

Eye gaze fixations and gaze-contingency during face perception: a research program

Bruno Rossion (text updated, august 2015)¹

<http://face-categorization-lab.webnode.com/research/eye-movements-gaze-contingency-and-face-perception/>

For a long time I was convinced that studies of eye gaze fixations during face perception were not very informative for understanding the nature of face perception processes. We all know the textbook images of eye gaze fixations from the classical studies of Yarbush (1967), with preferential explorations centered on each of the eyes and the mouth. Nice pictures, but not very surprising, and not very informative about the nature of face perception.

I also understood from various sources that despite being terrible at recognizing faces upside-down, eye movement patterns were not fundamentally different for pictures of faces presented upright and upside-down. This lack of effect has been reported in the literature by Williams & Henderson (2007), although this kind of observation must have been made previously by many researchers who did not dare reporting an absence of effect.

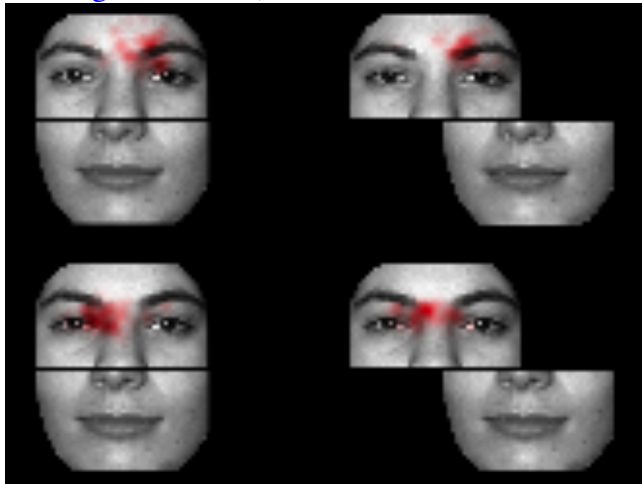
The problem for eye movement studies of face perception is that face perception is usually very fast. One can detect a face in a few hundreds of milliseconds at most, including a behavioral response (gazing towards a face in a 2 alternative forced choice display can even be faster, Crouzet, Kircher & Thorpe, 2010). And studies using Event-Related Potentials (ERPs) show that faces presented at fixation are discriminated from other visual stimuli as early as 130 ms (onset of the N170 time window, see <http://face-categorization-lab.webnode.com/research/time-course-of-face-processing-the-n170/>), or perhaps even earlier (Rossion et al., 2015; see <http://jov.arvojournals.org/article.aspx?articleid=2213210>). This duration is too short to initiate a second saccade. Moreover, many ERP studies, including studies performed in our lab, have shown that sufficient evidence to discriminate *individual* faces has already accumulated during that N170 time-window (Jacques et al., 2007), i.e. clearly below 200 ms.

So why having an interest in eye gaze fixations on faces? In fact, our first study was performed in order to show that eye gaze fixations were indeed *not* informative for what we were interested in: we simply recorded eye gaze fixations when people were exposed to the composite face illusion in a behavioral task, measuring holistic face processing (de Heering et al., 2008). As usual in this task, people have to match the top identical halves of two faces presented in succession. They make mistakes when the bottom halves are of different facial identities, because the top halves are erroneously perceived as being of different identities (Young et al., 1987). This illusion is released when the bottom halves are slightly spatially misaligned from their top halves (see Rossion, 2013 for an extensive review).

In our study, despite fundamentally different behavioral responses in the aligned and misaligned conditions, we showed that participants' eye gaze fixations were exactly the same: they kept fixations on the top half of the face (even higher than usual, probably because of the instructions). Thus, despite being strongly influenced by the nature and alignment of the

¹ Author's note: this text summarizes the research and research program pursued in the author's laboratory (Face Categorization Lab) at the University of Louvain. It is not meant to provide a review of eye gaze fixations on faces and gaze-contingency in particular. The text also reflects the author's personal view on theoretical and methodological issues concerning this topic.

bottom face half, their eye gaze fixation patterns were identical in the 2 conditions (de Heering et al., 2008).



This may seem like a null result, not worth being reported. And, as a matter of fact, we struggled a bit to publish it ! Yet, we believe that it was important to report something like that, since it could always be claimed that in this composite face paradigm, people are influenced by the bottom halves of the faces just because they look at it (especially in the aligned condition). Also, we were interested in testing the composite face paradigm in children (de Heering et al., 2007) and prosopagnosic patients (Ramon et al., 2010), and we could not present our stimuli for short durations with these participants.

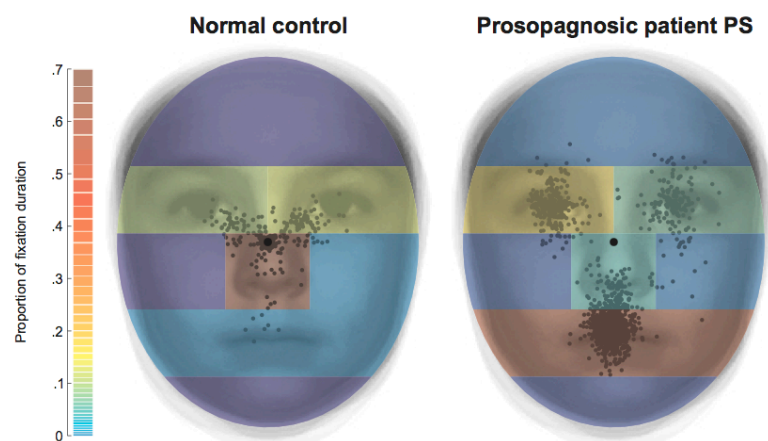
It was therefore important to show that even when people have the time to look at the bottom half of the faces in this paradigm, well ... they don't.

We concluded that **holistic face processing can be independent of gaze behavior**, as the observations of Williams and Henderson (2007) on inverted and upright faces also suggested. Yet, while some have taken such observations as evidence that eye movement patterns cannot be informative of the nature of face perception, which is characterized by holistic/configural processing, I started to change my mind at that time...

Indeed, together with my colleagues Philippe Lefèvre and Jean-Jacques Orban de Xivry at UCL, we recorded eye gaze fixations of the case of prosopagnosia PS (Rossion et al., 2003; see <http://face-categorization-lab.webnode.com/research/acquired-prosopagnosia/>)

We recorded her eye movements when PS engaged in a familiar face identification task (with faces of children from her kindergarten). Irrespective of her performance, she fixated the mouth most of the time (about 60%), a result that was predicted based on previous studies with her (Caldara et al., 2005). However, she also focused, to a lesser extent, on the eyes of the faces, exactly on the eyeballs.

The most interesting observation of this study (Orban de Xivry et al., 2008) turned out to be the comparison between her pattern of eye gaze fixations and the pattern of the control participant: her age-matched colleague, who was also familiar with the children of the classroom. In striking contrast to PS, this person did not fixate at all on the features !



Rather, she fixated in the middle of the face, slightly below the eyes. The contrast between the eye gaze fixation patterns of the typical observer and the case of acquired prosopagnosia is

striking: virtually no overlap between the fixations of the prosopagnosic patient and the normal observer. In fact, we realized that this observer's pattern of fixation was fundamentally different than the natural exploration of faces as illustrated in Yarbus' displays. Rather, Yarbus's pictures of the patterns of fixations for a face look like those of a case of prosopagnosia ! However, the patterns of fixations recorded by Yarbus and others correspond to a free exploration of a face, for several minutes, not to the fixation patterns of someone involved in a face identification task.

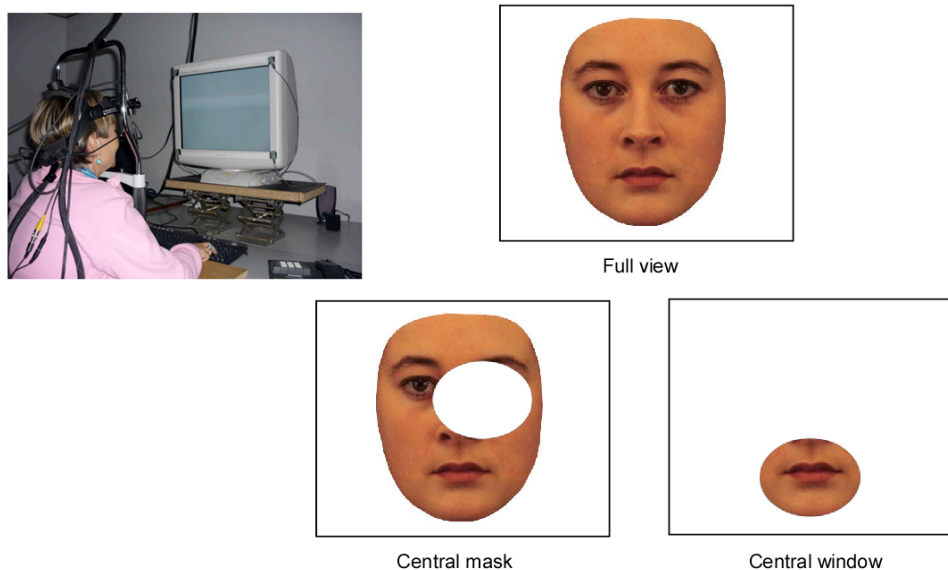
Importantly, a paper published at about the same time than our paper, but with normal observers, showed indeed that about 2 fixations on the center of the face suffice for face recognition (Hsiao & Cottrell, 2008; see also the work of Peterson & Eckstein, 2012).

Therefore, even when an observer takes time to identify a face, it is not primarily the features that are fixated upon (Orban de Xivry et al., 2008). Rather, the observer fixates in what can be described as the "center of mass" of the face: the point from which the whole of the face would be best perceived. This point would be slightly higher on the face than the geometric center, because of the larger number of diagnostic elements located in the top part of the face.

In contrast, fixating on the center, in between features, is not a good strategy for the prosopagnosic patient PS: she never fixates that center of mass. It seems that **she has to fixate exactly on a specific feature** to extract diagnostic information to recognize the face.

Based on the contrasted pattern of fixations observed for the patient PS and the typical observer, we then developed a novel approach to understand this issue.

Together with Karl Verfaillie, Peter de Graef and Goedele Van Belle, who developed the method at KUL, we decided to stimulate PS with **gaze-contingent** information. That is, we tracked her eye movements and revealed to her roughly only one central feature of the face at a time (**window condition**). That is, if she fixated the right eye, she would see the right eye only. If she then fixated the mouth, she would see the mouth only, etc ...



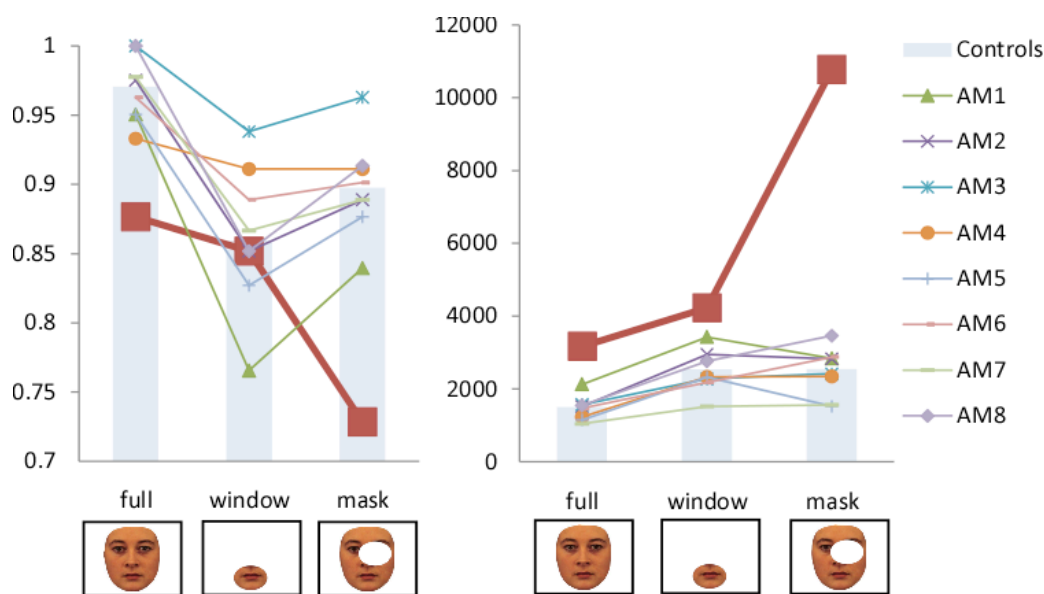
We reasoned that her performance should not be affected very much in this condition, because, based on our previous observations, we hypothesized that she was only able to

extract information from one (fixated) feature at a time (loss of holistic/configural processing).

Then, and most interestingly, we tested whether, in the absence of information from the fixated feature, she would still be able to process the face. To do that, we used gaze-contingency to selectively mask the fixated feature of the face (**mask condition**).

In the mask condition, if a normal observer processes the face holistically, he/she should not be affected too much. Let's say that we usually fixate on the center of mass of the face, as illustrated above. If a mask covers the area of fixation, all features of the face, which convey the diagnostic information for recognition, are still available. However, if one processes a face like a case of acquired prosopagnosia, masking a central feature can be detrimental. The other features are still available, but perhaps the prosopagnosic patient cannot extract diagnostic information from these features when they are not fixated. That is, the **perceptual field of the prosopagnosic patient would be restricted to one feature of a face at a time**.

These predictions were completely confirmed, and in fact, the results were even better than what we would have expected: there was a clear double dissociation between PS' and the typical observers' patterns of performance. PS did not show a major decrease of performance in the window condition, but was largely impaired and slow (almost 12 seconds by trial !) in the mask condition (Van Belle et al., 2010a).



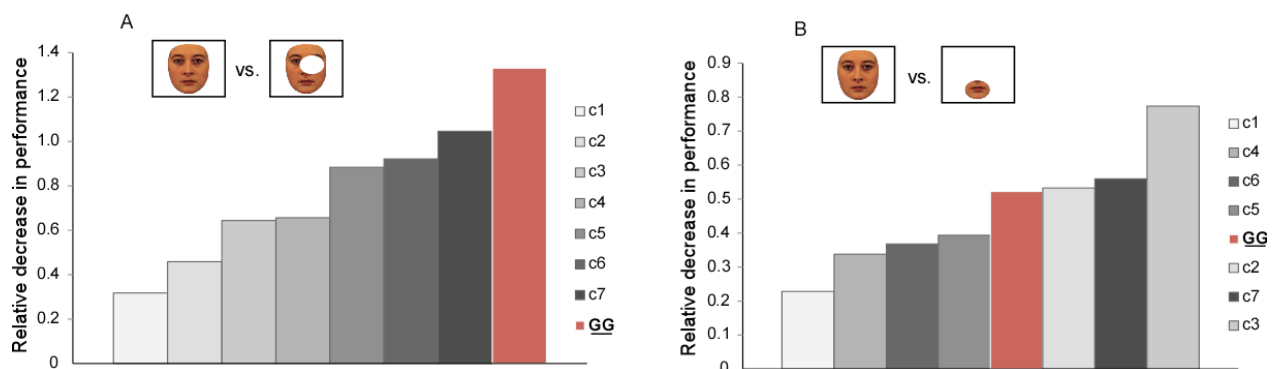
It is as if PS was almost **unimpaired** when she was forced to use one feature at a time (the feature that she could choose to fixate) in the **window** condition. And, at the same time, it seems she **could hardly** match the individual faces if she was prevented from applying her feature-by-feature strategy (in the **mask** condition).

These findings with gaze-contingency shed new lights on the understanding of the nature of acquired prosopagnosia (and thus on what is critical in our expert ability to individualize faces): **these people cannot perceive an individual face as a whole**. Whereas normal observers can fixate on one eye and still extract diagnostic information from the mouth and other parts of the face, patients with prosopagnosia *have to* fixate the mouth, or the part that they want to use to individualize the face.

Importantly, this impairment is not due to a low-level visual defect (Van Belle et al., 2010a): PS sees very well in the periphery. In fact, her small scotoma is paracentral and falls completely in the window/mask area. Therefore, if anything, this scotoma makes the window condition harder for her (perhaps explaining why she is slightly slower than controls in that condition), but does not affect the mask condition. Moreover, if you move PS and the normal observers away from the monitor, making the viewing size of the face smaller, but keeping constant the relative size between the face and the window/mask area, you get the same pattern of performance (Van Belle et al., 2010a).

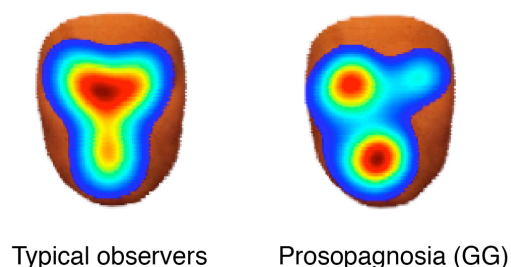
Finally, there is independent evidence that PS's holistic perception of nonface patterns is preserved: when she has to focus on a small letter in a Navon Navon hierarchical letter pattern, her performance is influenced by the large letter, just like normal observers (Busigny & Rossion, 2011). Her holistic perception of faces is not completely impaired either: when she has simply to detect faces, as in Mooney or Arcimboldo patterns, she is fine (face detection, Mooney or Arcimboldo faces) (Rossion et al., 2011). It is only when she has to *individualize* a face that PS shows a **reduced perceptual field**, relying on a feature-by-feature strategy and being unable not to do that.

Following this first evidence, we found that other cases of prosopagnosia following a different pattern of brain damage: of GG (Busigny et al., 2010) and LR (Bukach et al., 2006) also showed the same profile of response: relative to normal controls, they were more impaired at recognizing faces in the mask condition than in the window condition (Van Belle et al., 2011; Busigny et al., 2014).



These observations indicate that despite different patterns of brain damage, a common aspect of these patients with acquired prosopagnosia is that they can't individualize a face by means of holistic processing.

Interestingly, GG also showed the same pattern of eye gaze fixations as described for PS above (fixations on the mouth or eye, while normal observers fixate in the centre of the face).



In parallel to the gaze-contingency study with PS, we also used the mask/window stimulation paradigm in an experiment with normal observers, testing the hypothesis that the **inversion effect** (<http://face-categorization-lab.webnode.com/research/face-inversion/>) would be

modulated by this manipulation. Specifically, in line with the perceptual field hypothesis (Rossion, 2008; 2009) we predicted:

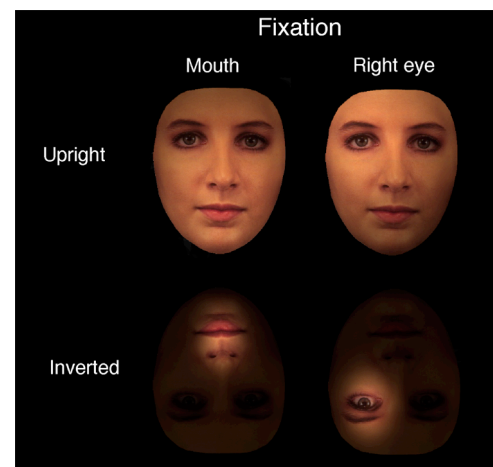
A **decrease** of the face inversion effect in the **window** condition

(forcing people to process the face feature by feature)

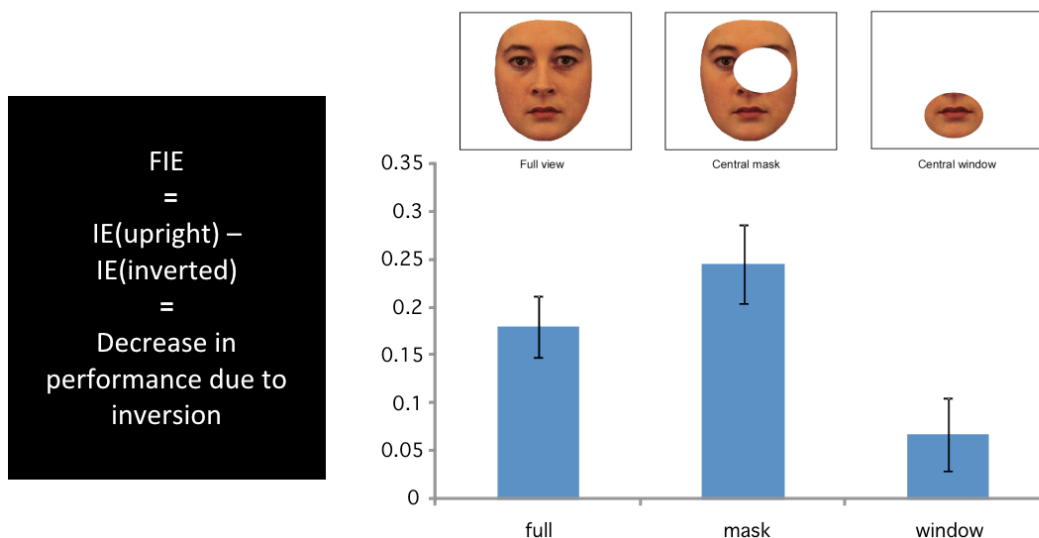
An **increase** of the face inversion effect in the **mask** condition

(promoting holistic processing by preventing the reliance on a fixated feature)

This study was performed only in normal observers (Van Belle et al., 2010b).



The data fit very well the predictions (Van Belle et al., 2010b), showing that eye movements *can be diagnostic* about the nature of face perception using face inversion. Most importantly, these observations directly support the view that the face inversion effect is due to a loss of holistic face perception: observers have a reduced perceptual field when dealing with inverted faces.

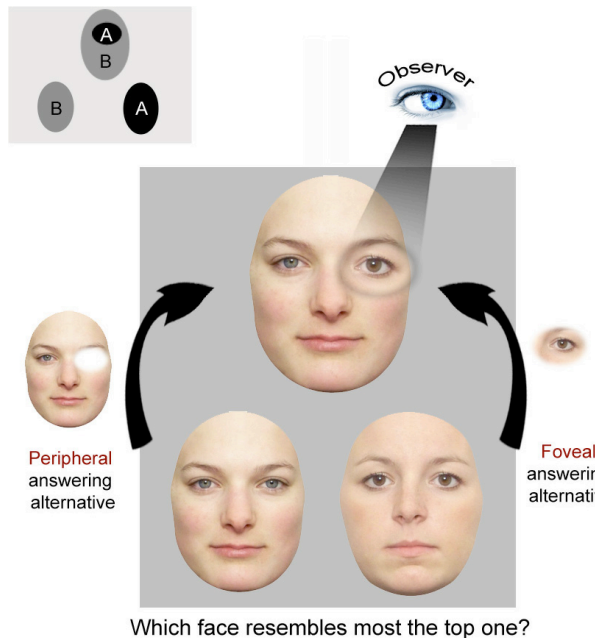


FIE: Index of increase of inverse efficiency because of inversion

Finally, most recently (Van Belle et al., 2015), we used gaze-contingency in a paradigm without decrease of performance for inverted faces. We used a similar approach as Miell et al. (2011) in which two face identities are displayed on top of each other, simultaneously providing one identity information on the window of fixation (i.e., roughly one face part), and the other identity information outside of that fixated part. Using this approach with famous faces, these authors showed that a given observer can use both kinds of information, the fixated part and the periphery, respectively, to recognize a face. In itself, this finding should be treated with caution: the relative use of information at the fixated part *vs.* the periphery is highly dependent on the size of the stimulus and the gaze contingent window. If the size of the window is small relative to the face, observers will rather use information displayed in the

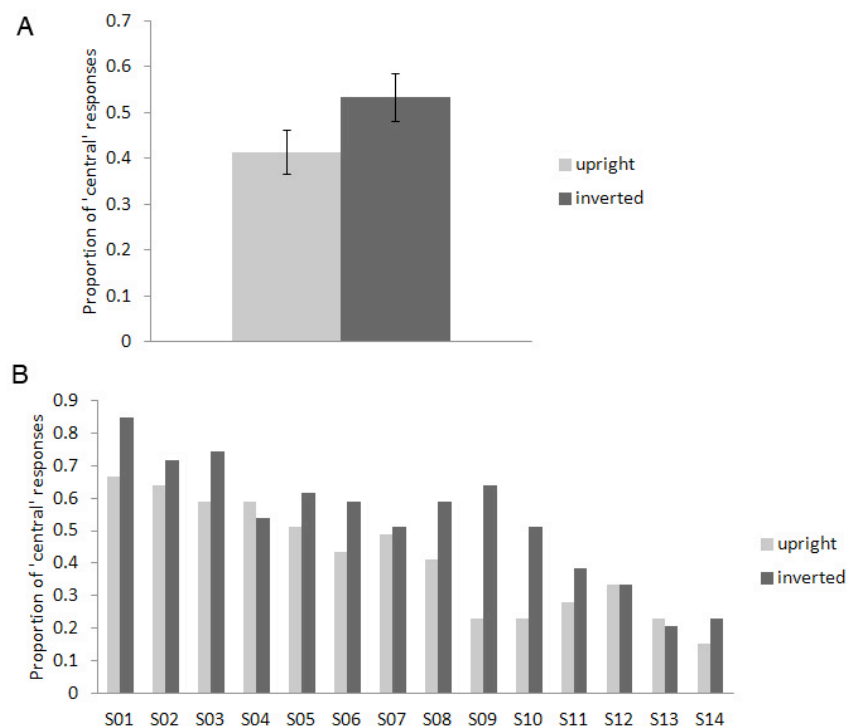
periphery, unless the whole display is very large. What is important is to show that for a *fixed size*, the relative use of information displayed in the window *vs.* the periphery varies with the same transformation (here inversion).

To do that, we showed a full face made of two individual faces: one that corresponded to the fixated part in a gaze-contingent way, and the other one to the nonfixated area of the face.



In a 2AFC matching task, a target face is composed of the two faces used as response alternatives in a gaze contingent way, with the visual information in the central window belonging to one response, and the surrounding part of the target face belonging to the other response alternative. Faces were presented either upright or upside-down.

We reasoned that if inversion reduces the perceptual field, inverting the exact same face should increase the proportion of responses based on the fixated part ("part-based responses"), all other parameters remaining constant.



We first adjusted the relative size of the window and the stimulus to obtain roughly 50% of response based on the window, for upright faces. Then, we tested participants with these faces upright and inverted faces. Overall, the proportion of part-based responses differed

considerably between participants, from 76% to 19% of the trials, in line with Miellet et al. (2011). However, most importantly, all other aspects than orientation of the stimulation being constant, the proportion of choices based on the “central” window (i.e., part-based responses) was significantly higher for inverted ($M = 53\%$) than for upright faces ($M = 41\%$) !

Thus, these observations show that, all other parameters being equal (i.e., face size and relative size of the window to the face size), typical observers rely relatively more on the gaze-contingent fixated part of a face for inverted as compared to upright faces. They are in line with our previous results (Van Belle et al., 2010b) but the gaze contingency morphing approach provides a significant advantage: the observers always see upright and inverted faces in full view rather than with limited windows of vision or faces masked with a central hole. Moreover, here there is no measure of performance. Therefore the difference observed between upright and inverted faces is not explained by a difference in local processing efficiency, and points to a *qualitative* rather than quantitative difference between the perception of upright and inverted faces.

We also tested the prosopagnosic patient PS in that experiment with upright faces ... and she always selected the face corresponding to the fixated (central) part, ignoring the whole face (Van Belle et al., 2015).

Altogether, these observations support the view that the perceptual field of view of PS and other prosopagnosic patients is reduced when individualizing faces, being limited to one face part at a time. Similarly, when a typical observers see inverted faces, this perceptual field is also reduced (Rossion, 2008; 2009; 2013).

Given the interest of the method, the research program on eye movements and face perception goes on in our lab, with studies performed primarily by Goedele van Belle, Meike Ramon (contrasting familiar and unfamiliar face perception), and in collaboration with Philippe Lefèvre at UCLouvain.

BIBLIOGRAPHY (lab papers on this topic) and main finding(s) of each paper: 2008-2015

All papers available as pdfs here:

<http://face-categorization-lab.webnode.com/publications>

1	<p>Orban de Xivry, J.-J., Ramon, M., Lefèvre, P., Rossion, B. (2008). Reduced fixation on the upper area of personally familiar faces following acquired prosopagnosia. <i>Journal of Neuropsychology</i>, 2, 245-268.</p> <p><i>First eye movement study of PS (prosopagnosia), who was involved in a familiar face recognition task (children of the kindergarten where she works). The results show that she focuses most of the time on the mouth (60%). More strikingly, she fixates exactly on each facial feature (mouth, left eye, right eye) while a normal observer who is familiar with the faces fixates in between features, in the centre of the face below the eyes during face identification (“center of mass” of the individual face).</i></p> <p>Paper first submitted to <i>Behavioural Neurology</i></p>
---	--

2	<p>de Heering, A., Rossion, B., Turati, C., Simion, F., (2008). Holistic face processing can be independent of gaze behavior: Evidence from the face composite effect. <i>Journal of Neuropsychology</i>, 2, 183-195.</p> <p><i>In this study, we show that eye gaze fixations remain in the top half of the face during the composite face task, whether performance is affected (aligned) or unaffected (misaligned) by the bottom half.</i></p> <p>Paper first rejected in <i>Perception</i> (hard to publish an absence of difference !)</p>
3	<p>Van Belle, G.*, Ramon, M.*, Lefèvre, P., Rossion, B. (2010). Fixation patterns during recognition of personally familiar and unfamiliar faces. <i>Frontiers in Cognitive Science</i>. (* equal contribution). Front. Psychology, doi: 10.3389/fpsyg.2010.00020</p> <p><i>Here we looked at fixation patterns on personally familiar faces and found that their individual features are processed more (i.e., they receive more fixations overall) than those of unfamiliar faces. Interestingly, differences (albeit can arise relatively early, i.e. from the first meaningful fixation on).</i></p> <p>Paper first submitted to <i>Frontiers in Cognitive Science</i></p>
4	<p>Van Belle, G., de Graef, P., Verfaillie, K., Busigny, T., Rossion, B. (2010). Whole not hole: expert face recognition requires holistic perception. <i>Neuropsychologia</i>, 48, 2609-2620.</p> <p><i>To our knowledge, the first study to use gaze-contingency in a face perception task, presented as a talk at the VSS2009 meeting: Journal of Vision August 2009, Vol.9, 541. doi:10.1167/9.8.541. The study was performed in normal observers and prosopagnosic patient PS. The results show a striking dissociation between a condition in which only one fixated feature is revealed at a time (window: relatively less impairment for the prosopagnosic patient than normal observers) and a condition in which the fixated feature is masked (mask: much larger impairment for the prosopagnosic patient). This is probably one of our most interesting studies, showing a striking double dissociation between the patient and the controls, in a simple paradigm.</i></p> <p>A really simple and clean study ... paper rejected without review by a commercial editorial board in a number (4) of “high impact factor” journals, including <i>Current Biology</i>. Then sent to <i>Neuropsychologia</i> where we got our first (constructive) reviews.</p>
5	<p>Van Belle, G., Lefèvre, P., Laguesse, R., Busigny, T., de Graef, P., Verfaillie, K., Rossion, B. (2010). Feature-based processing of personally familiar faces in prosopagnosia: Evidence from eye gaze-contingency. <i>Behavioural Neurology</i>, 23, 255-257.</p> <p><i>A brief report replicating the difficulty of the prosopagnosic patient PS at individualizing faces with gaze-contingent masks of the facial features, this time applied to personally familiar faces (children of her kindegraten).</i></p> <p>Paper first submitted to <i>Behavioural Neurology</i></p>
6	<p>Van Belle, G., de Graef, P., Verfaillie, K., Rossion, B., Lefèvre, P. (2010). Face inversion</p>

	<p>impairs holistic perception: Evidence from gaze-contingent stimulation. <i>Journal of Vision</i>. May 1;10. pii: 10.5.10. doi: 10.1167/10.5.10.</p> <p><i>When restricting perception to one fixated feature at a time by a gaze-contingent window, performance in an individual face matching task was almost unaffected by inversion. However, when a mask covered the fixated feature, the decrement of performance with inversion was even larger than in a normal—full view—condition. This effect was independent of the distance (size) of the stimulus. This study provides evidence that the face inversion effect is caused by an inability to perceive the individual face as a whole rather than as a collection of specific features and thus support the view that observers' expertise at upright face recognition is due to the ability to perceive an individual face holistically.</i></p> <p>Paper rejected without review by the commercial editor of <i>Current Biology</i>. Then submitted to <i>Journal of Vision</i></p>
7	<p>Van Belle, G., Busigny, T., Lefèvre, P., Joubert, S., Felician, O., Gentile, F., Rossion, B. (2011). Impairment of holistic face perception following right occipito-temporal damage in prosopagnosia: converging evidence from gaze-contingency. <i>Neuropsychologia</i>, 49, 3145-3150.</p> <p><i>In this paper, we show that the pure case of prosopagnosia GG, who has unilateral right hemispheric damage (lingual, parahippocampal and medial part of the fusiform gyrus) also presents with a relatively larger impairment in recognizing faces when preventing him from seeing the central feature of the face (contingent mask) than when restricting his perception to one feature at a time (contingent-window). This is the same pattern of performance as patient PS (Van Belle et al., 2010, paper below), despite almost no overlap between their brain damage.</i></p> <p>Paper first submitted to <i>Neuropsychologia</i></p>
8	<p>Busigny, T., Van Belle, G., Jemel, B., Hosein, A., Joubert, S., Rossion, B. (2014). Face-specific impairment in holistic perception following focal lesion of the right anterior temporal lobe. <i>Neuropsychologia</i>, 56, 312-333.</p> <p><i>There is only one gaze-contingent experiment in this extensive case report of prosopagnosia (LR, a patient with right anterior temporal lobe damage). The experiment shows also a profile of response similar in the patient LR as for GG and PS: a relatively larger impairment for matching faces with a gaze-contingent mask than a window, contrary to normal observers.</i></p> <p>Paper first submitted to <i>Neuropsychologia</i></p>
9	<p>Van Belle, G., Lefevre, P., & Rossion, B. (2015). Face inversion and acquired prosopagnosia reduce the size of the perceptual field of view. <i>Cognition</i>, 136, 403-408.</p> <p><i>A study in which participants had to choose which of two faces matched a target face placed on top; this target face corresponding to the face on one side for the participant's fixated part, and to the other face for the rest of the target face. There was no good or bad answer, simply a preference of similarity base don one part or the whole face. With the same parameters, participants preferred relatively more the</i></p>

	<p><i>face based on a single fixated part when all stimuli were inverted. A very elegant demonstration that our perception of upright and inverted faces differ qualitatively. We also tested the prosopagnosic patient PS in that experiment with upright faces ... and she always selected the face corresponding to the fixated (central) part, ignoring the whole face.</i></p> <p>Paper first rejected after review (?) in <i>Psychological Science</i>. A clear conflict of interest with an editor who should have never taken this paper and made us waste our time... the whole editorial procedure was a disgrace there. Published after constructive reviews in <i>Cognition</i>.</p>
--	---