Visual Cognition

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Face gender recognition in developmental prosopagnosia: Evidence for holistic processing and use of configural information

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Face identification deficits in developmental prosopagnosics (DPs) have been thought to be due to general difficulties with processing configural face information and integrating configural and parts information into a coherent whole (holistic processing). Gender recognition provides a further opportunity to more fully examine this issue as this ability may be intact in DPs and it has been shown to depend on processing configural information and holistic processing in neurotypical individuals. In the present study we first determined that, indeed, gender discrimination performance was similar in DPs and controls. Second, we found that inversion and scrambling (which we propose measures holistic processing and sensitivity to configural information, respectively) produced comparable deficits in DPs and controls, suggesting that both groups use holistic processing and configural information to recognize gender. This indicates that holistic processing and using configural face information are not general impairments in DP and may be more specific to face identity.

Keywords: Developmental prosopagnosia; Face inversion; Gender recognition; Holistic processing.

Effortlessly matching a face to one of thousands in memory is an exquisite human skill. Evidence suggests that the simultaneous integration of configural (subtle spacings amongst features), parts, and facial contour information into a single representation is what enables normal perceivers to identify a face so accurately and effortlessly (Richler, Cheung, & Gauthier, 2011). Though precisely what aspects of the face predominates in this holistic representation continues to be debated (McKone & Yovel, 2010; Rossion, 2008), researchers *have* agreed on measures that capture aspects of holistic processing, such as a marked decrement in performance when inverting the picture plane (face inversion effect; Yin, 1969).

Related to holistic processing, researchers have also demonstrated enhanced abilities for processing configural information (i.e., spacings amongst features) when judging facial identity. For example, neurotypical[1] individuals are much more sensitive to feature spacing changes when identifying upright faces compared to objects or inverted faces (Sekunova & Barton 2008). Moreover, neurotypical subjects are much worse at identifying scrambled faces with rearranged, intact parts compared to complete faces (Collishaw & Hole, 2000).

This advantage in processing configural face information may be from a specialized "configural processing" mechanism distinct from holistic processing (Maurer, Le Grand, & Mondloch, 2002). Alternatively, since holistic processing allows one to consider multiple features at once, sensitivity to configural information could be a direct consequence of faces being processed holistically (Rossion, 2008). Even if enhanced sensitivity to configural information is a consequence of holistic processing, it is important to quantify in its own right because it isolates sensitivity to internal feature spacing changes, whereas measures of holistic processing reflect the combined integration of parts, spacing, and facial contour information. In the present study, we suggest that the face inversion effect measures holistic processing and that scrambling intact face parts specifically measures sensitivity to configural information.

Besides identity, gender can also be easily recognized from a face. Face gender recognition has similarly been shown to rely on holistic processing, especially when cues such as hair and makeup are less prominent. For example, face gender inversion effects show effect sizes (Zhao & Hayward, 2010; Cohen's $d = 2.59$) comparable to inversion effects in recognition of familiar faces (Collishaw & Hole, 2000; Cohen's $d = 1.76$). Also, using the composite task (another traditional holistic processing measure), Baudouin

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[1] We consider neurotypical individuals as those who have neurological development and face processing abilities that are consistent with what most researchers would regard as normal. According to this definition, nonneurotypical individuals would include developmental prosopagnosics and those suffering from autism spectrum disorders.

& Humphreys (2006) showed that when subjects were to name the gender of one half of the face (e.g., top half) they received interference from the irrelevant half of the face (e.g., bottom half) when it was a different gender. This effect size (Cohen's $d = 1.37$) was similar to identity tasks (Macchi Cassia, Picozzi, Kuefner, Bricolo, & Turati, 2009, Cohen's $d = 0.90$; Rossion & Boremanse, 2008, Cohen's $d = 1.69$). Face gender recognition also shows similar robust performance decrements as identity recognition when configural information is disrupted, such as when scrambling intact face parts (Zhao & Hayward, 2010). Thus, substantial evidence suggests that face identity and gender are processed in a holistic manner and, in both, performance is sensitive to changes in face configuration.

Studying gender recognition in developmental prosopagnosics (DPs), individuals with severe lifelong face identification difficulties, provides another way to compare the mechanisms of face identity and gender processing. DPs typically show marked deficits in holistic processing of face identity as measured by reduced face inversion and part–whole task effects (another traditional holistic processing measure), particularly when the task involves distinguishing the eye region (DeGutis, Cohan, Mercado, Wilmer, & Nakayama, in press; Le Grand et al., 2006). Additionally, DPs show marked impairments when discriminating face identity based on configural changes, such as when changing the position of facial features or making feature shape changes (Yovel & Duchaine, 2006). DPs are, however, relatively normal at face identity discrimination when lower level cues are prominent, such as eye and lip shading (see Yovel & Duchaine, 2006; though Le Grand et al., 2006, show more mixed results).

In contrast to identity recognition, reports suggest that adult DPs have normal gender recognition (Dobel, Bölte, Aicher, & Schweinberger, 2007; Le Grand et al., 2006; Nunn, Postma, & Pearson, 2001). This raises the interesting theoretical possibility that at least for gender recognition, prosopagnosics might show intact holistic processing capacities and be sensitive to changes in facial configuration. However, the evidence for normal gender processing in DPs could be stronger. Nunn and colleagues used magazine pictures, where the likely use of make-up could have been an extraneous cue. Also of concern is the very high scores for controls and DPs in Le Grand et al. (95.3% and 94.6%, respectively; 2006) and in Dobel et al. (100% for both groups; 2007). A lack of a difference in gender performance at or so close to ceiling cannot be regarded as evidence for normal DP abilities. In summary, previous research on normal subjects suggests that the perception of gender is mediated by holistic processing and is sensitive to changes in configural information. Initial, but not fully satisfactory, evidence suggests that prosopagnosic individuals have normal gender perception.

In light of these studies, the first goal of the current study was to more definitively determine that prosopagnosic individuals are equivalent to

controls in their gender recognition performance. As such, we sought to create a more challenging test of gender recognition that relies on face-specific processing mechanisms. The second goal was to determine if DPs show the same characteristics of holistic processing and sensitivity to disruption of facial configuration for gender as controls (comparing upright to inverted and scrambled performance). As a point of reference, we included a test measuring upright and inverted face identity perception (Cambridge Face Perception Test; Duchaine, Germine, & Nakayama, 2007). We reasoned that if DPs have general deficits in holistic processing and rely more on nonholistic mechanisms than controls (e.g., eye and lip shading), for both gender and identity they should demonstrate less of a decrement in performance after disrupting the upright face configuration. If, however, DPs successfully rely on holistic face processing to recognize gender, they should show similar performance decrements with inversion and scrambling as controls. This outcome would suggest that DPs are able to process faces in a holistic manner and make use of configural face information for some face tasks.

METHOD

Participants

Twelve DPs (seven female; $M = 41.1$ years, $SD = 10.6$) who lived in the greater Boston area were recruited from www.faceblind.org over a 1-year period (June 2009–May 2010), and 28 matched controls (14 females; $M = 43.9$ years, $SD = 12.7$) were recruited through the study pool at Harvard University and a community message board (see Figure 1 and Table 1). All participants gave informed consent in compliance with the Institutional Review Boards of the VA Boston Healthcare System and Harvard University. All testing took place at either the Vision Sciences Laboratory at Harvard or the Boston VA hospital in Jamaica Plain.

Each DP participant reported a significant lifelong history of facial recognition deficits and completed a detailed questionnaire our lab has found to be diagnostic for prosopagnosia (for more details, see DeGutis et al., in press). We excluded two participants who possibly were on the autism spectrum (scored above 32 on the autism spectrum quotient questionnaire; Baron-Cohen & Wheelwright, 2001). Additionally, each participant had to score 1.7 standard deviations worse than the previous reported control mean on the Cambridge Face Memory Test (CFMT; Duchaine & Nakayama, 2006). Further confirming their prosopagnosia, DPs completed the Cambridge Face Perception Test (CFPT). Due to experimenter error, one DP did not complete the inverted trials portion of the CFPT. Finally, to examine whether the observed effects were driven by less impaired DPs, we also performed a median split of the DP group based on CFMT score.
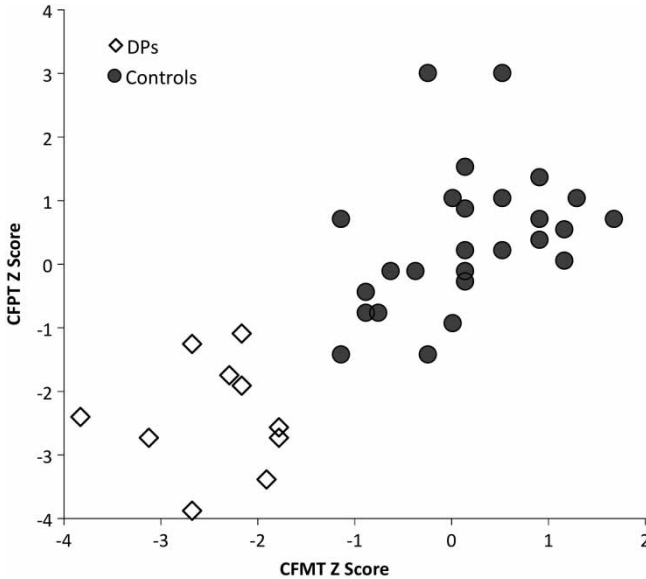
Figure 1. Performance of DPs and healthy controls on Cambridge Face Perception Test (CFPT, upright faces) and Cambridge Face Memory Test (CFMT).

Control participants reported having never experienced difficulties with face recognition and all scored within 1.7 standard deviations of the mean of previous reported controls on the CFMT (Duchaine & Nakayama, 2006).

TABLE 1
Developmental prosopagnosic (DP) demographics, raw number correct for the Cambridge Face Memory Test (CFMT), number of errors for upright and inverted portions of the Cambridge Face Perception Test (CFPT), and error rate on face gender tasks

				CFPT		Face gender recognition tasks		
Subject	Age	Sex	CFMT	Upright	Inverted	Upright	Inverted	Scrambled parts
S1	46	M	28 (−3.83)	66 (−2.40)	82	.20 (−1.29)	.27 (.15)	.43 (−.85)
S2	30	M	33 (−3.11)	70 (−2.73)	94	.09 (.56)	.32 (−.69)	.35 (.35)
S3	46	F	37 (−2.68)	52 (−1.25)	60	.13 (−.09)	.20 (1.09)	.23 (2.04)
S4	30	F	37 (−2.68)	84 (−3.88)	–	.21 (−1.42)	.36 (−1.18)	.39 (−.34)
S5	56	F	40 (−2.29)	58 (−1.75)	72	.07 (1.01)	.21 (.98)	.41 (−.65)
S6	46	M	41 (−2.17)	50 (−1.09)	64	.09 (.62)	.28 (−.03)	.35 (.35)
S7	43	M	41 (−2.17)	60 (−1.91)	64	.13 (−.11)	.36 (−1.18)	.33 (.55)
S8	54	F	43 (−1.91)	78 (−3.39)	76	.09 (.56)	.31 (−.43)	.35 (.29)
S9	25	F	44 (−1.78)	70 (−2.73)	72	.11 (.36)	.24 (.57)	.32 (.75)
S10	35	F	44 (−1.78)	68 (−2.57)	60	.04 (1.47)	.13 (2.07)	.32 (.68)

Z-scores relative to control performance are in parentheses.

Two participants were excluded because performance on the CFMT fell more than 1.7 standard deviations below the mean. All participants completed the CFMT, and all but two completed the CFPT. The inclusion of more control subjects than DPs was to ensure that null effects between groups would not be due to a random sampling bias in the control group.

Procedure

Cambridge Face Perception Test.   The CFPT is a computerized sorting task designed to assess facial identity discrimination ability (see Duchaine, Germine, & Nakayama, 2007). Participants see a target face and have to arrange six morphed faces from most like to least like the target face. The number of errors from the correct sequence of morphed faces is the dependent measure. Participants performed eight sorts for both upright and inverted faces.

Gender recognition task.   We used 40 cropped front-view photographs of unfamiliar Caucasian university students (20 males/20 females) from the MIT Face Database (see Figure 2). The faces did not have makeup, facial hair, or obvious gender grooming cues. Analyses of upright trials showed strong internal consistency (Cronbach's alpha = .79/Guttman's lambda 2 = .80), indicating that the task was highly reliable.

Inverted faces were created by rotating the upright faces 180° and scrambled faces were created by cutting each upright face into 10 components (two eyes, two eyebrows, two cheeks, nose, mouth, chin, and forehead) and rearranging these components into a new, nonface configuration. To avoid ceiling effects, stimuli were displayed for 2 s and we confirmed below-ceiling performance with extensive piloting. After 2 s, the screen displayed "Male or Female?" until a response was made. All participants completed three blocks of 40 trials in the following order: (1) Scrambled parts, (2) inverted faces, (3) upright faces.
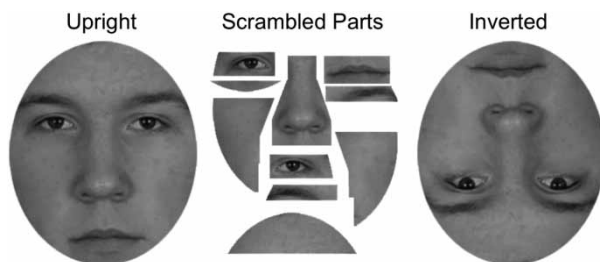
Figure 2.   Example of upright, scrambled, and inverted face stimuli used in the gender recognition task. (Source: Russell, 2009. Permission was obtained from the author.)

RESULTS

### Cambridge Face Perception Test: Upright and inverted performance

As shown in Figure 3, we replicated previous reports that DPs are worse than controls on upright face identity matching, $t(31) = 6.60$, $p < .001$, and that DPs show less of a face inversion effect than controls: DP/Control $\times$ Upright/inverted ANOVA interaction, $F(1, 31) = 21.45$, $p < .0001$.

Gender recognition: Upright faces

We next determined whether DPs and controls had comparable upright face gender recognition performance. As can be seen in Figure 4, DPs and controls showed nearly identical error rates, $t(34) = 0.46$, $p = .65$. To assess whether DPs and controls differ in their male/female response bias, we used a signal detection approach (analysis of d' and criterion) and found that both groups showed a male response bias, male bias > 0, controls $M = 0.58$, $SD = 0.56$, $t(25) = 5.43$, $p < .0001$; DP $M = 0.36$, $SD = 0.36$, $t(9) = 3.20$, $p < .05$, though there was no significant difference between groups ($p > .2$). Signal detection sensitivity (d') showed no difference between groups, $t(34) = 0.48$, $p = .63$, replicating the error rate results.
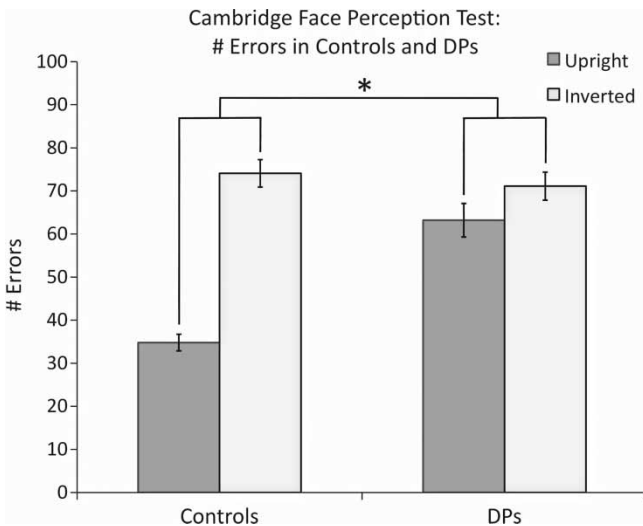
Figure 3. Upright and inverted Cambridge Face Perception Test performance for DPs and controls. Error bars indicate the standard error of the mean. *Indicates a significant group by upright/inverted interaction.
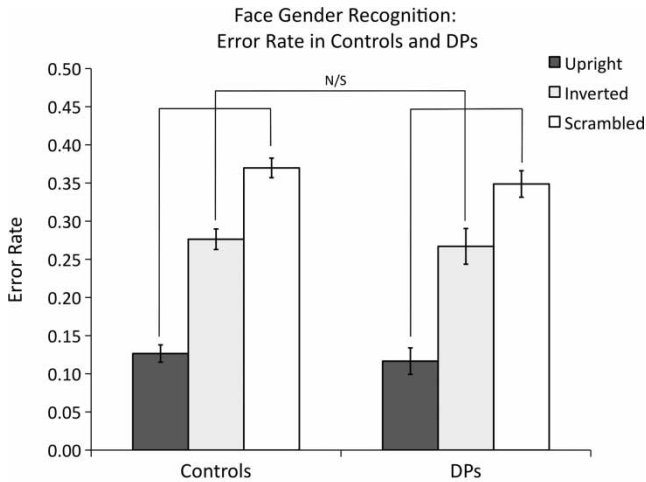
Figure 4.   Upright, scrambled parts, and inverted face gender performance for DPs and controls. Error bars indicate the standard error of the mean. N/S indicates that there is no significant interaction between group and upright/inverted nor a significant interaction between group and upright/parts.

Gender recognition: Scrambled face parts and inverted faces

As can be seen in Figure 4, DPs did not differ from controls in scrambled parts, $t(34) = 0.89$, $p = .38$, or inverted performance, $t(34) = 0.36$, $p = .72$, with both groups performing significantly better on inverted faces than scrambled parts: Controls, $t(25) = 5.71$, $p < .0001$; DPs, $t(9) = 2.76$, $p < .05$. Next, to compare DPs' and controls' performance decrements, we ran two ANOVAs (Group $\times$ Upright/Scrambled; Group $\times$ Upright/Inverted), which importantly revealed no significant interactions ($ps > .6$). Signal detection analyses did not reveal a significant response bias for scrambled parts or inverted faces in either group ($ps > .1$), and there were no differences between groups ($ps > .55$). Additionally, d' results showed no significant differences between DPs and controls ($ps > .4$), replicating the error rate results,.

More and less impaired DPs vs. controls

We additionally tested whether the five most impaired DPs (CFMT $M = 36.0$) or five least impaired DPs (CFMT $M = 41.6$) differed from controls. For upright gender recognition, least impaired DPs showed a trend towards having a *lower* error rate ($M = 0.09$, $SD = 0.04$) than controls ($M = 0.13$), $t(29) = 1.84$, $p = .08$, whereas most impaired DPs ($M = 0.15$, $SD = 0.06$) and controls did not differ, $t(29) = 0.68$, $p = .5$. There were no significant differences between controls and either group of DPs on inverted or scrambled trials ($ps > .1$) and, importantly, no significant interactions when

examining either Group × Upright/Inverted or Group × Upright/Scrambled ANOVAs ($ps > .5$).

DISCUSSION

Our results demonstrate that, although impaired at discrimination and holistic processing of face identity, DPs perform as well as controls at gender recognition and suggest that this is at least partly due to reliance on holistic processing and the use of configural information. These results call into question the idea that DPs are unable to process *any* aspect of faces in a holistic manner or are in general not sensitive to facial configuration. Rather, our results suggest that DPs can engage holistic mechanisms and make use of configural information when the task relies on face representations that are potentially less detailed and highly overlearned, as may be the case with face gender.

The current results are consistent with previous reports of spared face gender recognition in DPs (Dobel et al., 2007; Le Grand et al., 2006; Nunn et al., 2001), but extend these findings in two important ways. First, the current study forced DPs to make gender judgements based on internal components and precluded them from using grooming and makeup cues. This minimized ceiling effects and likely engaged face-specific mechanisms. Additionally, by including inverted and scrambled face conditions, the current study demonstrated that DPs use similar information as controls to determine gender.

What mechanisms do inverting and scrambling faces disrupt? Both disrupt sensitivity to perceiving configural information (Maurer et al., 2002; Schwaninger, Lobmaier, & Collishaw, 2002), with scrambling abolishing the perception of any configural information and inversion particularly disrupting the perception of long-range spatial relations (Sekunova & Barton, 2008). Additionally, inversion disrupts holistic processing, the integration of both parts and spacing information. Thus, the inversion decrement could also reflect difficulty discriminating the shapes of individual features (McKone & Yovel, 2010), which can also be diagnostic to gender recognition. Because DPs and controls showed significantly larger performance decrements with scrambling than inversion, the current results suggest that, in both groups, configural information may be more diagnostic to gender than feature shapes. However, this conclusion must be taken cautiously since the order of trials was not counterbalanced, which may have led subjects to show less of a performance decrement on the inverted condition.

The current results suggest that DPs can use face-specific mechanisms for gender recognition but are unable to use these mechanisms to recognize identity, possibly having to rely more on nonface-specific parts-based processing. This potential use of different mechanisms for gender and

identity processing in DPs contrasts evidence that controls process face identity and gender using the same processing route (Richards & Ellis, 2008). To further test whether DPs use a different route to recognize gender and identity, future studies could measure whether gender and identity processing interact in DPs, such as determining whether DPs are faster at recognizing the gender of repeated faces (Goshen-Gottstein & Ganel, 2000).

One reason why DPs may be able to utilize face-specific mechanisms to recognize gender is because gender recognition relies on less detailed representations than identity. For example, O'Toole, Abdi, Deffenbacher, and Valentin (1993) found that the aspects of faces that allow gender discrimination occur in the first few principal components, which involve lower spatial frequency cues, whereas those useful for face identification reside in later principal components. It may be possible that DPs can develop a cursory representation sufficient for recognizing gender and potentially for detecting faces too, but are unable to develop an intricate enough face representation to allow successful recognition of identity. Another factor is that gender may be particularly overlearned through repeated exposure and constant feedback starting in infancy (Leinbach & Fagot, 1993). Through continuous practice DPs may eventually be able to create holistic representations of each gender. Though these possibilities of relatively normal gender processing in DPs are intriguing, it should be noted that DPs may still process and represent gender in subtly different ways than controls. A recent study by Chatterjee and Nakayama (in press) provides compelling evidence that DPs also make normal masculinity/femininity ratings of faces, though additional studies using techniques such as face gender adaptation would be useful to determine if DPs' gender processing is truly "normal".

Though the current results cannot determine if DPs are completely "normal" at processing gender, they do call into question the assertion that DPs in general have holistic face processing deficits and are insensitive to configural face information. Our results rather suggest that DPs' holistic deficits are specific to building a detailed representation of face identity. In contrast to this idea, Palermo and colleagues (2011) recently found holistic face processing deficits in DPs for both identity and emotion. However, they used the composite task, which as a measure of face identity holistic processing has shown to be highly inconsistent at quantifying impairments in DPs (e.g., using the exact task as Palermo et al., 2011, Le Grand et al., 2006, show normal composite effects in DPs) compared to face inversion and part–whole tasks (for a recent review, see DeGutis et al., in press). Thus, the face inversion effect likely better captures DPs' face identity holistic processing deficits and may be better suited for comparing recognition of nonidentity information from faces. Future studies of face emotion recognition using face inversion would be useful to determine if holistic processing of faces in DPs extends to emotion recognition.

In summary, the current results demonstrate that DPs can successfully recognize gender from faces and do so, similar to controls, in a holistic manner and by utilizing configural information. We interpret this as evidence that DPs, despite not being able to build a holistic representation detailed enough to recognize face identity, can create a cursory face representation that is sufficient for recognizing gender from faces.

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