STRATEGIES FOR ADDRESSING PROSOPAGNOSIA AS A POTENTIAL SOLUTION TO FACIAL DEEPFAKE DETECTION

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ABSTRACT

The detection of deep fakes simulating human faces for potentially malicious motives is a constantly developing and interesting subject. According to prosopagnosia research, certain facial features and how they move can help people with the disorder recognise others. This paper outlines studies in the area of detecting and addressing the effects of prosopagnosia. For the first time, we suggest that the findings of these studies could be applied to the detection of deep fake faces, drawing a link between the facial features and movements most useful in combating the effects of prosopagnosia, with the features most productive for analysis in deep fake facial detection.

KEYWORDS

Deep fake detection, Facial recognition, Prosopagnosia, Deep learning & Biometric

1. INTRODUCTION

Advances in deep-fake technology present challenges around security and identity. As the realistic nature and credibility of computer-generated faces has evolved and improved, it is increasingly possible for fake facial images to be used in a manner conducive to deception. Consequently, technology for the detection of deepfakes must also evolve.

Prosopagnosia is a condition whereby a person has difficulty recognising faces of other people, even those who they know well. It is also referred to as face-blindness. A number of recent studies have shown that the effects of prosopagnosia can be mitigated somewhat by identifying which parts of a face, and which facial movements, are more beneficial to the subject recognising the other person, and to encourage coping mechanisms around those features.

In this paper we suggest that the findings of studies in mitigating the effects of prosopagnosia could be utilised in the detection of deepfake faces. This paper reviews studies in prosopagnosia mitigation with a view to identifying the parts of the face, and the facial movements, which are most useful in identifying faces. The work is reviewed in the context of applying the identified mechanisms for coping with prosopagnosia to the field of deepfake facial detection. The thesis being that those facial features and movements which are most suitable for facial distinction by someone with prosopagnosia may be the features that are most useful in distinguishing a deepfake face from a real face.

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2. BACKGROUND

Digital services provide platforms that enable users to create, share, and distribute digital assets. Such assets take the form of a mixture of text, images, sound, and videos. Due to the lack of strict restrictions on the reproduction of digital assets, they are widely replicated and distributed with minimal user expertise. It is important to be able to identify when a digital asset has been shared in a way that its provenance becomes questionable; we term such an asset as 'fake'.

Provenance is a general term indicating the perceived past ownership of an item. For a digital asset provenance is generally more difficult to ascertain. For example, a movie distributed by a publisher using Digital Rights Management (DRM) may not be considered fake while the versions of the movie not protected by DRM can be considered fake.

Deepfakes are created by digitally introducing additional images to augment the original image depicted in the source material [3]. Deepfake software that is widely available often focuses on the process of substituting one face for another in the video content and also on concurrently manipulating the accompanying voice. There has been an increased proliferation of deepfakes due to their ease of creation based on the availability of different software applications that allow users to easily create fake videos [4].

A current focus of cybersecurity research is in developing algorithms to expose deepfake content, due to the difficult in identifying real digital assets from their fake counterparts. Many international projects and competitions have been designed to detect fake content such as the Media Forensics Challenge (MFC2018) run by the National Institute of Standards and Technology (NIST)[5] and Facebook, as well as the Deepfake Detection challenge (DFDC) [6]. Much emphasis has been put on biometric models as they have produced better outputs that cannot be easily imitated based on the unique attributes of individuals.

Investigations have been conducted to assist researchers in understanding the underlying concepts of biometric models. The investigations focus on the facial region, which offers information about deepfake detection [8]. In this comparative analysis we aim to identify the most successful methods utilised to detect deepfakes. Despite the possibilities that emerge in the identification of the fake contents based on technical anomalies, they can be confused by the immense improvement of deepfakes creation techniques. So, detection techniques need to be focused more on understanding facial recognition using medical science. One such area is congenital prosopagnosia (CP), a neurological disorder characterised by the inability to recognise faces, even the faces of friends and family.

This study entails a survey of deepfake detection and prosopagnosia to explore potential connections between the two topics. Prosopagnosia has been identified and studied for many years. However, determining the neural foundations of developed illnesses such as prosopagnosia remains a problem, since routine MR brain scans do not show any clear anomalies. Therefore our study relies on exploring available research on CP to use the information from those studies to explore the field of deepfakes. Identification of the critical facial features assists in the accurate reproduction of faces and reinforces facial recognition techniques to overcome the issue of deepfakes. Exploring the overlap between these two different disciplines may provide valuable insight into the direction for further research.

In this paper a background is provided about the concept of deepfake technology and the problems that it causes, along with a brief introduction to prosopagnosia. The rest of this paper is organised as follows: section 3 - methods and data collection; section 4 - comparison of deepfake detection methods; section 5 –a detailed review of prosopagnosia and facial recognition including face processing, eye movement, and fixation in prosopagnosia patients. Section 5 also provides detection clues for the identification of faces and information about the use of training sessions for accurate face processing. The section 6 provides an in-depth discussion on the overlap between deepfake detection methods and prosopagnosia.

3. METHOD

Our primary research adopts secondary data in deepfake and prosopagnosia studies. The deepfake detection methods have been restricted in the last five years to all articles that may have used detection methods. Moreover, previous studies that are related to prosopagnosia based on face recognition have been used as data sources. The research discussion centres on what we know of face blindness. This medical condition prevents people from recognizing faces, which is similar to the potential of computer graphics required to produce a recognizable face. Do they inform each other?

The articles are organized in order, based on the published dates from oldest to newest. The data has been sourced from past research publications and reports published in reliable databases. We have only included articles published in English.

3.1. Data Collection

The data has been collected from the most relevant databases like IEEE Xplore Digital Library, ACM Digital Library, Springer Lecture Notes in Computer Science (LNCS), The British Medical Journal (BMJ) and Medicine Net. The keywords used for collecting the articles were fake image and video, detection deepfake, digital forensics manipulation, detection, face recognition, prosopagnosia, and face blind. All information extracted from the articles has been sorted in tables based on their classification to ensure easy access.

4. COMPARISON BETWEEN DEEPFAKE DETECTION METHODS

The classification of facial manipulation based on the level of manipulation can be categorised into four groups. Fig. 1[1] outlines the description of face manipulation based on the digital assets level of change. The four categories are:

Entire Face Synthesis: This form of manipulation utilises a Generative Adversarial Network (GAN) to create an otherwise non-existent face. This technique can produce an astonishing outcome of high-quality images[7].

Identity Swap: The face of a real person in a video can be replaced using this type of manipulation for the face of another person. Deepfake techniques are utilised to swap the face of the target with the source face [1].

Expression Swap: This face manipulation is also known as face reenactment, which utilises GAN architecture to modify the facial expression of the person[3].

Attribute Manipulation: This form of manipulation, also known as face editing or face retouching, entails editing a few facial characteristics so as to achieve minor changes without altering the person's identity[8].

The focus of this study is Identity Swap, in which an in-depth evaluation of the processes involved in replacing the face of the target person in a video using deepfake techniques with the face of the source are explored and reviewed.

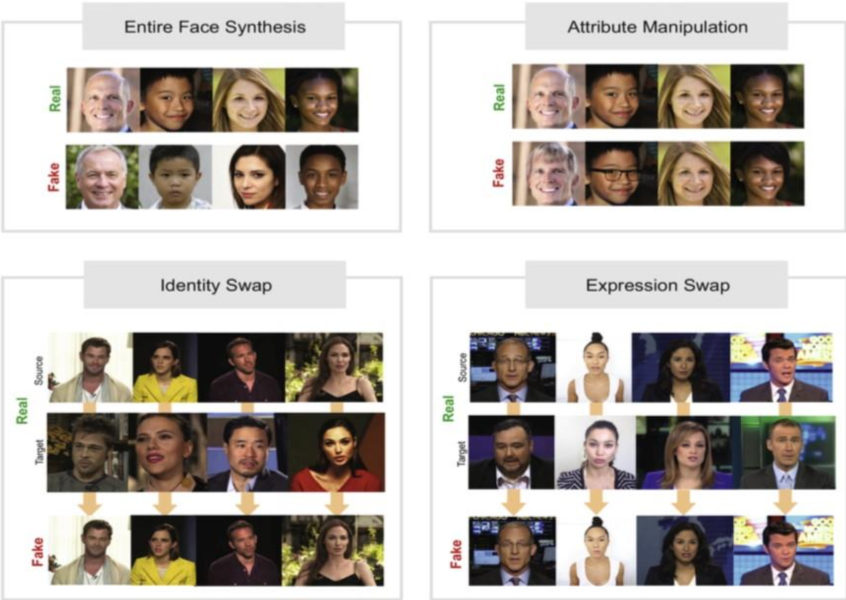

Figure 1. Examples of deep fake and real [1]

Deep detection methods are classified into three groups based on the attributes used in identifying deepfakes:

Biometric Models: There are human traits that are used in the detection and recognition of fake videos. The research conducted by Menotti et al[9] focuses on the application of biometrics systems as detection clues through the engagement of two approaches. The identification and authentication of people have been aided through the application and development of biometric systems, utilised by international, national, and personal entities as an integral security mechanism. Three important modalities are suggested for investigating spoofing detection: the iris, fingerprint, and face. These detection techniques are based on two algorithms, achieving architecture optimisation and filter optimisation.

Anomalies models: The artefacts left from the deep fake development process are the integral elements utilised by these methods to detect fake digital content. Kakaletsis and Nikolaidis [10] proposed a method based on a developed algorithm, which utilises sharpness estimation metrics. These algorithms are an extension of a metric known as Cumulative Probability of Blur Detection (CPBD). This algorithm is applied to the stripes around the foreground of the human figure, acting as the detection clue.

Compound Models: This method utilises the combination of different clues concurrently. Mittal et al, [11] explore this new approach to detecting emotions by proposing a Multimodal Emotion Recognition Algorithm (M3ER). The method utilises three cues (face, text, and speech) through the use of Canonical Correlational Analysis to distinguish between effective and ineffective artifacts. It is noted that one of the challenges associated with the application of this method is the potentail difficulty in identifying the cues to be combined to generate the expected outcome.

This section aims to identify the methods researchers have utilised to detect deepfakes and the detection clues deployed in the last five years of research. A comparative analysis of the available deepfake detection methods based on five criteria is shown in Table 1.

Table 1: Comparative between Deep Fake Detection Methods

Techniques	**Medium**	**Cite**	**Detection clues**	**Accuracy**
(GANs) model	Video	[7]	Eyes blink(Biometric models)	87.5%
CNN	Image	[9]	Iris-face-fingerprint (Biometric models)	98.93%
CPBD metric	Video	[10]	Sharpness of figure (Anomalies in image/video)	78.57%to71.43%
DNN	Video	[11]	The research utilised cues such as face, text and speech for the detection of sensory noises(Combined)	from 82.7% to 89.0%
CNN (Resnet50 model.)	Video	[12]	Landmarks the face, Head Pose estimator(Combined)	95.5%
CNN	Image	[13]	By detecting the modified face regions in an image(Anomalies in image/video)	94% to 74.9%
CNN	Video	[14]	Track the movement of the pixels(Anomalies in image/video).	92.36%
SWIR imaging system.	Image	[15]	Skin detection(Biometric Models)	(A) Masking Method- 49.0% B) ROI Method - 73.5%
(PPG) and LBP features.	Video	[16]	Bydetecting the pulse of the face(Biometric Models)	86.50%to95.08%
control the LED light intensity .	Video Image	[17]	The reflection of light in the face.(Biometric Models)	From 69% to 77%
CNN	Image	[18]	Observing some facial muscles(Biometric models)	non
DNN	Image	[19]	Discriminative feature in images generated by one of the GAN methods(Anomalies in image/video)	94.7%
SVM	Video Image	[20]	The deviation from the landmark location of the deepfake from the original face provides a clue for detection(Anomalies in image/video)	non
RNN	Videos	[21]	Exploit temporal discrepancies across frames caused by manipulations of faces(Anomalies in image/video)	98%
LRCN	Video	[22]	Detection of eye blinking in the videos(Biometric models)	non
DFT-MF model	Video	[23]	Mouth and teeth(Biometric models)	71.25%
(LSTM) model	Video	[25]	Frame sequence(Anomalies in image/video)	82%
(EM) algorithm	Image	[26]	Trace the pixels within the image(Anomalies in image/video)	From 88.40% to 99.81%

5. PROSOPAGNOSIA AND FACIAL RECOGNITION

Prosopagnosia is a condition that prevents the recognition of faces, even the faces of those familiar to the subject [27]. The condition is also referred to as “face blindness”. Recent studies review the struggle of subjects when attempting to match faces and judge facial expressions [28,29,31,32]. An object is first examined before judgment is made, with the orientation and judgment processes being different. Results show that unusual and normal arrangements of facial patterns are not significantly different. The research further establishes that subjects had difficulty recognising familiar faces, as well as unusual and normal arrangements of objects [33].

Facial recognition is a complex process: the left and right hemispheres of the human brain influence facial recognition [32]. Structures in the left hemisphere have an impact on the recognition of facial expressions. In contrast, the structures in the right hemisphere impact recognising figural and form components that are critical to facial recognition [34].

The brain undertakes a feature by feature analysis when a non-verbal component, such as a face, is the stimulus; this process takes place in the brain’s left hemisphere. The right hemisphere assesses familiarity. Sequential presentation of stimuli such as the face is considered more effective in recognition than a typical presentation, especially for an individual whose right hemisphere is damaged [28].

When evaluating the ability of people with prosopagnosia to recognise faces and facial expression, it is evident that sufferers can differentiate between typical and Thatcherized faces, and have a partial ability to recognise facial expressions. Thatcherization consists of a face image wherein the eyes and mouth have been turned upside down relative to the rest of the face. The results point to patients having lost their configural processing ability, affecting their ability to categorise typical and Thatcherized faces. However, they had intact feature processing ability that supported emotional face categorisation and differentiation between typical and Thatcherized faces[31].

5.1. Face Processing, Eye Movement and Fixation of Prosopagnosia Patients

An established mechanism for recognizing a person is to observe their facial features, especially the internal components such as the eyes, nose and mouth. According to Henderson, Williams and Falk [27], people focus more on specific attributes in the faces of others that give them a unique identity. This point is further explained by Van der Geest et al. [35], who confirmed that the most compelling features that grip the attention of an individual while looking at the face of another person are the eyes and the mouth. These features are critical for assessing another person’s identity, mental state and emotional condition.

However, based on the findings of Schwarzer et al. [36], prosopagnosia patients depend on external features such as the hair, neck and chin to give unique attributes to others. An individual’s face provides little information for people with CP, making them depend on alternative sources of information such as body movement [37]. Similarly, Bobak et al. [38] further explain that the nose region is a useful source of face recognition and can easily be used for telling the difference between individuals with similar attributes. Bate et al. [39] builds upon this by recognising the effectiveness of eye-movement (EM) analysis concerning the patient.

5.2. Detection Clues for Identifying Face in Prosopagnosia

Prosopagnosia usually affects people from birth, and they have to live with it for their entire lives. It may severely impact negatively on their lives because they cannot recognize their friends, family members or partners. This challenge has made people with the condition seek alternative methods of face detection. One way of achieving face recognition is by relying on external features that are often unique to individuals. According to Schwarzer et al. [36], external features such as hair, necks and chins are the critical elements used by patients to recognise people within their vicinity. It is worth noting that this strategy requires complex analysis; otherwise, it may not be practical, causing individuals with the condition to avoid social interactions or have an overwhelming fear of social situations. For instance, Bate et al. [39] concluded that individuals with prosopagnosia could easily recognise the faces of others by relying on features external to the face.

Bennetts et al. [37] find that observing a face in motion can assist people in the general population to recognise others, and a similar result was obtained in individuals who rely on movement cues as a supplementary strategy for processing faces. For accurate analysis, there is a need for further investigation to examine the strategy in the context of familiar face recognition. The study concludes that individuals are better at recognising faces when movement is involved compared to situations with still images. A clear outcome through observing a familiar face in motion can significantly assist people with prosopagnosia to enhance face recognition in certain circumstances. They can learn and identify patterns in facial transition whereby movement is a vital cue under conditions of face recognition impairment.

Patients with prosopagnosia tend to rely more on the shape of the mouth than nose structures to recognise people [32]. Burra, Kerzel, and Ramon[40] affirm that people with CP rely on external features for face recognition because they have difficulty processing information based on the eye region. Diaz [41] also found that the participants in the study relied on non-facial cues such as hairstyle, gait and voice as well as location to recognize people. Moreover, Caldara et al. [42] concluded that the lower part of the face, especially the mouth and the external contours, can be instrumental when processing familiar faces. This is in marked contrast to normal observers who use eye information to identify familiar faces. Fine [43] also identified that features such as unusual clothing or a particular facial element such as a type of moustache could assist in facial recognition. Amanda et al.[44] present their arguments for effective face recognition based on eyebrows, blemishes and other distinctive features such as skin tone.

5.3. Rehabilitation and Training of Face Processing

Based on earlier studies about face recognition, critical analysis has been conducted to identify techniques that can be adopted to improve face recognition for individuals with prosopagnosia. Schmalzl et al. [38] investigated face-processing skills, training of familiar face recognition and analysis of visual scan paths for faces. During the experiment, the subject was asked to decide whether 90 pairs of simultaneously presented faces were the same face or not, based on three conditions: first the ”spacing”, then the ”feature”, and lastly, the ”contour” set.

Table 2: Face Recognition in Prosopagnosia Condition.

Source	Recognition Clue in prosopagnosia
[32]	Mouth then the Nose.
[36]	External features, such as hair, neck,and chin.
[37]	Alternative sources of information (e.g., bodies or movement).
[40]	External features – avoid processing information using the eye region.
[39]	External features.
[42]	The lower part of the face, including the mouth and the external contours, as normal observers typically do when processing unfamiliar faces.
[44]	eyebrows, blemishes, distinctive features, skin tone.
[43]	Extra facial Information e.g., wear unusual clothing, characteristics or particular facial things e.g., type of moustache.
[41]	Non-facial cues contextual and visual cues to identify individuals like Hair style, clothing, gait, voice, and location.

The results obtained before training were (accuracy: eyes, 25%, nose, 20%, mouth, 45%). After training, the subject still directed the largest percentage of dwell time to the nose (M 1⁄4 35.5%), followed by brow (M 1⁄4 27.1%), eyes (M 1⁄4 25.4%) and mouth (M 1⁄4 2.7%), respectively. The pattern for familiar faces (nose, 28.9%; eyes, 29.2%; brow, 29.1%; mouth, 2.2%) was different from the one for unfamiliar faces (nose, 42.2%; eyes, 21.7%; brow, 25.2%; mouth, 3.2%), with eyes being focused on longer than brow for familiar faces. This experiment represents the second successful training study in childhood CP, showing that improvement in recognition of familiar faces can be rapidly obtained and long-lasting through targeted training. In addition, it represents the first report of eye movement recordings in childhood CP, suggesting that abnormal scan paths for faces might be a common underlying factor of this condition.

A similar investigation by Pizzamiglio et al. [32]focused on improving the subject's ability to explore face's internal features and identify specific facial features of familiar and unfamiliar faces. This provided the subject's family with strategies to use in the future. Before training, most fixations were nose, 34%; eyes, 20% and mouth, 46%. After training, LG's fixations over the eyes increased to 39%, the mouth decreased to 31%, while the percentage over the nose did not vary. None of the differences among the three regions was significant. At follow-up, the percentage of fixations over the eyes showed an additional increment reaching 51%, whereas it decreased 17% for the nose and remained the same at 32% for the mouth. The eyes now received a higher percentage of fixations than the nose and the mouth. The post-training and follow-up eye movement recordings showed that the subject had improved in identifying familiar and unfamiliar, incomplete and complete faces. Additionally, the subject's parents reported that in day-to-day life, they noted improved ability to recognise familiar people even when they were disguised or had modified their appearance by cutting their hair. This information complies with the findings of Bate et al. [39], where their subject's training programme was designed to improve the ability to make fine-grained discrimination between faces, targeting processing at the perceptual rather than the mnemonic level. Before the training, the subject spent less time on the inner features and more time on the outer features for all faces regardless of expression. The subject spent 46.18% of the time on internal features and 48.56% of the time on exterior features in the neutral emotion. After the training was completed, there was a marked improvement in perception of trained and untrained faces, and more time was spent on examining the inner facial features.

Mayer and Rossion [29] describe a training exercise to concentrate on, and verbalise, the internal facial features of different faces. Before training, it was identified that subjects relied on non-facial features and/or features like a moustache, scar or blemish for facial recognition. After training, the participants started to rely more on the internal components of the face for recognition. It was concluded that there was a significant improvement in recognising faces using internal features, subjective improvement, and increased confidence.

Brunsdon et al.[40] designed a training programme to improve the subject's ability to perceive and discriminate between facial features and facial characteristics, while decreasing reliance on nonfacial cues such as hairstyles and glasses. The training was also intended to reduce the tendency to mistake unfamiliar faces for close family members and improve ability to recognise the faces of family members. Before the training, the assessment results suggested that perception of facial features, especially the eye and nose regions, were poor since difficulty was exhibited in extracting certain information regarding the features of the face. After training, there was a significant improvement in overall ability to discriminate between the eyes, nose and mouth features. DeGutis, Cohan and Nakayama [41] conducted training to integrate spacing information from the mouth and eye regions. The participants performed well on the objects and body conditions before training and focused on specific features of the face, like the mouth, more than other features. The training improved perceptual integration abilities across the entire face rather than specifically to the eye and mouth regions. From the findings, there were improvements in front-view face discrimination and clear evidence of holistic face processing.

Several conclusions can be made from these studies into rehabilitation of prosopagnosia. Firstly, individuals with the disorder often focus on external facial cues to clearly identify others; hence, they avoid internal facial features, especially the eyes and nose and the area between them. Secondly, several training and rehabilitation programmes are based on changing eye movement and fixating to persuade them to focus on internal features to improve their ability to recognise faces. This is because individuals with CP have impaired holistic processing of the face, making it necessary for them to consider multiple facets of the face to recognise people. Furthermore the eye and the nose regions are more reliable for face recognition than mouth morphology. Finally, this study found that it is beneficial to distinguish more than one element for practical face recognition.

6. Conclusions on the Influence of Prosopagnosia on Deepfake Detection Methods

The study of prosopagnosia helps us identify the facial features that give us clues to facial recognition. However, based on the results of a face recognition blindness case study, we can suggest that the eyes and the nose can provide information for facial recognition more so than the mouth region. Most people who have face blindness focus on the mouth and external facial features to identify faces. As Mann et al.[30] put it, ”training can be used to improve facial recognition performance”. So, the majority of rehabilitation and training programmes for CP patients focused on changing eye movement and encouragement to concentrate more on the internal facial features, especially the eyes and the nose, as well as the area between them, which showed improvement in the patients' performances. To further investigate this supposition, we reviewed the accuracy of all the deepfake detection methods that used biometric clues in Table 1, and found them to be in agreement.

The research conducted by Jung and Jun [7] showed a method of identifying deepfake videos using the blinking of the eyes as the clue, the accuracy of this method is 87.5%. Another method illustrated by Jafar et al.[23]to detect deepfake video was using the mouth and teeth as clues with an accuracy of 71.25%. The method that relies on the eye region achieved higher accuracy rates than the method that depends on the mouth region. Another suggestion to get more accuracy in detecting deepfake is to use more than one cue to improve facial recognition. This should include one of the internal features of the face as referred to in our first suggestion. To verify this, we consider Table 1 and compare the accuracy of these two methods, and the method conducted by Jung and Jun.[7], which relies on one clue: the blinking of the eyes with an accuracy of 87.5%. On the other hand, we have a method conducted by Menotti et al.[9]that relies on three biometric clues. In this study, the detection clues revolve around the iris, face and fingerprint. The accuracy is 98,93%, which is the highest compared to the previous methods. Moreover, the method conducted by Menotti et al.[9] meets the conditions provided by our suggestions because it uses a combination of clues which include the internal region of the face.

This paper has identified a number of studies indicating that coping methods for prosopagnosia can be built around specific areas of the face and facial movements. Our contention is that issues around the detection and identification of deepfake faces could be addressed through adopting a similar approach. Further work will address this through modelling deepfake detection routines based on the findings from the studies on prosopagnosia mitigation.

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