (Donchin, 1981; Neville et al., 1986; Donchin and Coles,1988; Annet & Mukundan, 1996; Mukundan & Rohrbaugh, 1998; Sudha &Mukundan,1998; Mukundan et al., 1999; Silva et al., 2007). The P300 response corresponds to the awareness of a novel stimulus with the familiarity of the stimulus determining the magnitude of the ERP. It persists for not more than 200 ms. Knowing and remembrance are contemplated to be two distinctive neurocognitive processes (Mandler 1980). Knowing is a crucial process in which an external prototype is compared with and recognized as a familiar internal prototype. Recollecting a completed event or action which may be delightful, sad or traumatic results in remembrance of an autobiographical experience that may encompass complete or almost complete recovery of all characteristics of sensory-motor information from the memory (Polich J., *et al*. 1994). Proprioceptive and emotional constituents experienced during that event or action also trail around with remembrance (Polich J., *et al*. 1994, Biederman, I. 1987, Biederman, I. 2001). These components influence the EEG recording done during the process of remembrance.

The method of providing hints or provoking an individual to recollect a particular event is referred to as cueing. It helps in identifying the occurrence of different processes in the brain which in turn helps to investigate the participation of the concerned individual in the specific activity. While recollecting a particular event, context and time-related information also may be remembered. A cue is characteristic to an individual as only individuals closely associated with the concerned event will respond to the cue and recall the event. When the same cue is presented to those not associated with the event, it will not trigger any memory linked to it.

BEOS was invented by Prof C.R. Mukundan for the purpose of forensic investigation. It is a technologically advanced system which has the potential to ascertain the occurrence of "Experiential Knowledge" in the individual who is investigated. It involves eliciting a unique signature of electrical oscillations from the activity in the brain which is triggered by the display of probes. It is the experiential knowledge (EK) that is measured while the subject remembers the autobiographical episode and the individual's involved. Often in the investigation of a crime, individuals may not perfectly recall each and every detail of the specific event. At times, the investigating team may also be provided with information that is nothing more than a confabulated memory or fabricated information. In due course of time, memory is affected which can be examined using BEOS. It can also determine genuine recollection and experiential knowledge.

There are researches in abundance that exhibit the efficiency of BEOS in the field of forensic investigation. To quote a few researches: "Effect of repeated probes on creating experiential knowledge" by Pravesh Charan Isai and Dr. Priyanka Kacker (2020) examining what may lead to false statements by eyewitnesses and memories. "Experiential knowledge of positive and negative experiences on remembrance and neural response using neuro signature system (BEOS)" by Dr. Priyanka Kacker (2018) elaborating on the remembrance of positive and negative experiences. Another research is "Cyber Crime Investigation through BEOS profiling" by Grandhi Saroja

Roy and Dr. Priyanka Kacker (2020) with the objective of investigating the possibility of finding the offender by employing the hacking techniques while generating the probes.

A study titled "Experiential knowledge (EK) on confabulated and real experiences using Neuro-signature system: A pathway to criminal justice" was planned with the motivation of substantiating the declarations and explanations provided by the suspects, victims, witnesses assisting the process of forensic investigation by Dr. Priyanka Kacker and Ms Amrita Ajitprasad (2020) year of publication. The study examined EK of individuals in three levels: Real experiences, confabulated experiences and imagined experiences. The results showed that EK scores were triggered on personal experiences rather than the confabulated experiences. Another key observation was more EK was generated on actual experiences than imagined experiences. This research study equips us with the required knowledge to understand BEOS as an investigative tool that aids in forensic investigation and can be used as corroborative evidence in court.

BEOS can also prove to be useful in military interrogation and can support operations during anti-cyber theft, drug abuse cases, counter terrorism, etc, thus working towards safeguarding the interest of national security.
The following section, will elaborate the concept and working of eye-tracking, the metrics involved, capacity of eye tracking in the field of forensic investigation, other areas of application and the concerns to be addressed in employing eye-tracking in forensics.

3. EYETRACKING

A popular quote by William Henry, "The eyes shout what the lips fear to say." Eye tracking has been an efficacious tool in the field of engineering and science and technology since years. With the constant upgradation and improvement in making the eye tracking devices inexpensive, sophisticated and accessible, it has found its utilization in the field of healthcare, vigilance, biometrics, military and marketing etc. Eye-tracking, also known as gaze-based biometrics is in a nascent stage in the field of forensics.

Every individual possesses a unique sequence of eye movements which is the fundamental concept that backs up eye-tracking. Eye movements are difficult to replicate and fabricate. In the contemporary eye-tracking devices, a high-resolution camera coupled with near infrared mechanism is employed to follow the trail of the path followed by gaze. The basic principle employed in this device is known as the Pupil Center Corneal Reflection (PCCR). It involves ushering a near-infrared light so as to approach the pupil located at the centre of the eyes resulting in perceptible reflections from both the pupil and the cornea, a transparent outer layer of the eye. These reflections are traced by the infrared camera. This entire process is referred to as Pupil Center Corneal Reflection (PCCR). So, it is the light reflected that gives a tip off to the eye tracking device regarding the motion of the eye and its direction. Eye tracking computes visual attention and impartially invigilates when, what, and where people look.

3.1 ARENA OF APPLICATIONS OF EYE-TRACKING

Eye tracking has a wide spectrum of applications and its sphere of influence is increasing day by day. Gaze-based analysis provides a plethora of information which has to be processed resulting in application-based feature selection. The two main upcoming areas where Eye-tracking is gaining its ground is Neuromarketing and Forensic Investigations. Below are presented a few case studies on the application of Eye-tracking in Forensic investigations.

3.1.1. FORENSIC INVESTIGATION

LIE DETECTION

The Polygraph technique has been an established technique for detection of deception and is widely used regardless of the heap of the shrewd remarks and issues with accuracy. The flaws in this technique call for raising its validity and reliability. Several researches evidence that eyes can substantially reveal deception through three different attributes i.e pupil dilation, fixation points and blinks. These are extremely vital as they are closely related to the cognitive mechanisms that are associated with deception.

Studies conducted on the pattern of fixation points during a Guilty Knowledge Test established that the fixation patterns of deceptive subjects were remarkably different than innocent subjects, suggesting it to be an efficacious method for detection of deception (Derrick. D. C., 2010). Arousal and cognitive load act as contributing factors for elevated pupil dilation and blinking which is closely related to deception (Zuckerman, M. et al., 1981). The rationale for this event is that when an individual falsifies, he or she has to encounter several additional cognitive processes in comparison to someone who says the truth due to the synchronous thinking of the truth and the fabricated answer (Patnaik, P. et. al., 2016).

Conveying a message intelligently with the objective of making someone develop a false belief is known as deception (Buller, D. B., 1996; Ekman, P., 1985). Converus, a private enterprise designed the Eye Detect exam which is lie detection determined by the eye tracking method. The advantage of eye-tracking over traditional polygraph testing is that it is inexpensive and requires one fifth of the time required for traditional testing. A standard lie detection procedure demands a trained investigator, requires at least 90 minutes for completion and the final report may take several hours to be available. On the other hand, the Eye Detect exam test requires 30 minutes for completion and the analysis takes approximately five minutes. Practically, Eye Detect delivers an accuracy of 85% and when used in combination with Polygraph, with the same result the accuracy jumps to 98%. Comparatively, Eye Detect is more comfortable as no wires are attached physically and the choice of language is an additional benefit.

CRIMINAL LINEUP IDENTIFICATION

During any investigation, erroneous confirmation of the identity of an individual is a notable issue. In order to get an insight of the issue, a study was conducted to study Criminal line up identification in depth by Flowe and Cottrell (Flowe, H., Cottrell G. W., 2011; Mansour, J. K., Flowe, H. D.). In the experiment by byFlowe and Cottrell, eyetracking is employed to acquire the information of the face length and the number of occurrences of visual analysis of each face. Through this, the experimenters aim to intensely scrutinize the decision-making mechanisms in simultaneous line ups, where innocent individuals are arranged in an orderly manner with a suspect planted randomly. The experiment was designed in the following manner: The photograph of a 'suspect' referred to as the target individual is presented to a certain number of eyewitnesses. They then go through a series of tests in which different faces are displayed. Fifty percent of the tests muster target photographs i.e the 'suspect' and the rest comprise of doppelgangers i.e look-alikes. Two new vogues came into picture during the first visits on the identification line up: Faces that were approved as a perfect match were scrutinized for a longer period of time in comparison to other faces and in addition to this, in the absence of any match, irrespective of the target or the look-alike, the scrutinizing time was longer as compared to others.

Similarly, when the eyewitnesses returned for another line up identification, they contemplated the unmatched faces for a considerably longer period and the frequency of visits was also higher. These demeanours were not outlandish for the law enforcement officials. However, the experimental results point out to the fact that decision-making processes during line up identification can be quantified with the help of the time for which the gaze is persistently fixed on the face and the frequency of the views of the faces. In any probability, when an eyewitness is incapable or unable to identify positively, his or her gaze data could still be used as corroborative evidence as an aid to investigation.

Therefore, the law enforcement officers should be cognizant of the fact that comparing and analyzing the gaze patterns and other valuable eye-tracking data will help them to get a deep insight of the trends, behaviours and even aid in understanding how to design different criminal line up identification parades.

DRIVING

A preliminary study was undertaken, designed and accomplished by Qin, L. et. al. (2018) with the aim of evaluating the impact of the speed of an automobile on the eye movements of the driver at the doorway of the tunnels located on the highway during the day and night. A highway tunnel is tubular in shape and appears to be partially enclosed. Due to the special structure of the tunnel, an alternation of brightness and darkness takes place during the day and the phenomenon of visual adaptation and lagging occurs post making an entrance into the tunnel (Qin, L. et. al. 2017, Yang, C. et. al., 2011, Beka, M.C., 2005). Both, the change in light and the related phenomenon have a head-on impact on the driving performance and the workload which may turn out to be the impelling cause of traffic accidents (Shimojo, A. et. al., 1995; Yeung, J.S., Wong, Y.D. 2014). Numerous researches have evidenced that visual perception constitutes 80 percent of the information received by the motorists while driving which is why the changing information, visual in nature to a great extent is associated with traffic

accidents (Du, Z.-G. et. al., 2007; Sivak, M., 1996; Mäntyjärvi, M. et. al., 1998; Yan, Y. et. al., 2014; Guo, Y.S. et. al., 2006; Zhao, B., 1998). This lays the foundation for the need of a gaze-based analysis of a driver paving the way to design a blueprint to spread awareness regarding safe driving and to make cutbacks in the number of accidents.

This experiment evaluated three eye-movement dimensions: pupil area, fixation duration and the number of fixations and the impact of speed on them (Jacob, R.J.K.; Karn, K.S., 2003; Yuan, W., 2008). The experimental results depicted the following: during the day on nearing the tunnel doorway, the pupil expanded thus, increasing its size and at night, the pupil constricted, decreasing its size on nearing the tunnel doorway, and increased after crossing the tunnel entrance. A remarkable correlation was observed between the pupil size and the automobile speed during the day whereas during the night, an insubstantial correlation was obtained. In addition to this, the average number of fixations diminished during the day when nearing the doorway of the tunnel along with having a noteworthy negative correlation with the automobile speed. Moreover, the automobile speed was found to notably negatively correlate with the duration of average fixation during the day. On the other hand, the average fixation duration and the average number of fixations failed to display any meaningful affiliation with the automobile speed.

Though this pilot study employed a small sample size due to safety factors, time and financial constraints, the results provide a different approach towards the factors causing accidents and strategies to invigorate the infrastructure conditions while driving eg: lighting facility, set in place the speed reduction markings and actively working traffic signals etc. Further research with larger sample size based on different factors such as weather, experience of driving, gender etc. can be also taken into consideration.

Another research titled "Driving with Distraction: Measuring Brain Activity and Oculomotor Behaviour Using fMRI and Eye-Tracking" by Yuen, N. H. et. al. (2021) was conducted to understand the brain activity in-depth that assists an individual while driving. fMRI and eye-tracking technology was employed along with simulation of the task of driving which included distraction.

EVIDENCE RECOGNITION IN CRIME SCENE INVESTIGATIONS

Forensic officers or crime scene investigators act as the epicentre of crime investigations. Their decision-making skills are of prime importance as it will exert a strong influence on the swiftness and the quality of the results which in turn will impact the success rate of solving a case. During evidence collection, inability to identify the requisitions of any object at the crime scene will equate to missing an opportunity to form and understand the theory and motive behind the crime. Therefore, it is imperative for the crime scene investigators to correctly identify and examine forensic evidences that have the potential to approve or refute propositions and suppositions.

Research was conducted that made an attempt to ascertain whether the plethora of information provided by the gaze-based biometric could potentially be employed to get an eyeful of the calibre and the proficiency of a crime scene investigator. 32 individuals were chosen and classified as experienced professionals or trained apprentices depending on their educational qualification and professional background. Every individual had to don a mobile eye-tracker device and was assigned the task of analysing a mock crime scene. The fixations, fixation duration, gaze patterns, reconstruction accuracy were measured. Duration of search on particular AOI's and the sequence of search were found to be remarkably different between the two groups. Expert group showcased differing search periods with similar search sequences in comparison to the apprentices. Presence of latent variable in this study hints at future research. This experiment largely suggests better detection of evidence and acknowledging its importance. An important advantage of employing the Eye-tracking technology is that it facilitates easy scrutiny and identification of evidence with the help of gaze patterns and fixation points. Also, it will prove to be an added benefit in training sessions wherein unnoticed or disregarded evidences can be taught to be attended to by the experts. It makes personalized training and determination of crucial areas where rectification is required, achievable.

PERSONAL INJURY

Several researches established that foot travellers concentrated their gaze two to three metres ahead on the pathway. Taking these researches to a higher level, research was conducted employing eye tracking technology to evaluate eye-movements while moving from one place to another in a real-time environment. These researches paved the way for evaluating personal injuries causing in civil litigations. Empirical research was

accomplished to back the opinion of experts in a civil litigation dealing with the accountability of an establishment for a personal injury (WhetselBorzendowski, S.A., 2016). Five volunteers were asked to don a mobile eye-tracking device and were assigned the task of walking along two different pathways that encompassed the entire area where the petitioner claimed to be injured. Consistent with the earlier researches, the results of this study established that the volunteers did fix their gaze on the path ahead. Also, the fixation duration on the final destination displayed longer periods of time in comparison to fixations on other regions and elements and objects. Such empirical data is dependable and trustworthy and can assist in the expert opinion substantiating the justifications of an expert.

ANALYSIS AND INTERPRETATIONS OF SKELETAL REMAINS

A pilot study, first of its kind was planned and conducted with the objective of evaluating the gaze pattern strategies and obtaining an insight into the decision-making process taking place in the estimation of skeletal remains Nakhaeizadeh, S. et. al., (2020). Three experts were chosen for this study and were asked to wear a mobile eye-tracking device. They were assigned the task of determining the sex and the age at the time of death of a set of skeletal remains that were obtained from a familiar archaeological sample. During this study, the fixation points of the experts i.e the characteristics of the skeleton they concentrated upon, the time for which fixation occurred i.e. fixation duration along with the number of times the experts visited the specific characteristics and the duration of the visits were determined.

On analysis, it was found that there were differences in the gaze pattern strategies in terms of the fixation points, visit duration, and visit counts between the volunteers. The results furnished a vision to design a blueprint of how eye-tracking can be employed to completely delve into the various mechanisms involved in reconstructions and interpretations made by the forensic anthropologists.

3.1.2 NEUROMARKETING

In simple terms, Neuromarketing is the application of Neuroscience to the field of marketing. It's ultimate goal is to draw insight and get an in-depth understanding of consumer behaviour, their decision-making process and reactions that are generated at an unconscious level. Acting on the insights obtained from surveys and focus groups is like taking a leap of faith.

What draws the attention of Consumers? How do they perceive a product as useful or interesting? These are the key questions to which if answer is sought, will result in successful marketing with certain profit.

Eye tracking helps understanding what draws a customer to a specific product, the way the customer is related to the product and its packaging, and the positive or negative ways the customer interacts with, consumes, or uses the product. Eye tracking has great potential either alone as main search tool or in combination with other equipment that is being used in Neuromarketing, such as fMRI, PET-SCAN or EEG. Some studies have used Eye tracking to investigate the role of various stimuli on the shelves (Chandon, Hutchinson, Bradlow, & Young, 2009). The ET technology assesses exactly where the consumers look. These studies help to gain insights into how to gain attention of consumers and how to make marketing effective.

The key characteristic of Eye-tracking in market research is that it can provide insights into participants' habits even when these participants are unaware that they are being observed. Though neuromarketing is still in its developing stages in India, eye-tracking is employed to conduct several researches and explore all the facets of consumer behaviour. Quoting a few researches from the suite available:A Ph.D. thesis was designed and completed by Eleanor Trimble (2017) titled "The Influence of Colour Priming on Consumers' Physiological Responses in a Retail Environment Using EEG and Eye-Tracking". The goal of this research was to measure the impact of a retail environment on the emotions and cognitive responses of a consumer regarding products. A simulation of a real-world retail shop was created and the volunteers were asked to shop and choose three facourites. A portable EEG and eye-tracking device were used to measure the emotional responses and gaze bias for the chosen and primed products respectively. The responses for prime matching-coloured products were different in comparison to that for the non-prime matching-coloured products which was evidenced by the EEG data recorded and analysed. Similarly, the EEG data obtained suggested a remarkable difference in emotional reactions towards the preferred prime-coloured products. The research conclusion was that priming strongly impacted the decision -making process in retail shopping pertaining to fashion sector.

Research was conducted using EEG and eye-tracking technology to test the effectiveness of advertisements (Wang, L 2019). Another study was conducted to evaluate various factors and suggest a layout that enhances the design of packaging of educational toys titled "Neuromarketing applied to Educational Toy Packaging" (2020). Neuromarketing methodologies, eye-tracking and galvanic skin response in combination with qualitative research methods were employed to understand the factors that motivate the purchase of educational toys.

A study "Shopping experience by Emotion tracking technology" was conducted by Nithya, M. et. al. (2019) with the objective of evaluating the experience of consumers during the process of purchase. The implication of this research was to acquire the specifics of consumer's shopping experience and accordingly alter or modify the shop to fulfil the needs of the consumer. The researchers employed EEG and eye-tracking device with the help of which they were able to measure the gaze and emotions of customers during purchase. EEG recordings facilitated the analysis of basic emotions, for instance, finding elements or attributes that made the consumers feel happy or caused frustration. This information would give the direction of improvement.

Other researches conducted were "Do You See What I See? Effectiveness of 360-Degree vs. 2D Video Ads Using a Neuroscience Approach" by Austin-Azofra, J. M. et. al. (2021) thatcompares cognitive and emotional responses to 360-degree vs. static(2D) videos."A comparative analysis ofneuromarketing methods for brandpurchasing predictions among young adults" is a research done by Garczarek-Bąk, U. et. al. (2021) to determine predictive value of purchase of brands.

4. CONCLUSION

In this modern era, where existing technology is upgraded every day and ground-breaking innovative techniques are discovered and put on show, criminal offenders are becoming increasingly furtive in their actions. With time, an offender has become adept in the techniques and approach employed to commit a crime.
In the present-day scenario, there exists a lacuna in the techniques, approaches and the instruments used for investigation. The domain of investigating any offense is no longer restricted to detection of deception (Lie detection). The boundaries of investigation have now broadened to finding the roots of the biological, social and psychological characteristics in reference to the individuals involved in the crime.

Forensic psychology and neuropsychology are interlocked with each other encompassing effective tools to distinguish between normal and criminal behaviour. Several neuropsychological techniques can be exploited to the fullest as an aid to investigation tool in the forensic context. In order to avert backsliding of criminal behaviour and safeguard the societal wellbeing, financial support needs to be provided by the respective authorities towards invention and innovation of new instruments and techniques that would aid the investigating team and the judicial authorities to make effective decisions.

There is a body of research that provides an understanding of how neuropsychological methodologies and techniques are scientifically validated and can be employed in the forensic investigation. There is a pressing need for collaboration between the disciplines of forensic psychology and neuropsychology which will aid in a work environment that aims at providing an investigation procedure of high standards. It is the application of innovative, ground-breaking, scientifically-validated technology that will lead to progress of the legal domain.

Thus, there exists a synergy between Neuropsychology and Forensic psychology and efforts need to be made to get both fields to work together to obtain a deeper insight into the perplexing questions arising in legal investigations.

5. REFERENCES

[1] Ahlstrom, U., Friedmanberg, F. (2006) Using eye movement activity as a correlate of cognitive workload. *International Journal of Industrial Ergonomics,* 36(7), 623-636.
[2] Annet, C., Mukundan, C. R. (1996). Social drinking – part-II: Auditory evoked potentials, P300 responses and contingent negative variation in social drinkers. *Nimhans Journal*, *14*(1), 22–30.
[3] Bartol, C.R., Bartol, A.M. (2008). Introduction to Forensic Psychology. *Research and application*, 2nd Edition, Barnes and Nobles New York.

[4] Beech, A., Carter, A., Mann, R., & Rotshtein, P. (2018) (Eds.), *The Wiley Blackwell Handbook of Forensic Neuroscience*. Oxford, UK: Wiley-Blackwell.
[5] Beka, M.C. (2005). A study on tunnel lighting. *J. Light. Des. Appl,* 6, 10–16.
[6] Berger, H. (1929). Über das Elektrenkephalogramm des Menschen [On the electroencephalogram of humans]. Archiv für Psychiatrie und Nervenkrankheiten, 87, 527-570.
[7] Biederman I. (1987). Recognition-by-components: A theory of human image understanding. *Psychological Review,* 94(2), 115-147.
[8] Biederman I. (2000). Recognizing Depth-Rotated Objects: A Review of Recent Research and Theory. *Spatial Vision,* 13(2-3), 241-253.
[9] Buller, D. B., Burgoon, J. K. (1996). Interpersonal deception theory. *Communication Theory*, 6, 203-242.
[10] Butz, M. V., Kutter, E. F. (2017). How the mind comes into being: Introducing cognitive science from a functional and computational perspective. New York, NY: Oxford University Press.
[11] Cantoni, V., Musci, M., Nugrahaningsih, N., Porta, M. (2018). Gaze-based biometrics: An introduction to forensic applications. *Pattern Recognit. Lett., 113*, 54-57.
[12] Chandon, P., Hutchinson, J.W., Bradlow, E.T., Young, S. H. (2009). Does In-Store Marketing Work? Effects of the Number and Position of Shelf Facings on Brand Attention and Evaluation at the Point of Purchase. *Journal of Marketing, 73*, 1 - 17.
[13] Cheng, J., O'Connell, M. E., Wormith, J. S. (2019). Bridging Neuropsychology and Forensic Psychology: Executive Function Overlaps with the Central Eight Risk and Need Factors. *International Journal of Offender Therapy and Comparative Criminology*, 63(4), 558-573. doi:10.1177/0306624X18803818
[14] Derrick, D. C., Moffitt, K., Nunamaker, J. F. Jr., (2010). Eye Gaze Behavior as a Guilty Knowledge Test: Initial Exploration for Use in Automated, Kioskbased Screening. *43rd Annual Hawaii International Conference on System Sciences*, Computer Society Press, Poipu, Hawaii.
[15] Donchin, E. (1981). Surprise! . . . surprise? *Psychophysiology*, *18*(5), 493–513. doi:10.1111/j.1469-8986.1981.tb01815.x PMID:7280146
[16] Donchin, E., Coles, M. G. H. (1988). Is the P300 component a manifestation of context updating? *Behavioral and Brain Sciences*, *11*(03), 357–374. doi:10.1017/S0140525X00058027
[17] Ekman, P. *Telling Lies*, Norton, New York, 1985.
[18] Flowe, H., Cottrell, G. W. (2011). An examination of simultaneous line up identification decision processes using eye tracking. *Applied Cognitive Psychology*, 25(3), 443-451.
[19] Garczarek-Bąk, U., Szymkowiak, A., Gaczek, P., Disterheft, A. (2021). A comparative analysis of neuromarketing methods for brand purchasing predictions among young adults. *Journal of Brand Management*, 1–15. Advance online publication. https://doi.org/10.1057/s41262-020-00221-7
[20] Grandhi, S. R., Kacker, P. (2020). Cyber Crime Investigation Through BEOS Profiling, *Gap Interdisciplinarities: A Global Journal of Interdisciplinary Studies*, 03(02), 67-72.
[21] Grimshaw, G. (2018). Affective neuroscience: A primer with implications for forensic psychology. *Psychology, Crime & Law, 24*(3), 258-278. https://doi.org/10.1080/1068316X.2017.1420188
[22] Guo, L.Y., Liang, B. (2009). Study on lighting control system of the tunnel on expressway. *Microcomput. Inf.* 7, 38–39.
[23] Guo, Y.S., Fu, R., Yuan,W., Zhang, J.F. (2006). Influences of passage width on driver's dynamic vision and operation behavior. *China J. Highw. Transp*. 19, 83–87.
[24] Heilbronner, R. L., Frumkin, I. B. (2003) Neuropsychology and Forensic Psychology. *Journal of Forensic Neuropsychology*, 3:4, 5-12, DOI: 10.1300/J151v03n04_02
[25] Hom, J. (2003). Forensic Neuropsychology: are we there yet? *Archives of clinical neuropsychology: the official journal of the National Academy of Neuropsychologists, 18(8)*, 827-45.
[26] Hu, J. (2010). Biometric System based on EEG Signals by feature combination. *2010 International Conference on Measuring Technology and Mechatronics Automation (ICMTMA)*, pp. 752–755
[27] iMotions. (2017). *Eye Tracking The Complete Pocket Guide.* iMotions. https://imotions.com/guides/eye-tracking/
[28] Isai, P.C., Kacker, P. (2020). Effect of repeated probes on creating Experiential knowledge. Gap Interdisciplinarities, 03(03), 17–29.
[29] Jain, A. K., Dass, S.C., Nandakumar, K. (2004). Soft biometric traits for personal recognition systems, in: Biometric authentication. *Springer*, 731-738.
[30] Jacob, R. J. K., Karn, K. S. (2003). Eye tracking in human-computer interaction and usability research: Ready to deliver the promises. *Mind*, 2, 573–605.
[31] Juarez, D., Tur-Viñes, V., & Mengual, A. (2020). Neuromarketing Applied to Educational Toy Packaging. *Frontiers in psychology*, *11*, 2077. https://doi.org/10.3389/fpsyg.2020.02077
[32] Kacker, P. (2018). Experiential knowledge of positive and negative experiences on remembrance and neural response using neuro signature system. *Journal of Clinical Psychiatry Cognitive Psychology*, 2(1), 19-25.
[33] Kacker, P. (2020) Forensic Psychological Investigation During and After the Pandemic 2020: A Technology – Based Futuristic Approach. *Encyclopedia of Covid*. Edited by: Gurudutta Japee and Preeti Oza. Apple Books Publishers and Distributors. pp. 219-230, ISBN: 978-93-87515-96-3

[34] Kacker, P., Ajitprasad, A. (2020). Experiential Knowledge on Confabulated and Real Experiences Using Neuro-Signature System: A Pathway to Criminal Justice. *Gap Interdisciplinarities, 03*(03), 30–36.
[35] Kacker, P., Pandya, A. (2020). Forensic Psychology for Prevention of Crime and Rehabilitation Of Offenders: Public Health Perspectives. *GAP Indian Journal of Forensics and Behaviour Sciences,* 01(01), 5–7.
[36] Kumar, K., Vyas, J. M., Kacker, P. (2018). Forensic Psychological Investigative Techniques Eliciting cues to deception and truth in Crime Investigation: In Indian scenario. *Research Journal of Social and Life Sciences*, Vol. XXIV, June 2018
[37] Khemchandani, R., Kacker, P. (2020). The Experience of Post-Traumatic Stress Disorder and Domestic Violence. *GAP Indian Journal of Forensics And Behavioural Sciences*. 01(01), 1–4.
[38] Kozel, F. A., Johnson, K. A., Mu, Q., Grenesko, E. L., Laken, S. J., George, M. S. (2005). Detecting deception using functional magnetic resonance imaging. *Biological psychiatry*, *58*, 605-613. https://doi.org/10.1016/j.biopsych.2005.07.040
[39] M. Nithya, S. Shobana, Ramesh, S., Shyamaladevi, S., Rangarajan, R. (2019). Shopping Experience by Emotion Tracking Technology. *International Journal of Research and Analytical Reviews (IJRAR)*, 6(2), 138-141.
[40] Mansour, J. K., Flowe, H. D. (2010). Eye tracking and eyewitness memory. *Forensic Update 101*.
[41] Mäntyjärvi, M.; Tuppurainen, K.; Rouhiainen, H. (1998). Visual function in professional truck drivers. *Int. Arch. Occup. Environ. Health,* 71, 357–362.
[42] Menezes, R., Kacker, P., Mukundan, C.R. (2020). Impact Of Hemispheric Dominance on Behavioural Laterality Style, *GAP Indian Journal of Forensics and Behavioural Sciences*, 01(01), 31-39. https://doi.org/10.47968/gapijfbs.11006
[43] Mukundan, C. R. (2018). Forensic Applications of Recording the Neurocognitive Processes of Remembrance. *Peer Reviewed Journal of Forensic & Genetic Sciences,* 2(3), 134-141. 10.32474/PRJFGS.2018.02.000140.
[44] Mukundan, C. R., Kacker, P. (2020). Brain And Mind: Mind Created from The Brain – Dependent on Material: Scientific Principles and Relationships in The Brain, And on The Independently Created Mind Relationships and Principles. *GAP Indian Journal of Forensics and Behavioural Sciences*, 01(01), 62-65.
[45] Mukundan, C. R., Rohrbaugh, J. (1998). NIMHANS-NIAAA (NIH) collaborative project report on Psychophysiological and Neuropsychological correlates of recovery from alcoholism. Technology Information Forecasting & Assessment Council - Directorate of Forensic Sciences (TIFAC-DFS) Project Report (2008) on Normative Data for Brain Electrical Activation Profiling.
[46] Nandini, N., Kacker, P. (2017). Paranormal Movie Based "Experiential Knowledge" Using Brain Electrical Oscillations Signature (BEOS) Profiling. *Indian Journal of Health and Wellbeing, 8(11)*, 1285-1290.
[47] Nakhaeizadeh, S., Morgan, R. M., Olsson, V., Arvidsson, M., Thompson, T. (2020). The value of eye-tracking technology in the analysis and interpretations of skeletal remains: A pilot study. *Science & justice: journal of the Forensic Science Society, 60 1*, 36-42.
[48] Neville, H. J., Kutas, M., Chesney, G., & Schmidt, A. L. (1986). Event-related brain potentials during initial encoding and recognition memory of congruous and incongruous words. *Journal of Memory and Language*, *25*(1), 75–92. doi:10.1016/0749-596X(86)90022-7
[49] Tran, D., Huang, X., & Sharma, D. (2012). A Proposed Feature Extraction Method for EEG-based Person Identification. In H. R. Arabnia (Ed.), *ICAI 2012: Proceedings of the 2012 International Conference on Artificial Intelligence, WORLDCOMP'12,* 2, 826-831. CSREA Press. http://world-comp.org/p2012/ICA4683.pdf
[50] Patnaik, P., Woltz, D. J., Hacker, D. J., Cook, A. E. Ramm, M. D. L. F., Webb, A. K., Kircher, J. C. (2016). Generalizability of an Ocular-Motor Test for Deception to a Mexican Population. *International Journal of Applied Psychology*, 6 (1) 1-9.
[51] Pendse, A., Kacker, P. (2020) Remembrance of Recent Vs. Remote Memory of an Event: A Key to Investigation of Cold Cases. *The Indian Police Journal*, 67, 89-95.
[52] Polich J. *et al.* (1994). P300 from a single auditory stimulus. *EEG and Clinical Neurophysiology*, 92(3), 253-261.
[53] Qin, L.; Dong, L.; Xu, W.; Zhang, L.; Yan, Q.; Chen, X. (2017). A vehicle in light brightens; vehicle out, light darkens energy-saving control system of highway tunnel lighting. *Tunn. Undergr. Space Technol,* 66, 147–156.
[54] Qin, L., Dong, L., Xu, W., Zhang, L., & Leon, A.S. (2018). Influence of Vehicle Speed on the Characteristics of Driver's Eye Movement at a Highway Tunnel Entrance during Day and Night Conditions: A Pilot Study. *International Journal of Environmental Research and Public Health, 15*(4), 656. https://doi.org/10.3390/ijerph15040656
[55] Shimojo, A.; Takagi, H.; Onuma, H. (1995). A simulation study of driving performance in long tunnel. *In Proceedings of the Vehicle Navigation and Information Systems Conference, in Conjunction with the Pacific Rim Transtech Conference, 6th International VNIS, a Ride into the Future, Seattle, WA, USA*, 96–103.
[56] Sivak, M. (1996). The information that drivers use: Is it indeed 90% visual? *Perception*, 25, 1081.
[57] Suresh, S., Mukundan., C. R. (1998) Visual Information in Young, Middle and Elderly Subjects – An Event Related Potential Study. *In proceedings of 9th World Congress of the International Organization of Psychophysiology*, Taormina, Sicily, Italy, 14-19.
[58] Trimble, E. (2017). The Influence of Colour Priming on Consumers' Physiological Responses in a Retail

Environment Using EEG and Eye-Tracking. *Doctoral Dissertation, University of Manchester. https://www.escholar.manchester.ac.uk/uk-ac-man-scw:313259*

[59] Wang, J. T., Spezio, M., Camerer, C. F. (2010). Pinocchio's pupil: using eye tracking and pupil dilation to understand truth telling and deception in sender-receiver games, *The American Economic Review*, 100(3), 984-1007.

[60] Wang L. (2019). Test and Evaluation of Advertising Effect Based on EEG and Eye Tracker. *Translational neuroscience*, 10, 14–18. https://doi.org/10.1515/tnsci-2019-0003

[61] Watalingam, R. D., Richetelli, N., Pelz, J. B., Speir, J. A. (2017). Eye tracking to evaluate evidence recognition in crime scene investigations. *Forensic Sci Int. 2017 Nov*, 280, 64-80. doi: 10.1016/j.forsciint.2017.08.012. Epub 2017 Aug 23. PMID: 28961443.

[62] Webb, A. K., Hacker, D. J., Osher, D., Cook, A. E., Woltz, D. J., Kristjansson, S., Kircher, J. C. (2009). Eye movements and pupil size reveal deception in computer administered questionnaires. *International Conference on Foundations of Augmented Cognition, Springer*, 553-562.

[63] WhetselBorzendowski, S.A., Campbell, A.O. (2016). The Utility of Mobile Eye Tracking Technology in the Forensic Analysis of Personal Injury. *Proceedings of the Human Factors and Ergonomics Society Annual Meeting, 60*, 485 - 488.

[64] Yan, Y., Yuan, H., Wang, X., Xu, T., Liu, H. (2014). Study on driver's fixation variation at entrance and inside sections of tunnel on highway. *Advances in Mechanical Engineering*, 7, 273427:1–273427:10. doi:10.1155/2014/273427

[65] Yang, C., Fan, S., Wang, Z., Li, W. (2011). Application of fuzzy control method in a tunnel lighting system. Math. *Comput. Model. Int. J,* 54, 931–937.

[66] Yeung, J. S., Wong, Y. D. (2014). The effect of road tunnel environment on car following behaviour. *Accid. Anal. Prev,* 70, 100–109.

[67] Yuan, W. (2008). Study on Drivers' Dynamic Visual Characteristics Experiments of Urban Road Environment. *Ph.D. Thesis, Chang'an University, Xi'an, China*.

[68] Yuen, N. H., Tam, F., Churchill, N. W., Schweizer, T. A., Graham, S. J. (2021). Driving with Distraction: Measuring Brain Activity and Oculomotor Behavior Using fMRI and Eye-Tracking. *Frontiers in Human Neuroscience*, https://doi.org/10.3389/fnhum.2021.659040

[69] Zhao, B. (1998). Driver's dynamic visual characters and its effects. *J. Highw. Transp. Res. Dev*, 15, 102–104.

[70] Zuckerman, M., DePaulo, B. M., Rosenthal, R. (1981). Verbal and Nonverbal Communication of Deception. *Advances in Experimental Social Psychology*, 14, 1-59.