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Holistic face perception: Mind the gap!

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The most widely used measurement of holistic face perception, the composite face effect (CFE), is challenged by two apparently contradictory goals: having a defined face part (i.e., the top half), and yet perceiving the face as an integrated unit (i.e., holistically). Here, we investigated the impact of a small gap between top and bottom face halves in the standard composite face paradigm, requiring matching of sequentially presented top face halves. In Experiment 1, the CFE was larger for no-gap than gap stimuli overall, but not for participants who were presented with gap stimuli first, suggesting that the area of the top face half was unknown without a gap. This was confirmed in Experiment 2, in which these two stimulus sets were mixed up: the gap stimuli thus provided information about the area of a top face half and the magnitude of the CFE did not differ between stimulus sets. These observations indicate that the CFE might be artificially inflated in the absence of a stimulus cue that objectively defines a border between the face halves. Finally, in Experiment 3, observers were asked to determine which of two simultaneously presented faces was the composite face. Perceptual judgements for no-gap stimuli approached ceiling; however, with a gap, participants were almost unable to distinguish the composite face from a veridical face. This effect was not only due to low-level segmentation cues at the border of no-gap face halves, because stimulus inversion decreased performance in both conditions. This result indicates that the two halves of different faces may be integrated more naturally with a small gap that eliminates an enhanced contrast border. Collectively, these observations suggest that a small gap between face halves provides an objective definition of the face half to match and is beneficial for valid measurement of the behavioural CFE.

Keywords: Composite face effect; Holistic face perception; Visual illusion.

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One of the most compelling phenomena in face perception arises when the top half of a face is aligned with the bottom half of another face, creating a composite face: a composite face made of two halves of famous faces is perceived as a novel face configuration, so that it is difficult to recognize the two original faces used to create the composite face (Young, Hellawell, & Hay, 1987). With unfamiliar faces, the alignment of two identical top halves with different bottom halves creates two different whole face configurations, so that the identical top halves are erroneously perceived as being different from each other: the composite face illusion. When the bottom face halves are misaligned from the top face halves, this illusion is broken (Figure 1; Hole, 1994; see also Figure 1 in Rossion & Boremanse, 2008 or Rossion, 2013). Hence, when human observers are asked to judge whether two identical top halves of a face are the same, they make more mistakes and/or are slower when the top and bottom halves are aligned than when they are misaligned with each other (i.e., the composite face effect, CFE). Over the past two decades, this composite face paradigm has been used in numerous studies that have provided information about the specificity and nature of integration of facial parts into a unified representation ("holistic face perception"), the impairment of this process in acquired prosopagnosia, its developmental course, temporal dynamics and neural basis (see Rossion, 2013 for an extensive review).

In order to provide an adequate measure of holistic face perception, it is important that a composite face is perceived as a veridical face rather than as a face made of two different face halves. Of course, composite stimuli should be created so that the top and bottom parts seem to go together naturally. Yet, for the purpose of the task, the top face half should be clearly defined to the observers: they need to know where the border between the top and bottom half of the face lies. To deal with this issue, some studies insert a small gap between the top and bottom face halves (see the female composite pair in Figure 1; e.g., de Heering & Rossion, 2008; Gao, Flevaris, Robertson, & Bentin, 2011; Rossion & Boremanse, 2008; Wiese, Kachel, & Schweinberger, 2013).

On the one hand, since the composite face paradigm is supposed to measure the mandatory integration of the two face halves into a unified representation (i.e., holistic perception), adding a gap between the two face halves is counterintuitive because it could reduce the integration of the two face halves into a unified representation. On the other hand, without such a gap, or other cues indicating clearly the border between the top and bottom halves in each trial (e.g., lines at the edge of the face as in Susilo, Rezlescu, & Duchaine, 2013), observers may attempt to match two top halves containing some information that *is* physically different (e.g., the lower part of the nose) in the task. Thus, the composite face stimuli without a gap may lead to "different" responses for aligned composite face trials, not because of an illusion but because the decision is based on information that physically differs between the two faces. Moreover, the aligned face condition is typically compared to a misaligned face condition,

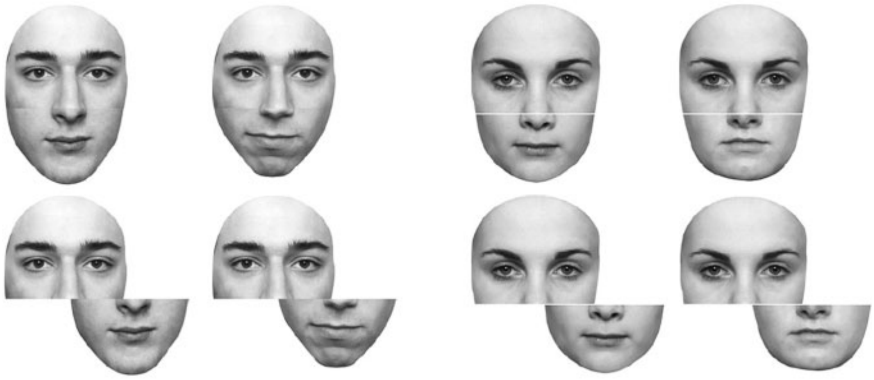

Figure 1. Example stimuli used in this study. The first row demonstrates a male and a female composite pair. In the second row, bottom halves of the stimuli are misaligned, a manipulation which obliterates the illusion of the top halves of each pair being different.

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in which the spatial misalignment provides information about the border between the top and bottom halves. Therefore, the CFE in a given study could be artificially increased because the two halves are segmented in the misaligned condition, and not segmented in the aligned condition (i.e., a methodological confound). This is not a minor issue, since the majority of studies using a standard composite face paradigm do not include a gap or any other stimulus cue that objectively defines the border between the top and bottom face halves (e.g., de Heering, Wallis, & Maurer, 2012; McKone, 2008; Robbins & McKone, 2007; Taubert, 2009; Taubert & Alais, 2009; Xiao, Quinn, Ge, & Lee, 2012), including many studies using the "Jane" set of stimuli (e.g., Le Grand, Mondloch, Maurer, & Brent, 2004; Letourneau & Mitchell, 2008; Mondloch & Maurer, 2008; Mondloch et al., 2010; Palermo et al., 2011) as well as the original composite face studies (Hole, 1994; Young et al., 1987).

Interestingly, or rather, unfortunately, the prediction is the same in both cases (i.e., a methodological confound without a gap or a disruption of perceptual integration with a gap): the CFE should be larger without a gap inserted between the two face halves than with a gap. Strangely enough, despite the wide use of the composite face paradigm, the dominant paradigm to measure holistic face perception (Rossion, 2013), the comparison of the magnitude of the CFE for the same stimuli with and without a gap inserted between the two face halves has never been performed in the literature.[1] This is the main goal of the present study, in which we first compared the magnitude of the CFE for the same stimuli with and

[1] Taubert and Alais (2009) compared the performance for no-gap stimuli to stimuli with a large gap (a quarter of the height of the stimuli), but in that study, the magnitude of the CFE (i.e., aligned vs. misaligned) was not compared for these two conditions.

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without a gap inserted between the two face halves (Experiment 1). Importantly, gap and no-gap stimuli were blocked in this experiment, so that we were able to test an order effect, i.e., whether having seen the stimuli with a gap at first, and thus having a better knowledge of the border between the top and bottom halves, would influence the magnitude of the composite effect for no-gap stimuli.

EXPERIMENT 1

Methods

Participants. Twenty-eight participants (mean age = 22 years, range = 19–26 years, 23 female) recruited from a collegiate campus (University of Louvain) gave voluntarily written consent to participate in this paid experiment.

Stimuli. Two sets of composite stimuli were used: one set with a gap and another set without a gap between the top and bottom face halves. Ten full-front photographs of Caucasian faces (half female) with neutral expressions were first prepared in Adobe Photoshop CS5 by cropping the faces to exclude external features, standardizing the faces by height, converting into greyscale, and equalizing by mean pixel luminance. To create composite stimuli, these faces were horizontally split into top and bottom halves at 5% of the height of the face above the nostrils using a MATLAB script. For each of the original images, the top face half was combined with four bottom halves from different identities of the same sex, creating a total of 40 composite stimuli. When necessary, the bottom half was adjusted to align with the width and nose of the top half; additionally, each bottom face half was adjusted to match the apparent luminosity of its paired top half. The two stimulus sets both used these 40 images, the only difference being that in the set with a gap the top and bottom face halves were separated by a gap of 0.5% of the image height. Finally, control "misaligned" stimuli were created, by translating the bottom half of each image 50% to the right of the top half. The stimuli are available to be freely downloaded here: *http://face-categorization-lab.webnode.com/resources/stimuli-composite/*.

Procedure. In each trial, participants were instructed to respond by selecting a key on a computer keyboard whether the top halves of two consecutively presented face stimuli (target and probe) were the same or different. There were six conditions within each of the two stimulus sets, arising from three identity factors and two alignment factors. The identity factor of each target and probe pair could be "same" (target and probe faces having the same top and bottom half identities), "composite" (the same top halves but different bottom halves), or "different" (different top and bottom halves); the alignment was either "aligned" (the top and bottom face halves are aligned) or "misaligned" (the bottom face half is misaligned to the right). The critical trials were the composite trials, aligned and misaligned. Different identity trials served primarily to balance the number of correct same and different responses apart from composite identity trials. The same identity condition is used to provide a further baseline for the composite identity condition (see Rossion, 2013 for a full discussion of the rationale behind this paradigm).

Faces within each target/probe pair were matched for alignment and sex, and each stimulus identity was represented equally as a target or probe (8–12 repetitions each). The exact same trials were used for each of the stimulus sets. There were 30 trials presented for each of the six conditions for each stimulus set, for a total of 360 trials. Trials were separated into six blocks of 60 trials each, in which condition was randomized. However, the stimulus sets were not mixed: participants first completed three full blocks of stimuli without a gap consecutively or three blocks of stimuli with a gap consecutively (this order was counterbalanced across participants).

Using E-Prime 2.0, stimuli were displayed on a computer monitor at a size of approximately 2.8 by 3.7 degrees of visual angle (for aligned target stimuli), centred on a white background. A black fixation cross, when present, was elevated from the centre of the screen to just below the approximate level of the eyes in the top half of the face stimuli. In each trial, there was presented sequentially: (1) a fixation cross for 200 ms, (2) a blank screen for 150 ms, (3) a target face for 200 ms, (4) a blank screen for 400 ms, and finally (5) a probe face, presented for 500 ms (Figure 2). A blank screen was shown until a response was given, at which point a 1300 ms inter-trial-interval, consisting of a fixation cross, began. To avoid low-level matching, the probe stimulus was presented at a 5% larger size than the target stimulus.

Analyses. Accuracy and response time (RT) were recorded for each trial, and means by condition within each stimulus set were computed; for RT, trials were considered only when a correct response was given. Since participants were not given a time limit for a response, for each participant outlying trials with RTs above three standard deviations from the mean were excluded from analyses.

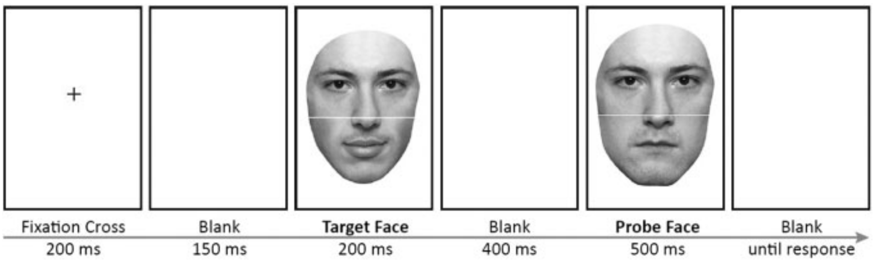

Figure 2. A schematic of the timeline of a single trial. The condition depicted in this example is an aligned composite pair from the gap stimulus set. Trials were separated by an inter-trial interval of 1300 ms.

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Statistical analyses were conducted with SPSS PASW 18. Composite trials were analyzed in a two-way repeated-measures ANOVA, with two-level within-subjects variables: *stimulus set* (gap or no-gap) and *alignment* (aligned or misaligned), and one between-subjects variable: *order* (gap trials completed first or second). These analyses were performed uniquely for each accuracy and RT. Control same identity trials were analyzed separately with the same design.

Results

Accuracy. Analysis of composite trials revealed no main effect of *stimulus set* ($F(1,26) = 3.36$, $p = .08$, $\eta_p^2 = 0.11$) and a main effect of *alignment* ($F(1,26) = 46.9$, $p < .001$, $\eta_p^2 = 0.64$). Most importantly, this effect was qualified by a significant interaction with *stimulus set* ($F(1,26) = 8.56$, $p = .01$, $\eta_p^2 = 0.25$), reflecting the smaller CFE for gap than no-gap stimuli, i.e., the smaller difference between misaligned and aligned accuracy (Figure 3; gap: 12.1%, SE = 2.07%; no-gap: 16.1%, SE = 2.37%). There was also a significant interaction with the between-subjects factor of *order* with *stimulus set* ($F(1,26) = 6.57$, $p = .02$, $\eta_p^2 = 0.20$) and a three way interaction between *order, alignment,* and *stimulus set* ($F(1,26) = 5.82$, $p = .02$, $\eta_p^2 = 0.18$), reflecting that the larger composite effect found for no-gap stimuli is present only for those participants completing no-gap trials before gap trials (Figure 4). The interaction between *order* and *alignment* was not significant ($F(1,26) = 2.02$, $p = .17$, $\eta_p^2 = 0.07$). For same trials, there were neither main effects of *stimulus set* ($F(1,26) = 1.20$, $p = .28$, $\eta_p^2 = 0.04$) nor *alignment* ($F(1,26) = 0.01$, $p = .94$, $\eta_p^2 = 0.00$), and no significant interaction was found between these factors ($F(1,26) = 0.09$, $p = .76$, $\eta_p^2 = 0.00$). There were also no interactions between *order* and *stimulus set* ($F(1,26) = 3.68$, $p = .07$, $\eta_p^2 = 0.12$), *order* and *alignment* ($F(1,26) = 0.10$, $p = .75$, $\eta_p^2 = 0.00$), or *order, stimulus set* and *alignment* ($F(1,26) = 0.96$, $p = .34$, $\eta_p^2 = 0.04$).

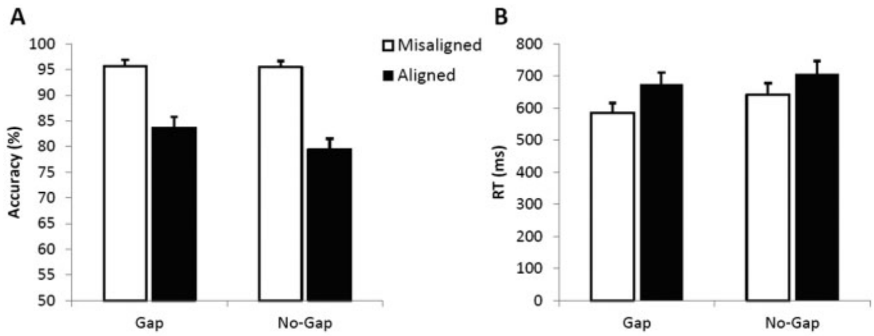

Figure 3. Experiment 1 results: accuracy for blocked gap vs. no-gap composite trials, aligned and misaligned. A. Accuracy (% correct); B. Correct RTs.

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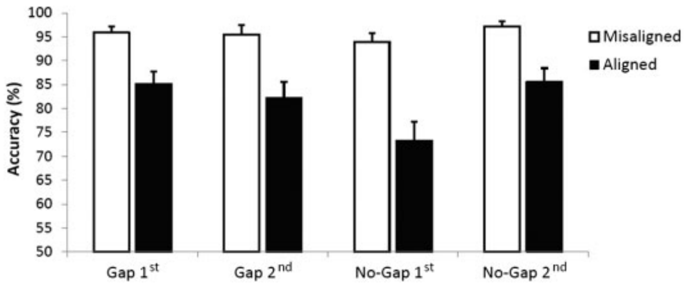

Figure 4. Influence of order on the CFE in Experiment 1. Gap 1st shows the eight participants who performed trials of stimuli with a gap first, No-Gap 2nd is these same participants then doing trials with stimuli without a gap. No-Gap 1st depicts participants who started with stimuli without a gap, and finally their scores on stimuli with a gap are shown in Gap 2nd.

Correct RTs. For composite trials, main effects of *alignment* ($F(1,26) = 30.0$, $p < .001$, $\eta_p^2 = 0.54$) and *stimulus set* ($F(1,26) = 4.59$, $p = .04$, $\eta_p^2 = 0.15$) were found, however there was no interaction between these factors ($F(1,26) = 1.65$, $p = .21$, $\eta_p^2 = 0.06$). There was an interaction between *order* and *stimulus set* ($f(1,26) = 19.1$, $p < .001$, $\eta_p^2 = 0.42$), with the participants completing their second stimulus set trials more quickly (Figure 4). There were no significant interactions between *order* and *alignment* ($F(1,26) = 0.01$, $p = .95$, $\eta_p^2 = 0.00$) or *order, stimulus set* and *alignment* ($F(1,26) = 1.63$, $p = .21$, $\eta_p^2 = 0.06$). For control same identity trials, there was not a main effect of *stimulus set* ($F(1,26) = 3.57$, $p = .07$, $\eta_p^2 = 0.12$), while the effect of *alignment bordered on significance* ($F(1,26) = 4.27$, $p = .05$, $\eta_p^2 = 0.14$); no significant interaction was found between these factors ($F(1,26) = 0.48$, $p = .50$, $\eta_p^2 = 0.02$). There were significant interactions found only between *order* and *stimulus set* ($F(1,26) = 19.5$, $p < .001$, $\eta_p^2 = 0.43$) and *order, stimulus set* and *alignment* ($F(1,26) = 6.06$, $p = .02$, $\eta_p^2 = 0.19$), reflecting participants' greater speed for the first stimulus set with which they were presented, especially for misaligned trials (Table 1). The interaction between *order* and *alignment* did not reach significance ($F(1,26) = 0.43$, $p = .52$, $\eta_p^2 = 0.02$).

Discussion

In this experiment, the CFE is larger when the exact same stimuli do not have an inserted gap between the top and bottom halves, as predicted. As explained in the introduction, this effect could be due to two factors: either the gap slightly disrupted the perception of the two halves as an integrated unit, or the participants in the no-gap condition were unable to define exactly what the "top half" of the face is and partly used the bottom half to make their judgement. The results suggest that the second account is correct: participants who perform the blocks of no-gap stimuli first ("No-Gap 1st") have a larger CFE than with the gap stimuli. However, if the task is performed on no-gap stimuli after having seen the gap stimuli in the first block ("No-Gap 2nd"), then the CFE does not

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TABLE 1
Experiment 1 results for accuracy and correct response time (RT). Results are shown for both composite and same conditions, aligned and misaligned

	Accuracy				*RT*			
	Gap		*No-Gap*		*Gap*		*No-Gap*	
	%	*SE*	*%*	*SE*	*%*	*SE*	*%*	*SE*
Composite								
Aligned	83.6	2.13	79.4	2.66	674	35.9	707	39.9
Misaligned	95.7	1.15	95.5	1.07	585	30.0	640	37.1
Same								
Aligned	94.8	1.22	95.9	0.91	599	26.0	633	33.6
Misaligned	94.9	1.53	95.7	1.03	583	28.4	624	35.9

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differ for gap and no-gap stimuli (Figure 4). This suggests that seeing the gap in the first block of stimuli helped defining the location of the top face halves. If this is the case, there should not be any larger CFE for no-gap stimuli when mixing up no-gap and gap stimuli, as tested in Experiment 2.

EXPERIMENT 2

Rationale

The design was identical to Experiment 1, except that the trials with gap and no-gap stimuli were mixed together within blocks.

Methods

Participants. There were 28 participants (mean age = 22 years, range = 18–30 years, 21 female) recruited at a collegiate campus, none of whom took part in Experiment 1; all signed informed consent and received monetary compensation.

TABLE 2
Experiment 2 results for accuracy and correct response time (RT). As in Table 1, results are shown for both composite and same conditions, aligned and misaligned

	Accuracy				*RT*			
	Gap		*No-Gap*		*Gap*		*No-Gap*	
	%	*SE*	*%*	*SE*	*%*	*SE*	*%*	*SE*
Composite								
Aligned	82.6	2.66	82.5	2.65	694	35.1	698	37.2
Misaligned	93.6	1.83	94.4	1.07	626	31.7	617	34.4
Same								
Aligned	94.6	1.92	96.1	0.86	637	32.2	636	31.9
Misaligned	94.8	1.38	94.1	1.18	621	34.2	640	33.0

Stimuli. The stimuli in this experiment were identical to those used in Experiment 1.

Procedure. The design, including precise target/probe pair identities, and testing conditions matched that of Experiment 1 exactly, with one exception: within each block of 60 trials, condition and stimulus set were both randomized.

Analyses. Analyses were performed exactly as in Experiment 1, without order as a between-subjects factor.

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Results

Accuracy. A main effect of *alignment* was found for composite trials ($F(1,27) = 36.9$, $p < .001$, $\eta_p^2 = 0.58$), reflecting the CFE (measured as misaligned minus aligned accuracy) present for both stimulus sets (Figure 5; gap: 11.0%, SE = 2.10%; no-gap: 11.9%, SE = 2.44%) (see Table 2 for all results). However, there was neither a main effect of *stimulus set* ($F(1,27) = 0.10$, $p = .75$, $\eta_p^2 = 0.00$) nor an interaction between *alignment* and *stimulus set* ($F(1,27) = 0.14$, $p = .71$, $\eta_p^2 = 0.01$). For control same trials (Table 1), there were no main effects (*alignment:* $F(1,27) = 1.23$, $p = .28$, $\eta_p^2 = 0.04$; *stimulus set:* $F(1,27) = 0.08$, $p = .78$, $\eta_p^2 = 0.00$), and no interaction between these two factors ($F(1,27) = 1.72$, $p = .20$, $\eta_p^2 = 0.06$).

Correct RT. Similarly to the results for accuracy, there was a main effect of *alignment* for composite trials ($F(1,27) = 57.5$, $p < .001$, $\eta_p^2 = 0.68$), but neither a main effect of *stimulus set* ($F(1,27) = 0.11$, $p = .75$, $\eta_p^2 = 0.00$), nor an interaction between *alignment* and *stimulus set* ($F(1,27) = 1.05$, $p = .31$, $\eta_p^2 = 0.04$). Regarding same trials, there were not any main effects (*alignment:* $F(1,27) =$

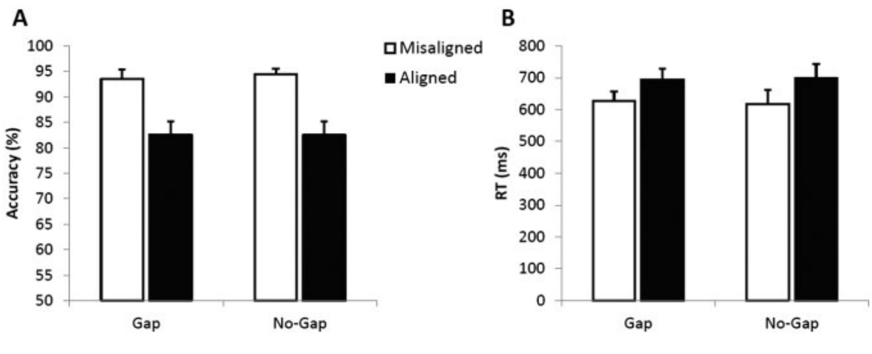

Figure 5. Experiment 2, mixed gap vs. no-gap trials, results: accuracy for gap vs. no-gap composite trials, aligned and misaligned.

0.99, $p = .33$, $\eta_p^2 = 0.04$; *stimulus set:* $F(1,27) = 1.53$, $p = .23$, $\eta_p^2 = 0.05$), and no interaction between these factors ($F(1,27) = 2.07$, $p = .16$, $\eta_p^2 = 0.07$).

Discussion

In this second experiment, with the exact same stimuli as in Experiment 1, we did not find an increased CFE for stimuli without a gap inserted between the top and bottom halves. There was still a 1% larger CFE for the no-gap stimuli in terms of accuracy, but this difference was not near significance. This finding, which contrasts with the findings of Experiment 1, suggests that when participants are presented with gap stimuli together with no-gap stimuli, they know better what is meant by the "top half" and the apparent advantage of no-gap stimuli is decreased. However, when participants are presented with no-gap stimuli only, they have difficulties defining exactly what the "top half" of the face is and partly use the bottom half—which differs physically in the composite face trials—to make their judgement (i.e., a methodological confound artificially increasing the CFE).

EXPERIMENT 3

Rationale

The results of the two experiments above suggest that any advantage of face stimuli without a gap in terms of the magnitude of the CFE is due to a methodological confound rather than a better integration of the top and bottom halves than when a gap is present. Experiment 3 builds on these observations to provide evidence that integration of the top and bottom halves of composite stimuli corresponds better to veridical stimuli with than without a gap. To test this, we relied on a novel illusion described in the recent review of the CFE (Rossion, 2013), according to which adding a small gap between the two face halves makes it much more difficult to perceive the two face halves as originating from different face identities than without a gap (Figure 6). That is, since individual faces differ greatly in shape and surface properties, a composite face stimulus appears very much like a face made of two halves coming from different faces (see Figure 1 in Hole, 1994; Figure 1 in Young et al., 1987; and in many studies using composite faces, as reviewed by Rossion, 2013). Paradoxically, with a gap, the exact same composite face stimulus is perceived as if there were no discrepancies in surface properties between the two face halves, which seem to form a seamlessly uniform surface (Figure 6). We refer to this novel visual illusion as the *gap composite face illusion*, because the addition of a separation between the two face halves seems indeed to facilitate rather than prevent or disrupt the perception of the face as a single unit.

In order to provide quantitative evidence for this phenomenon, we designed a simple experiment in which we asked people to judge which one of two faces

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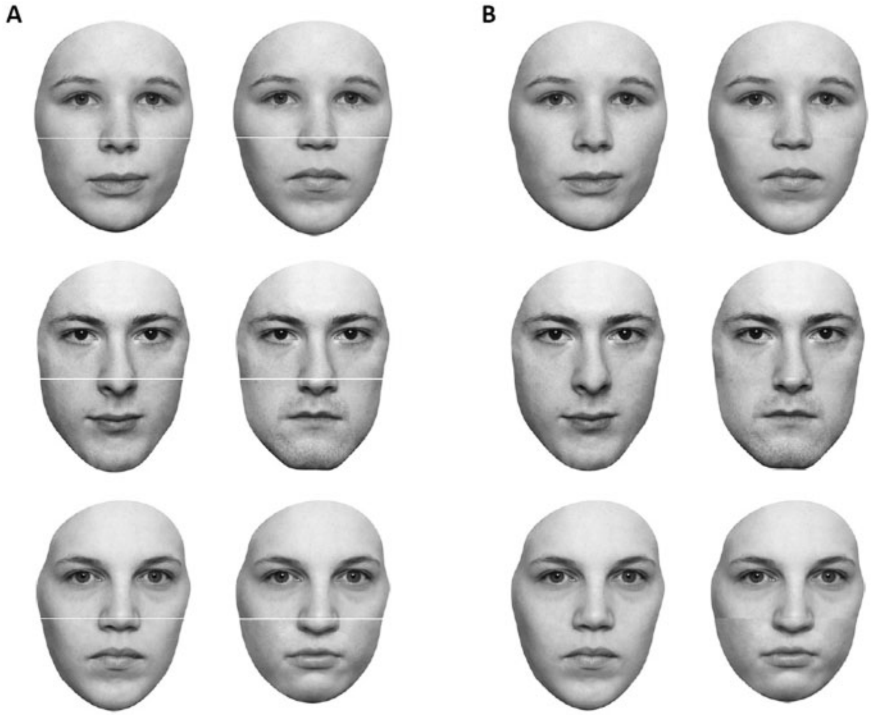

Figure 6. The gap composite face illusion, in which separating face halves paradoxically increases the perception of continuity, due to the removal of low-level mismatch between different face halves. In both A and B, the images in the left column are veridical faces, and the images in the right column are composite faces of those identities by row. A. Stimuli with a gap between face halves; B. The same face stimuli without a gap.

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presented side-by-side was the composite face. We hypothesized that for the exact same stimuli, this judgement would be considerably easier when there is no gap than when there is a gap between face halves. In addition, to test the putative contribution of high-level visual processes in this task, we presented the exact same faces upside-down, a manipulation that not only disrupts face recognition performance (e.g., Freire, Lee, & Symons, 2000; Rossion, 2008; Yin, 1969 for a review), but also reduces or abolishes the CFE (e.g., Hole, 1994; McKone et al., 2013; Rossion & Boremanse, 2008; Susilo et al., 2013).

Methods

Participants. Ten participants (mean age = 24 years, range = 19–37 years, eight female) associated with the University of Louvain, Belgium, took part in this experiment, none of whom had participated in Experiments 1 or 2. All participants gave written informed consent and received monetary compensation.

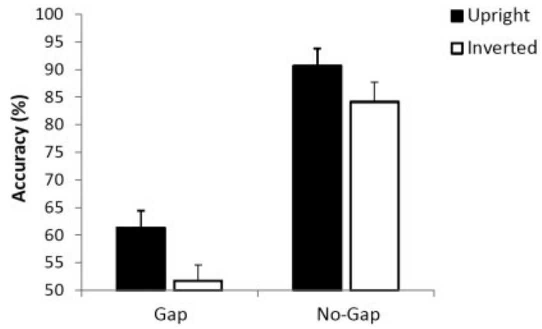

Figure 7. Results for Experiment 3, comparing accuracy in identification of the veridical face from a composite face.

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Stimuli. The 10 original identities, as described in the Stimuli section of Experiment 1, were used here, as well as five additional identities, prepared in the same way, for a total of 15 original identities (eight female). For each original identity, one corresponding composite identity, using the same top half and a bottom half from a different identity, was created as described in Experiment 1, although misaligned stimuli were not generated (for the 10 original identities used in Experiment 1, the composite identity used was also used in Experiments 1 and 2). Here, in total, 15 original identities and 15 composite identities were used, and these identities were represented in two sets of stimuli, those with and without a gap.

Procedure. A pair of face stimuli were presented side-by-side, one of which was a composite face, i.e., created from top and bottom halves coming from different identities, and the other an original face, i.e., comprised of top and bottom halves coming from the same original face. Each original identity was presented with its matching composite identity, so that the two identities presented shared a top half from the same identity. Participants were informed of this manipulation and performed a forced choice task: they were instructed to choose which face was the original by selecting a corresponding key on a computer keyboard. The design was controlled so that the original face appeared on the left side on half of the trials. The two faces presented were always either both female or both male.

A 2 × 2 repeated-measures design was used, with factors of stimulus set (gap or no-gap) and orientation (upright or inverted), leading to four conditions in total. Each trial consisted of a blank white screen for 350 ms, followed by the simultaneous presentation of a pair of two face stimuli for up to 20 s, followed by a blank white screen: when a response was given during either the face presentation or the blank screen afterwards, a blank 1500 ms inter-trial interval began. Face stimuli were presented on a computer monitor, each at a size of approximately 3.5 by 4.8 degrees of visual angle each. After a block of 60 randomized trials, there was a brief pause, followed by a second block of 60 randomized trials. In the second block, each original and composite face pair was presented as a second repetition per each condition. The experiment lasted about 10 minutes in total and was run using E-Prime 2.0.

Analyses. Accuracy and RTs were recorded for each trial, and means were computed for each condition; for RT, only correct response trials were considered. Given the unlimited response time, trials with RTs above three standard deviations from the mean for individual participants were excluded. Statistical analyses were performed with SPSS PASW 18. A two-way repeated-measures ANOVA, with two-level within-subjects variables of *stimulus set* (gap or no-gap) and *orientation* (upright or inverted), was performed separately for each accuracy and RT.

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Results

Accuracy. Mean accuracy for upright trials without a gap approached ceiling (Figure 7; M = 90.6%, SE = 3.17%), while was not greatly above chance for upright trials with a gap (M = 61.3%, SE = 3.10%). When orientation was inverted, mean accuracy dropped for both stimulus set conditions (no-gap: M = 84.1%, SE = 3.62%; gap: M = 51.7%, SE = 2.87%). There were significant main effects of *stimulus set* ($F(1,9) = 91.8$, $p < .001$, $\eta_p^2 = 0.91$) and *orientation* ($F(1,9) = 7.56$, $p = .02$, $\eta_p^2 = 0.46$), and no interaction between these factors ($F(1,9) = 0.58$, $p = .47$, $\eta_p^2 = 0.06$).

Correct RTs. Mean correct RTs analysis is less informative and reliable, given that accuracy rates in the gap condition are only slightly above chance level for upright stimuli. Nevertheless, participants were faster for stimuli without a gap presented upright than for upright stimuli with a gap (no-gap: M = 1163 ms, SE = 73.84 ms; gap: M = 1533 ms, SE = 99.86 ms); this pattern was also present for inverted stimuli (no-gap: M = 1287 ms, SE = 76.34 ms; gap: M = 1576 ms, SE = 105.2 ms). There was a significant main effect of *stimulus set* ($F(1,9) = 23.5$, $p = .001$, $\eta_p^2 = 0.72$). The main effect of *orientation* bordered on significance ($F(1,9) = 4.92$, $p = .05$, $\eta_p^2 = 0.35$), and there was no interaction between these factors ($F(1,9) = 2.49$, $p = .15$, $\eta_p^2 = 0.22$).

Discussion

Experiment 3 provided original evidence that when a gap was present, participants were almost unable to determine which of the two faces was made of two halves belonging to different faces, i.e., a composite face: both the composite and the original face looked like plausible combinations. In contrast, eliminating the gap between the top and bottom halves made it easy to identify which of the two faces of a pair was a composite face. Importantly, that inverting the faces without a gap only reduced performance in the task by about 7%, also rules out an alternative interpretation of our observations, i.e., that the presence of a gap distorts the original face so that participants are unable to determine which one is the original face in the judgement task. If this was the correct explanation, then participants should also be at chance level when composite and original face stimuli without a gap are inverted, arguably a more severe transformation of the face stimulus than adding a gap.

At first glance, there is a contradiction between the larger CFE found Experiment 1 and the easier segmentation of the two face halves in Experiment 3 for no-gap than gap stimuli. However, these experiments are designed to measure different processes (holistic face perception in Experiment 1 and differentiability of face halves in Experiment 3) and so rely on paradigms addressing the integration of face halves in different ways. The composite face paradigm in Experiment 1 requires participants to complete a task describing only the top half of the face, while Experiment 3 requires that participants explicitly search for a mismatch between the two halves. Moreover, the timing of the presentation restricts a comparison, since it is limited to 200 ms in the first task to prevent fixations to the lower half of the face (de Heering, Rossion, Turati, & Simion, 2008), while there is virtually an unlimited amount of time (20 seconds) to perform the task in Experiment 3.

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GENERAL DISCUSSION

To summarize, in Experiment 1 we contrasted for the first time the composite face effect (CFE) for the same stimuli with or without inserting a small gap between the top and bottom face halves. As expected, we reported a larger CFE without a gap, a difference which is not negligible—about 4% accuracy in total, i.e., 33% of the effect—and could have been due to a better integration of the two halves or an ambiguity in the definition of the top half in the absence of a gap. The disappearance of the larger CFE for no-gap stimuli when participants first saw the stimuli with a gap in Experiment 1, as well as in Experiment 2, in which the trials with and without a gap were mixed, altogether favours the second interpretation: the CFE might be artificially increased when there is an ambiguity in the definition of the top half in the absence of a gap. Strikingly, in Experiment 3, in the presence of a gap participants were almost unable to determine which of the two faces was made of two halves belonging to different faces, i.e., a composite face: both the composite and the original face looked like plausible combinations (Figure 6). In contrast, eliminating the gap between the top and bottom halves made it easy to identify which of the two faces of a pair was a composite face. Thus, this last experiment provided original evidence that when using composite stimuli, the presence of a small gap facilitates rather than decreases the integration of the top and bottom halves into a veridical face.

The immediate implication of these findings is that, from a methodological standpoint, introducing a gap between the top and bottom halves of composite faces is important to accurately measure holistic face perception, without artificially conflating the CFE. Such a stimulus cue might be particularly important when comparing different groups of participants, for instance typical adults to children (e.g., Susilo, Crookes, McKone, & Turner, 2009) or patients (e.g., Avidan, Tanzer, & Behrmann, 2011; Busigny, Joubert, Felician, Ceccaldi, & Rossion, 2010) for whom the instruction to "use the top half of a face only" in the task might not be well understood.

The first goal for composite face stimuli we identified was to provide a clear definition of what is meant by "the top face half" for task performance. In the present studies, a gap objectively defined face halves, but even without a gap, the definition of the top and bottom halves might still be quite clear when there is an enhanced border contrast between the two halves, arising from local differences in luminance and texture, as shown in Experiment 3. In fact, such a border is even more clearly visible on many examples of the stimuli sets used in previous studies (e.g., de Heering et al., 2012; Hole, 1994; McKone, 2008; Robbins & McKone, 2007; Taubert, 2009; Taubert & Alais, 2009; Young et al., 1987; Xiao et al., 2012). However, this border contrast varies from stimulus to stimulus, depending on the particular top and bottom halves that are aligned with each other, making the definition of the top half variable across trials. An extreme case of such variability occurs when composite and original stimuli are mixed in the paradigm, so that a border is visible on the former and not on the latter kind of stimuli (e.g., Susilo et al., 2009, Figure 1). This contrast border may also impose variation across conditions, e.g., only in a control trial with identical faces will there always be the same amount of border contrast between face pairs.

More problematic are the composite stimuli without a separation between top and bottom face halves which have attempted to remove the contrast border, as in the "Jane" set (e.g., Le Grand et al., 2004; Letourneau & Mitchell, 2008; Mondloch & Maurer, 2008; Mondloch et al., 2010; Palermo et al., 2011). This makes the definition of the target top half ambiguous. Moreover, in this particular stimulus set, smoothing the texture and adjusting luminance across face halves to remove the contrast border has unfortunately resulted in the top face halves not being strictly physically identical (see Figure 1 in Mondloch et al., 2010).

The point here is not to question the results of the above studies that did not include a gap between the top and bottom face halves. In general, studies using the "Jane' set of stimuli usually run aligned and misaligned trials in separate blocks and some of these studies at least test and report an absence of order

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effect (e.g., Le Grand et al., 2004; Mondloch & Maurer, 2008).[2] Moreover, these studies usually report large and replicable composite face effects, which might have only been inflated in the absence of an objective marker defining the top half. However, the absence of an objective marker defining the target top half might be more problematic when dealing with stimuli that could be associated with a weak CFE, such as inverted faces or nonface objects: the absence of a gap might be sufficient to generate a significant CFE for such stimuli, changing the conclusions of a study.

The advantage for task definition for stimuli with a gap might be vitiated if the presence of a gap violated the second goal for composite face stimuli, i.e., decreased perceptual integration of the two face halves. Instead, we have shown that a small gap does not decrease the perception of the two halves of composite faces as making a veridical face, a finding which may seem paradoxical at first. One way to understand this result is through the Gestalt laws of grouping. The human visual system tends to enclose a line or a space by completing a contour and ignoring such gaps in a figure, the so-called Gestaltist law of closure (Pomerantz & Kubovy, 1986; Wagemans et al., 2012; Wertheimer, 1925/1967). As long as the gap is not so large as to break the continuity of the contour of the face, the visual system readily completes the face stimulus. In natural scenes, faces may be partly occluded by closer objects, such that the separation of face halves by a gap does not contradict the law of past experience. Notably, such principles do not apply to the manipulation used in the control condition, i.e., laterally misaligning the top and bottom halves, even if only by a small fraction of the face width (i.e., 8%, Laguesse & Rossion, 2013).

Furthermore, and most importantly considering the present results, without a gap the two face halves may form a contiguous border, which is enhanced (i.e., border contrast), so that subtle differences in luminance are more readily perceived (Mach, 1865; Ratliff, 1965). This phenomenon appears to be a particular case of figure-ground segregation, where borders are defined by luminance and texture (Regan, 2000). Given that cells in early visual areas such as the primary and secondary visual cortices (V1 and V2) signal border ownership of luminance and texture contours (Chaudhuri & Albright, 1997; Nothdurft, Gallant, & Van Essen, 2000; Zhou, Friedman, & von der Heydt,

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[2] It should also be noted that comparing the present study to that of Le Grand et al. (2004) and Mondloch and Maurer (2008) is difficult, because these studies have different experimental designs. Notably, only in the present study was a condition of "same" trials used, for which both the top and bottom halves were identical; not having this condition may encourage a bias for "same" responses for composite trials (see Rossion, 2013). Moreover, these studies blocked the alignment factor, but over what we take to be several blocks. For instance, Mondloch and Maurer's (2008) study did not have seven misaligned blocks then seven aligned blocks, but rather had seven conditions, randomly varying the aligned/misaligned blocks for each participant, preventing a real analysis of an overall effect of order for the factor "alignment."

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2000), early visual areas may drive the augmented mismatch between face halves. However, the results of inversion from Experiment 3, a decrease that did not interact with the main effect of the presence/absence of a gap, indicates that high-level processes are also implicated in the task. One possibility is that the border between the two halves is less salient in an inverted face due to a lack of reentrant inputs from high-level visual representations (e.g., Chen et al., 2014). Another possibility is that due to holistic face perception the local discontinuity created by the border affects the perception of the whole face, not just the local border, when the stimulus is upright, but not when the stimulus is inverted.

Here, a separation of face halves by the use of a gap is proposed, although other methods to address the issue of defining a top face half have been implemented, e.g., including a line between face halves (e.g., Avidan et al., 2011). However, this manipulation may draw attention toward the imposed high local contrast around or colour of the line. Similarly, lines at the edges of the faces to indicate the face halves (Susilo et al., 2013) may draw attention outside of the face. The top half of the face might alternatively be defined by a region, such as "the region around the eyes", but this would impose ambiguity about the precise area of interest and the importance of specific facial features. Another possible way to define the top half of the face is through the use of practice trials (e.g., Le Grand et al., 2004), in which the top face half could be clearly demarcated; however, even if this is done meticulously, it may be impossible to generalize the top half from one stimulus to another, since the location of the end of the top face half, often set relative to facial features, e.g., at the tip of the nose, may vary from stimulus to stimulus. In the present study, the second face in a trial pair, i.e., the probe, appeared at a slightly larger size, which additionally changes the position of the edge of the top face half. For these reasons also, it may be difficult to generalize the location of the top face half from misaligned trials.

Using a gap clearly defines the top face half for every stimulus, without drawing attention to the area of join between halves. In practice, there is no rule as to the exact position of the gap, which ranges from just below the eyes in the original composite face study (Young et al., 1987) to the tip of the nose in most studies. As for the size of the gap, a good rule of thumb would be to make it as small as possible (here, 0.5% of the face height), as long as it is clearly visible. Although not done previously to our knowledge, a systematic (i.e., parametric) investigation of the size of the gap between the two face halves would be welcome investigation in this literature (as performed recently for evaluating the degree of misalignment between face halves in the misaligned trials; Laguesse & Rossion, 2013).

To conclude, over the past two decades, the composite face paradigm has been used in numerous studies that have provided information about the specificity and nature of perceptual integration between facial parts ("holistic face perception"), the impairment of this process in acquired prosopagnosia, its developmental course, temporal dynamics and neural basis (see Rossion, 2013, for an extensive review). Yet, in the majority of studies, the absence of a small gap between the stimuli may or may not create an artificial variable contrast border that makes the definition of the top face half ambiguous, and may artificially inflate the composite face effect due to a lack of a clearly defined top face half. We suggest that future behavioural studies using the composite face paradigm are improved by systematically introducing a small gap between the face halves, objectively defining the target top face half.

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DISCLOSURE STATEMENT

No potential conflict of interest was reported by the authors.

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