

How Does the Brain Recognize Faces?: Facial Recognition and its Scopes in Technology

Alessandra M. Arpon^{1*}; Aman Mohamed Ashique²;
Zeinab Mahmoud³; Maham Nadeem⁴

^{1,2,3,4}Faculty of Humanities and Social Sciences MIE-SPPU Institute of Higher Education Doha- Qatar

Corresponding Author: Alessandra M. Arpon^{1*}

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Abstract: No two people look the same, even though human faces share many basic characteristics. What still defines diversity today is the variances in the form, size, and color of each human being. This paper emphasizes the significance of facial recognition since it heavily impacts a person's socialization process and neurodevelopment throughout the course of their lifetime. People depend on this brain function because human faces are utilized to extract socially significant information that is crucial for daily interactions and maintaining personal relationships. How the brain recognizes faces is still not completely known to this day. Scientists have conducted studies using rhesus monkeys and discovered that a set of neurons in the temporal lobe, particularly the Fusiform Face Area, is involved in recognizing facial features. These sets of neurons work to recognize faces; however, the exact position and number of these neurons are unidentified. The following topics within the sectors of facial recognition technology are covered, how facial recognition has paved its way to technology and the betterment of society. Moreover, covering the early development of facial recognition technology, which was initially developed by Woodrow Wilson Bledsoe with the use of computers in 1963. The findings of this paper indicate that while technological innovations in the field of facial recognition have demonstrated an increase in safety and security in every sector, their lack of transparency and inherent flaws can create problems and mistrust among members of society. Because of its many applications and significance, facial recognition is a topic that needs further investigation. The goal of this paper is to provide future scholars and researchers focusing on the effects of facial recognition technology with insights into a variety of sectors.

Keywords: Facial Recognition, Machine Learning, Facial Recognition Technology.

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I. INTRODUCTION

Human faces are frequently similar in that they have two eyes, a nose, and a mouth, yet the features of human faces differ greatly in color, size, and shape. The diversity of current society is the result of each person having a distinct blend of traits from their parents and direct ancestors. However, humans have become highly skilled over time at distinguishing the variation of features we see in faces and recognizing these faces.

The moment a baby is born, facial recognition begins, influencing the individual's neurodevelopment and social interaction throughout their lifetime. Faces are the most informative stimuli; a person's expression can provide information about their identity, sex, age, race, mood, and focus direction [1]. Facial recognition can be used to derive socially important information about an individual's relationships, attractiveness, and emotional state. However,

delays in facial recognition may occur. This happens when a person struggles to distinguish between the distinctive features of each person. These delays may be the cause of neurological disorders such as autism, Turner syndrome, and numerous others which might cause noticeable shifts in their level of sociability. In social situations, this may show up as hesitation or unease. Facial recognition is crucial for interpersonal dynamics and effective communication. People tend to depend on this brain function to stay acquainted with the various people in their lives [2]. Humans' capability to quickly process and recognize facial information in less than a second is crucial for navigating daily social interactions with ease. It was believed to have been essential to the survival of the primates who preceded humans [3].

How does the brain really recognize faces? It was thought that the brain has a specific area designated for recognizing faces called the Fusiform Face Area (FFA) in

the temporal lobe. This region of the brain, in contrast to the Lateral Occipital Complex (LOC), which concentrates on identifying objects based on their individual features, processes the face (holistic processing), that is, it processes the relationships between the various parts and features that consist of a face. Although it is primarily believed to be specialized for identifying faces, there is a disagreement, that goes on to state it is also most active when a subject matter expert in identifying objects that they are particularly skilled at [4].

A study in relation called "Becoming a Greeble Expert" focused on exploring the mechanisms for facial recognition where they used artificial objects as stimuli called 'greebles.' In this study, respondents were made to be experts in recognizing these so-called Greebles through various levels (i.e. sex, family, and individual) where they were trained in 8-10 sessions. Researchers found that during this experiment the FFA part of the brain was most active compared to the LOC which focuses more on object recognition and found Neuronal Inversion Effects (NIE) where FFA levels were higher when greebles were upright rather than inverted [5]. Additional studies were conducted, and one of these studies refuted the findings of Gauthier and Tarr. Brant, Wagemans, and Beeck (2011) made a similar study by replicating their ways of the experiment. They found that all subjects thought of Greebles as faces regardless of whether they were encouraging or discouraging them as living beings [4]. Further igniting the debate that facial recognition is the only function of FFA. However, issues were also found during Brant et. al's experiment, indicating that they couldn't replicate the experiments of Gauthier and Tarr correctly, raising questions about whether the proper training treatment was followed during the experiment.

This process is much more complicated than what was thought, though theories and discoveries have been made about sensory neurons that specialize in processing facial information, where and how the brain recognizes familiar faces is unclear (Freiwald, n.d.) [6]. In the first explanation of this phenomenon, the temporal lobe was identified as a critical location for facial recognition due to neuronal activity there being particularly picked for facial stimuli. The first account of face-selective neurons in the brain was given by Perrett and colleagues (1982), who concentrated their research on locating and quantifying the number of neurons in the temporal lobe that exhibit strong facial features and face selection in the rhesus monkey's superior temporal sulcus (STS). Their research paved the way for our current understanding of the neurological underpinnings of facial recognition. In the study, 497 neurons were tested for facial stimuli responses in rhesus monkeys from the STS using extracellular neuronal recordings. It was discovered that 48 of these 497 neurons responded to faces more strongly than any other neuron. After demonstrating active engagement and reaction times that corresponded with the presentation of the facial stimuli, these neurons were classified as face-activated neurons. These neurons were then evaluated for different ways to process sensory information. The study concluded that a portion of these

neurons is highly selective for visual stimuli of faces and facial features but exhibits little to no response to other stimuli. There had never been a description of this kind of extremely selective response to faces in brain neurons [7, 8].

Recent research has led scientists to reconsider how the brain processes facial recognition. Chang and Tsao (2017) [9], for example, studied how the coordination of hundreds of neurons in groups helps rhesus macaque monkeys recognize faces by focusing only on specific physical features. Two rhesus macaque monkeys were used in this research by scientists to map the locations of animal facial cells. Using functional magnetic resonance imaging, the researchers saw which areas of the monkeys' brains lit up in response to seeing human faces or other items. The study used a set of 2,000 human faces which varied in terms of features such as eye and hairline shapes, among other things. According to the findings of these investigations, a total of 205 neurons were recorded within the two monkeys, each of which reacted differently to different combinations of certain facial characteristics. Following that, Chang and Tsao wanted to test their theory that each neuron was more tuned to some physical features than to others within the sets of specific physical features. To test this theory, they attempted to recreate the faces that the monkeys were shown based on each neuron's response to the set of characteristics, and they discovered that they could almost perfectly recreate the faces based on the strength of those signals. Put differently, Leopold asserts that the brain "is able to realize that there are key dimensions that allow one to say that this is Person A and this is Person B" and that "the neuron is not a face detector, it's a face analyzer" [10]. However, little is currently known about the precise position and quantity of neurons in the brain that are devoted to facial recognition [8].

After gaining widespread exposure, facial recognition was integrated into technology due to its useful applications to real-world issues. In addition, to it being a basic human behavior that is necessary for relationship building to be successful [11]. Facial recognition technology (FRT) was initially developed by a team of researchers led by Woodrow W. Bledsoe. They carried out two studies that were regarded as the first attempt to establish a computerized facial recognition system to test the hypothesis that computers could recognize faces similarly to how brains do. The first study set out to determine whether it was feasible to build a device that could tackle simple face recognition problems using the computers that existed then. To identify the identity of a person that the machine is unfamiliar with, the study was carried out using high-resolution pictures taken from the same angle and perspective. The following report covered the project's expanded goals to a more complex facial recognition problem (i.e. different angles, perspectives, and lighting conditions). The report stated that their goals were much above what the technology could do at the time [12].

Facial recognition is a biometrics approach that uses automated techniques to confirm or identify a human being based on their appearance [11]. With time, FRT has been

incorporated into more facets of public life [13]. There are three processes involved in facial recognition using computer technology. First, one needs to detect the existence of a face. Second, the face needs to be measured to determine the individual's features. Thirdly and ultimately, the face's identity, sex, race, and expression must all be classified using the measurement [1]. FRT is still facing obstacles in some specific areas, such as position and lighting variations, but FRTs are already being employed in a wide range of fields to achieve specific goals adapted for each sector. To address these issues, several approaches and solutions have been put forth that appear promising [11]. Further breakthroughs and innovations being made and produced as these technologies are being incorporated into an increasing number of fields as society and technology continue to progress. Law enforcement and healthcare are two examples of such professions, that will be discussed in more detail.

II. BODY

➤ Technology

Bledsoe and his team of researchers paved the way for the future of FRT. Utilizing two studies and the ambitions Bledsoe had for this kind of technology has made way for many studies that explore the various fields that will be talked about. FaceIt, made by Identix, is an example of modern FRT; it automates the face identification process and has an easy-to-use interface. This technology is very similar to the Bledsoe facial recognition system, which uses feature sets in its device [14].

A study by Heo, Abidi, Paik, and Abidi (2003) used the FERET database to assess the FaceIt software. It is thought that this software was the most accurate on the market at the time. Two experiments were carried out for this study. The identification experiment was the first and concentrated on image variables, such as emotion, illumination, age, position, and face size, which were the main concerns of FRT. The two primary components of this experiment were the detailed test, which concentrated on the changes that impacted the system's performance, and the overall test, which monitored FaceIt's overall accuracy rates. The surveillance experiment was the name of the second experiment that was carried out. A tiny computer camera captured live face photos from actual scenes for this experiment. To observe how the variances were affecting things. They experimented with various lighting setups and database sizes. These tests revealed that a person's traits affect how accurate the facial recognition program is. More unique characteristics make a person easier for the software to identify. Despite the experiment's positive outcomes, it was determined that its chances of success would be reduced in practical settings [15].

A later device called the FaceReader addressed facial expressions, which serve as dynamic modifiers in face processing. Over 1000 institutions, research facilities, and businesses use Face Reader software worldwide since the program is a quick, flexible, objective, accurate, and user-friendly tool that can record audio and video and instantly

analyze data from live, video, or still images. Its specific role in facial recognition is that it operates through three stages: first, it detects faces using the Viola-Jones algorithm; second, it accurately models faces using an algorithm based on the Active Appearance method; and third, it classifies facial expressions by training an artificial neural network with more than 10,000 manually annotated images [16]. Facial recognition can either increase or decrease a person's trust in security-related situations. In terms of medical care, it might act as a clear indication of mental processes that manifest in a person's face. Additionally, in the classroom, identifying students' facial expressions and features gives teachers insightful input on their comprehension, level of engagement, and emotional state during talks. enabling the instructor to modify their strategies to create a more engaging and productive atmosphere. Overall, facial signals and the ability to identify them from a person's face features give rich information in a variety of areas and open new possibilities for improving society

➤ Brain and Healthcare

Facial recognition is becoming increasingly crucial in the healthcare industry. It helps to recognize body indicators like pain and discomfort, which not only helps with security but also supports faster and more responsive care. FRT has facilitated the identification and monitoring of patients, as well as the diagnosis of genetic, physiological, and behavioral disorders. Even though facial recognition has many benefits, its drawbacks are highlighted by different lighting conditions, facial occlusions, and technology constraints [17].

This kind of medical technology maps out a person's facial features using software, which stores the information as a face template. Following that, a database that compares facial photos for authentication or verification is created using these machine learning approaches. Even though it is now being used as a verification tool, machine learning has the potential to be a helpful tool for diagnosing or learning about diseases [18]. The facial traits of an individual can be used by doctors to make initial diagnoses and treatment decisions about certain diseases (e.g., Down syndrome, Turner syndrome, etc.). Early on in these disorders, a person's facial characteristics may exhibit less noticeable symptoms, which may go unrecognized by the unaided eye or healthcare personnel who lack the necessary training to recognize these variations. At that point, FRT enters the picture as a potential medium for resolving this issue. Treatment for these illnesses is frequently delayed, not to mention issues like places with limited access to healthcare resources, expensive medical care, and lengthy wait times for physical exams. Computer-aided face diagnosis facilitates rapid non-invasive disease screening, making hospitalization a more successful and efficient means of diagnosing illnesses [19].

By optimizing facial recognition technology and integrating it with artificial intelligence, a study by Amin and Neoaz (2025) sought to demonstrate the potential of these tools in detecting depression. Traditionally, clinicians have relied on structured interviews and standardized survey

questionnaires to diagnose depression in patients. This study does, however, demonstrate how modern equipment might offer a different and possibly more effective approach to evaluation. The advanced artificial intelligence shown in this study has the potential to improve speed, accuracy, and potentially reduce diagnostic errors. Given that AI systems can integrate and evaluate a wide variety of patient data through multimodal data analysis, they are particularly good at identifying depression. Certain facial expressions convey emotions, and those who are depressed display these expressions differently than those who are not. Facial recognition is expected to grow increasingly important because of these new technologies, which will change mental health diagnosis and improve service quality [20].

Combining facial recognition with neurological data offers a powerful and innovative approach to monitoring mental health conditions. Tanveer, Ahmed, and Khan (2025) demonstrated how this integration provides objective, real-time evaluations of mental illnesses by merging facial expression analysis with electroencephalography (EEG) brainwave data and sophisticated graph algorithms. Their AI system captures and analyzes subtle emotional cues from facial micro-expressions alongside neural connectivity patterns identified by EEG, which reveal disrupted brain networks associated with disorders like anxiety, bipolar disorder, and depression. For example, patients with anxiety exhibit characteristic fearful facial expressions detectable by the AI, paired with altered EEG signals showing excessive amygdala connectivity. Similarly, depressive states are marked by reduced facial expressivity coupled with decreased communication between the prefrontal cortex and limbic brain regions. The fusion of these modalities enables clinicians to obtain a comprehensive profile of a patient's mental state, enhancing diagnostic accuracy beyond traditional observational methods. Moreover, ongoing monitoring supported by this technology facilitates timely adjustments in treatment strategies, potentially improving patient outcomes. Despite challenges like data complexity and the necessity for extensive computational resources, this interdisciplinary method stands out as a promising advancement in personalized psychiatric care [21].

Neurological healthcare may also benefit from this technology's optimization, particularly regarding facial emotions. Early diagnosis and treatment of degenerative and neurological diseases including Parkinson's disease and Alzheimer's disease have been found to benefit from facial expression analysis. Early identification and treatment of many disorders are hampered by manual procedures. Recent research indicates that the application of modern facial recognition technology can help overcome this constraint. This method may open the door for future treatments of related illnesses and provides a more accurate and efficient means of identifying the emotions associated with these conditions [22]. Additionally, combining facial recognition through other forms of sensors or visual signals may help to increase the effectiveness of this strategy. Using body signals like heartbeat to recognize patient emotions more accurately is effective [23].

Security wise in healthcare, patient misidentification can pose a risk in healthcare settings and lead to several problems, including giving the wrong medication to the wrong person. A mobile health app was created for patient identification to get beyond the present restrictions on patient identification in the medical field. In essence, it seeks to offer a simpler substitute method for patient identification. It assessed sixty-two pediatric patients (both inpatients and outpatients) who had been tracked throughout the facilities for patient verification purposes and had been registered for the facial recognition test. The study's findings demonstrate that the app was able to check every patient with 99% accuracy even after surgery, regardless of whether they were asleep or under anesthesia [24]. Furthermore, earlier technologies had limitations in the healthcare sector and could only identify and cure genetic problems. Another study analyses the shared characteristics of hundreds of syndromes using DeepGestalt, a facial analysis framework that uses computer vision and deep learning algorithms to determine an individual's phenotypes of genetic illnesses. In three of the studies in this investigation, DeepGestalt performed better than physicians. A data set containing more than 17,000 photos representing more than 200 symptoms was used to train this classifier. In the last trial, DeepGestalt was able to diagnose the syndrome on 502 distinct photos with 91% accuracy. According to the findings, phenotypic assessments in clinical genetics, genetic testing, research, and precision medicine are enhanced by DeepGestalt [26]. Lastly, facial recognition technology is proposed to do away with the requirement for identity documents, enabling customized services and streamlining the visitor check-in procedure. Contactless check-in systems that use facial recognition reduce administrative burdens [25].

➤ Security

Nowadays, phones and other gadgets may unlock themselves using facial recognition, which is largely utilized in daily life. It serves as a purpose of protection, safety and security of individuals and can be expanded for use in various places like personal devices, health industries, government and law enforcement etc. Through the usage of technology, biometrics are made and used for this very purpose because of the uniqueness of facial features among humans and replicating the similar ability to differentiate among individuals are wired into a system of framework and databases on devices to help it. FRT is used to match faces of people in photos or videos and easily correspond with the database to find the right matching recipient. It is also through the help of IoT (Internet of Things) which is a form of network that connects technologies like devices, cloud servers or databases and gadgets to enhance better communication and exchange of data and information has shown to improve the effectiveness of facial recognition by enabling connected devices to share and process data efficiently [25]. Facial recognition is shown to be one of the few biometrics which produces best results of high accuracy and low error, with Crumpler (20020) reporting an accuracy of 99.97% based on NIST's Facial Recognition Vendor Test (FRVT), which was used to match individual with images of them by a verification test [27].

Along with the advancements in deep learning, the refinement of MobileNet convolutional neural networks (CNNs) have improved the feasibility of facial recognition on mobile and devices with limited resources. MobileNet's lightweight architecture is designed to reduce the computational requirements, which makes it suitable for real time facial-recognition applications. The improved MobileNet model described by Thakur and Khan (2024) incorporates techniques such as batch normalization, skip connections and data augmentation, with the authors reporting a recognition accuracy of approximately 95% for their proposed model [28]. These characteristics make the approach suitable for distribution on smartphones and edge devices where processing power and memory are limited. IoT integration further improves this capability by connecting mobile devices with cloud or edge infrastructure, facilitating data sharing and computational offloading. According to Thakur and Khan (2024), traditional models are 10-15% less accurate than the improved MobileNet model. They also reported an approximately 30% reduction in latency, which enables faster facial recognition responses in security sensitive applications [28]. The use of advanced processing techniques can help maintain performance under challenging conditions, such as variations in lighting and partial occlusion. Overall, the combination of an enhanced MobileNet model and IoT infrastructure provides a potentially scalable, low-latency, and accurate framework for facial recognition across diverse real-world applications [28, 29, 30].

Facial recognition has been widely and mostly been used in handheld devices or gadgets such as a mobile phone or laptops to access personal information in them or. There was a prior study on the usage of facial recognition technology by Wen Kun Zhang and Min Jung Kang (2019) used it as a form of payment method which they conducted using Chinese customers as an example. It has been said that even though people use passwords for atm or bank transactions people tend to overuse the same password at multiple places too or try to keep it simple to be easily remembered but by doing so will only expose themselves to dangers and their passwords can be shared or hacked into. Thus, they tried to see how many are willing to use facial recognition payments systems by taking into consideration security, visibility, openness, social image and the expected effort. It is an effective alternative that can be used in place of passwords and pins that may be overused or forgotten. The study was made to see how many people will come forth with accepting the new feature and useful results have been shown from those who did. The technology must be something that can be easily demonstrated and shown to individuals their purpose, uses and how effective it can be. There were still people who feared for their safety when using something new and different [31]. That is why it is important for the provider to have some sort of leverage such as a loyalty program to draw more customers towards the innovation. The first and utmost importance is the safety and trust between the provider or producer and customer.

FRT can be also used in schools, hospitals, industries, airports etc. to create a better well informed and secure

environment. It is a crucial element in the government and law enforcement to help them in their various tasks which include in finding of missing people through images like passport photo or ID or any other source, used in police cases such as murder, rape, battery and assault etc. and can be used as a tool to fight off any corruption or crime [32]. It has opened wide areas for faster and better performances in many sectors and boosting its purpose and uses along with it. Recent legal scholarship recognizes that existing privacy laws are insufficient to regulate facial recognition technology (FRT), especially as its use expands in digital surveillance and law enforcement. Traditional privacy protections, which focus on physical searches, do not address the complexities posed by automated, real-time biometric identification systems (Yanisky-Ravid & Fleming, 2024). These scholars strongly advocate for stricter regulatory frameworks to prevent misuse and protect civil liberties. Yanisky-Ravid and Fleming (2023) particularly call for banning the indiscriminate use of FRT in sensitive contexts due to heightened privacy and ethical concerns, especially involving vulnerable populations such as minors [33, 34]. Kim (2023) echoes these concerns by demanding enhanced transparency through regulatory oversight and approval of each new use of FRT to minimize discriminatory and oppressive outcomes. Both emphasize establishing clear accountability mechanisms, including private rights of action and independent investigations for instances of misuse and misidentification [34]. Complementing these perspectives, Gültekin-Várkonyi (2024) explores the European Union's data protection challenges concerning FRT use in law enforcement, highlighting risks such as non-compliance with data minimization, purpose limitations, and algorithmic accuracy. The study advocates for transparency and robust safeguards to ensure FRT enhances public security without undermining individual rights [35].

Along with its usage and importance it brings to help and save lives can also have a great deal of negative impact on them such as the multiple cases of misuse of technology where deepfakes were created to replicate a person's image for scandalous threats or blackmails especially towards celebrities and actresses or can also be used for cyberbullying as well [36]. The flaws in the technology can also result in employment losses, privacy invasion, biased outcomes, and a decline in public trust. Privacy intrusion and surveillance of biometric data through FRT's pose significant privacy implications if misused by organizations or individuals thus urging them to disclose their collection methods and ensure user consent. If not controlled and used appropriately, the technology's potential for widespread monitoring, lack of transparency, and technological flaws present significant hazards [22]. Scholars warn that algorithmic bias is a critical issue in facial recognition technology (FRT), with higher misidentification rates for racial minorities and non-male genders. This bias emerges mainly because the training datasets are often disproportionately composed of lighter-skinned, male faces, leading to skewed system performance that disadvantages underrepresented groups. For example, error rates for darker-skinned women have been reported to exceed 34%, while those for lighter-skinned men can be as low as 0.8%,

highlighting significant disparities (Buolamwini & Gebru, 2018). Such systemic biases not only perpetuate inequality but also contribute to discriminatory policing practices, wrongful accusations, and social injustice. To mitigate these challenges, solutions require the development and use of more representative and diverse training datasets that reflect the demographic makeup of the broader population. In addition, transparency in algorithm design and deployment is essential, ensuring that stakeholders understand the limitations and risks of FRT [38]. Furthermore, global regulatory and ethical frameworks emphasize the importance of explicit, informed consent over implied consent, especially concerning persistent biometric tracking in public spaces, to safeguard individual privacy and civil rights [39]. Without such comprehensive measures, the deployment of FRT risks harming marginalized communities and undermining trust in these technologies.

➤ *Law Enforcement*

Facial recognition is fundamental to human social interaction and plays a vital role in many facets of daily life, such as public safety, professional and personal partnerships, and interpersonal relationships. The complex brain mechanisms behind facial recognition have been clarified by recent developments in cognitive neuroscience, providing important new information that can guide and change law enforcement procedures, especially when it comes to criminal identification. Research employing neuroimaging methods, such as functional magnetic resonance imaging (fMRI), has identified specific brain areas associated with facial processing, including the superior temporal sulcus (STS) and the fusiform face area (FFA) [40].

Recent work by Yu et al. (2024) revealed that the superior colliculus, a midbrain structure, can detect faces within 40-50 milliseconds of exposure. This shows that face recognition begins not only in higher cortical areas like the fusiform face area but also through a rapid, evolutionarily older circuit. Such things can help explain why humans reflexively notice faces even in peripheral vision or poor lighting [41]. During face perception, these areas are essential for extracting facial features, processing identity-related information, and integrating contextual cues [42]. Rossion (2024) emphasizes the role of the anterior fusiform gyrus (antFG) as a central hub in the facial network. Unlike the posterior FFA and OFA, the antFG integrates perceptual and semantic information, allowing us to link a face to identity and social meaning. This means recognition is not limited to feature analysis but extends into memory and interpretation [43]. Furthermore, studies indicate that facial recognition entails intricate relationships between top-down cognitive functions including emotion control, memory, and attention, and bottom-up sensory processing [44]. There is great potential for increasing the precision and dependability of criminal identification processes through the application of cognitive neuroscience research to law enforcement. For example, a study conducted in 2017 by Edelman and colleagues showed that eyewitness identification techniques can be improved by applying neuroscientific concepts, which reduce the possibility of erroneous identifications and

enhance the likelihood of accurate recognition [45]. These guidelines seek to reduce the influence of cognitive biases on investigative outcomes by teaching law enforcement officers about the limitations of human memory and the variables, like stress and suggestibility, that affect eyewitness evidence. Furthermore, automated systems for monitoring and suspect identification have been developed because of advances in facial recognition technology. But these systems' efficacy depends on their capacity to replicate human-like facial recognition skills, which are shaped by intricate neural networks. More advanced and biologically inspired facial recognition algorithms have been made possible using computational modelling approaches in a study by Jones et al. (2020) to replicate the brain mechanisms of facial recognition [46]. These algorithms can identify suspects from surveillance film and forensic evidence quickly and accurately, which could improve law enforcement's capabilities. A 2025 study by Cuellar et al. tested facial recognition systems on degraded police images - low resolution, motion blur, and poor lighting - and found accuracy dropping sharply. False negatives and false positives increased, with women and black individuals disproportionately misidentified. This shows that the very conditions in which law enforcement relies on FRT are the same conditions that amplify its weaknesses [47]. Cognitive neuroscience findings have the potential to enhance criminal identification accuracy while also providing valuable insights for legal processes and policymaking concerning eyewitness testimony, lineup procedures, and the acceptance of forensic evidence. Through the incorporation of multidisciplinary viewpoints from the fields of cognitive neuroscience, psychology, and law, researchers and experts can work together to create evidence-based plans that improve the consistency and equity of criminal justice systems.

Learning more about how the human brain recognizes individuals can be very beneficial to law enforcement. It can enhance investigative techniques like facial recognition technology, eyewitness identification, and deceit detection by comprehending the brain mechanisms underlying person recognition. Even with the possible advantages, ethical and privacy issues must be addressed for law enforcement to use technology responsibly. By combining the fields of neuroscience and law enforcement, we may strive toward a more secure and efficient method of preventing and solving crimes. Taliaferro (2025) analyzed U.S. city – level deployments of police facial recognition and found only mixed effects on arrests and violent crime reduction. While some jurisdictions saw improved identification of suspects, others showed little measurable benefits. This raises questions about whether the current applications truly deliver on their promises of public safety [48].

➤ *Education*

The improvement in computer vision and cameras has led to the rise of FRT, and these systems work by scanning and comparing faces to a database of unknown faces. Facial recognition can help in attendance tracking in schools and universities, to verify the identity of employees, to unlock smartphones and even for surveillance purposes in some

countries. It reduces organizational workload and ensures efficiency. It enhances campus security by determining who is allowed access to specific areas. Learning experiences can be customized to each student's distinct facial expressions, emotions and level of participation by integrating facial recognition technology into instructional software, and it can be used for monitoring exams to prevent cheating.

Facial recognition technology identifies and authenticates people's identities by detecting, capturing and matching faces to images from a database [49]. Press sources from October 2021 state that nine schools in North Ayrshire accepted face scans as payment for school lunches. This new approach led to the speeding up of lines and it is more COVID-secure than card payments. Around 97% of parents and children gave approval for this new arrangement. David Swanston argued that transaction time is very significant and a secondary school must serve up to 1000 students in around 25 minutes. He said that facial recognition technology could cut the average time to five seconds per student. Facial recognition is prevalent in the US, especially in schools. Schools spend 2.7 billion dollars annually on campus security products and services because of school shooting incidents. These systems can recognize unusual people and can spot things that look like guns. This helps schools know who's permitted on campus and to keep track of identified individuals around the school premises [50]. The capacity to know where students and staff are means that 'Schools can stay focused and better analyze potential threats. Other than schools, it's also used in online learning. For instance, the use of webcam-based facial recognition ensures the integrity of different aspects of online courses. Similarly, another facial recognition technology called E-assessment security confirms the identity of students who take their tests online and makes sure they stay present during the whole test.

At times, facial recognition systems struggle with validity, which results in categorizing students based on race and gender, like non-white faces. The existing racial biases and stereotypes can worsen within school systems. Students are unable to blend in and they feel uncomfortable because of constant surveillance. Students use coping strategies to hide and maintain privacy in school. Facial recognition can be used to misuse power and normalize controlling behavior. Students cannot express themselves and they feel uncomfortable adjusting their facial expressions, as it ignores individuality and emotions [51]. Students are unable to maintain privacy because of constant surveillance and monitoring. There is compulsion and a lack of informed consent because of facial recognition.

About fifty years ago, Vygotsky introduced the Zone of Proximal Development in education (ZPD). According to the ZPD, learning and development depend on an ideal balance between support and challenge. This should be customized for each person based on their specific developmental stage [50]. The ZPD model was groundbreaking as it emphasized the learning process over the learning product and stressed the role of nurture in unlocking the internal potential of students. Some decades

later, research on the biology of learning revealed a beautiful alignment with Vygotsky's theory, showing that environmental factors have a specific impact on brain neuroplasticity and are highly affected by environmental factors, and the ratio of demands to resources greatly influences brain neuroplasticity [53].

In a study investigating the development of a facial recognition-based attendance management system as an alternative to conventional methods of attendance tracking. Conventional methods like fingerprint scanning and manual roll calls are unhygienic, inefficient and prone to mistakes. According to the latest studies, facial recognition technology is a contactless and incredibly effective alternative that reduces administrative workload and avoids proxy attendance. The system can detect and identify student faces in real time using methods such as Convolutional Neural Network (CNN)-based deep learning models, Principal Component Analysis (PCA) and Eigenfaces. CNN models provide better accuracy across a variety of lighting conditions, angles and occlusions than conventional techniques like PCA, which are best for frontal faces. The findings of the study show that the system demonstrates high levels of accuracy in frontal face recognition, with a detection rate of 98.7% and recognition accuracy of 95% [54], but the performance goes down with changes in facial orientation, like side angles or profile views. In comparison to earlier methods, face recognition-based attendance systems increase security, accuracy and efficiency. Future directions include adopting advanced deep learning for more reliable recognition, multi-camera integration for wider coverage and cloud-based analytics for real-time monitoring and insights [56].

III. CONCLUSION

This paper's results include how the brain perceives faces. Several studies have revealed that neurons in the temporal lobe are more adept at identifying the combination of facial traits that make up the face. The investigations concluded that additional research is necessary to learn more about the workings of the brain's facial recognition system and the applications of facial recognition in technology. Numerous experiments have demonstrated the accuracy of FRT, with the FaceIt programme being thought to be the most accurate. Researchers Heo, Abidi, Paik, and Abidi (2003) evaluated the accuracy using the FERET database. Their FaceReader system divides face classification into three stages, enhancing accuracy in recognizing facial characteristics and emotional expressions. This technology can enhance assurance in educational settings, healthcare, and security.

Following this, FRT has revolutionized patient identification and diagnosis of genetic, physiological, and behavioral disorders. By mapping facial features with the help of a software, doctors can make preliminary judgments on specific diseases, reducing errors in healthcare settings. The limited research on healthcare indicates that further studies and optimization of these technologies are greatly needed. The potential applications of facial recognition,

especially when integrated with other forms of data and technology in healthcare have been shown, and continue to be shown, to be valuable and essential. FRT technology, particularly in personal gadgets, is enhancing safety and security in various industries. Its effectiveness in identifying faces in images and videos, combined with IoT, ensures a secure environment. However, it also poses risks like privacy invasion and surveillance without user consent. Cognitive neuroscience which provides important new understandings of the brain underpinnings of facial recognition with significant ramifications for criminal identification and law enforcement. Using this information to improve technology capabilities, guide investigation procedures, and advance legal reforms, scholars and practitioners can collaborate to create more equitable and dependable systems for person identification in legal settings. FRT is changing schools by improving security, tracking attendance, and recognizing students' unique facial expressions. However, it can also cause issues like racial biases and discomfort among students. In education, the zone of proximal development (ZPD) focuses on finding a balance between providing support and posing challenges, with the environment affecting brain flexibility. Students need to actively participate in their learning while also keeping their privacy in mind. FRT has been used in various sectors such as law enforcement, education, healthcare, businesses, and airports. However, its lack of openness and technological flaws can cause challenges and distrust among society's citizens. To minimize risks and increase effectiveness, it is crucial to consider the technology's limits and uses, adjust it according to the environment, and provide necessary updates. By addressing these flaws, technology can be more effective and accessible to society, ensuring its continued use and benefits. To fully capitalize on the benefits of facial recognition technology, further research needs to be done.

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AUTHOR CONTRIBUTIONS

A. Arpon contributed to writing the original draft, including the abstract, introduction, and the technology and healthcare section of the literature review. A. Ashique contributed to writing the original draft, including the abstract and the security section of the literature review. Zeinab M. contributed to writing the original draft for the law-enforcement section of the literature review. Maham N. contributed to writing the original draft for the education section of the literature review. All authors contributed to the conclusion and reviewed and approved the final manuscript.

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