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Movement Cues Aid Face Recognition in Developmental Prosopagnosia

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Objective: Seeing a face in motion can improve face recognition in the general population, and studies of face matching indicate that people with face recognition difficulties (developmental prosopagnosia; DP) may be able to use movement cues as a supplementary strategy to help them process faces. However, the use of facial movement cues in DP has not been examined in the context of familiar face recognition. This study examined whether people with DP were better at recognizing famous faces presented in motion, compared to static. ***Methods:*** Nine participants with DP and 14 age-matched controls completed a famous face recognition task. Each face was presented twice across 2 blocks: once in motion and once as a still image. Discriminability (A) was calculated for each block. ***Results:*** Participants with DP showed a significant movement advantage overall. This was driven by a movement advantage in the first block, but not in the second block. Participants with DP were significantly worse than controls at identifying faces from static images, but there was no difference between those with DP and controls for moving images. ***Conclusions:*** Seeing a familiar face in motion can improve face recognition in people with DP, at least in some circumstances. The mechanisms behind this effect are unclear, but these results suggest that some people with DP are able to learn and recognize patterns of facial motion, and movement can act as a useful cue when face recognition is impaired.

Keywords: biological motion, developmental prosopagnosia, face perception, face recognition

Prosopagnosia is a condition characterized by a severe, relatively selective deficit in face recognition. In developmental prosopagnosia (DP), these deficits are present from early childhood, in the absence of neural damage (Susilo & Duchaine, 2013). The cognitive presentation of DP is heterogeneous (Behrmann & Avidan, 2005), but it is common for people with DP to use atypical strategies to recognize others—for example, focusing on body shape, clothing, or bodily movement as cues to a person's identity (Duchaine & Nakayama, 2004). To date there has been little investigation into whether these strategies are effective. This study focuses on whether one particular supplementary cue—movement—can improve familiar face recognition in DP.

There is substantial evidence that movement can facilitate face recognition in the general population. Numerous studies suggest that typical perceivers are more accurate and faster at matching faces viewed in motion (Rosenblum et al., 2002; Thornton & Kourtzi, 2002); better at identifying faces learnt in motion (Butcher, Lander, Fang & Costen, 2011; Lander & Bruce, 2003; Pike, Kemp, Towell, & Phillips, 1997), and more accurate at identifying degraded images of familiar faces that are presented in motion (Knight & Johnston, 1997; Lander, Bruce, & Hill, 2001; Lander, Christie, & Bruce, 1999). There are several reasons why movement may facilitate face recognition (O'Toole, Roark, & Abdi, 2002). First, movement may allow people to build a better three-dimensional representation of the face and head via structure-from-motion processes (the representation enhancement hypothesis); second, people may learn to identify characteristic patterns of face and head motion associated with a particular person (e.g., an unusual way of moving the eyebrows or tilting the head; the supplemental information hypothesis); and third, the social cues carried in movement (e.g., emotional expressions, speech, eye gaze) may attract attention to the identity specific areas of the face (e.g., eyes, mouth), facilitating identity processing (the social signals hypothesis).

Although findings of a movement advantage are quite consistent, several studies have found that movement is primarily useful when static face recognition is impaired in some way (e.g., via negation or blurring; Knight & Johnston, 1997; Lander et al., 2001). These findings suggest that movement cues are generally used as a supplement to static cues in typical perceivers (O'Toole et al., 2002).

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If facial movement can be used to supplement poor static information in typical perceivers, it raises the question of whether prosopagnosic participants—who show impaired static recognition even without any image degradation—can use movement information in a similar way. Two studies have addressed this question. Steede, Tree, and Hole (2007) found that a DP patient (C.S.) matched and learned shape-normalized moving faces at a similar level to controls. More recently, Longmore and Tree (2013) found a significant movement advantage for face matching in three out of four participants with DP. However, a fourth DP did not show this effect, and they also found no comparable motion advantage in a learning task, suggesting that, like other face processing skills (e.g., static face matching), people with DP can vary significantly in their ability to extract and match facial movement.

The results from Steede et al. (2007) and Longmore and Tree (2013) support the idea that people with DP are capable of extracting facial movements and using them as a cue to identity, at least in the short term. Roark, Barrett, Spence, Abdi and O'Toole (2003) suggested that, in typical participants, the neural networks involved in the structure-from-motion path converge with those involved in static face processing; whereas idiosyncratic facial movements are likely processed in the superior temporal sulcus (STS), separate from the neural regions involved in processing "unchangeable" aspects of the face (Haxby, Hoffman, & Gobbini, 2000). Recent research using TMS and fMRI (Pitcher, Duchaine & Walsh, 2014) has found further evidence that dynamic and static facial aspects are processed via dissociable cortical pathways, with the STS strongly involved in dynamic face processing. It is possible that the neural pathways involved in processing facial biological motion (i.e., the STS) may function relatively normally in DP. However, other research has found that some participants with DP show impairments on more general biological motion tasks—for example, when asked to lip-read or discriminate body movements (Lange et al., 2009). Lange et al. (2009) suggested that their results reflected a generalized deficit for configural processing in some cases of DP, which affected both static face processing and biological motion processing. However, this deficit was not present in all cases of DP. Taken together with the finding that at least some aspects of the face and biological motion processing systems are dissociable (Pitcher et al., 2014), it remains possible that at least some people with DP may be able to use facial movement as a cue to identity.

To date, no research has investigated the movement advantage for familiar faces in DP. This is interesting because familiar face recognition is one of the more ecologically valid tasks used to investigate the movement advantage, and familiar face tasks appear to show the most robust movement advantage in the typical population (see Roark et al., 2003), perhaps because as a face becomes more familiar we learn its characteristic movements. Familiar face recognition has, however, been examined in a case of acquired prosopagnosia (following neurological damage,), HJA (Lander, Humphreys, & Bruce, 2004). Despite showing a significant movement advantage for face matching, HJA showed no such advantage for face learning or famous face recognition. Although acquired cases of prosopagnosia are not directly comparable to DP (HJA presented with a host of perceptual deficits in addition to prosopagnosia; see Lander et al., 2004), this case does indicate that the ability to extract and use motion cues in matching tasks does not necessarily translate to the ability to use motion cues in identification tasks. In other words, although people with DP may be able to hold movement information in memory for a short period of time—sufficient for the matching and learning tasks used in previous studies (e.g., Longmore & Tree, 2013; Steede et al., 2007)—it is still unclear whether they can build up a long-term representation of idiosyncratic facial movements that are linked to semantic information about a person and can facilitate recognition.

The current study examined the use of movement information in famous face recognition in nine participants with DP. This is important for several reasons: first, studying the use of movement cues to supplement recognition may give us more insight into the nature of the deficit found in DP. For example, if facial biological motion improves face recognition in participants with DP, it would demonstrate that they are not only able to extract and use motion cues to recognition in the short term (Longmore & Tree, 2013; Steede et al., 2007) but are also capable of building up long-term representations of idiosyncratic facial movements that can cue identity recognition. Second, current assessment and rehabilitation programs in prosopagnosia focus almost exclusively on static faces (e.g., Duchaine & Nakayama, 2006; Duchaine, Germine, & Nakayama, 2007; Bate, Bennetts, et al., 2014). However, if some people with DP are able to use motion to facilitate recognition, these cues may become a focus of training programs in future research.

Methods

Participants

Nine adults with DP took part in this study (four male, mean age = 54.5 years, SD = 10.1). All participants had contacted our laboratory because they experience severe difficulties with face recognition in everyday life. Prior to the investigation, each participant attended an initial diagnostic testing session, consisting of a short interview about their neuropsychological history, difficulties with face recognition, and a battery of neuropsychological tests (see Table 1). All participants reported apparently lifelong and severe difficulties with face recognition and recounted multiple instances of failures of face recognition in everyday life. No participant had experienced neurological illness or trauma, their difficulties were therefore regarded as developmental in origin.

Neuropsychological testing included various face processing tests alongside tests of lower-level vision. Face processing skills were assessed using the Cambridge Face Memory Test (CFMT: Duchaine & Nakayama, 2006), a famous faces test (Duchaine et al., 2007), and the Cambridge Face Perception Test (CFPT: Duchaine et al., 2007). These tests assess face learning, long-term memory for faces, and face perception, respectively. Details of individual tests, administration, and norms are available from the accompanying publications, and are also detailed in Bate, Cooks, et al. (2014). Participants were selected based on scores more than 2 SD below published norms for the CFMT and the famous faces tests (although it is not uncommon, poor performance on the CFPT is not necessary for a diagnosis of prosopagnosia).

Each DP was also assessed on their ability to recognize facial expressions using the Reading the Mind in the Eyes Test (Baron-Cohen, Wheelwright, Hill, Raste, & Plumb, 2001), and their low-level perceptual matching skills using subtests from

Table 1
Demographic Characteristics, Scores on Standardized Tests of Face Processing, and the Movement Advantage for the Developmental Prosopagnosics Who Participated in This Study

Characterisic	Controls (N = 14), M (SD)	DP1	DP2	DP3	DP4	DP5	DP6	DP7	DP8	DP9
Age	57.7 (7.17)	63	63	64	65	51	44	53	52	36
Gender	9 F	M	M	M	F	F	M	F	F	F
Hand	13 R	L	R	R	R	R	R	R	L	R
IQ	119.7	119	119	119	125	119	119	120	120	113
Face processing tests										
CFMT	59.6 (7.6)[a]	31*	28*	39*	42*	33*	39*	31*	42*	29*
CFPT	36.7 (12.2)[b]	72*	52	52	58	46	54	54	48	66*
Famous faces	89.5 (5.33)[c]	33.33*	43.40*	59.57*	56.67*	48.33*	70.59*	30.77*	37.73*	46.42*
Mind in eyes	26.2 (3.6)[d]	32	21	27	32	30	24	24	28	27
Lower-level vision (BORB)e										
Length match	26.9 (1.6)	28	27	28	25	25	27	25	25	28
Size match	27.3 (2.4)	28	29	28	28	24	24	27	29	29
Orientation match	24.8 (2.6)	28	26	28	25	26	23	23	27	28
Position of gap	35.1 (4.0)	37	33	37	36	40	35	36	37	34
Object decision test	114.7 (5.7)	121	116	120	117	119	118	114	117	120
Face recognition										
A moving	0.87 (0.08)	0.76	0.75	0.85	0.91	0.93	0.93	0.77	0.90	0.82
A static	0.86 (0.10)	0.52*	0.82	0.87	0.85	0.91	0.84	0.57*	0.81	0.66
Movement advantage										
Raw score	0.01 (0.07)	0.24	−0.07	−0.02	0.07	0.02	0.08	0.20	0.09	0.16
z-score	—	3.13*	−1.21	−0.44	0.75	0.14	1.1	2.65*	1.04	2.03*
Faces removed from analysis	1.73 (2.25)	3	6	6	4	2	1	5	11	4

Note. A higher score in the CFPT equates to worse performance, chance performance is 93.3. CFMT = Cambridge Face Memory Test; CFPT = Cambridge Face Perception Test; M = male; F = Female; L = left-handed; R = right-handed.
[a] CFMT; norms from Duchaine and Nakayama (2006), maximum score 72. [b] Cambridge Face Perception Test; norms from Duchaine et al., 2007. [c] Norms from Duchaine et al., 2007, score represents the percentage of faces that the participant correctly identified, corrected for individuals that were not known to the participant. [d] Norms from Baron-Cohen et al., 2001, maximum score 36. [e] Birmingham Object Recognition Battery; norms from Humphreys and Riddoch, 1993, maximum scores 30; 40 (position of gap); 120 (object decision).
* indicates performance > 2 *SD* from norm.

the Birmingham Object Recognition Battery (BORB: Humphreys & Riddoch, 1993). When compared with appropriate published norming data, no participants showed significant impairment in any of the tests.

Fourteen control participants, matched to the DP group according to age, gender and estimated IQ (using the Wechsler Test of Adult Reading; Wechsler, 2001; see Table 1), also participated in this study. All reported normal or corrected-to-normal vision. Exclusion criteria were low-level visual problems, or a history of significant psychiatric or neurological illness.

All participants provided written consent and participated on a voluntary basis. The study was approved by Bournemouth University's Ethics Committee.

Stimuli and Procedure

Stimuli consisted of 30 faces of famous people and 10 faces of unknown people, matched to the famous faces for general visual appearance (see Figure 1 for examples). Each face was shown both as a moving clip and a static image, resulting in 80 trials.

Moving clips were extracted from TV and movie productions and showed the head and shoulders of the person (sometimes the whole upper body) from a frontal viewpoint. Movement was primarily nonrigid (speech, expressions), but included some rigid motion (head turning and nodding). Static clips showed a single freeze-frame extracted from the moving sequence, selected to avoid any unusual momentary expressions or head angles. All images were converted to greyscale and presented for 2.5 s at 30 fps.

Stimuli were presented using ePrime 2.0 software (Psychology Software Tools, Pittsburgh, PA), displayed on a Samsung 22-inch LCD monitor with a refresh rate of 60 Hz. Images were between 180 and 300 pixels tall. The experiment was conducted in two blocks, with block order counterbalanced between participants, and the order of trials semirandomized. In the first block, half of the faces were moving and half static; in the second block, the identities of the moving and static faces were reversed. After each clip, participants had to identify each person, by naming or providing some other uniquely identifiable information. If they did not think the face was familiar, they responded "unknown." There was no time limit for participants to respond.

After both blocks were completed, the list of the famous people was read to each participant, and they were asked to rate their familiarity with each person on a 5-point scale ranging from 1 (*unfamiliar*) to 5 (*very familiar*). Before analysis, data for any faces that were unfamiliar to individual participants (rated 1 or 2) were removed. Between zero and six faces were removed for controls, and between one and 11 for the DP participants (see Table 1). The remaining faces were rated as highly familiar for both groups (DP: M = 4.67, SD = 0.24; control: M = 4.63, SD = 0.36).

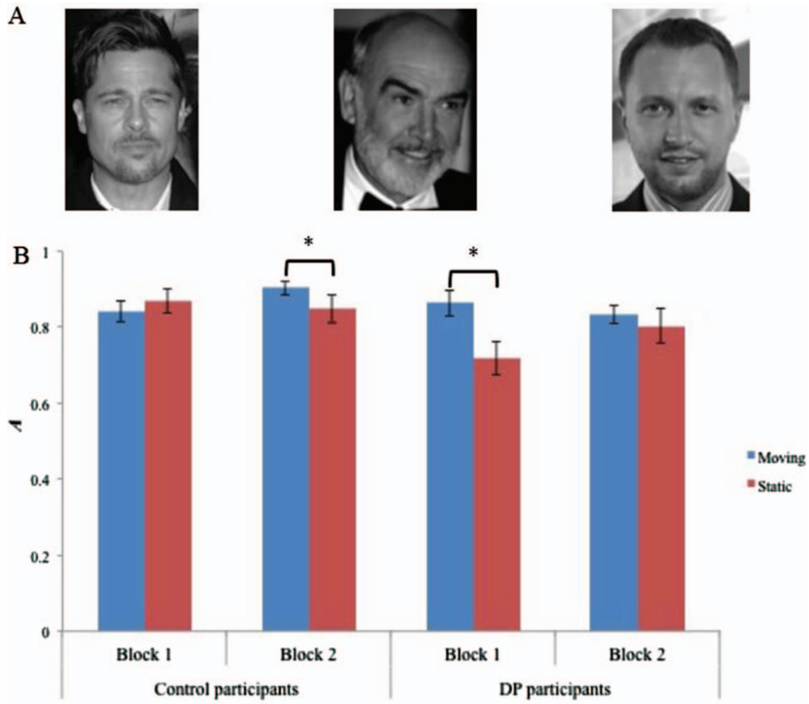

Figure 1. A: Sample images of the famous face stimuli. Pictures show (left to right): Brad Pitt, Sean Connery, and an unfamiliar face. Note these exact images were not used in the experiment. Images copyright of Shutterstock. B: *A* results for participants with DP and matched controls. Blue (lighter gray) bars represent faces seen in motion, red (darker gray) bars represent faces seen as static images. See the online article for the color version of this figure.

Results

Hits and false positive responses were combined using nonparametric signal detection measures *A* (sensitivity) and *B* (bias) (Zhang & Mueller, 2005).[1] One control participant was removed prior to analysis as their mean hit rate was more than 2 *SD*s from the mean for the control group, and their responses in the name familiarity task indicated that they had not understood the task.

A series of 2 (Group) × 2 (Presentation Style) × 2 (Block) mixed analyses of variance (ANOVAs) were conducted. Block was included as a factor because each face was viewed twice (once in the first block and once in the second), and it is possible that the effect of motion changed once participants were familiar with the faces in the set.

A scores are illustrated in Figure 1, and displayed individually for each DP in Table 1 (averaged across block). The ANOVA revealed a significant main effect of presentation style, $F(1, 20) = 7.44$, $p = .013$, $\eta^2_p = .27$, indicating that participants were significantly more accurate at recognizing the famous faces from moving clips than static images. Indeed, seven of the nine participants in the prosopagnosia group displayed this pattern of results (see Table 1). There was no main effect of group, $F(1, 20) = 2.37$, $p = .139$, $\eta^2_p = .11$, or block, $F(1, 20) = 2.50$, $p = .130$, $\eta^2_p = .11$, and all two-way interactions failed to reach significance, $ps > .05$. However, the three-way interaction between presentation style, group, and block was significant, $F(1, 20) = 16.29$, $p = .001$, $\eta^2_p = .49$. This may reflect the fact that DP participants performed better with moving than static stimuli in both blocks, although Wilcoxan signed rank tests revealed that the difference only reached significance in the first block, $p = .021$, and not the second block, $p = .441$. Conversely, controls showed a modest cross-over effect, displaying no movement advantage in the first block, $p = .433$, but a significant advantage in the second block, $p = .034$.

Although the two-way interaction between group and presentation style did not reach significance, there was a trend, $F(1, 20) = 3.80$, $p = .065$, $\eta^2_p = .16$, and planned comparisons examined whether the effect of motion differed between DP and control participants. Mann-Whitney *U* tests confirmed that, as expected, participants with DP were less accurate than controls in the static condition, U $(n_1 = 13, n_2 = 9) = 32.5$, $p = .044$, but not the moving condition, U $(n_1 = 13, n_2 = 9) = 43.5$, $p = .332$. Wilcoxon signed-ranks test revealed no significant effects of motion for controls, Z $(n = 13) = -1.16$, $p = .248$, but participants with DP performed better with moving than static clips, Z $(n = 9) = -2.01$, $p = .0.44$.

Analyses of hits and FAs were broadly consistent with the overall *A* analysis. Analysis of the *B* scores displayed no significant main effects or interactions. Analyses of familiarity ratings for the first compared to the second block revealed no significant differences, overall or within the control and DP groups (all *p*s >

[1] We carried out the same analyses using nonparametric measures *A'* and *B"*, and the results were broadly consistent with the reported analysis. See Zhang and Mueller (2005), for a justification for the use of *A* instead of *A'*.

.05), excluding the possibility that the block results arose because of differences in familiarity across groups or blocks.

Discussion

This study examined whether people with DP showed a movement advantage for familiar face recognition. We found that movement can improve familiar face recognition in those with DP—that is, participants with DP showed a movement advantage in a famous face identification task. Put another way, participants with DP were significantly worse than controls at static face recognition, but there was no significant difference between the groups for moving faces.

The DP results were driven by a significant movement advantage on the first viewing of each face, which was attenuated on the second exposure due to improved performance in the static condition. This finding suggests that people with DP can extract useful identity information from moving faces, and that they can use this information to access semantic information about a person, but the benefits are somewhat transient and dependent on context. This implies that, like typical participants, people with DP can use movement as a supplementary cue—DP participants may have focused on movement information only when static cues were insufficient to complete the task (Block 1); but in Block 2, prior knowledge of the face set (or perhaps more basic picture recognition) could have allowed participants to focus on specific cues unique to each individual, improving static face recognition and rendering the use of movement cues unnecessary.

The size of the movement advantage varied across the sample of DP participants, in line with previous studies that have found heterogeneity in the general cognitive characteristics of DP (see Susilo & Duchaine, 2013), and other studies examining movement in DP (Lange et al., 2009; Longmore & Tree, 2013). Currently it is unclear why some people with DP show a large benefit of movement and others do not. It may be that particular cognitive characteristics (e.g., better face matching abilities) lead to a larger movement advantage; unfortunately, the sample size in this study is too small to examine these factors. Another possibility is that individuals with DP have preferred "strategies," and individuals that focus on motion in their daily lives are simply more practiced at using those cues. This explanation may also account for the difference between the current group results and the findings for HJA, who acquired prosopagnosia later in life (Lander et al., 2004): People with DP may be accustomed to using alternative cues to identity, whereas HJA, having relied on typical face recognition processes for most of his life, may not have learnt to focus on motion as a cue to identity.

These results suggest that people with DP have learnt characteristic patterns of motion for familiar faces, and can use them as an alternate route to recognition when static cues are insufficient (supplemental information hypothesis; Roark et al., 2003). This lends support to the theory that neural processing of static and moving faces may dissociate (Pitcher et al., 2014), and at least some elements of facial biological motion perception (perhaps those that rely on separate processes from static faces) may be preserved in prosopagnosia (Lange et al., 2009). Consequently, facial motion may serve as an efficient supplementary strategy for some individuals with prosopagnosia.

Although this is a promising avenue for future research, the fact that people with DP show a movement advantage for face recognition does not preclude some abnormalities in biological motion processing. Some people with DP can identify familiar faces based on unusual static information (e.g., hairlines, etc.; Behrmann & Avidan, 2005), similarly, it is possible that the DP participants in the current study were using unusual motion cues when asked to identify famous faces (see also Steede et al., 2007).

Although the use of idiosyncratic motion information could explain the movement advantage for people with DP, it is by no means the only possible explanation. For example, seeing a face in motion provides more views of the person (the moving images in this study contained 30 still frames per second), which may offer more opportunities for a DP to match the face to their stored representation (Knight & Johnston, 1997; Lander et al., 1999). Similarly, seeing a face in rigid motion (e.g., head turning) may help build a better structural representation of the face and head, thereby improving recognition (the representation enhancement hypothesis; Roark et al., 2003). However, given the clips used in this study contained limited rigid information, this is an unlikely explanation for the results.

It is also possible that movement attracts attention to more identity-relevant areas of the face. Moving faces carry a variety of social cues (e.g., expressions, eye gaze, speech), and these cues may attract attention to the internal features of the face (the social signals hypothesis, Roark et al., 2003). Internal features are particularly important for facial recognition (Ellis, Shepherd, & Davies, 1979), but DP participants tend to avoid them when viewing static images (Schwarzer et al., 2007). Using moving faces may have oriented DP participants toward the internal features of the face, thereby helping them to extract useful identity information and improving subsequent recognition performance. Future studies may consider using eye-tracking and shape-normalized avatars (Steede et al., 2007) to disentangle the different explanations for the movement advantage, and clarify when and why moving stimuli are beneficial to face recognition.

Regardless of why it occurs, the fact that the majority of the DP participants tested in this study showed a movement advantage for familiar face recognition suggests that movement cues can constitute a useful supplementary cue for face recognition, which has implications for training programs designed to improve recognition in those with DP. To date, training programs have exclusively used static stimuli, and they have had mixed success (Bate & Bennetts, 2014), but these results indicate that future work should consider incorporating or focusing on movement cues.

In conclusion, the current findings suggest that movement can facilitate familiar face recognition in DP. Although the mechanisms underlying this advantage remain unclear, these results confirm that at least some facial biological motion processing is preserved in DP. Current training programs aimed at improving face recognition in DP have tended to ignore the role of supplementary cues, but our findings suggest that drawing attention to movement information may be a useful technique to compensate for perceptual deficits in DP.

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