Article

PERCEPTION

Differences in face recognition predict the understanding of events during natural viewing

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Abstract

Understanding everyday events is essential for navigating and facilitating successful social interactions. Face recognition is thought to play a critical role in how we associate and interpret events in the real world. In this study, we explored this issue using a natural viewing paradigm in which participants watched a movie containing a rich and detailed narrative. To determine the importance of face recognition in event comprehension, we compared age-matched, neurotypical control participants and individuals with developmental prosopagnosia (DP) – a lifelong deficit in the ability to recognize faces. After watching the movie, participants were assessed on their comprehension of the events from the movie. We found that DPs showed a significant reduction in their understanding of the events from the movie compared to neurotypical controls. We also found that individual differences in face recognition predicted event comprehension. Together, these results demonstrate the importance of face recognition for understanding naturally unfolding events in everyday life.

Keywords

face recognition, developmental prosopagnosia, natural viewing, social cognition

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Introduction

Event comprehension involves the cognitive processes that enable individuals to perceive, interpret, and remember sequences of actions or environmental changes as coherent and structured events (Kurby & Zacks, 2008). These processes are fundamental to making sense of everyday experiences, narratives, and social interactions (Baldassano et al., 2018). In social contexts, event comprehension requires the ability to dynamically track individuals across time (Radvansky & Zacks, 2011). Face recognition is thought to play a pivotal role in understanding events (Milivojevic

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et al., 2016), as it allows the attribution of mental states, the interpretation of interpersonal relationships, and the construction of coherent representations of unfolding social events (Frith & Frith, 2006).

While the recognition of familiar faces is straightforward for most human observers, there are some people who struggle to recognize people from their face. Developmental prosopagnosia (DP) is a neurodevelopmental condition defined by the inability to recognise faces, despite otherwise normal visual processing (Behrmann & Avidan, 2005; Cook & Biotti, 2016; Duchaine & Nakayama, 2006). Unlike acquired prosopagnosia, where individuals experience face recognition deficits following brain damage, DP occurs in the absence of brain injury. The prevalence of DP is reported to be around 2% of the general population (DeGutis et al., 2023; Kennerknecht et al., 2006). However, other studies have suggested that DP is best understood not as a discrete condition, but as representing the lower end of a continuum of face processing ability in the population (Barton & Corrow, 2016; Russell et al., 2009).

Despite relatively high prevalence rates, the impact of DP beyond face recognition is often overlooked. Nonetheless, a few studies have investigated the negative psychosocial consequences that accompany DP. Individuals with DP often report avoidance of social situations that can lead to a loss of self-confidence and limit employment opportunities (Dalrymple et al., 2014; Yardley et al., 2008). The ability to recognise faces can also affect the size of friendship groups (Dalrymple et al., 2014; Diaz, 2008; Wang et al., 2022) and influence the quality of relationships (Engfors et al., 2024; McKone et al., 2023). In extreme cases, DP can lead to the development of social anxiety disorder (Davis et al., 2011; Yardley et al., 2008). These studies show that DP can have real world effects on social interactions.

In this study, we directly tested the role of face recognition in event comprehension using a naturalistic paradigm. These paradigms preserve the rich and detailed sensory input characteristic of everyday experiences while capturing the complexity of social interactions, making them particularly well-suited for investigating real-world event comprehension (Redcay & Moraczewski, 2020; Sonkusare et al., 2019). To determine whether face recognition is important for understanding events that occur during natural viewing, we compared neurotypical participants with DPs. Participants viewed a movie taken from a TV series (Life on Mars), which contained a rich and detailed narrative (Noad & Andrews, 2024). Participants were then assessed on their ability to understand the events from the movie. The Prosopagnosia Index (PI-20; Shah et al., 2015), a questionnaire used to provide diagnostic evidence for DP, includes the item 'I sometimes find movies hard to follow because of difficulties recognizing characters'. However, the direct relationship between face recognition and event comprehension has not been empirically tested. Our hypothesis was that participants with DP would show an impaired ability to understand the events as a result of their inability to recognise faces. Our findings show that individuals with DP have impaired event comprehension and that individual differences in face recognition predict the understanding of events during natural viewing.

Methods

Participants

Twenty-eight developmental prosopagnosic participants (M_{age} = 43.6 years, age range: 21–66, 11 male) and 32 control participants (M_{age} = 37.4 years, age range: 21–61, 11 male) completed the experiment online through the Pavlovia platform (https://pavlovia.org). All participants were unfamiliar with the TV show Life on Mars and were fluent English-speakers. They all had normal or corrected-to-normal vision and had no history of neurological conditions by self-report. Written informed consent was obtained for all participants and the study was approved by the Psychology Research Ethics Committee at the University of York.

Table 1. Individual scores on the PI20 questionnaire and Cambridge Face Memory Test (CFMT) used to validate developmental prosopagnosia. High scores on the PI20 indicate more prosopagnosic traits. Low scores on the CFMT show worse face memory performance.

Participant	Age	Gender	PI20 Score	CFMT Score (%)	zPI20	zCFMT
1	66	M	92	45.8	5.93	−4.40
2	54	F	85	59.7	5.16	−2.84
3	36	M	73	59.7	3.85	−2.84
4	60	M	91	47	5.82	−4.27
5	50	M	88	48.6	5.49	−4.09
6	50	F	82	55.6	4.84	−3.30
7	44	F	54	51.4	1.76	−3.78
8	56	F	80	52.8	4.62	−3.62
9	42	M	76	62.5	4.18	−2.53
10	34	F	89	47.2	5.60	−4.25
11	56	M	84	51.4	5.05	−3.78
12	25	M	72	44.5	3.74	−4.55
13	51	M	75	45.8	4.07	−4.40
14	29	F	83	59.7	4.95	−2.84
15	58	F	90	52.8	5.71	−3.62
16	21	M	80	48.6	4.62	−4.09
17	44	F	82	62.5	4.84	−2.53
18	27	F	86	41.7	5.27	−4.87
19	41	F	70	29.2	3.52	−6.27
20	51	F	94	55.6	6.15	−3.30
21	58	F	81	44.5	4.73	−4.55
22	22	F	81	51.4	4.73	−3.78
23	58	F	74	58.3	3.96	−3.00
24	29	M	93	45.8	6.04	−4.40
25	45	F	68	62.5	3.30	−2.53
26	29	M	72	66.7	3.74	−2.06
27	61	F	81	36.1	4.73	−5.49
28	25	F	75	50	4.07	−3.93
DPs mean			80.39	51.34		
DPs SD			8.96	8.52		
Comparison mean			38.0	85.0		
Comparison SD			9.1	8.9		

Note: Control comparison data ($N = 54$) for the PI20 and CFMT were taken from Biotti et al. (2019).

Diagnostic Tests

DP participants were recruited through www.troublewithfaces.org and other online sources. To determine diagnostic evidence for the presence of DP, all DP participants completed the PI20 – a 20-item self-report measure of prosopagnosic traits (Shah et al., 2015), and the Cambridge Face Memory Test (CFMT) – an objective measure of face recognition (Duchaine & Nakayama, 2006). The CFMT is commonly used to show diagnostic evidence for DP, as it has been shown to discriminate between individuals with and without face memory deficits (Duchaine & Nakayama, 2006). To be classified with DP, a participant had to score above the established threshold (>65) on the PI20 ($M = 80.3$, SD = 8.96), and two standard deviations below the typical mean (<65%) on the CFMT ($M = 51.3$, SD = 8.52; Table 1). Combining diagnostic evidence from self-report and objective measures is thought to provide reliable identification of DP (Gray et al., 2017; Tsantani et al., 2021). One participant scored slightly above the CFMT threshold (66.7%) and one participant score slightly below the PI20 threshold (54). These participants were included in the

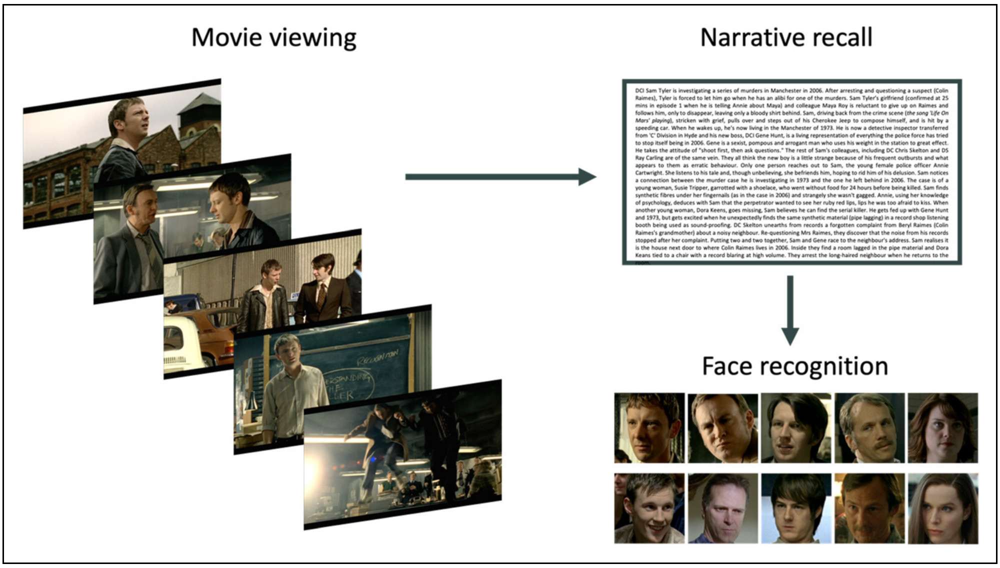

Figure 1. Natural viewing paradigm and experimental design. Participants watched a 20-minute movie from the TV series Life on Mars. Participants were then tested on their understanding of the events from the clips in two narrative understanding tasks: a free recall of the video, and structured questions about specific events from the video. Recognition of the faces from the video was tested using a face recognition memory test, including (top) target identities and (bottom) foils both from unseen episodes of the show and images from outside the show.

sample due to showing clear face recognition deficits on the other measure (i.e., within DP range for the PI20 or the CFMT), and also self-reporting problems with face recognition. Control participants all scored within the normal range on the CFMT (>65%) ($M = 82.1$, $SD = 8.25$).

Stimuli and Experimental Design

Participants viewed a 20-min (1170 s) movie constructed from audio-visual clips from the first episode of BBC TV series Life on Mars (Figure 1, left). Participants were asked to watch and attend to the movie for the duration. The movie contained a complex and rich naturalistic narrative involving ten unique characters who appeared across fourteen clips.

Narrative Understanding Analysis

After watching the video, participants were tested on their understanding of the movie (Figure 1, top right). Participants were asked to (1) recall the movie in as much detail as possible, providing an unconstrained written response, and (2) answer a set of eight structured questions about specific events in the video. Each question was accompanied by a static image of the relevant event in the video.

To assess whether the groups differed in their understanding of the narrative of the movie, the two tasks were graded by two raters using a predefined marking scheme (see Noad & Andrews, 2024). The free recall test was marked relative to 10 key events that occurred during the encoding video. Raters assigned a mark of 0, 1 or 2 for each point depending on whether the test showed no, partial or a full description of the event, for a possible total of 20 marks. The 8 structured questions were marked in a similar manner, for a possible total of 16 marks. Further analysis was based on the average scores across raters. Differences between groups in narrative measures were tested using Welch's two sample *t*-tests. To assess reliability between raters on the grading of the free recall and structured question task, inter-rater reliability was calculated using an intra-class correlation coefficient (ICC) using a two-way mixed model with agreement definition. Excellent agreement between raters was found for the free recall task [ICC of 0.87 with 95% confidence intervals of 0.78–0.92, $F(59, 59) = 7.38$, $p < .001$] and for the structured question task [ICC of 0.89 with 95% confidence intervals of 0.81–0.93, $F(59, 59.6) = 8.98$, $p < .001$]. ICC greater than 0.75 indicates good reliability between raters.

To further explore how natural events are understood in DP, the free recall responses from each participant were compared to a synopsis of Life on Mars using Latent Semantic Analysis (LSA). LSA is a natural language processing technique that can uncover underlying structures in a text by analysing the relationships between words, and can map texts onto a semantic space (Landauer et al., 1998). This technique can be used to compare the semantic similarity between two texts. Here, we compared the free recall of the narrative from each participant to an online synopsis of the first episode of Life on Mars (implemented on http://wordvec.colorado.edu). The General Reading up to first-year college (300 factors) embedding space was used. This space uses a variety of texts, novels and other information from the TASA (Touchstone Applied Sciences Associates, Inc.), involving over 30,000 documents and 92,000 terms. High similarity of the participant's free recall response to the synopsis indicates a high similarity in contextual usage of words across the texts.

Face Recognition Analysis

Recognition of the faces from the movie was measured using a face recognition memory task after watching the video clips (Figure 1, bottom right). Faces were presented individually in a random order and remained on screen until a response was made. Participants were required to press a button to indicate if the identity of the face corresponded to any of the actors from the video they had watched. Images from the main 10 actors were used in the test. Static images were taken directly from the TV series but were not images seen in the movie. Another image of each actor was taken from outside of the Life on Mars TV series, leading to a total of 19 target faces (one actor did not have any photos available outside of the show). Two foil images of different identities were selected to match each of the targets in age, expression, gender, hairstyle and general appearance for both images from the TV series and out of the TV series (leading to a total of 40 foils).

Face recognition performance was calculated using the mean sensitivity (d') for discriminating between faces of characters present in the movie and faces of foils who were not present in the movie. d' was calculated based on hit rates (i.e., correct recognition of the face as present in the movie/number of targets) and false alarm rates (i.e., incorrectly responding that foil was present in the movie/number of foils) for each participant ($d' = z$ hit rate – z false alarm rate). To avoid d' infinity in cases where the hit rate was 1 and/or the false alarm rate was 0, d' was calculated using log linear correction (Hautus, 1995). A d' score of 0 indicates the observer cannot distinguish between target faces and foils (chance performance). Hits and false alarms were also analysed independently to determine if there were differences in response bias.

While accuracy is typically used to classify DPs, it has been shown that they can perform within typical accuracy limits when tasks have an unlimited presentation time (Dobel et al., 2007; Duchaine & Nakayama, 2004). Previous studies have recommended incorporating response time (RT) alongside accuracy (Fysh & Ramon, 2022). Balanced Integration Score (BIS) is a way of integrating an individual's accuracy and response time (Liesefeld & Janczyk, 2019, 2023). BIS has previously been shown to be a good measure of performance in DP, where accuracy is often prioritised over response time (Lowes et al., 2024). A higher BIS score shows better performance while controlling

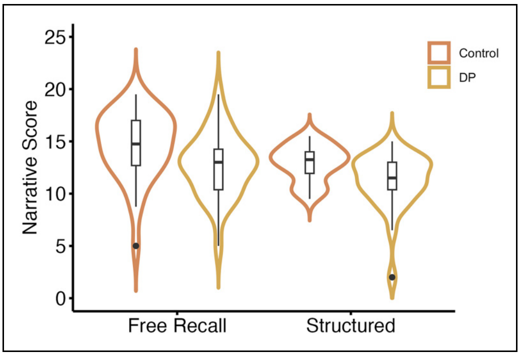

Figure 2. Significantly lower narrative understanding scores were found in individuals with DP compared to age-matched control participants after watching the movie. A reduction in performance was evident for both the free recall task and the structured questions task.

for speed accuracy trade-offs, while a lower BIS score demonstrates poorer performance. BIS is calculated by subtracting a participant's standardised RT on correct trials from their standardised accuracy score (BIS = z accuracy − z RT). The control mean (and standard deviation) accuracy and RT on the face recognition memory test were used to calculate Z scores for control and DP participants.

Results

Impaired Understanding of Narrative in DP

We calculated the narrative understanding score for each participant on the free recall task and structured narrative question task. Narrative understanding scores were compared between the DPs and control participants (Figure 2). The DPs had significantly lower narrative understanding scores on both the free recall [$M_C = 14.7$, $SD_C = 3.20$, $M_{DP} = 12.7$, $SD_{DP} = 3.01$, $t(57.6) = 2.40$, $p = .020$, $d = .62$] and structured questions [$M_C = 12.9$, $SD_C = 1.71$, $M_{DP} = 11.2$, $SD_{DP} = 2.67$, $t(44.9) = 2.91$, $p = .006$, $d = .77$].

To further explore the understanding of events in the movie, we compared the free recall responses of each participant to a synopsis of the movie using Latent Semantic Analysis. A higher LSA score indicates a greater similarity in the language used to describe the events. Having found a large effect of narrative, we performed a one-tailed t-test on LSA scores between groups. However, control and DP participants did not show a significant difference in the similarity scores between their free recall responses and a general synopsis of the video clips [Figure 3(a); $M_C = 0.68$, $SD_C = 0.06$, $M_{DP} = 0.68$, $SD_{DP} = 0.06$, $t(56.8) = 0.11$, $p = .458$, $d = .03$].

Interestingly, the differences in narrative understanding between groups on the free-recall task did not appear to be explained by lack of content, as no significant differences were found between controls and DPs in the word count of the free recall responses [$M_C = 461.0$, $SD_C = 241$, $M_{DP} = 482.9$, $SD_{DP} = 307$, $t(51.0) = 0.39$, $p = .762$, $d = .08$] (Figure 3(b)).

Recognition of Faces in DP

To explore learning of faces in naturalistic settings in DP, we calculated performance for each participant on the face recognition memory task. We analysed the hit rate and false alarm rate (Figure 4). There was a significant difference in hit rate between groups [$t(56.3) = 4.32$, $p < .001$, $d = 1.08$], with DPs showing a lower hit rate than controls ($M_C = 13.4$, $SD_C = 2.47$, $M_{DP} = 10.7$,

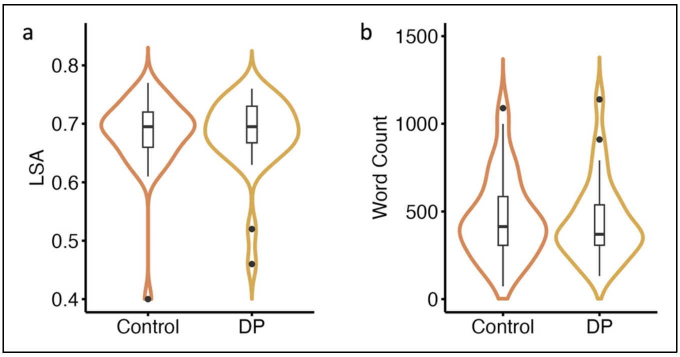

Figure 3. (a) Latent semantic analysis (LSA) showed that age-matched control participants and individuals with DP exhibited no difference in the semantic similarity of their free recall of the narrative and an objective synopsis of the video. (b) DPs did not show any difference in word count on the free recall task, despite showing significantly lower understanding of the narrative. These results suggest that differences between groups do not reflect differences in the overall content or level of effort.

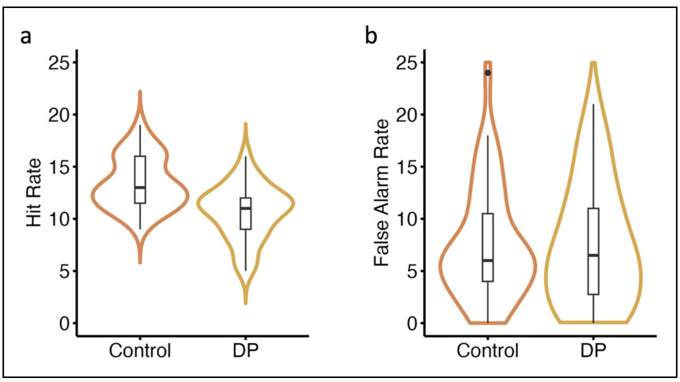

Figure 4. (a) Individuals with DP had a lower hit rate on the face recognition memory test compared to age-matched control participants. (b) DPs showed a similar false alarm rate to control participants.

$SD_{DP} = 2.61$). However, there were no significant differences in false alarms between the groups [$t(55.3) = 0.03$, $p = .979$, $d = 0.01$; $M_C = 7.54$, $SD_C = 5.44$, $M_{DP} = 7.5$, $SD_{DP} = 5.92$]. These combined to give significant difference in d' scores [$t(55.6) = 2.43$, $p = .018$, $d = 0.61$] between control participants ($M_C = 1.54$, $SD_C = 0.60$) and DPs ($M_{DP} = 1.17$, $SD_{DP} = 0.63$), shown in Figure 5(b).

To further explore face recognition in DP, we compared response times (RT) for correct trials (Figure 5(a)). A t-test showed significant differences between groups [$t(44.4) = 2.90$, $p = .006$, $d = 0.76$], with DPs having longer reaction times ($M_C = 1.85$, $SD_C = 0.60$, $M_{DP} = 2.41$, $SD_{DP} = 0.89$). Given the significantly increased response times in DP, we used Balanced Integration Score (BIS) to incorporate the response time with accuracy on the face recognition test (Figure 5(b)). We then compared BIS scores using a *t*-test (Figure 5(c)). There were significant differences between groups [$t(44.0) = 3.89$, $p < .001$, $d = 1.02$], which reflected lower BIS scores in the DP group ($M_C = 0.00$, $SD_C = 1.24$, $M_{DP} = -1.56$, $SD_{DP} = 1.85$).

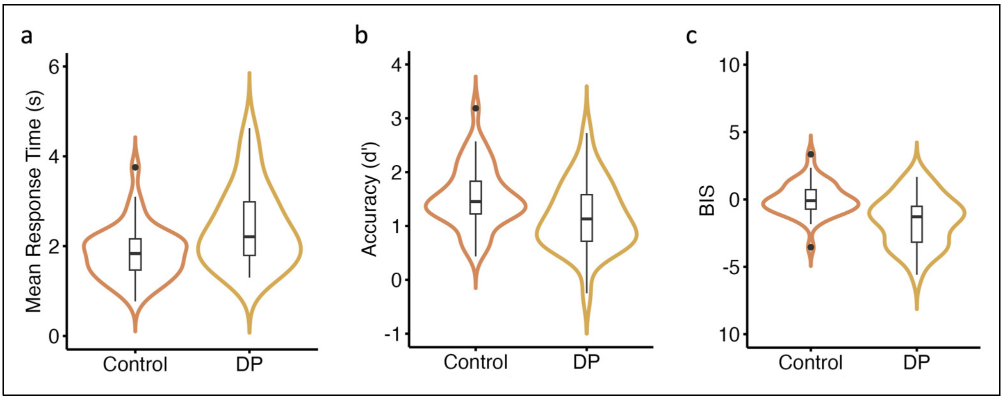

Figure 5. (a) DPs showed significantly longer response times compared to age-matched control participants in the face recognition task. (b) Face recognition measured through d prime was significantly lower in DPs compared to controls. (c) Balanced integration scores (BIS) incorporated the response time with accuracy on the face recognition test. DPs showed a significantly lower BIS indicating poorer face recognition performance.

Finally, we asked whether individual differences in narrative understanding would predict differences in face recognition. To test this, we calculated the overall narrative score by combining the free-recall and structured question task. We then correlated this with face recognition using the BIS scores, to take into account the accuracy and response time. Figure 6 shows that there was a significant correlation between overall narrative understanding and face recognition measured on the face recognition task from this study [$r(58) = .35$, $p = .006$] and the CFMT [$r(58) = .33$, $p = .010$].

Discussion

The ability to track information, such as the presence of individuals, is considered crucial for understanding events in everyday life (Baldassano et al., 2018). This study investigated the role of face recognition in understanding events during naturalistic viewing. We employed a natural viewing paradigm to examine narrative comprehension in neurotypical individuals and those with DP. Our results demonstrated a reduction in understanding in individuals with DP, suggesting that facial recognition is crucial for interpreting naturally unfolding events. We also found that individual differences in face recognition predicted event comprehension.

Compared to age-matched control participants, DPs showed lower scores in two tasks of narrative understanding. This did not reflect a difference in the willingness to engage with the task or the semantic content of the responses, as we found no difference in the word count or semantic analysis of the free-recall task between DPs and control participants. The findings of this study suggest that the deficit in face recognition in DP affects other aspects of cognition. This aligns with previous research showing the broader impact of DP, such as avoiding social situations and social anxiety (Dalrymple et al., 2014; Yardley et al., 2008). Our results suggest that the reduced comprehension of the narrative in movies in individuals with DP may reflect a more generalized difficulty in understanding everyday events.

Previous studies have suggested that DP is best understood, not as a discrete condition, but as representing the lower end of a continuum of face processing ability in the population (Barton & Corrow, 2016; Russell et al., 2009). To test whether individual differences in face recognition could also predict the understanding of events, we measured the recognition of the faces from the movie.

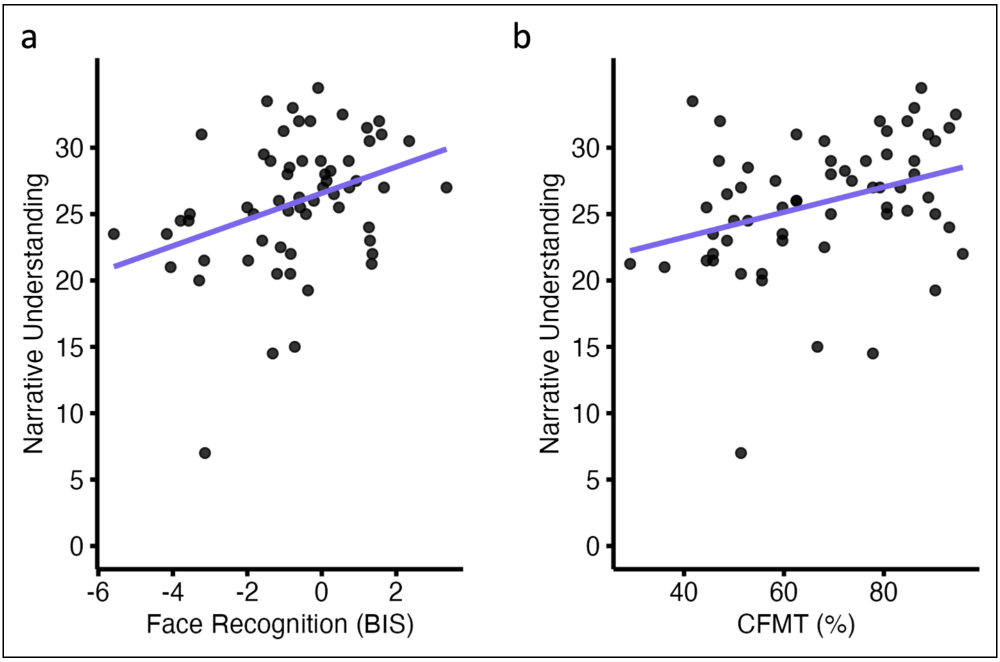

Figure 6. (a) Narrative understanding is positively correlated with performance on the face recognition test and (b) on the Cambridge Face Memory Test (CFMT) across all participants.

Across all participants, we found a significant correlation between face recognition and the understanding of events. This suggests that variability in the ability to recognize faces can influence the ability to interpret events during natural viewing.

Previous research has shown that non-visual, semantic and episodic information about individuals, such as who a person is, what they do and where we usually see them, is important for learning new faces (Noad & Andrews, 2024; Schwartz & Yovel, 2016). For example, in a previous study using this paradigm, we compared participants who viewed a movie in its original sequence with participants who viewed the same movie content in a scrambled sequence (Noad & Andrews, 2024). Despite the fact that both groups received the same overall visual experience with the faces, we found that participants who viewed the movie in the scrambled sequence had a lower understanding of the narrative and that this led to lower face recognition. In this study, we demonstrate the reverse effect; impairments with face recognition can disrupt the understanding of events. Given that acquisition of episodic information is important when becoming familiar with a face, this may exacerbate problems in learning new faces in individuals with DP.

In real world environments, faces are typically learned within rich, social contexts. Thus, replicating these conditions in the lab is crucial for studying face processing. Natural viewing paradigms, such as movie watching, offer a unique opportunity to examine face learning under conditions that closely mirror real-world experiences (Redcay & Moraczewski, 2020). To our knowledge, no prior studies of DP have investigated learning of new faces in natural viewing conditions. Our findings reveal significant differences in face recognition between individuals with DP and control participants and that this impairs their ability to comprehend social events, particularly in dynamic, natural viewing contexts where sensory input is constantly changing.

While numerous studies have proposed that deficits in face recognition occur in isolation from other impairments (Barton et al., 2019; Bate, Bennetts et al., 2019; Garrido et al., 2018), growing evidence suggests that individuals with DP can have co-occurring deficits in non-face object recognition (Barton et al., 2019; Barton & Corrow, 2016; Biotti et al., 2017; Duchaine et al., 2007; Epihova et al., 2022, 2023) and even in broader cognitive abilities, such as topographical navigation (Bate, Adams et al., 2019; Corrow et al., 2016; Klargaard et al., 2016). Consequently, the observed reduction in narrative understanding among individuals with DP may reflect a more generalized difficulty in information processing that extends beyond face recognition deficits. This raises the possibility that deficits in face recognition may not be the sole contributor to impairments in narrative understanding. Future work could explore this hypothesis by examining event comprehension in contexts that do not contain faces, such as audio-based narratives, or movie sequences without face-related content.

We did not find a difference between DPs and control participants using a semantic analysis of the text (LSA, Landauer et al., 1998). This analysis involved comparing the free recall of the narrative from each participant to an online synopsis of the movie. This suggests that the LSA and human ratings explore event comprehension in different ways. The LSA uses statistical analysis to detect patterns in word usage, which captures semantic similarity based on co-occurrences of words. The LSA appears to provide a measure of similarity in the overall linguistic content, whereas the human raters provide a measure of overarching event comprehension.

The findings from this study hold significant implications for the rehabilitation of DP. While substantial efforts have been made to understand the processes underlying DP, comparatively less attention has been directed toward effective rehabilitation strategies (Bate & Bennetts, 2014; J. M. DeGutis et al., 2014). Previous attempts at remediation have primarily focussed on visual processing abilities (Corrow et al., 2019; DeGutis et al., 2007; J. DeGutis et al., 2014). These techniques involve training individuals on visual strategies, such as relying on specific facial features or distinguishing characteristics (Adams et al., 2020). These visual rehabilitation methods are predicated on the hypothesis that the face processing network has the potential for functional reorganisation (DeGutis et al., 2007). However, the efficacy of these interventions has yielded mixed results, with only modest success in the most promising cases. The current study introduces an alternative approach, highlighting the potential of focussing on non-visual information associated with a person as a novel intervention strategy. Strengthening the conceptual representation of a person may facilitate face recognition in individuals with DP. Interestingly, improvements in overt recognition of individuals with acquired prosopagnosia have been shown when familiar faces that shared conceptual information were also presented (De Haan & Campbell, 1991).

In conclusion, this study provides the first empirical evidence for impaired event comprehension in individuals with DP. The observed reduction in event understanding was not due to differences in effort or detail, as indicated by comparable word counts in the recall of events between groups. These findings align with a growing body of literature emphasizing the interaction between visual and non-visual information in the recognition of familiar faces, particularly in naturalistic viewing conditions. These results underscore the broader, everyday impact of DP and suggest potential avenues for future interventions targeting non-visual aspects of face processing.

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Ethical Approval and Informed Consent Statements

The Psychology Research Ethics Committee at the University of York approved the study. Participants gave written consent prior to taking part in the study.

Author Contribution(s)

Kira N Noad: Conceptualization; Formal analysis; Investigation; Methodology; Software; Visualization; Writing – original draft; Writing – review & editing.
Timothy J Andrews: Conceptualization; Investigation; Supervision; Writing – original draft; Writing – review & editing.

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Declaration of Conflicting Interests

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Data Availability Statement

The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

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