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Holistic face processing can be independent of gaze behaviour: Evidence from the composite face illusion

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People tend to perceive identical top halves (i.e. above the nose) of two face stimuli as being different when they are aligned with distinct bottom halves. This composite face illusion is generally considered as the most compelling evidence that facial features are integrated into a holistic representation. Here, we recorded eye-movements during the composite face illusion in a delayed matching task of top halves of faces. Behavioural results showed a strong composite face effect, participants making more mistakes and taking longer time to match two identical top halves of faces when they were aligned (vs. misaligned) with different bottom halves. Importantly, fixation sites and eye-movements were virtually identical when the top and bottom parts were aligned (composite illusion) or misaligned (no illusion), indicating that holistic face processing can be independent of gaze behaviour. These findings reinforce the view that holistic representations of individual faces can be extracted early on from information at a relatively coarse scale, independently of overt attention.

People tend to perceive two identical top parts of an upright face stimulus as different if their respective bottom parts differ. This composite face illusion vanishes if the top and the bottom parts of the faces are laterally offset (i.e. misaligned). The composite face illusion is usually taken as strong evidence that facial features are integrated into a holistic representation of an individual face by human observers (e.g. de Heering, Houthuys, & Rossion, 2007; Goffaux & Rossion, 2006; Hole, 1994; Le Grand, Mondloch, Maurer, & Brent, 2004; Michel, Rossion, Han, Chung, & Caldara, 2006; Singer & Sheinberg, 2006; Young, Hellawell, & Hay, 1987). Holistic face perception, defined simply here as *the representation of multiple features of a face as a perceptual unit*,

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is considered as a fundamental aspect of our face-processing system (e.g. Farah, Wilson, Drain, & Tanaka, 1998; Maurer, Le Grand, & Mondloch, 2002; Sergent, 1984a).

The question we consider in the present study is whether eye-movements play any role in holistic face perception as measured through the composite illusion. On the one hand, several sources of evidence indicate that individual holistic face representations are extracted from the visual stimulus even before the movements of the eyes. First, studies with brief stimulus presentation of lateralized stimuli have shown right-hemisphere superiority for face processing that has been related to privileged holistic encoding (Hillger & Koenig, 1991; Sergent, 1984b). Furthermore, behavioural experiments showed that two to four faces can be processed during a single eye fixation of about 200 ms (Näsänen & Ojanpää, 2004). Neurophysiological data also support the view that holistic representations of individual faces are extracted early on. For instance, face-selective cells in the monkey inferotemporal (IT) cortex (e.g. Desimone, Albright, Gross, & Bruce, 1984; Gross & Sergent, 1992; Perrett, Rolls, & Caan, 1982; Rolls, 1992) start discharging at about 80–130 ms after stimulus onset (Bullier, 2001; Oram & Perrett, 1992). A large proportion of these IT cells respond to the whole face stimulus and do not discharge if parts of the face are removed (Tanaka, 1996; Wang, Tanaka, & Tanifuji, 1996) or if all face parts are present but scrambled (Desimone *et al.*, 1984), suggesting that they represent faces holistically. Moreover, recent event-related potential (ERP) evidence report that upright but not inverted faces can be discriminated on the face N170 event-related potential (ERP), indicating that holistic face processes are involved early on when individualizing faces (Jacques, d'Arripe, & Rossion, 2007). Thus, overall, a number of elements support the idea of an early extraction of holistic individual face representations in the human brain, largely independent of eye-movements.

On the other hand, it has been clearly shown that eye-movements are functional in face processing (Henderson, Williams, & Falk, 2005). More specifically, it has been proposed that gaze behaviour may differ during analytical and holistic processing of faces (Schwarzer, Huber, & Dümmler, 2005). In this study, participants were free to categorize the faces by either focusing on one specific feature or taking the overall similarity relations of the faces into account. Participants who took into account multiple features rather than a single one in the task were classified as holistic processors. They fixated more on the area of the eyes and nose than the analytic processors. The authors therefore concluded that eye-movement patterns may be a good indicator of holistic face processing (Schwarzer *et al.*, 2005).

The current study aimed at disentangling these proposals and was designed, more generally, to determine whether eye-movements play a role during the face composite illusion, considered as the best marker of holistic face perception. When the face composite illusion is adapted to a matching paradigm with individual faces, it is reflected by increased mistakes and response times when participants are asked to match two identical top parts of a face stimulus aligned with distinct bottom parts (see also de Heering *et al.*, 2007; Goffaux & Rossion, 2006; Hole, 1994; Le Grand *et al.*, 2004; Michel *et al.*, 2006; Singer & Sheinberg, 2006; Young *et al.*, 1987). The effect is thought to arise because the bottom part of the aligned face influences the perception of the fixated top part. Hence, the illusion of a different identity perceived on the top part of the face is thought to occur, while viewers do not look at the bottom part. However, this assumption has never been shown to our knowledge, since eye-movements are not recorded in this paradigm. In the present study, unlike what is commonly done in free-viewing studies of face perception during eye-movement recordings (e.g. Althoff & Cohen, 1999; Groner, Walder, & Groner, 1984; Henderson, Falk, Minut, Dyer, & Mahadevan, 2001; Janik, Wellens, Goldberg, & Dell'Osso, 1978; Luria & Strauss, 1978; Mertens, Siegmund, & Grüsser, 1993; Schwartzer *et al.*, 2005; Walker-Smith, Gale, & Findlay, 1977; Williams & Henderson, in press), participants were explicitly told to focus on the top part of the composite faces during the matching task. This restricted viewing condition was consistent with the initial experiment (Young *et al.*, 1987) and previous studies and was essential to reveal the composite face illusion.

There are three possible outcomes of such an experiment. If gaze behaviour is identical in the critical aligned and misaligned conditions while participants show a significant composite face effect, this will indicate that holistic face perception can be completely independent of eye-movements during individual discrimination. On the contrary, if participants orient their gaze differently to the top face part in the aligned condition when compared with the misaligned condition, this would support the view that eye-movements can be used as a reliable index of the strategies used in face perception. Finally, if participants, despite the instructions, orient more their gaze to the bottom part of the face stimulus when the two parts are aligned (composite illusion), this will suggest that the composite face effect may not be due to the top part being perceived differently. Rather, it would emerge because participants attend the bottom part of the face in the aligned but not in the misaligned condition, and extract direct information from this bottom part that influences their performance. This would be a serious limitation of the face composite illusion, at least in paradigms for which the duration of the stimuli is longer than the minimal time required to perform eye-movements.

Methods

Participants

Twelve Caucasian adults participated in the study (mean age = 20.9 years; one male; one left-handed). All of them had normal or corrected-to-normal visual acuity. The data of two additional participants were not included in the results reported here. Indeed, compared with the other participants, their number of fixations and mean fixation time (sec) exceeded (three standard deviations) the group's average in the trials of interest of the experiment ('aligned same' (AS) and 'misaligned same' (MS) trials), at least in one of the region of interest (three ROIs: top part of the face (ROI 1); bottom part of the face (ROI 2); and out of the face (ROI 3)).

Stimuli

The original sample constituted 30 hairless full-front greyscale female Caucasian faces posing with neutral expression. All images were centred on their pupils making the eyes appearing exactly at the same place in relation to the background, independent of their identity. All the face images were placed on a black background. The size of the aligned faces subtended $7.8 \times 9.6^{\circ}$ of visual angle.

To create the composite set of faces, the original stimuli were divided into top and bottom segments by dividing them in the middle of the nose using Adobe Photoshop 7.0. The segments of these original stimuli were either aligned or misaligned in reference to the initial experiment of Young *et al.* (1987). Then, for each original stimulus, two composite face stimuli were constructed by joining the top segment of the original face to the bottom segment of another face stimulus: one in which the two halves were aligned, and one in which they were misaligned. These faces were used in 'same' (AS and MS) trials. Two additional composite stimuli were also constructed, one aligned and one misaligned, having both the top and the bottom part different from the original face. These were used in 'different' (AD and MD) trials. All the trials were constructed by randomly associating an original (first face) and a composite (second face) stimulus, the latter being extracted from the AS, MS, AD, or MD condition. These faces were presented sequentially to the participants.

Apparatus

Each participant sat in a dark room at 80 cm from a computer screen. This distance, from the camera to the eye, was under the maximal distance (i.e. 100 cm) at which the ASL (Applied Science Laboratories) eye-tracking system is effective with adults. The system was developed for the automatic registration of eye-movements and consisted of an infrared camera located at the base of the computer screen. Helped by a remote control and the participant's left eye image on a monitor, an experimenter blind to the purpose of the study guided the camera to keep the participant's eye constantly on focus. The eye-tracking system automatically detected the position of the pupil and the corneal reflection of the infrared light-emitting diodes (LEDs) in the eye. Because these signals changed in relation to the participant's gaze direction, the apparatus determined, with a frequency of 50 Hz, the x–y coordinates corresponding to the participant's fixation points during stimulus presentation. Two crosses of different colours corresponding to the signals coming from the participant's pupil and corneal reflection were superimposed on the images of the stimuli presented, giving a second experimenter a direct indication of the quality of the signal collected during the experiment.

Procedure

The experiment started with a calibration followed by an experimental stage. During the calibration, a second experimenter adjusted the detection parameters of the pupil and the corneal reflection to the particularities of each single participant (e.g. pupil diameter). Then a spot light was used to attract the participant's gaze towards several predetermined locations essential to calibrate his/her eye-gaze. At this point, the signals of the pupil and the corneal reflection started to be detected and recorded. On the basis of this initial calibration, the eye-tracking system could determine the precise direction of the participant's gaze during the experimental session. The registration of eye-movements always started at the fixation-cross presentation. The recording was switched off when the second stimulus presentation ended, following the observer's response. Participants' behavioural responses were concurrently collected using E-prime 1.1.

The experiment consisted of 120 experimental trials (30 AS; 30 AD; 30 MS; and 30 MD) randomly displayed in two blocks of 60 trials. Participants were instructed to focus on the top parts of the faces in order to decide as quickly as possible whether the two top parts were identical (left response key in AS and MS trials) or not (right response key in AD and MD trials). The order of the keys was counterbalanced across participants. Before starting the experiment, each participant was familiarized with the experiment through 10 practice trials. Feedback was provided on the practice trials but not on the experimental trials. Each trial started with a fixation-cross presented in the middle of the screen for 300 ms followed by a blank screen for 200 ms and a first face for 600 ms. After a second 300 ms blank screen, a second stimulus was presented and disappeared as soon as the participant pressed a key (maximal presentation time = 2,500 ms). The inter-trial interval was 1,000 ms. Analyses focused on differences in performance for same trials between the misaligned (MS) and the aligned (AS) conditions, reflecting the composite face illusion.

ASL Eyenal software was used to process raw data (i.e. x–y coordinates) of the eye-tracking system. In order to determine participants' number of fixations and mean fixation time (sec) towards each ROI (top part of the face (ROI 1), bottom part of the face (ROI 2), and out of the face (ROI 3)), we defined for each participant four fixation files that reduced raw eye positions from AS, AD, MS, and MD trials to a series of fixation points. Fixations were defined as remaining within one degree of visual angle for more than 100 ms. They were also distinguished from very small involuntary eye-movements and from saccades (rapid voluntary eye-movements from one fixation point to the other). As a result, the number and the amount of time each participant spent looking at various face elements were determined.

Results

Behavioural results

Paired samples t tests were performed on participants' response accuracy (percentage of correct responses on same trials) and response times (second) for correct trials with test condition ('aligned same' (AS) vs. 'misaligned same' (MS)) as within-subject factor. There was a strong composite effect on both accuracy (AS: 82% vs. MS: 94%, $t(11) = 3.043$, $p = .011$) and response times (AS: 0.703 sec vs. MS: 0.615 sec, $t(11) = 4.937$, $p = .000$).

Eye-tracking results

In line with behaviour, the distribution of eye-movements was analysed for each participant for first and second faces presented during the critical AS and MS correct trials. Analyses were based on the number of times (Σ) each participant fixated a given area (top (ROI 1) or bottom of the face (ROI 2)) in each experimental condition (AS and MS). Similarly, we also calculated the average amount of time (X) that the participant spent fixating these areas collapsing separately the 30 AS trials and the 30 MS trials. These values were then averaged across all participants for both first and second faces (see Tables 1 and 2). Four distinct analyses of variance (ANOVA) were also performed on participants' number of fixation and mean fixation time (sec) on first and second faces, with the part of the face (top vs. bottom) and the face condition (aligned vs. misaligned) as within-subjects factors.

Table 1. Distribution of looking time on first faces, considering all participants

Face condition/Part of the face	Top	Bottom
Mean number of fixation (*N*) (*SD*)		
Aligned (AS)	50.417 (6.667)	0.083 (0.289)
Misaligned (MS)	50.167 (7.234)	0.083 (0.289)
Mean fixation time (sec) (*SD*)		
Aligned (AS)	0.483 (0.076)	0.0004 (0.001)
Misaligned (MS)	0.477 (0.065)	0.0002 (0.0009)

Table 2. Distribution of looking time on second faces, considering all participants

Face condition/Part of the face	Top	Bottom
Mean number of fixation (*N*) (*SD*)		
Aligned (AS)	40.167 (13.730)	0.250 (0.866)
Misaligned (MS)	43.833 (13.677)	0.250 (0.622)
Mean fixation time (sec) (*SD*)		
Aligned (AS)	0.557 (0.160)	0.003 (0.010)
Misaligned (MS)	0.481 (0.130)	0.002 (0.005)

Distribution of looking time on the first face

Participants' first fixation was almost always (98%) directed to the top part of the original faces in both aligned (AS) and misaligned (MS) trials. Furthermore, first fixation's mean duration was not significantly different for AS and MS trials: 0.337 sec for AS trials and 0.328 sec for MS trials, $t(11) = 1.198$, $p = .256$ (see Table 1).

For the first face, there was no effect of the face condition (aligned vs. misaligned) neither on the number of fixation ($F(1, 11) = 0.061$, $p = .809$) nor on the mean fixation time ($F(1, 11) = 1.306$, $p = .277$). However, as expected, there were strong main effects of the part of the face (top > bottom) on the number of fixation ($F(1, 11) = 658.623$, $p < .0005$) and the mean fixation time ($F(1, 11) = 562.894$, $p < .0005$). There was no hint of an interaction between the face condition and the part of the face, neither for the number of fixation ($F(1, 11) = 0.06$, $p = .812$) nor the mean fixation time ($F(1, 11) = 1.116$, $p = .313$).

In sum, adult participants remained focused on the top part of the first face stimulus presented for 600 ms and did not show any differential pattern of fixation between aligned (AS) and misaligned (MS) trials. It is worthy to note that the short presentation of first face could have minimized differences in scanning. We will therefore focus on participants' gaze behaviour on the second face, prompting the composite illusion.

Distribution of looking time on second faces

Participants' first fixations were always nearly oriented to the top half of the faces in both AS and MS conditions (frequency: 95% (AS trials) and 94% (MS trials), $t(11) = 0.788$, $p = .448$) and lasted almost the same time (mean duration: 0.379 (AS trials) and 0.353 sec (MS trials), $t(11) = 2.000$, $p = .071$) (see Table 2).

Interestingly, a significant main effect of the face condition (aligned vs. misaligned) was found on mean fixation time ($F(1, 11) = 14.875$, $p = .003$), participants fixating AS trials longer on average, but not on the number of fixation ($F(1, 11) = 2.85$, $p = .119$). As with first faces, analyses revealed highly significant main effects of the part of the face (top vs. bottom) on the number of fixation ($F(1, 11) = 120.89$, $p < .0005$) and the mean fixation time ($F(1, 11) = 162.408$, $p < .0005$). A significant interaction between the face condition and the part of the face was found on mean fixation time ($F(1, 11) = 15.898$, $p = .002$) but not on the number of fixation ($F(1, 11) = 2.906$, $p = .116$). Thus, participants did not only fixate longer to the top when compared with the bottom parts of the faces (see examples in Figure 1), but also their overall mean looking time was longer on the top parts of aligned than misaligned faces. This was confirmed by a subsequent paired *t* test that indicated a longer mean fixation time (sec)

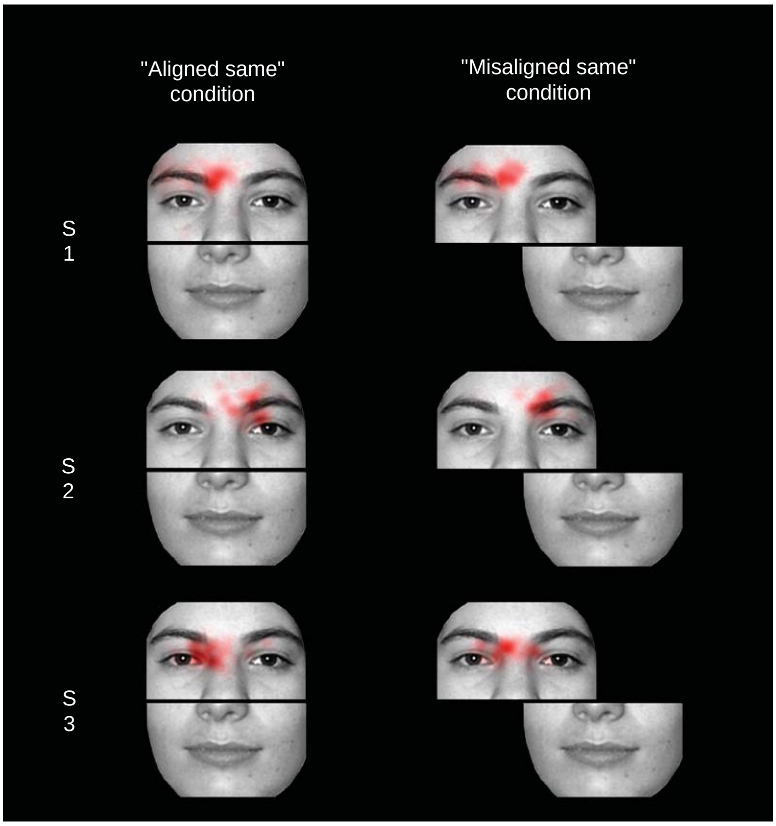

Figure 1. Locus of fixation of three participants in the 'aligned same' (AS) and 'misaligned same' (MS) condition during the composite task. The intensity of the colour was normalized within the participant.

on top parts of aligned test faces (Mean = 0.56 sec; $SD = 0.16$) when compared with top parts of misaligned test faces (Mean = 0.48 sec; $SD = 0.13$), $t(11) = 3.93$, $p = .002$.

However, behavioural data (AS: 0.703 sec; MS: 0.615 sec) were strictly linked to eye recording data (AS: 0.56 sec; MS: 0.48 sec), as suggested by the high correlations between participants' response times (RTs) and their mean fixation time (sec) in aligned (AS; Pearson correlation = .797; $p = .002$) and misaligned (MS; Pearson correlation = .747; $p = .005$) conditions. As longer fixations were correlated to longer response times in both AS and MS trials, we included participants' differential response times (AS response times – MS response times) as a covariate in an ANCOVA (analysis of covariance) to test whether the differential result found when contrasting participants' mean looking time on the top parts of the faces in the aligned and misaligned conditions would still hold when the variability of this latter factor is neutralized (Rousselle & Noël, 2007). In other words, the ANCOVA analysis was aimed at disentangling whether the face condition (aligned vs. misaligned) would still affect the mean fixation time after removing the variance induced by the covariate (i.e. differential response times). The ANCOVA on mean fixation time (sec) with behavioural response times as covariate revealed a main effect of the part of the face (top vs. bottom, $F(1, 10) = 43.144$, $p < .0005$) but critically, no effect of the face condition (aligned vs. misaligned, $F(1, 10) = 0.01$, $p = .922$) and no interaction between the face condition and the part of the face ($F(1, 10) = 0.005$, $p = .944$). This absence of interaction indicates that the longer mean fixation time on the top parts of aligned versus misaligned faces was strictly due to the time devoted to respond (i.e. aligned faces being processed more slowly).

It is also interesting to note that when controlling for response times, participants' mean time of fixation on the top part of the aligned face was not correlated to the strength of their respective composite effect (MS score – AS score) when it was calculated in both accuracy rates (Pearson correlation: .453, $p = .162$) and response times (Pearson correlation: .244, $p = .469$). Similarly, the time they spent fixating the top part of the face in the misaligned condition was not correlated to the strength of their composite effect when expressed in accuracy rates (Pearson correlation: .242, $p = .474$) or response times (Pearson correlation: .342, $p = .304$).

In sum, these results show that participants' gaze behaviour was not oriented to the bottom parts of the second faces neither in the aligned (AS) nor in the misaligned (MS) condition (see Figure 1). Participants were rather fixating the top part of the aligned (composite illusion) and misaligned (non illusion) faces for the same amount of time, at virtually identical locations (see Figure 1).

Discussion

The current study aimed at determining whether eye-movements play any role in driving the composite illusion. Unlike in free-viewing studies (e.g. Schwarzer *et al.*, 2005) but in agreement with the classical face composite paradigm (Young *et al.*, 1987), participants were instructed to fixate a specific location (top part) of the face stimulus during the task. The eye-movement recordings show that the instructions are respected: the interference of the bottom part takes place without participants looking at it. The fixation location distribution that we observed most probably results from the combined effects of the instructions ('fixating the top part') and the spontaneous orientation towards the eyes when a face has to be recognized (Henderson *et al.*, 2001). Participants generally (95% of the time) fixated the top part of the aligned face (i.e. second face prompting the composite illusion) as soon as it appeared on the screen, and one can reasonably assume that within this first glance (mean fixation = 0.379 sec), the features of this composite face were integrated into a holistic representation. In other words, the perception of the fixated feature (the top face part) was influenced by another facial feature (i.e. the bottom part of the face), even without participants looking at the latter. Then, the participants either extended their first fixation or moved their eyes to another point-of-regard, still on the top part of the face (i.e. ROI 1). Altogether, they spent in average 0.56 sec ($SD = 0.16$) fixating the top parts of the aligned composite faces and made one to five fixations before pressing the response key. Their looking time was significantly longer in aligned (AS) than in misaligned (MS) trials, but this was strictly linked to behaviour, for a longer time needed in the aligned when compared with the misaligned condition to match the two representations. Furthermore, their gaze behaviour location on the top part was virtually identical in the aligned and misaligned conditions, indicating that holistic face perception can be independent of gaze behaviour.

Reporting identical gaze behaviour during the presence or absence of interference between face features (the hallmark of holistic face perception, see Goffaux & Rossion, 2006) is interesting for a number of reasons. First, these observations indicate that one can measure holistic face perception independently of eye-movements. This holds when eye-movements are restricted to half of the face by instructions, but also under free viewing condition, as recently suggested by an eye-movement study on the face inversion effect (Williams & Henderson, in press). While it has clearly been demonstrated that the inversion of a face stimulus dramatically affects holistic face perception (Sergent, 1984a; Tanaka & Farah, 1993; Young *et al.*, 1987), Williams and Henderson (in press) showed that the facial features selected for fixation during recognition of upright faces are very similar to those selected for fixation during recognition of inverted faces when participants were allowed to move their eyes freely. According to these authors, the face inversion effect is therefore not a result of a different pattern of eye-movements during the viewing of the face. Conversely, Schwarzer *et al.* (2005) argued that differences in analytical and holistic face processing can be detected early in gaze behaviour. However, and importantly, in this last study, the authors acknowledge that so-called 'holistic processors' may have resolved the task using an additive strategy based on a more dispersed gaze behaviour over different and larger facial areas rather than an integrative strategy. Here, while we also considered holistic face processing as arising when multiple features are taken into account, we specifically asked participants to focus on one 'feature' only (the top part of the face) and measured the interference of another feature (the bottom part) behaviourally. We showed that facial features are interdependent during individual face processing, despite participants focusing only on one face 'feature'. Thus, our paradigm is unlikely to reveal an additive strategy of the participants: they have to take into account only one part of the face, but cannot prevent seeing it as different when it is aligned with the other part. It is important to note that our study also differed from Schwarzer *et al.*'s experiment on several aspects related to the task and the stimuli. Here, participants simply had to match or discriminate individual top parts of the face, which were not manipulated, whereas in Schwarzer *et al.*'s study, faces were purposefully constructed so that they could be categorized based on either a single or multiple feature information.

In sum, we found that eye-movements are not a necessary correlate of holistic face perception, but this does not exclude their potential role in helping to integrate multiple features of a face into a holistic representation under different circumstances (Schwarzer *et al.*, 2005). More generally, even though we have observed a strong indication of holistic face perception independent of eye-movements, the absence of correlation between specific eye-movement patterns and holistic perception in the face composite paradigm does not rule out their potential contribution in building robust holistic representations of faces during the microgenesis of face perception (Sergent, 1986), or their functionality during individual face encoding (Henderson *et al.*, 2005). Also, at present, although the current findings show that eye-movements may not represent a necessary requirement for holist effects, it is still not possible to make strong statements about the reverse; that is eye-movements have no effect at all on holistic face processing. Future studies might further investigate this issue examining whether unrestricted eye-movements (free-viewing) on one side, and strictly restricted eye-movements (e.g. eye-movements restricted to a marked area subtending 1° of visual area) on the other side modulate or not holistic face processing, increasing, or decreasing the face composite effect.

A second interest of the present findings is that they indirectly reinforce the view that the building of a holistic perceptual representation is based on information conveyed by low spatial frequencies of the stimulus (Goffaux & Rossion, 2006; Sergent, 1986). This is because, at least with the size of stimuli used here, the bottom parts of aligned faces appear at relatively coarse spatial frequencies to the participants, due to the loss of visual resolution as the angular distance (i.e. retinal eccentricity) from fixation point increases (Curcio & Van Allen, 1990; Henderson, 2003). During an ocular fixation, only a very restricted foveal region of 2° (Anstis, 1974; Riggs, 1965) is perceived distinctly (Rayner & Pollatsek, 1992) even though we are usually not aware of this decrease in acuity because of compensating eye-movements (Séré, Marendaz, & Hérault, 2000). In the present study, almost every fixation was directed to the top halves of these faces (ROI 1) subtending approximately 7.8° of visual angle horizontally and 4.8° vertically. Consequently, if the fixation falls into ROI 1 and if high acuity vision is effectively restricted to a small region of 2° surrounding the fixation point (Anstis, 1974; Riggs, 1965), acuity towards the bottom half of the face (ROI 2) should be relatively poor (see Figure 2).

The demonstration that low spatial frequencies supports holistic face perception independently of gaze behaviour reinforces the view that a holistic representation can be extracted within the first glance at a face stimulus, as initially proposed (Galton, 1883). Our findings also suggest that the composite face illusion, which is extensively used in the face literature (e.g. Goffaux & Rossion, 2006; Hole, 1994; Le Grand *et al.*, 2004; Michel *et al.*, 2006; Singer & Sheinberg, 2006; Young *et al.*, 1987), is not due to an overt attentional bias, i.e. participants paying more attention to the bottom part of the face stimulus in the aligned condition because it is closer spatially. Nevertheless, one may still argue that while participants maintain eye fixation on the top part of the face stimulus equally well in the two conditions, they could also allocate more covert

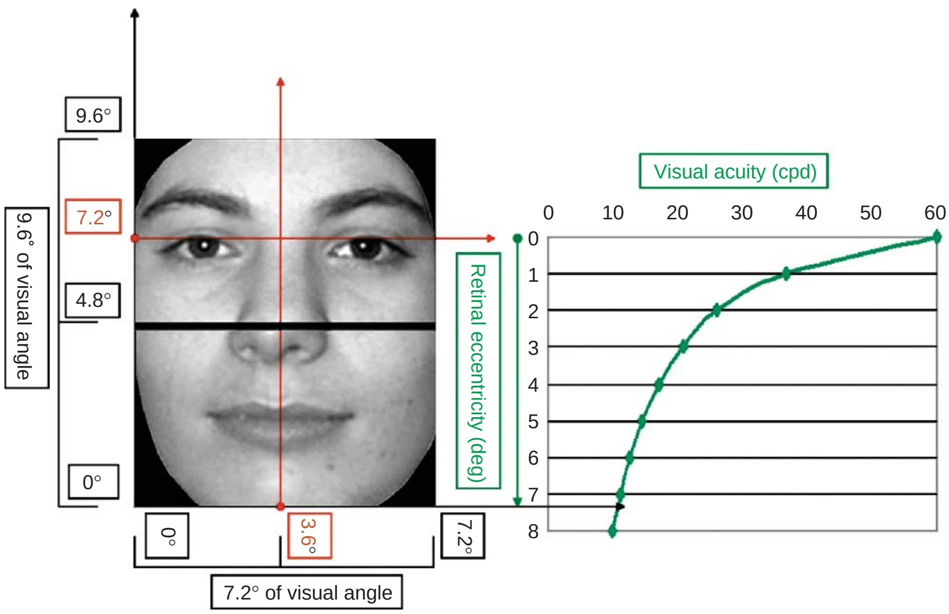

Figure 2. Simulation of the drop of acuity with increasing eccentricity from an arbitrary fixation point (*x*–*y* coordinates: 3.6°; 7.2°) as a function of the equation: A (acuity) = 60/(1 + 0.625 × E (eccentricity)) (Séré *et al.*, 2000). If one considers an arbitrary fixation right in the middle of ROI 1 (*x*: 3.6°; *y*: 7.2°), eccentricities of 1–8° of visual angle can be computed to simulate the spatial resolution of the eye during the perception of aligned composite face stimuli. There is a progressive deterioration of acuity from 36.81 to 10 cycles per degree. Thus, information perceived only at a relatively coarse scale in the bottom part of the face can modulate the perception of the top part.

attention to the bottom part when it is aligned with the top part and consequently, be less attentive to the top part of the aligned stimulus, leading to its slower and less accurate processing. That is, we cannot fully exclude the possibility that the interference observed in the aligned condition is not due to the top part being perceived differently, but to the bottom part automatically attracting participants' attention, in a bottom-up fashion. However, this is very unlikely because there is an evidence that holistic face processing takes place automatically (Boutet, Gentes-Hawn, & Chaudhuri, 2002; Khurana, Smith, & Baker, 2000). Taken together, the observations of identical gaze behaviour during the presence or absence of holistic interference thus supports the view that holistic face-processing effects reflects the perceptual integration of facial features independently of overt attention.

A final consequence of the findings is that holistic face perception can only be supported in visual areas where the receptive fields of cells are large enough to encompass information from the lower part of the stimulus. In monkeys' visual areas, the receptive field sizes of the neurons become larger by a factor of approximately 2.5 with each succeeding stage of the visual pathway consisting (at least) of V1, V2, V4, TEO, and TE (e.g. Rolls, 2003; Rousselet, Mace, & Fabre-Thorpe, 2004). TEO and TE are parts of the monkey inferotemporal cortex (IT) showing a large proportion of face-selective cells (Logothetis, 2000). Whereas cells near the fovea in V1 have a receptive field extending from 0.5° to 1°, they approximate 8° in V4, 20° in TEO, and 50° in TE (Boussaoud, Desmione, & Ungerleider, 1991). Taking into consideration this receptive field magnification along the ventral visual stream and the size of the aligned face stimuli used in the present experiment (7.2° horizontally and 9.6° vertically), the effects observed here could not take place before V4, and more certainly reflect processes taking place at non-retinotopic high-level visual areas beyond that stage (Grill-Spector & Malach, 2004). This observation is thus entirely congruent with recent neuroimaging studies in humans using the face composite illusion, which indicate a predominant role of the non-retinotopic right 'fusiform face area' ('FFA') in perceiving individual face stimuli holistically (Schiltz & Rossion, 2006).

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