Acquired prosopagnosia and provoked overt face recognition: is variation the key to neural face representation?

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ABSTRACT

Prosopagnosia, refers to neurological patients who cannot recognise familiar others from the sight of their face (Bodamer,1947). Case studies of prosopagnosics have been crucial in the development and constraint of face processing theories. Previous research has evidenced some prosopagnosics ability to respond to familiar faces below the level of conscious awareness (covertly). Other researchers have reported covert to overt face recognition in some prosopagnosics under specific conditions. The present study has replicated this effect with prosopagnosic Herschel by using varied images of a familiar person's face. Overt recognition was elicited for public figures both before and after the onset of Herschel's prosopagnosia- evidencing new face representations have been established since his diagnosis. Results show stored semantic knowledge can be activated by varied representations of the same face, alluding to how faces are learnt and represented in the brain. Findings are discussed in the context of theoretical implications, clinical application and future avenues of research.

INTRODUCTION

Acquired Prosopagnosia (AP) manifests as an inability to recognize others through inspection of their face. Symptoms vary across patients indicating no single cause of the deficit. AP suggestibly arises through the breakdown at different levels of face processing (Sergent & Signoret, 1992). In the late 20th century, case studies of APs allowed psychologists to distinguish between overt and covert face recognition. These processes differ in terms of a patient's insight into their ability to recognise faces (Young & DeHaan, 1992, pg. 77).

Covert facial recognition (CFR) refers to the ability of some APs to discriminate familiar from unfamiliar faces, despite lacking awareness of this. This phenomenon has been robustly demonstrated in APs using both psychophysiological (e.g., Bauer, 1984; Tranel & Damasio, 1985) and behavioural measures- tasks which are sensitive to face familiarity but face identification responses are not required (e.g., De Haan, Young, & Newcombe, 1987). Overt face recognition (OFR) refers to the very function in which APs are impaired. OFR describes the process of recognising a face and the experience of familiarity and knowledge of that person which occurs whilst doing so.

Sergent and Poncet's seminal case study of patient P.V (1990) demonstrated the possibility of temporarily provoking OFR in a prosopagnosic through the use of a semantic activation task.

Researchers first demonstrated P.V.'s ability to covertly recognise a set of politician's faces, despite her showing no conscious recognition of them. Later, P.V. was shown eight politicians faces simultaneously and asked to identify them, which she initially was unable to do. When told the faces shared an occupation, P.V. stated they were politicians. Spontaneously, she was able to name almost all the faces accurately, whilst providing relevant semantic information about the politicians (meaningful knowledge the politicians e.g., Jeremy Corbyn is an ex-Labour Leader in UK Parliament).

Results suggested OFR was triggered by simultaneous presentation of faces from the same category (politicians). Common semantic information was raised above a threshold level, causing links between faces and the memory of that person to be established. Results demonstrated P.V.'s prosopagnosia reflected difficulties accessing relevant memories of individuals. It was inferred AP was not amnesic in nature, but resulted from the breakdown of different levels of face-recognition processes (Sergent & Poncet, 1990).

Nevertheless, provoked OFR has only been replicated in a limited number of studies (De Haan et al. 1991; Sergent & Signoret, 1992a; Diamond et al., 1994). Further research showed likelihood of occurrence increases by narrowing of semantic categories of target faces e.g., showing eight actors faces from the same TV show. Self-generation of semantic information was also found to be crucial for OFR to occur. Covert to overt recognition was hoped to be a basis of rehabilitation for APs, however the effect was deemed too inconsistent to be of use in applied clinical settings (DeGutis et al., 2014). Research of covert to provoked OFR has consequently laid dormant in recent years.

The present study adapted Sergent & Poncet's (1990) classic study with the aim of provoking OFR in a 65-year-old prosopagnosic, Herschel (a pseudo name used to preserve anonymity). Unlike classic semantic activation tasks which elicit face recognition through exposure to different faces from shared semantic categories (e.g., politicians); the present study used simultaneous presentation of multiple varied images of one face. If OFR occurred it could be attributed to variation in images, not a result of semantic activation of an occupational category. The authors theorise that individuals learn faces through repeated and varying exposures to that stimulus, an intuitive consequence of the varying perceptual conditions (e.g., lighting, angles, expressions, location) of the real world in which we see faces. These varied face representations may be distributed widely across the brain, linked by the semantic information (the identity and relevant knowledge) of whom the face belongs.

This research aimed to address the following questions: (i) How are faces learnt and recognised? (ii) Can face learning occur independently of core face processing regions (i.e., is face learning reliant on the right fusiform gyrus, rFG)?

A familiarity phase involved exposing Herschel to varied images of the same public figures (PFs) serially. This set a baseline performance, and faces deemed familiar were removed from the array. Next, a recognition phase aimed to elicit OFR in Herschel. This involved showing participants 6 varied images of the same PF simultaneously. During stimulus presentation questions were asked which increased in specificity.
Experimental stimuli were split into conditions: pre-2008 and post 2008 (aiming to provide evidence of face learning since Herschel's AP onset). Consulting both the aforementioned theory and previous evidence two hypothesis were made:

(1) Herschel will perform poorly in the familiarity phase compared to controls, claiming the majority of images to be unfamiliar. Herschel may recognise a few highly distinctive images (e.g., Margaret Thatcher).
(2) In the recognition phase, Herschel will experience spontaneous OFR for a number of PFs in both the pre- and post-2008 conditions.

CASE REPORT: HERSCHEL

Herschel's full case report is provided by Rezlescu, Pitcher & Duchaine (2012). A brief summary is provided below:

Herschel is a prosopagnosic 65-year-old, right-handed British male. He suffered strokes in February and June 2008, and multiple transient ischemic attacks in August that year. As a result, Herschel experienced significant damage to the lateral occipitotemporal cortex, predominantly in the right hemisphere of the brain. Affected areas include some of the 'core' neural face processing regions: (i) the occipital face area (OFA) involved in the structural processing of invariant face features (ii) the right fusiform gyrus (rFG) involved in processing higher-level face information and mediating identification (Sergent et al., 1992; Hoffman & Haxby, 2000).

Herschel is not cognitively impaired and was reported in the 98th percentile for his age group in a standardized IQ test. Working memory and language tests were also reported to be within normal range.

Herschel showed persistent prosopagnosia, and some upper visual field loss. He has since performed in the upper ranges of visual acuity, contrast sensitivity, and colour perception tests. As Herschel's visual processing is unimpaired, the possibility the locus of Herschel's

prosopagnosia as being perceptual is ruled out. Behavioural studies show Herschel is impaired in facial recognition, face matching, and making judgements on facial expressions and gender.

METHODS

PARTICIPANTS:

The experimental condition consisted of one participant, Herschel. Herschel is a 65-year-old male with AP. A control condition consisted of three healthy age-matched controls (mean age= 71 years, SD= 6.34).

MATERIALS:

The experiment was run using Microsoft PowerPoint. Data collection was carried out remotely in one-to-one sessions with participants using zoom video conferencing technology.

Familiarity Task:

Experimental stimuli consisted of 60 headshots of 10 PFs (six unique photos of each PF). These were divided into two subcategories: pre-2008 and post-2008 (reflecting PFs from before and after prosopagnosia onset). 60 headshots of control PFs were also used (foreign celebrities, unfamiliar to all participants). A comprehensive list of stimuli used can be found in appendix A. Images were cropped ensuring participants would derive identity information from the PFs face alone. Experimental and control image presentation order was randomised using Microsoft Excel. There were two criteria for image selection: (i) Only colour photographs were used (ii) no two images of a PF could be taken from the same photoshoot (ensuring variability across all images).

Note: due to experimental error- one image was not present in the familiarity phase. A total of 59 experimental images were used (missing image: Paul McCartney, Image 5).

Recognition Task:

Experimental stimuli consisted of 20 slides (one for each PF). Each slide contained 6 images of the same PF (scaled to 6x5 cm and numbered 1-6). If participants recognised any images in the familiarity phase, these pictures were replaced with unseen headshots of the same person.

PROCEDURE:

Prior to the experiment, a pilot study was carried out to ensure the study design was appropriate. All experimental sessions were recorded with consent. Participants were paid £10 in Amazon vouchers for their time.

Familiarity Task:

Participants engaged in a short practice round using 3 images of arbitrary PFs, familiarising participants with the procedure. Familiarity task stimuli consisted of the 120 face images (60 experimental and 60 control). As shown in figure 1, images were presented serially on a white background for 3 seconds. Each face presentation was followed by an untimed interstimulus interval (a blank screen), in which participants could make their response. During interstimulus intervals, participants stated whether the face presented was familiar or unfamiliar, and gave any other information e.g., the person's name or occupation.

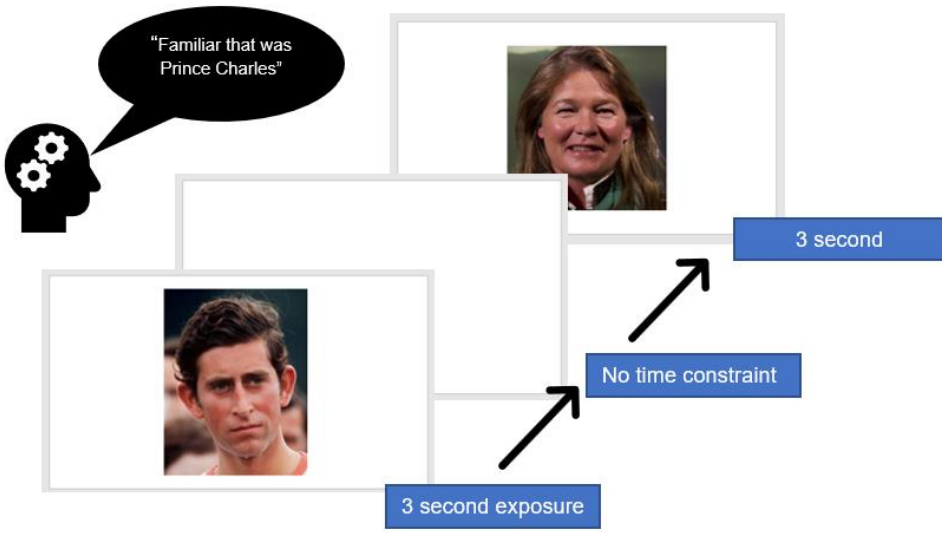

Figure 1. *Example stimuli used in the familiarity phase. Prince Charles (front; pre-2008), Charlene de Carvalho-Heineken (back; control). The PF image was presented for three seconds followed by a blank screen. Participants stated whether the face was familiar or unfamiliar; giving extra information if possible e.g., name, occupation.*

Recognition Task

Prior to this phase, images which had previously been stated as 'familiar' by participants were replaced with unseen headshots of the same PF. As illustrated in figure 2, participants were shown images of each PF for an unconstrained amount of time. During stimulus presentations, experimenters asked: *(i) Do you recognise any of these people? (ii) They are all the same person; do you know who? (iii) Can you give any information about the person?* If the subject recognised the PF, they indicated which images they recognised individually.

Figure 2. *Example stimuli for the recognition phase. Six images of Jeremy Corbyn numbered 1-6 (post-2008).*

RESULTS

Familiarity Phase

Data for both Hershel and controls are summarised in table 1. Hershel's prosopagnosia was displayed by his poor performance in identifying faces in this phase compared to healthy controls.

Hershel recognised 12/59 of the familiar faces presented: stating they were both familiar, and giving their names. This amounted to 4/10 PFs being identified: Liz Truss (2/6) Kier Starmer (2/6), Margaret Thatcher (5/6) and Bill Clinton (3/6). All other images were declared 'unfamiliar' (37/59). Hershel correctly labelled all control images as unfamiliar (60/60).

In contrast, 10/10 PFs were accurately identified by all control participants. Control images were also correctly labelled unfamiliar (mean correct rejections= 58/60).

Table 1. *Participants face identification performance on the familiarity phase.*

	Controls (n=3)	Herschel
Age	71	65
Number of Face Images Correctly Identified	57/59	12/59
Recognition Accuracy	96.61%	20.34%
S.D.	1.73	

Note. Mean scores are presented for the control condition, raw scores are presented for Hershel. Recognition Accuracy represents the percentage of known faces correctly identified by participants. A total of 59 familiar face images were displayed (6 images for each PF). 1 image was removed from data due to technical error (Paul McCartney image 5).

Recognition Trials:

As shown by figure 3, the control condition showed consistent ceiling effects, correctly identifying 10/10 of experimental PFs across recognition and familiarity trials. In contrast Herschel's performance showed a 30% improvement in the recognition phase, showing OFR for 7/10 of the PFs presented. This included faces which had been declared 'unfamiliar' in the first phase of the experiment.

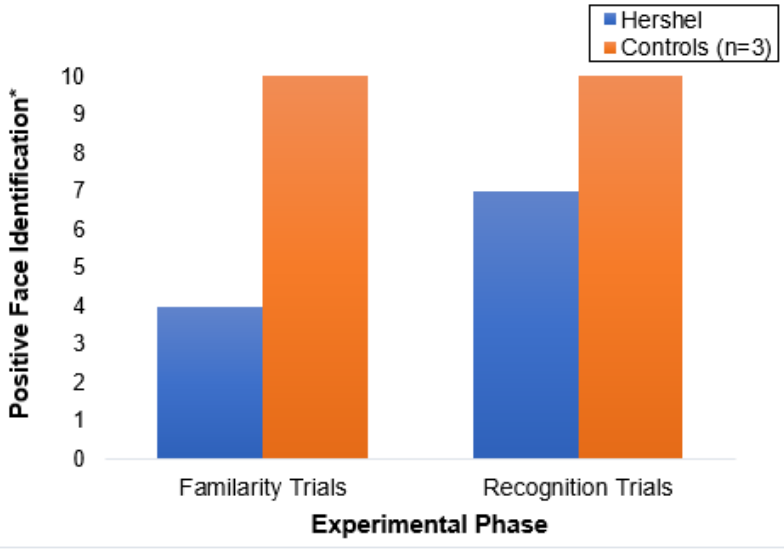

Figure 3. Bar chart comparing face identification performance across trials.

**Note.* Total number of known PF to be identified was 10 (5 pre-2008, 5 post-2008). Face identification criteria: at least one image of that individual is correctly named.

DISCUSSION

In light of present findings both null-hypothesis can be rejected. Hershel's poor performance compared to controls in the baseline familiarity phase gives some insight in to the extent of his prosopagnosia- (only 20.3% familiar PF images recognised). He did recognise at least one image of 4/10 PFs in this phase, stating they were identified due to distinctive features such as Margaret Thatcher's "pearl earrings", and Bill Clinton's "combed back hair". These extra-facial cues are known to be utilised by prosopagnosics to aid face recognition (Adams et al. 2020). Importantly, Herschel showed a marked performance in the recognition phase (30% increase in number of PFs identified) when varying images of the same PF were presented simultaneously. This occurred for both pre- and post-2008 condition images. Results will be discussed in the context of the present research questions: (i) How are faces learnt and recognised? (ii) Can face learning occur independently of core face processing regions (i.e., is face learning reliant on the right fusiform gyrus, rFG)?

Herschel overcame some of his prosopagnosic disturbance in the recognition phase, accurately identifying PFs whose faces he was previously unable to evoke even a sense of familiarity from. This suggests variation in images is reflective of how faces are represented in the brain, and the synchronous activations of varied representations of one known face is enough for links between that face and semantic information about that individual to be consciously established. Alternatively, as the majority of overtly recognised faces were politicians, it could be suggested Herschel's OFR was a result of self-generated semantic category activation (one of the conditions for OFR in the classic case studies). However, this is unlikely due to the OFR of Paul McCartney. Herschel accurately categorised McCartney as a musician, an occupation semantically unrelated to the other politicians recognized.

It could also be argued Hershel's OFR was due to the repeated exposure of face stimuli 'building up' to the threshold level of recognition. Shallice claimed that if a disorder is due to an access impairment (such as AP) repeated exposure to the same stimuli with the same task-requirement should 'warm up' previously inaccessible representations (Shallice, 1987). DeHaan and colleague's research challenged this idea by conducting a repeated verbal identification task of face images with prosopagnosic patient PH. They described the task as "unsuccessful in effecting any improvement of overt recognition" (1991, pg. 2585). Herschel's provoked OFR effects were likely not influenced by repeated presentation of face images, but two adapted replications of the current study are required to rule out this possibility. This will consist of the same stimuli format but using (a) two familiarity phases

prior to the recognition phase (b) A familiarity phase followed by a recognition phase, and then followed by another familiarity phase. We would expect no improvements across familiarity phases in study a, but the same OFR improvements in the recognition phase as found in present results. In study b, we would expect to see provoked OFR in the recognition phase, followed by a decrease in recognition in the following familiarity phase (due to the transient nature of provoked OFR).

In regards to the latter research question, Herschel's OFR of post-2008 PFs provides evidence of face learning in prosopagnosia. Herschel's lesion has damaged the OFA and the rFG, suggesting it is possible to build face representations independently of these 'core' face processing regions. It could be argued face representations are distributed across the "extended" face processing system such as prefrontal brain regions (e.g., the inferior frontal gyrus and orbitofrontal cortex) which serve a variety of cognitive functions related to the processing of changeable aspects of faces (Haxby et al., 2000; Ishai et al., 2005). This finding holds yet another intriguing avenue for further research.

Unfortunately, classic covert to provoked OFR methods do not hold promise for clinical applications due to (i) the transient nature of effects, and (ii) the limited number of prosopagnosics treatment could benefit. Bruyer (1991) comments that covert and OFR methods are not effective for patients whose disorders are perceptual in nature, or whose impaired function is not limited to face processing. Despite this, present findings contribute a new neurocognitive perspective of the importance of variability in how faces may be learnt and recognised. With further research, the development of clinical applications which take this perspective into account may be fruitful.

Finally, an issue in both the present study and wider literature of prosopagnosic research is controlling compensatory cues to identity. Prosopagnosics are well practiced at utilising atypical cues to identify others such as: extra-facial cues, distinguishing features (unusual eyebrows, blemishes, distinctive features, skin tone), and visual association i.e., creating memorable links between a person's identity using objects and locations (Adams et al. 2020). Herschel alluded to some of the cues listed during recognition e.g., when observing Ernie Wise images, he stated he could not recognise the face as there were "no distinctive facial blemishes", he also associated Prince Charles' face with the 'tweedy' material of his jacket. Though these details were seemingly insignificant to controls, Hershel has had 14 years-experience of using these cues as compensatory face identification tools. Future study replications will remove potential extra-facial cues by cropping around face images. Despite the benefits, such changes to methodology come at the cost of ecological validity. Across

the majority of face recognition literature, it can be argued face stimuli used (still images of faces) are unrepresentative of real-life face recognition. As we isolate faces from any other information, experimental stimuli become further isolated from their natural context. Compensatory cues may be controlled, but validity is eroded. The balance between these two issues must be carefully held.

In conclusion, variation could be a crucial factor in how faces are represented across the brain. Herschel's recognition of post-2008 PFs suggests face learning can occur independently of some 'core' face processing regions. It is recommended that both replication and extension is conducted to strengthen these results. The present findings hold cautious optimism in the development of theoretical understanding of how we learn and recognise faces.

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APPENDIX:

A list of the Public Figures used as experimental stimuli. Categories reflect each experimental condition.

Public Figures (Pre-2008):

1) Ernie Wise – Comedian.
2) Margaret Thatcher – Ex Prime Minister.
3) King Charles III – King of England.
4) Paul McCartney – Ex Beatles Band Member.
5) Bill Clinton – Ex US President.

Public Figures (Post-2008):

1) Meghan Markle – Ex UK Royal, Actress.
2) Jeremy Corbyn – Ex UK Labour Party Leader.
3) Kier Starmer- Leader of the UK Labour Party.
4) Priti Patel – Ex UK Home Secretary.
5) Liz Truss – Current UK Prime Minister.

Foreign Public Figures (Control condition):

1) Nikos Vertis – Singer (Greece).
2) David Bisbal – Singer (Spain).
3) Annalena Baerbock – Foreign Minister (Germany).
4) Carmen Calvo – Politician (Spain).
5) Jesse Klaver – Green Left Party Leader (Netherlands).
6) Joanne-Schmidt Neilsen- Secretary General of Save the Children (Denmark).
7) Prince Haakon – Prince of Norway.
8) Jason Clare – Minister of Education (Australia).
9) Sebastian Kurtz – Ex Chancellor (Austria).
10) Charlene de Carvalho-Heineken- Buisnesswoman (Netherlands).