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# Why Does Selective Attention to Parts Fail in Face Processing?

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One hallmark of holistic face processing is an inability to selectively attend to 1 face part while ignoring information in another part. In 3 sequential matching experiments, the authors tested perceptual and decisional accounts of holistic processing by measuring congruency effects between cued and uncued composite face halves shown in spatially aligned or disjointed configurations. The authors found congruency effects when the top and bottom halves of the study face were spatially aligned, misaligned (Experiment 1), or adjacent to one another (Experiment 2). However, at test, congruency effects were reduced by misalignment and abolished for adjacent configurations. This suggests that manipulations at test are more influential than manipulations at study, consistent with a decisional account of holistic processing. When encoding demands for study and test faces were equated (Experiment 3), the authors observed effects of study configuration suggesting that, consistent with a perceptual explanation, encoding does influence the magnitude of holistic processing. Together, these results cannot be accounted for by current perceptual or decisional accounts of holistic processing and suggest the existence of an attention-dependent mechanism that can integrate spatially separated face parts.

*Keywords:* face, holistic, configural, encoding, representation

Faces, relative to other objects, are believed to be processed more in terms of the whole rather than in terms of parts. A particularly powerful demonstration of this holistic processing is the difficulty observers experience when attempting to selectively attend to a part of a face presented in its intact configuration relative to a disrupted configuration (Boutet, Gentes-Hawn, & Chaudhuri, 2002; Farah, Wilson, Drain, & Tanaka, 1998; Gauthier, Curran, Curby, & Collins, 2003; Young, Hellawell, & Hay, 1987). Faces may be processed holistically because configural information, such as the spatial relationships between distant features, is particularly important in face perception. For example, recognition of an individual facial feature (e.g., the nose) is impaired when the spatial relations between features in a test face differ from those present in the studied face; this effect is not found with scrambled faces, inverted faces, or common objects (e.g., houses; Tanaka & Sengco, 1997). Therefore, it may be especially difficult to attend exclusively to part of an upright face because this means ignoring valuable information from the rest of the face.

Such holistic processing can be measured in a selective attention task, in which a study and test face are shown either simultaneously (Farah et al., 1998) or sequentially (Boutet et al., 2002). A face part (e.g., eyes) or region (e.g., top half) is cued, and the participants' task is to decide whether the cued part is the same or different in the study and test face. In this paradigm, the critical manipulation concerns the influence of the noncued, irrelevant information on matching performance (e.g., the effects of the lower half of the face when participants are cued to respond to the upper portion). In the *congruent condition*, the noncued, task-irrelevant information is the same as the cued, relevant information (e.g., both parts of the test face are the same as the study face, or both parts are different). In the *incongruent condition*, the irrelevant information differs from the relevant information (e.g., one part is the same as the study face, and the other part is different). The main result is that matching performance is better in the congruent condition than the incongruent condition (*congruency effect*). The congruency effect is reduced or eliminated when configural face information is disrupted either by inverting the face (Hole, 1994; Hole, George, & Dunsmore, 1999) or by spatially misaligning its top and bottom halves (Cheung, Richler, Palmeri, & Gauthier, in press; Richler, Gauthier, Wenger, & Palmeri, 2008; also sometimes referred to as the *composite effect*; e.g., Young et al., 1987). However, in an intact upright face, the whole interferes with attention to the parts, and this breakdown in selective attention has been interpreted as evidence in support of holistic face representation.

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The failure of selective attention to face parts is important for our understanding of face and object processing for several reasons. First, the congruency effect is larger for faces than for other objects (Farah et al., 1998; Gauthier et al., 2003). Furthermore, this effect has been used to argue that faces are represented as unitary, undecomposed wholes (Farah et al., 1998) and that encoding of such representations does not necessitate general attentional resources (Boutet et al., 2002). With objects, failures of selective attention to parts are also larger in expert observers than in novices (Gauthier et al., 2003; Gauthier & Tarr, 2002). The magnitude of this effect is correlated with changes in a face-selective cortical area, the fusiform face area, during the acquisition of perceptual expertise (Gauthier & Tarr, 2002) and it has been shown to be susceptible to interference between faces and objects of expertise, as measured behaviorally and with event-related brain potentials (Gauthier et al., 2003). Thus, why selective attention to parts often fails in face perception must be addressed to fully characterize how faces are processed as well as how perceptual expertise is acquired.

Critically, such holistic processing could be explained in at least two ways. According to the holistic encoding or template hypothesis, holistic processing arises because faces are encoded in such a way that individual parts are not explicitly represented, at least not independently from other parts. In other words, faces are encoded as a gestalt to fit a "face template" (Farah et al., 1998; Tanaka & Farah, 1993). This suggests that holistic processing is rooted in the perceptual process (Diamond & Carey, 1986; Farah et al., 1998; Goffaux & Rossion, 2006; Hole, 1994; Le Grand, Mondloch, Maurer, & Brent, 2004; Lewis & Glenister, 2003; Murray, Yong, & Rhodes, 2000; Tanaka & Sengco, 1997; but see Macho & Leder, 1998).

Alternatively, holistic processing could arise at a later, decisional stage of processing. In contrast to the holistic encoding or perceptual hypothesis described above, in which faces are represented as unified wholes, a decisional account of holistic processing suggests that parts are represented independently, but decisions about them are not made independently (Ashby & Townsend, 1986; Wenger & Ingvalson, 2002, 2003). Although postperceptual accounts have not often been considered in the literature on face perception, they are typically used to explain other failures of selective attention, such as those occurring in the Stroop task (MacLeod, 1991). The goal of this work is to investigate whether one aspect of holistic processing, the failure of selective attention to parts experienced by observers making judgments about faces, has a perceptual or a decisional locus.

Unfortunately, distinguishing between a perceptual or a decisional locus for holistic processing is not easy. Any judgment that an observer makes about a face depends on both perceptual representations and decisional mechanisms, and the effects of these two processing stages are typically confounded in behavioral analyses. Recently, some authors have turned to the general recognition theory framework (Ashby & Townsend, 1986) as a means to dissociate these underlying effects in a version of the face composite paradigm. In this multidimensional extension of signal detection theory, stimuli give rise to percepts drawn from multivariate normal distributions, and responses are determined by decision boundaries separating these distributions. Within this framework, holism arising from a perceptual locus (e.g., whether perception of part of a face depends on the identity of other part) can be distinguished from decisional holism (e.g., whether the decision boundary for judgments on one part depends on the identity of the other part).

Using this approach, Wenger and Ingvalson (2002, 2003) have uncovered evidence for decisional holism in a composite task with faces. However, the powerful analytical framework used in these studies requires a full confusion matrix based on participants' responses for all dimensions (in the composite task, both face halves) on each trial. This means that observers are asked to pay attention to all parts of both target and probe faces, unlike in a typical selective attention task in which holistic effects are found despite instructions to only attend to one part of the probe face, or even in some cases only one part of both probe and target faces (Gauthier et al., 2003). Indeed, one could argue that failures to ignore a face part are even more interesting when observers are explicitly instructed not to pay any attention to it. Importantly, more recent work using a hybrid task that bridges the two paradigms, including selective attention instructions but collecting responses for all face parts on each trial, also concluded that holistic effects in the composite paradigm arise mainly because of decisional factors (Richler et al., 2008).

One practical concern about these results is that because general recognition theory is a framework that is rarely used to study face processing, and because the multidimensional signal detection analyses required to disentangle perceptual and decisional holism are very complex, the impact of these findings in the face literature may be limited. More theoretically, the general recognition theory framework and the associated analyses are based on some assumptions, such as equal variances for all trial types (Kadlec & Townsend, 1992) and that all parts of the stimulus are sampled equally on every trial (Macho, 2007). These assumptions cannot be verified until after data have been collected. Furthermore, other lines of research have led researchers to suggest a perceptual locus for holistic processing. One recent example is the claim that holistic processing precedes the analysis of local features during face perception because it was found to rely mainly on low spatial frequency information (Goffaux & Rossion, 2006; but see Cheung et al., in press). For these reasons, we sought converging evidence on this issue by testing a counterintuitive prediction of the decisional account: the idea that the configuration of a studied face may not impact whether it is later processed holistically when compared with a second face.

To this end, we used a simple sequential matching selective attention paradigm, the composite task, and manipulated the configuration of either the study face or test face. Participants studied a composite face (made from combining the top of one face with the bottom of another face), the top or bottom part was cued, and then a second composite was shown at test (see Figure 1). Participants were asked to judge whether the cued part was the same or different in the test face. Previous research has repeatedly shown that changing the configuration of the test face (by misaligning its parts) reduces holistic processing. Here, we also investigate the role of configuration during the encoding and formation of a face representation by manipulating the configuration of the study face.

The predictions one can make in the experiments we present here depend on the presumed information processing locus of holistic effects in the composite task. If holistic processing emerges only at a decisional stage, manipulations applied to the study face will have less of an impact than those applied to the test face. However, if holistic processing stems from the holistic nature

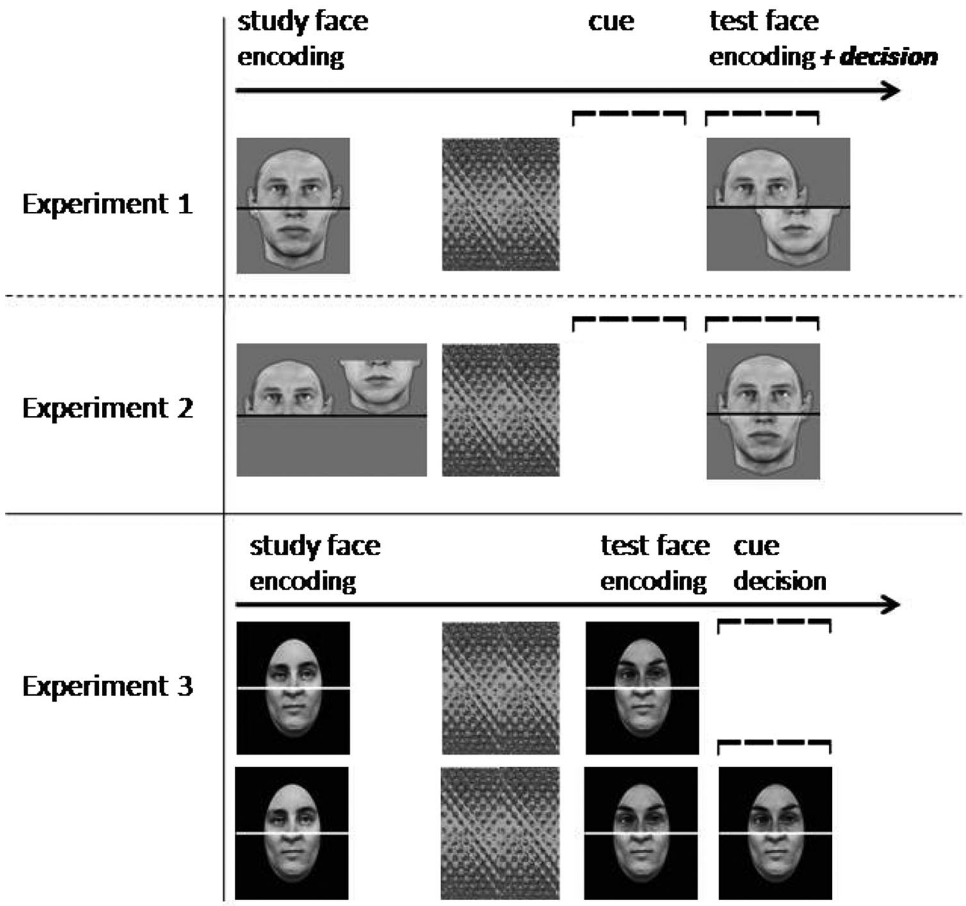


*Figure 1.* Example trials for Experiments 1–3. Observers were instructed to indicate whether the cued part was the same in a studied face and a test face that were separated by a blinking pattern mask. They were told to ignore the uncued part. Encoding occurs during the presentation of the both the study and test faces. In Experiments 1 and 2, the decision process also occurs when the test face is presented. In Experiment 3, the decision process occurs after the test face is encoded.

of face representations, configural manipulations of the study face should greatly impact holistic effects.

The logic for these prediction is as follows (see Figure 1): Encoding occurs for both the study and test face, so if holistic effects were at least in part due to holism of the perceptual representation, we would expect that altering the configuration of the study face or test face would yield comparable perceptual contributions. However, the decisional component of the task (which encompasses the comparison between study and test stimuli as well as response selection) occurs only at the time of the test face. The decisional account of holistic processing suggests that holistic effects arise because decisions about the parts of a face are not made independently. Crucially, this explanation does not depend on a holistic representation of the studied face and, therefore, would not be expected to depend on the presentation of a whole face at study. A critical finding would therefore be to find no effect of configuration at study, because this finding is incompatible with the holistic encoding account but predicted by the decisional account.

One previous experiment in which both study and test formats were manipulated was conducted by Boutet et al. (2002). Participants studied a face that was either upright or inverted, and they were tested on an upright face that was either aligned or misaligned. The authors argued that holistic processing occurs specifically at the time of encoding, because misaligning a test face only influenced matching performance when the faces were studied in their upright orientation but not when they were studied upside-down. They concluded that inversion interferes with the encoding of holistic face representations and that misalignment at test should not affect performance following encoding of inverted faces, because performance depends in this case on the retrieval of non-holistic representations. However, because the top and bottom halves of the test faces were either both the same or both different (thus, always congruent), this experiment did not assess the role of selective attention on the encoding of the cued and to-be-ignored face halves.

Qualitative predictions for Experiment 1 are illustrated in Figure 2. We predict that, replicating previous work, the congruency effect will decrease when the test face is misaligned. With respect to manipulating face alignment at study, if holistic effects arise during the encoding of the first studied face that has to be committed to short-term memory, as suggested by Boutet et al. (2002),

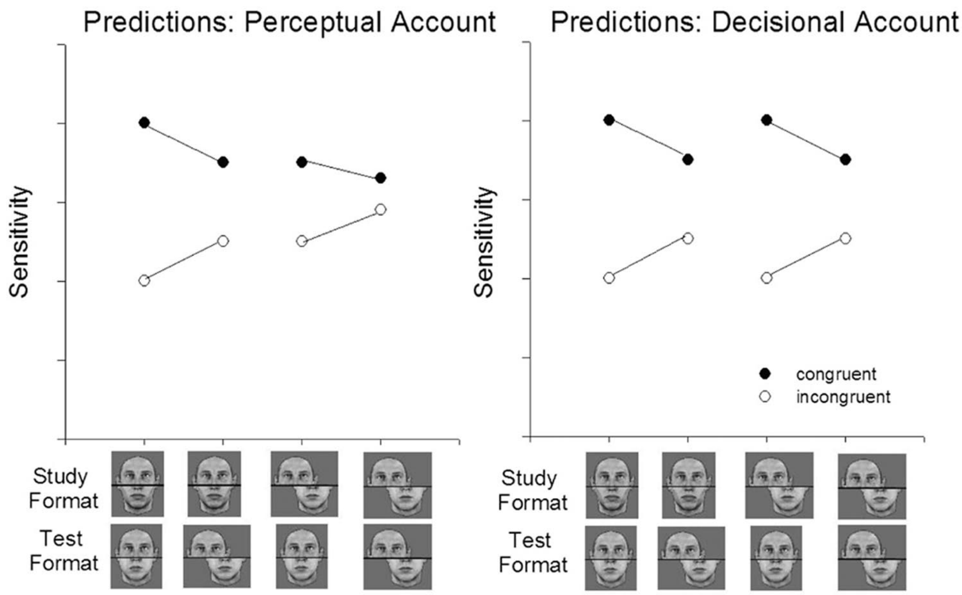


*Figure 2.* Predictions for Experiment 1 based on a perceptual account (right panel) or decisional account (left panel) of holistic processing. If holistic processing arises because of holistic encoding, then manipulations of face configuration at both study and test should influence the magnitude of the congruency effect, resulting in a smaller congruency effect when *either* the study face or test face is misaligned compared with when the study face and test face are both aligned. If holistic processing arises because of decisional factors, only manipulations at test should affect the congruency effect, resulting in comparable congruency effects when the study face is aligned or misaligned.

studying the first face in a broken configuration should promote encoding and storage (and later retrieval) of the face in terms of parts and therefore reduce (or even eliminate) the congruency effect (see Figure 2, left panel); in contrast, if the holistic effects observed in the composite task originate from stages of processing that operate only during the perceptual judgment, such as during the comparison of the two faces, or biases operating at the decisional stage (Richler et al., 2008; Wenger & Ingvalson, 2002, 2003), the manipulation of configuration at study may not be as influential as its well-studied effects at test, and whether the study face is aligned or misaligned should not impact the magnitude of the congruency effect (see Figure 2, right panel). The goal of the present experiments is to examine the extent to which congruency effects are influenced by spatial disruptions of face parts during encoding versus during the decision phase.

## Experiment 1

### Method

*Participants.* Twenty-one undergraduate students at Oberlin College (Oberlin, OH) with normal or corrected vision participated in this experiment for course credit. Data from 2 participants were discarded because of chance performance.

*Stimuli and procedure.* The stimuli were created from 12 digital images of similar male faces without hair, beards, or other salient diagnostic features (from the face database provided by the Max Planck Institute for Biological Cybernetics in Tuebingen, Germany). Each face was approximately 200 × 160 pixels in size and saved in gray-scale. The top and bottom halves of each face were saved as separate images and reorganized to create 24 composites. Parts were paired systematically so that each top or bottom appeared in two composites. A misaligned version was created for each composite by moving the bottom part toward the right by approximately 70 pixels (so that the edge of the bottom half fell on the center of the top half). A 3-pixel-thick black line was positioned at the seam between the two halves of each stimulus (or in the same position for isolated halves). This was done to make it completely unambiguous where the top half starts and the bottom half ends, which should, if anything, facilitate selective attention to the cued parts: Any holistic processing we measure cannot be attributed to participants being unclear about the part they were supposed to ignore. A 256 × 256 pixel nonsense texture mask was created with the glass "tiny lens" filter in Adobe Photoshop.

The experiment was conducted on Mac OS9 computers with RSVP software (Williams & Tarr, n.d.). On each trial (see Figure 1), a study stimulus was shown for 700 ms, followed by a flashing mask (four identical masks shown each for 120 ms, alternating with 50-ms blanks for a total of 630 ms), followed by a rectangular bracket cueing top or bottom judgments, shown for 300 ms and remaining on the screen when the test stimulus appeared. The cue appeared before the test face and remained present thereafter to ensure that participants were very clear on which part to attend and which part to ignore: Any holistic processing we measure is unlikely to be because of participants forgetting which part was relevant on any trial. The test stimulus stayed on the screen until the participant responded, or for 4,000 ms. Reaction times (RTs) were measured from the appearance of the test stimulus, and trials timed out after 5,000 ms. No feedback was given. Participants indicated by button press whether the cued part was the same at study and test. Participants were told to attend to both parts of the study face and to ignore the uncued part (if any) of the test face.

There were 624 experimental trials, and their order was randomized for each participant. There were 12 trials for each combination of study format (isolated, aligned, misaligned), test format (aligned, misaligned, isolated), congruency (congruent vs. incongruent), and correct response (same vs. different). Twelve practice trials were randomly selected for each participant from the 624 possible experimental trials and were not analyzed.

### Results

We used sensitivity ($A_z$), which measures performance independent of response bias, instead of accuracy for our analyses because several studies (Cheung et al., in press; Wenger & Ingvalson, 2002, 2003) reported important response biases in similar tasks (see also Gauthier & Bukach, 2007). Furthermore, $A_z$ has been shown to be more robust to influences of response bias on sensitivity in the case of unequal variances compared with other sensitivity measures (Verde, Macmillan, & Rotello, 2006). For brevity, we report sensitivity ($A_z$) only, which tended to be more sensitive than RTs. The RT pattern did not contradict the sensitivity pattern (and in most cases showed a significant effect in the same direction). Accuracy and RTs for correct responses are reported in Appendix A, and the effects of response bias in all the experiments presented here are summarized in Appendix B.

*Isolated conditions.* As can be appreciated from Figure 3, performance was better when an isolated part was presented at study compared with when an isolated part was presented at test. This was confirmed by a 2 × 2 repeated measures analysis of variance (ANOVA) with isolated part (study/test) and alignment (aligned/misaligned) as factors, which revealed a significant main effect of isolated part, $F(1, 18) = 22.843$, $p < .0001$. The main effect of alignment and the interaction were not significant.

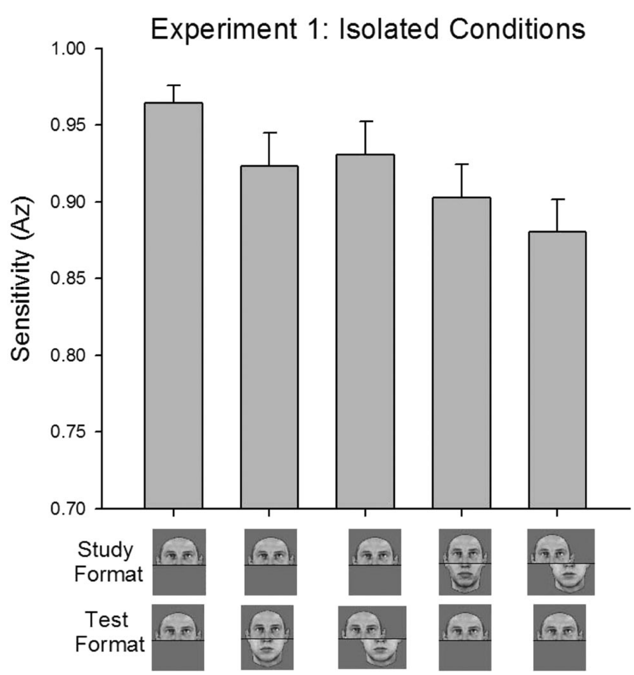


*Figure 3.* Mean sensitivity ($A_z$) for trials in which an isolated part was presented at study or test. Error bars show 95% confidence intervals of within-subjects effects for all data points except the baseline condition (isolated part presented at both study and test), in which error bars show standard error of the mean.

Paired *t*-tests comparing each isolated condition with the baseline condition in which an isolated part was presented at both study and test (Bonferroni-corrected for four comparisons; $\alpha = .015$) revealed that performance was impaired relative to baseline for all conditions except study-isolated/test-misaligned.

*Congruency effect.* As can be seen from Figure 4, a congruency effect is obtained in all conditions and is driven by interference on incongruent trials relative to the baseline trials in which an isolated half was presented at test. Additionally, the magnitude of the congruency effect is larger for aligned versus misaligned test faces.

Inferential statistics confirm these observations. A 2 × 2 × 2 repeated measures ANOVA was conducted with study format (aligned/misaligned), test format (aligned/misaligned), and congruency (congruent/incongruent) as factors. There was a main effect of congruency, with better sensitivity for congruent compared with incongruent trials, $F(1, 18) = 8.121$, $p < .05$. As expected, there was a significant interaction between test format and congruency, $F(1, 18) = 5.328$, $p < .05$. Post hoc tests (Scheffé's, $\alpha = .05$) revealed significant congruency effects for both test formats, although the congruency effect was larger when the test face was aligned compared with misaligned. Importantly, there was no interaction between study format and congruency, $F(1, 18) = 0.300$, $p = .591$.

One unexpected result was the interaction between study and test format, $F(1, 18) = 4.502$, $p < .05$. Post hoc tests revealed that when the study face was aligned, performance was better for aligned compared with misaligned test faces, whereas when the study face was misaligned, performance was the same for aligned and misaligned test faces. The three-way interaction between study format, test format, and congruency was not significant, $F(1, 18) = 1.287$, $p = .271$.

Congruency effects were due to interference rather than facilitation. Paired *t*-tests comparing each congruent condition or incongruent condition with its test-isolated baseline (Bonferroni-corrected for eight comparisons; $\alpha = .00625$) only revealed significant interference in the two conditions in which the test face was aligned (whether it was studied in an aligned or misaligned format) and no significant facilitation.

Note that beyond their use in determining the contribution of interference relative to facilitation, performance in the isolated trials is difficult to compare meaningfully with that of the other trials. At least, the interpretation with regards to holistic processing is complicated for several reasons. First, holistic processing in our paradigm is measured in terms of failures of selective attention. Although in both the isolated-study and isolated-test cases the other face in the trial has two parts, only in one case (study-isolated) are participants attempting to selectively attend to one of the face parts. Stimulus differences and task differences are therefore confounded. Second, differences between the isolated conditions are likely to arise on the basis of differences in encoding and working memory demands when an isolated part is presented at study versus test. For example, when an isolated part is presented

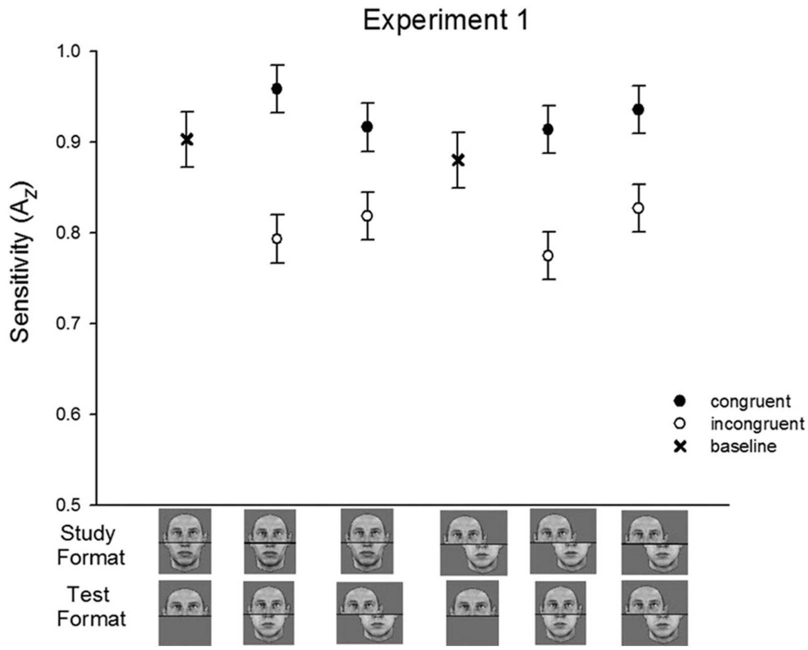


*Figure 4.* Mean sensitivity ($A_z$) for congruent and incongruent trials as a function of study format (aligned/misaligned) and test format (isolated/aligned/misaligned) in Experiment 1. Error bars show 95% confidence intervals of within-subjects effects for all data points except the isolated baseline conditions, in which error bars show standard error of the mean.

at study, only one part must be encoded and maintained in memory, whereas when an isolated part is presented at test, two parts must be encoded at study. In other words, there is simply more information to encode and store when an isolated part is presented at test. In addition, although performance when a second face part was added at either study or test was worse compared with the baseline, this is also not surprising, as encoding processes, which are affected by the presence of more information, occur at both study and test (see Figure 1).

### *Discussion*

The critical finding from Experiment 1 is that a congruency effect was obtained not only when the study face was encoded in a normal, aligned configuration but also when the study face was encoded in a misaligned configuration. That is, consistent with prior work, the congruency effect was larger for test faces that were aligned than those that were misaligned. However, inconsistent with a holistic encoding account, the magnitude of the congruency effect was not affected by the format of the study face. Also inconsistent with the holistic account is the finding that matching performance for a part was not better following the encoding of a misaligned study face (which should be encoded in terms of parts) than following the encoding of an aligned study face (which should be encoded as a whole face in this framework).

Why did we observe evidence of holistic processing when faces were misaligned? If holistic processing arises because faces are encoded as a gestalt, any disruptions of configuration should abolish holistic effects—a misaligned face does not fit into the face template. However, one explanation for why a congruency effect was observed for misaligned faces is that this specific spatial arrangement may not sufficiently disrupt the face configuration. Certainly, although the congruency effect was reduced with misaligned test faces, it was not abolished.

The goal of Experiment 2 was to determine whether a stronger manipulation of configuration at study would be more efficient in abolishing the congruency effect. To this end, participants studied all faces in an adjacent format (see Figure 1). This allowed us to test one account of Experiment 1, namely that encoding misaligned faces produced holistic processing because that configuration was not broken enough.

## Experiment 2

### *Method*

*Participants.* Twenty-one undergraduate students at Vanderbilt University (Nashville, TN) with normal or corrected vision participated in the experiment for course credit. Data from 1 participant were discarded because of chance performance, and data from another participant were discarded because of the use of incorrect response keys.

*Stimuli and procedure.* The materials and procedure were the same as in Experiment 1, with the following exceptions: Parts were always presented as adjacent at study (the bottom part was moved to the right side of the top part; see Figure 1); study images were shown for 1,200 ms; and the test stimuli could be isolated parts, adjacent parts, or an aligned face. Study stimuli were shown longer to ensure that both parts could be encoded given that they were further apart. There were a total of 12 practice trials (randomly selected from all possible trials) and 200 experimental trials (80 for each of the aligned and misaligned test conditions and 40 in the isolated test condition).

## Results

Analyses are reported here on sensitivity ($A_z$). Accuracy and RTs for correct responses are presented in Appendix C. As can be appreciated from Figure 5, a congruency effect was only observed for aligned test faces because of interference on incongruent trials.

These observations are confirmed by inferential statistics. A 2 × 2 repeated measures ANOVA on sensitivity with congruency (congruent/incongruent) and test format (aligned/adjacent) as factors revealed a significant main effect of congruency, with greater sensitivity for congruent compared with incongruent trials, $F(1, 19) = 9.719$, $p < .01$, and a significant main effect of test format, with greater sensitivity when the test face was presented in the adjacent format, $F(1, 19) = 4.435$, $p < .05$. There was also a significant Congruency × Test Format interaction, $F(1, 19) = 4.473$, $p < .05$. Post hoc tests (Scheffé's, $\alpha = .05$) indicated that the interaction was due to a congruency effect only in the aligned test condition.

Paired *t*-tests comparing each congruent or incongruent condition with the test-isolated baseline (Bonferroni-corrected for four comparisons; $\alpha = .0125$) only revealed significant interference when the test face was aligned and no significant facilitation.

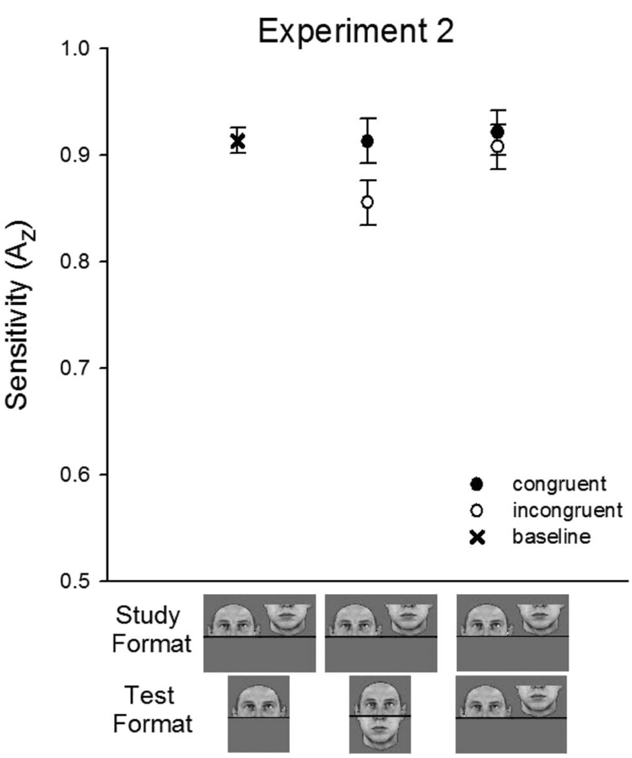


*Figure 5.* Mean sensitivity ($A_z$) and mean reaction time (in milliseconds) for correct responses (left column) for congruent and incongruent trials as a function of test format (isolated/aligned/adjacent) in Experiment 2. Faces were always studied in the adjacent format. Error bars show 95% confidence intervals of within-subjects effects for all data points except the isolated baseline conditions, in which error bars show standard error of the mean.

## Discussion

The results from Experiment 2 reveal that the congruency effect can be obtained even when disjoint face parts are studied provided that the test face is presented in a normal aligned configuration. That holistic processing occurs even when the study face is encoded as parts is surprising and suggests that holistic processing occurs at a decisional level rather than during encoding; holistic effects are unlikely to depend on a holistic representation of the study face if congruency effects are observed for aligned test faces even when the study face was encoded as parts.

An interesting possibility is that although misaligned and adjacent faces were presented in a broken configuration, the two face halves were integrated during encoding, resulting in an aligned face representation. Recent work has shown that temporally separated face parts are integrated as long as face parts are presented within 400 ms of each other (Anaki, Boyd, & Moscovitch, 2007; Anaki & Moscovitch, 2007), and effects of face inversion in a similar task to the one used here also arise when face components are presented sequentially (Singer & Sheinberg, 2006). Spatial integration may occur in a similar way as temporal integration, analogous to circumstances in which participants use eye movements to sequentially foveate different parts of the face and must integrate this information. It is possible that in Experiments 1 and 2, participants integrated the two misaligned face halves into a single face representation similar to the integration that occurs across multiple eye fixations (Hayhoe, Lachter, & Feldman, 1991).

However, there would have to be important constraints and limitations to spatial and temporal integration, otherwise we would constantly be creating incorrect hybrid faces when sequentially attending to parts of different faces. Why would the many cues provided in the task, suggesting that the two parts of the study face were indeed separate parts, be ignored? These cues included the distance between parts, the line separating them, the rearrangements of the same face parts into different faces over the course of several trials, and the instructions to ignore parts that could change. In addition, the misaligned and adjacent configurations would have disrupted the ability of eye movements to encode the spatial relations between features, a process that has been proposed to be important in the encoding of unfamiliar faces (Henderson, Williams, & Falk, 2005).

Therefore, before amending the holistic encoding account to include a spatial integration mechanism that integrates misaligned and adjacent face parts into a holistic face representation, it is important to ask whether there are any other alternatives to a decisional account of holistic processing. Indeed, there are several differences between the study and test faces in Experiments 1 and 2: First, the study face is always in memory, whereas the test face is visible to participants during the same–different judgment and response. In other words, the configuration of the test face may be more salient than that of the study face held in memory. Second, although the entire study face must be encoded because participants do not know which part is going to be cued, participants only need to encode the relevant part of the test face. Certainly it could be that integration of the adjacent parts at study occurred despite the fact that they were discontinuous because attention to both parts was required.

To test the impact of these differences, in Experiment 3 the study and test faces could each be either aligned or misaligned, and we removed the test face prior to the appearance of the cue (effectively postcueing the test face; see Figure 1). Thus, both the study and test faces were in memory when participants compared the two faces and selected a response, and both parts of the test face had to be encoded because participants did not know which part would be cued until after the test face disappeared. In this design, any effect we observe could be due to either making a judgment when both faces are in memory, or the postcue, which forces participants to encode the entire test face, or both. To distinguish between these possibilities, we also had a control condition in which the test face remained on the screen when the postcue appeared.

## Experiment 3

### Method

*Participants.* Eighty-eight participants with normal or corrected vision completed this experiment in exchange for either course credit or $6.00. Forty-eight participants were in the test face-absent condition (23 studied aligned faces, 25 studied misaligned faces), and 40 participants were in the test face-present condition (20 studied aligned faces, 20 studied misaligned faces).

*Stimuli.* Twenty female faces from the Max Planck Institute database were converted to gray-scale and cut in half to produce 20 face tops and 20 face bottoms that were 256 × 128 pixels in size. A white line, 3 pixels thick, separated the two face halves that were randomly combined on every trial, resulting in faces that were 256 × 259 pixels. Faces were presented inside an oval within a black rectangle on a white background to eliminate cues derived from the shape of the head or chin. Misaligned faces were created by moving the top part 35 pixels to the right and the bottom part 35 pixels to the left, such that the edge of one part fell in the center of the other part.

*Procedure.* We presented stimuli using Matlab 7.1 on an IBM computer with a 19-in. (48.26-cm) monitor (resolution: 1024 × 768, 85-Hz refresh rate). On each trial (see Figure 1), a fixation cross appeared for 500 ms, followed by a study face that was presented for 800 ms. The study face was either aligned or misaligned, depending on the study condition to which the participant was assigned. After a 500-ms random pattern mask, a test face was presented for 800 ms, after which a square bracket appeared, cueing participants to respond to either the top or bottom half of the face. Participants were instructed to judge whether the cued part was the same or different as in the study face. For the test face-absent group, the test face was no longer on the screen when the cue appeared. For the test face-present group, the test face remained on the screen when the cue appeared and until participants made a response. Participants had a maximum of 2,500 ms to make a response, and no feedback was given.

There were 160 experimental trials, and their order was randomized for each participant. Because of a minor programming error, there were between 7 and 10 trials for each test configuration (aligned vs. misaligned) crossed with the cued part (top vs. bottom), correct response (same vs. different), and congruency (congruent vs. incongruent). A 16-trial practice block preceded the experimental block.

### Results

Analyses are reported here on sensitivity ($A_z$). The RT pattern did not contradict the sensitivity pattern, and mean RTs and accuracy are presented in Appendix D. As can be seen in Figure 6, when the study face was aligned, the congruency effect was larger for aligned versus misaligned test faces, but when the study face was misaligned, the congruency effect was comparable for aligned and misaligned test faces. These effects were the same regardless of whether the test face was present or absent during the response phase.

A 2 × 2 × 2 × 2 mixed factors ANOVA was conducted on sensitivity ($A_z$), with test format (aligned/misaligned) and congruency (congruent/incongruent) as within-subjects factors and study format (aligned/misaligned) and test face condition (absent/present) as between-subjects factors. There was no main effect of test face condition, nor did it interact with any other factor.

There was a significant main effect of congruency, such that performance was greater for congruent trials compared with incongruent trials, $F(1, 84) = 44.522$, $p < .0001$. There was no significant main effect of study format; however, there was a significant Test Format × Study Format interaction, $F(1, 84) = 25.687$, $p < .0001$. Post hoc tests revealed greater sensitivity for misaligned test faces when the study face was also misaligned.

Critically, there was a marginally significant Test Format × Congruency interaction, $F(1, 84) = 3.816$, $p = .054$, which was modulated by an interaction with study format, $F(1, 84) = 5.012$, $p < .05$. Post hoc tests revealed that, as in the other experiments reported here, the magnitude of the congruency effect was smaller for misaligned test faces compared with aligned test faces when the study face was aligned. However, unlike the other experiments, there was no difference in the magnitude of the congruency effect for aligned versus misaligned test faces when the study face was misaligned. This difference was driven by a smaller congruency effect for aligned test faces when the study face was misaligned compared with aligned. Congruency effects for misaligned test faces were unaffected by study format.

### Discussion

Requiring participants to encode the entire test face by using a postcue altered the effects of study configuration. Specifically, whereas in Experiments 1 and 2 we observed larger congruency effects when the test face was aligned compared with other configurations regardless of study format, in Experiment 3, differences in the congruency effect based on the configuration of the test face were modulated by study format. That is, the congruency effect was larger for aligned test faces compared with misaligned test faces when the study face was aligned, but when the study face was misaligned, aligned and misaligned test faces led to comparable congruency effects.

The goal of Experiment 3 was to examine what happens to the congruency effect when both the study and test face are equated in terms of memory and encoding demands. That the test face-absent and test face-present conditions led to the same results rules out the possibility that study format produced no effect in Experiments 1 and 2, because the study face was in memory and the test face was visible and therefore more perceptually salient.

Although this experiment ruled out an effect of perceptual saliency in the composite task, it also demonstrated how the pre- and postcues

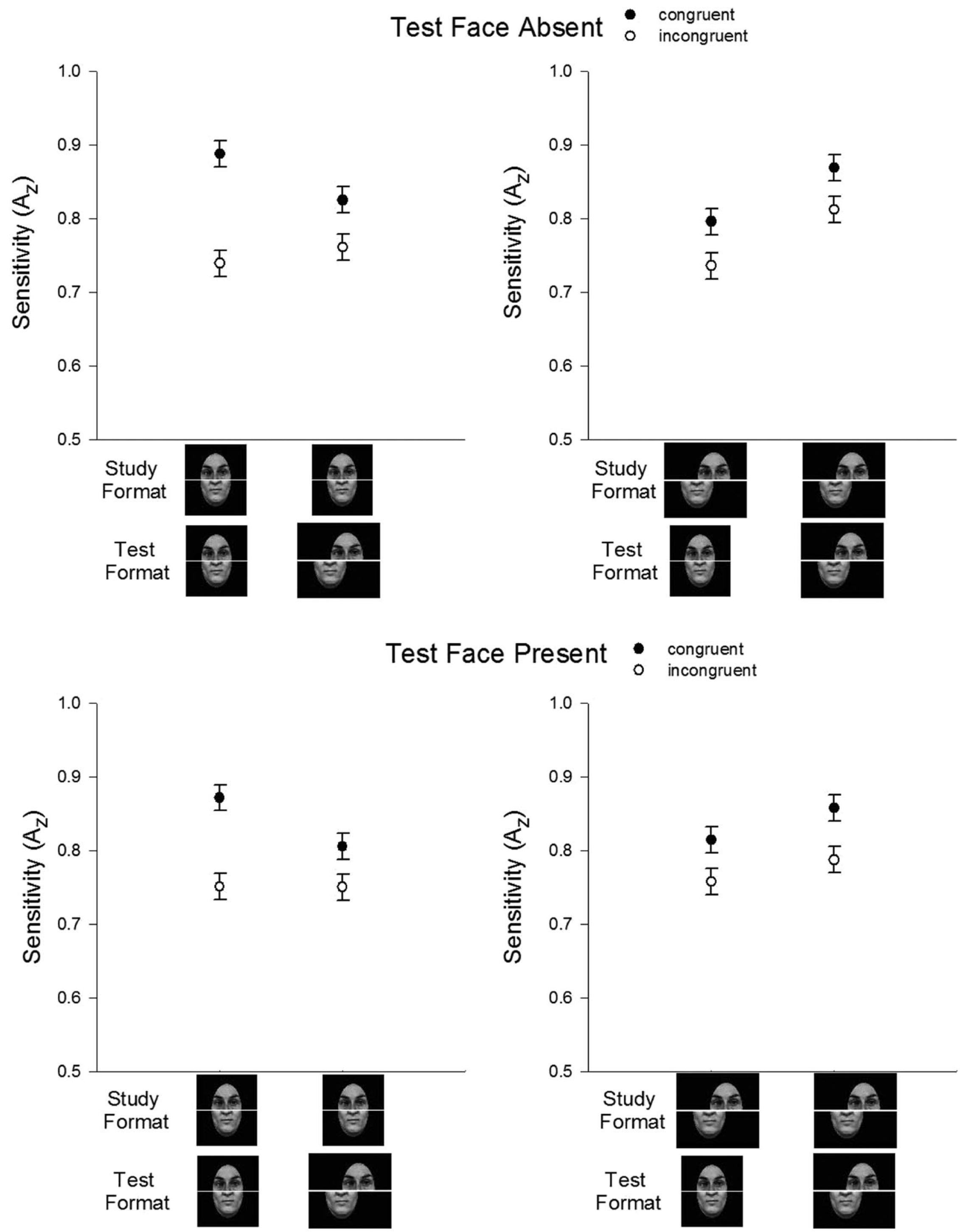


*Figure 6.* Mean sensitivity ($A_z$) for congruent and incongruent trials as a function of study format (aligned: right; misaligned: left) and test format (aligned/misaligned) when the test face was absent (top) and when the test face was present (bottom) in Experiment 3. Error bars show 95% confidence intervals of within-subjects effects.

determine whether the locus of the congruency effect is found at study or at test. In Experiment 3, when a postcue was used, the largest congruency effect was observed for the aligned *study* face; when study faces were misaligned, there was no effect of test configuration. This is in contrast to what we observed using a precueing paradigm in Experiments 1 and 2. Here, the aligned *test* faces produced a larger congruency effect, and this effect was independent of whether the study face was aligned or misaligned.

In fact, Experiment 3 is the first case in which aligned test faces failed to produce a larger congruency effect than test faces in the misaligned or adjacent configurations.

One possible explanation for the difference between Experiment 1 and Experiment 3 is that in Experiment 3, exposure duration of the test face was limited to 800 ms, whereas in Experiment 1, participants had, in theory, as long as 4 s to view the test face before responding (although they were encouraged to respond as quickly as possible and mean response times were around 1 s—see Appendix A). It may be that with potentially longer presentation times in Experiment 1, there was more time for attention to spread leading to more interference from irrelevant parts. Using the data from Experiment 1, in which presentation time of the test face was not constrained, we investigated whether the difference we observed between Experiment 1 and Experiment 3 was due to additional encoding time for faces presented at test in Experiment 1 by conducting correlational analyses between the magnitude of the congruency effect (difference between $A_z$ on congruent vs. incongruent trials) and average RT for all trial types. In other words, we ask whether participants who looked at face parts longer at test were more likely to experience interference when incongruent irrelevant face parts were present. The correlation between average RT and the magnitude of the congruency effect was not significant for any combination of study and test format ($ps > .10$), suggesting that the differences between Experiment 1 and Experiment 3 are not due to a better ability to selectively attend when the test face is presented for a shorter and limited duration.[1]

Another possibility is that the difference between Experiment 3 and the prior two experiments in which study format had little effect lies in the role of attention. If attention is necessary for spatial integration, we may have observed less holistic processing for misaligned or adjacent test faces relative to aligned test faces in Experiments 1 and 2, because cueing the relevant part before the test face appeared meant that the irrelevant face part did not have to be attended. In Experiment 3, on the other hand, both parts of the test face needed to be attended. For this reason, the two halves of misaligned test faces may have been integrated, leading to comparable effects of aligned and misaligned test faces. However, larger congruency effects were observed when both the study and test faces were aligned. This suggests that if spatial integration occurred, the process is not perfect, and misaligned face parts that are integrated do not result in a representation that is identical to the representation of an aligned face. The implication of this pattern of results for the locus of holistic processing is addressed in the General Discussion section.

## General Discussion

The purpose of this article was to determine whether holism in face processing arises during a perceptual stage, as suggested by the holistic encoding or template hypothesis (Farah et al., 1998; Tanaka & Farah, 1993), or during a later decisional stage, as suggested by work applying general recognition theory models (Wenger & Ingvalson, 2002, 2003). To distinguish between these possibilities, we manipulated the configuration of both the study and test faces in a sequential matching selective attention task. If holistic processing emerges because of holism in the perceptual representation, we would expect equivalent effects of manipulating the study and test faces because both faces are encoded; if holistic processing emerges because of holistic effects at a decisional stage, then manipulations at test would be more disruptive to holistic processing because the comparison and decision process can only occur during or following the presentation of the test face. Surprisingly, our results do not match these predictions: We observed separate effects of both study and test formats, the pattern of which cannot be accounted for by either the holistic encoding or template hypothesis or a decisional theory. We consider the perceptual and decisional account of holistic processing in turn.

According to the holistic encoding or template hypothesis, holistic effects are due to a face representation that is unparsed, in which parts are not coded independently. Furthermore, this theory suggests that, although information about parts is still available, configural and spatial information consistent with an upright aligned face must be preserved to form the face gestalt—the face must be organized to fit the "face template." The predictions of this model are very straightforward: Faces must be encoded to fit the face template to be processed holistically. However, several aspects of our results are inconsistent with this model. First, we found evidence of holistic processing for misaligned test faces in all of the experiments presented here. Although it is possible that the face halves of misaligned faces are spatially integrated to create an aligned representation, this is still at odds with the strong form of the holistic encoding hypothesis. Furthermore, in Experiment 2, we found holistic processing when adjacent face parts were studied. Importantly, this configuration did not lead to holistic processing when used at test, which suggests that adjacent face parts are not integrated when presented at test. Nevertheless, holistic processing was observed when adjacent parts were studied but the test face was aligned, implying that holistic processing does not depend on a holistic representation of the study face. However, an alternative explanation is that the adjacent parts of the study face could be integrated because of the attention required to both parts.

In Experiment 3, we equated the study and test face in terms of encoding demands by postcueing the test face. The holistic encoding hypothesis suggests that this manipulation should have eliminated any differences between effects of study format versus test format because both faces have to be encoded before selective attention is applied and a decision is made. Indeed, a misaligned studied face led to the same degree of holistic processing when matched to either an aligned or misaligned test face. It is difficult to compare this pattern directly with that obtained in the first two experiments: Is the absence of an alignment effect in the misaligned study conditions because of less holistic processing when the test face is aligned, or more holistic processing when the test face is misaligned? The postcueing used in Experiment 3 does not change the manner in which the study face is encoded, but it requires attention to both parts of the test face. Therefore, one possible account is that because participants were now required to attend to both parts of the test face, the parts of the test face were also integrated. Furthermore, if such spatial integration takes place and it is not perfect, it would explain why holistic processing was larger when both faces were aligned.

In sum, to account for our results based on the holistic encoding hypothesis, one needs to add to this theory an integration mechanism that is capable of building a holistic representation from face parts presented separately in space at the same time, only if both face parts are attended. Although temporal integration of face parts that fit

[1] Moreover, in ongoing experiments in our laboratory, the magnitude of the congruency effect remains stable for a wide range of presentation durations of the test face (50–800 ms).

together coherently into a gestalt (Anaki et al., 2007; Anaki & Moscovitch, 2007; Singer & Sheinberg, 2006) makes ecological sense and may even be required when exploring a face through eye movements (Henderson et al., 2005), spatial integration of face parts as separated, as they were in Experiment 2, appears more surprising. It implies a propensity to integrate attended face parts that is so strong that clear ego-centered and object-centered cues suggesting that the parts do not go together are ignored, even in a task in which integration goes against instructions and is disadvantageous to performance. If such a tendency exists, why do we not experience false conjunctions of the parts of different faces that we subsequently attend? Inasmuch as it is plausible that we may have developed very efficient perceptual routines for holistic processing of faces, it appears equally important that we would have learned that parts positioned incoherently in space cannot belong to the same face.

The alternative account of holistic processing suggests that holism arises during the decision process. In other words, face parts that may be represented separately are not treated independently when we make comparisons between, or judgments about, them. This model predicts that manipulations at test should be more influential than manipulations at study because the decisional aspects of the task can only occur after both the cue and test face have been presented. Both Experiments 1 and 2 are consistent with such an account because holistic processing occurred for aligned test faces regardless of study format. However, in Experiment 3, when the test face was postcued, we observed effects of study format, with the largest congruency effects when faces were studied and tested in an aligned configuration. It is possible that the considerable working memory load of encoding two full faces before selecting a response led to more rapid degradation of the memory of misaligned studied faces (Curby & Gauthier, 2007). However, this would support the idea that the perceptual representation of an aligned face is not the same as that of a misaligned face, which the decisional account tries to do away with. However, there is at least one sense in which Experiment 3 supports a decisional account. The effect of study format became obvious when the test face was postcued, a manipulation that should not influence how the study face is encoded. This suggests that at least some of the holistic effect may depend on how information is used during the decision.

In sum, our results suggest that neither a strong perceptual nor a strong decisional hypothesis is sufficient to explain why failures of selective attention arise in face processing. Our results point to the limitations of these accounts because they do not specify the role of attention to parts in the process of spatially (or temporally) integrating face parts. Such limitations are not surprising: The decisional account is rooted in a statistical framework that is not a model of the processes unfolding during face recognition, and the holistic encoding account is for the most part rooted in verbal formulations of how certain kinds of representations impact perceptual judgments, without a formal model.

The challenge of identifying the locus of holistic processing should not be underestimated because failures of selective attention can occur for both perceptual and decisional reasons (Richler et al., 2008; Wenger & Ingvalson, 2002, 2003). Adding to this complexity, it is possible that effects occurring at a decisional stage might influence the percept and vice versa. For example, Cheung et al. (in press) found that changing the perceptual information in a face by spatial frequency filtering led to differences in response bias. Separating these effects will ultimately require competing process models to be contrasted to see which can best fit empirical data. One model of face recognition has been able to account for the congruency effect and the decrease in the congruency effect when the test face is misaligned (Cottrell, Branson, & Calder, 2002; Richler, Mack, Gauthier, & Palmeri, 2007). However, it is unknown whether the model produces the same results as human observers when the study face is not aligned. Moreover, this model is limited in that it is unable to simulate conditions in which the test face is postcued. The current work suggests that not only will the successful model have to explain failures of selective attention in face perception but also how they depend on attention to parts during encoding and the potential role of spatial integration.

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## Appendix A

### Accuracy and RTs for Correct Responses in Experiment 1

| Study format | Test format | Congruency | Accuracy (%) | RTs for correct responses (in milliseconds) |
|---|---|---|---|---|
| Isolated | Isolated | N/A | 89.2 | 926 |
| Isolated | Aligned | N/A | 85.4 | 1,045 |
| Isolated | Misaligned | N/A | 89.7 | 987 |
| Aligned | Isolated | N/A | 82.7 | 1,022 |
| Aligned | Aligned | Congruent | 87.4 | 1,028 |
| Aligned | Aligned | Incongruent | 72.9 | 1,100 |
| Aligned | Misaligned | Congruent | 82.3 | 1,059 |
| Aligned | Misaligned | Incongruent | 75.9 | 1,099 |
| Misaligned | Isolated | N/A | 80.9 | 983 |
| Misaligned | Aligned | Congruent | 82.4 | 1,067 |
| Misaligned | Aligned | Incongruent | 70.8 | 1,079 |
| Misaligned | Misaligned | Congruent | 83.2 | 1,035 |
| Misaligned | Misaligned | Incongruent | 76.4 | 1,004 |

*Note.* RTs = reaction times; N/A = not applicable.

## Appendix B

### Results of ANOVAs on Response Bias (logβ) in Experiments 1–3

| Experiment | Conditions in which participants were more likely to say "different" | *p* |
|---|---|---|
| 1 | Study aligned | .028 |
| 1 | Study aligned test misaligned | .008 |
| 2 | Test aligned | <.0001 |
| 3 | Study misaligned test aligned | .002 |
| 3 | Test face present congruent | .007 |
| 3 | Test face absent test aligned incongruent | .003 |

*Note.* ANOVAs = analyses of variance.

(*Appendixes continue*)

## Appendix C

### Accuracy and RTs for Correct Responses in Experiment 2

| Test format | Congruency | Accuracy (%) | RTs for correct responses (in milliseconds) |
|---|---|---|---|
| Isolated | N/A | 83.1 | 748 |
| Aligned | Congruent | 83.0 | 1,105 |
| Aligned | Incongruent | 75.9 | 1,122 |
| Adjacent | Congruent | 83.8 | 1,002 |
| Adjacent | Incongruent | 82.5 | 1,052 |

*Note.* RTs = reaction times; N/A = not applicable.

## Appendix D

### Accuracy and RTs for Correct Responses in Experiment 3

| Test face condition | Study format | Test format | Congruency | Accuracy (%) | RTs for correct responses (in milliseconds) |
|---|---|---|---|---|---|
| Absent | Aligned | Aligned | Congruent | 79.87 | 726.79 |
| Absent | Aligned | Aligned | Incongruent | 66.44 | 829.00 |
| Absent | Aligned | Misaligned | Congruent | 72.90 | 786.84 |
| Absent | Aligned | Misaligned | Incongruent | 68.71 | 810.92 |
| Absent | Misaligned | Aligned | Congruent | 71.34 | 799.95 |
| Absent | Misaligned | Aligned | Incongruent | 65.94 | 828.93 |
| Absent | Misaligned | Misaligned | Congruent | 78.15 | 788.56 |
| Absent | Misaligned | Misaligned | Incongruent | 72.54 | 805.79 |
| Present | Aligned | Aligned | Congruent | 78.64 | 665.47 |
| Present | Aligned | Aligned | Incongruent | 67.66 | 744.65 |
| Present | Aligned | Misaligned | Congruent | 72.31 | 740.04 |
| Present | Aligned | Misaligned | Incongruent | 67.80 | 754.27 |
| Present | Misaligned | Aligned | Congruent | 71.94 | 714.68 |
| Present | Misaligned | Aligned | Incongruent | 68.61 | 755.67 |
| Present | Misaligned | Misaligned | Congruent | 77.12 | 684.02 |
| Present | Misaligned | Misaligned | Incongruent | 70.44 | 729.99 |

*Note.* RTs = reaction times.

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