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Becoming a Lunari or Taiyo Expert: Learned Attention to Parts Drives Holistic Processing of Faces

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Faces are processed holistically, but the locus of holistic processing remains unclear. We created two novel races of faces (Lunaris and Taiyos) to study how experience with face parts influences holistic processing. In Experiment 1, subjects individuated Lunaris wherein the top, bottom, or both face halves contained diagnostic information. Subjects who learned to attend to face parts exhibited no holistic processing. This suggests that individuation only leads to holistic processing when the whole face is attended. In Experiment 2, subjects individuated both Lunaris and Taiyos, with diagnostic information in complementary face halves of the two races. Holistic processing was measured with composites made of either diagnostic or nondiagnostic face parts. Holistic processing was only observed for composites made from diagnostic face parts, demonstrating that holistic processing can occur for diagnostic face parts that were never seen together. These results suggest that holistic processing is an expression of learned attention to diagnostic face parts.

Keywords: holistic face processing, learning, attention, novel faces

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Unlike other objects, faces are processed holistically rather than as constituent individual features (Tanaka & Farah, 1993). This is consistently demonstrated in the composite task, in which it is more difficult to ignore face parts compared with object parts, despite instructions to do so (Farah, Wilson, Drain, & Tanaka, 1998; Richler, Cheung, & Gauthier, 2011; Young et al., 1987). In this task, subjects attend to one face half and ignore the other half of two sequentially presented composites (consisting of top and bottom halves of different faces), and determine whether the relevant halves are the same or different. Holistic processing is inferred when information from to-be-ignored halves interferes with discrimination of the target halves.

While the composite paradigm operationalizes holistic processing as a failure of selective attention specific to aligned face halves, this essentially restates that the instructions are to selectively attend, and that subjects fail. It is important that several different mechanisms could underlie this effect (Richler et al., 2012). Indeed, the locus of holistic face processing is debated. According to the template hypothesis, faces are encoded to fit face templates, such that individual parts are not explicitly and independently represented (Farah et al., 1998; Tanaka & Farah, 1993). However, some aspects of holistic processing can be induced in novices, suggesting that it may be better understood as a strategy rather than a reflection of representational properties. For instance, when face and novel object composite tasks are interleaved, novel objects are processed more holistically when preceded by an aligned versus misaligned face (Richler, Bukach, & Gauthier, 2009). Grouping cues that disrupt object-based attention also disrupt holistic processing (Curby et al., 2012). Thus, holistic processing could arise from a learned strategy of attending to all face parts (Curby et al., 2012; Richler, Wong, & Gauthier, 2011). Some have argued that holistic processing cannot have an attentional locus because its phenomenology is a perceptual illusion (Rossion, 2013), or because it occurs as early as the N170 event-related potential (ERP) component (Jacques & Rossion, 2009). However, perceptual illusions can be modulated by attention (e.g., Alsius, Navarra, & Soto-Faraco, 2007; Zaretskaya, Anstis, and Bartels (2013), and spatial attention can influence early ERP components (Talsma & Woldorff, 2005). There is not sufficient evidence to reject a role for attention in supporting holistic processing in domains of expertise, including holistic face perception.

Here, we seek direct evidence for an attentional account of holistic face processing by determining how experience can result in holistic processing of faces from novel races. Using a similar paradigm, researchers have studied how individuation (learning to name individual objects) yields holistic processing with novel objects (Gauthier & Tarr, 1997; Gauthier, Williams, Tarr, & Tanaka, 1998). This effect is more than a result of experience with objects. When different training regimens equated in difficulty were compared, only subjects who individuated novel objects processed new objects from the trained category holistically (Wong et al., 2009).

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Because individuation is an important task we perform with faces, which are processed holistically, individuation was postulated to increase holistic processing. However, it is unclear *how* individuation leads to holistic processing. According to the attentional account, individuation leads to holistic processing because individuation encourages attention to all parts. However, because all face parts are shown at once when learning to individuate faces or objects, existing data do not address how important it is that all parts be attended. Using an individuation task where only part of the face is diagnostic, we ask whether learning to individuate when attention to the whole face is not required still promotes holistic processing.

In Experiment 1, three groups learned to individuate a novel race of faces, the Lunari. One group saw Lunaris with diagnostic information in both face halves (Both group). The other groups learned Lunaris for which most of the identifying information was in either the top (Top group) or bottom (Bottom group) face half. These three groups, as well as a no-training control group, were tested on a composite task with Lunaris after training to assess holistic processing. Critically, all groups were tested with the same novel Lunari exemplars that contained diagnostic information in both face halves; any group differences on this task could only be attributed to what was learned during training.

Lunari faces are novel, but faces nonetheless, and so they could be processed holistically to some extent without training; if experience with Lunari-specific features is irrelevant, all groups should show the same amount of holistic processing. However, if feature-specific experience matters for holistic processing (Bukach, Phillips, & Gauthier, 2010), the Both group should show more holistic processing than the control group. Critically, the novel aspect of our design concerns the Top and Bottom groups, which can reveal the role of attention to face parts. According to the attentional account, attentional weights may increase for face parts that are diagnostic during individuation, and these attentional weights may then be applied to new exemplars of the trained category. This leads to the prediction of asymmetric holistic processing: failures of selective attention for the Top and Bottom groups might only arise when instructed to ignore the face half that was diagnostic during training. A second version of the attentional account is that all parts of a face must have a history of having been attended to produce holistic processing, especially because holistic processing is operationalized as automatic attention to the whole face despite instructions to selectively attend. In this case, the Top and Bottom groups, who learned that one half of Lunari faces is not diagnostic, may process both halves of new Lunaris in a nonholistic manner.

To ensure that all trained groups learned to individuate the kind of Lunari faces used during training, we included face discrimination tasks before and after training, as in prior work with Hispanic and African American faces (McGugin, Tanaka, Lebrecht, Tarr, & Gauthier, 2010). In this task, new Lunari exemplars that contained the same type of diagnostic information as the training for each group (Top, Bottom, or Both parts) were used. We expect improvements in individuation for all three trained groups.

Experiment 1

Method

Subjects. Seventy-five subjects were randomly assigned to three training groups (Both: 18 women, 7 men; mean age = 24.2 years; Bottom: 18 women, 7 men; mean age = 22.6 years; Top: 14 women, 11 men; mean age = 22.1 year). A control group ($N = 26$) that received no training only completed the composite task. Subjects received $12/hour for participation. The study was approved by the Vanderbilt University Institutional Review Board.

Stimuli. A set of faces (obtained from Jim Tanaka) and made with the FaceGen software was modified using Adobe Photoshop to create Lunari faces with unique top and bottom halves (Figure 1). Specifically, the mouth was stretched such that it was as wide as the eyes, the ears were stretched downward until the bottoms of the ears were below the mouth, the area between the eyes was expanded to give the impression of a large bone above the nose (the "sign of the moon" giving its name to the race), the distance between the eyes and the eyebrows was expanded, and a second eyebrow was inserted above the original eyebrow. These manipulations were designed to ensure that there would be variation in both the top and bottom halves that would differ enough from typical faces to make the faces look novel.

Thirty Lunari faces were used for the pretest discrimination task and individuation training, and a completely different set of 30 was used for the posttest discrimination task. For the Both group, these faces were 60 faces with unique top and bottom halves. For each of the Top and Bottom groups, six base faces (either top or bottom) were chosen and combined with 60 unique complementary face halves (10 for each base face), for a total of 60 faces per group that

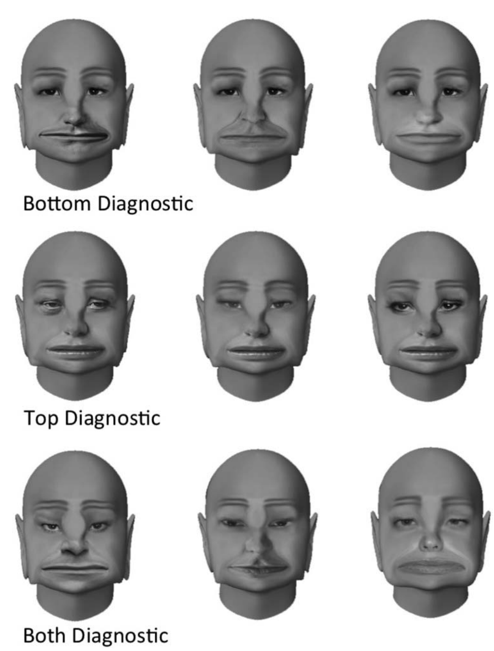

Figure 1. Example stimuli for each group. For the Both group, both face halves contained diagnostic information. In the Top and Bottom groups, most of the identifying information was contained in the top or bottom half, respectively.

therefore varied much more (10x more) for one part than the other. It was necessary to introduce *some* variation in the less diagnostic part because in the composite task, both parts must vary. If a part never varied during training, composite faces might appear to be nonvalid Lunaris.

For the composite task, a single set of 20 unique top and bottom halves not seen during training was used for all groups. The composite faces varied on the top and bottom, therefore all groups were tested on faces with the same amount of variation; any differences in composite task performance could only be attributed to training. The top and bottom face halves were randomly combined to form composite faces (400 × 400 pixels). A white line 6 pixels thick separated the face halves so that it was unambiguous where the top half ended and the bottom half began. Misaligned composites were made by shifting the top half 35 pixels to the left and the bottom face half 35 pixels to the right.

Procedure. Subjects completed three sessions (~45 min each) on different days over the course of a week. On the third day, subjects completed a posttraining composite task.

Face discrimination test. A 2-AFC discrimination test was completed before (pretest, Day 1) and after (posttest, Day 3) training with different sets of faces. Trials began with a fixation (850 ms), followed by a target face (125 ms), and a random-pattern mask (500 ms). After the mask, a novel distractor face and a face identical to the target appeared 311 pixels to the left and right of the center of the screen. Subjects chose the face that matched the target by pressing the left or right arrow keys. Subjects were asked to respond as quickly as possible. If no response was made within 2,000 ms, the next trial started. There were 80 trials.

Individuation training. Subjects learned unique names for a total of 12 faces. During training, subjects were shown faces with common male names (e.g., Paul, Ken), each presented twice. Names were randomly assigned for each subject. Training trials were followed by test trials, where faces were presented without names and subjects had to press the first letter of the face's name. If a face appeared that had no name association, participants were to press "n" to indicate "no name." There were 18 "no name" faces used during training. Incorrect responses were followed by feedback showing the correct name (including "no name").

There were three phases on each day of training. The details of each phase and the number of blocks per phase on each training day are shown in Table 1. All trained Lunaris were introduced by the end of Day 1 and were repeated on subsequent training days.

Composite task. Each trial started with a fixation cross (200 ms), followed by a study face (200 ms), blank screen (500 ms), and test face (200 ms). Subjects were instructed to judge if the cued half of the study and test composites were the same or different, while ignoring the other, irrelevant half. On congruent trials, the cued and irrelevant halves were associated with the same response (e.g., both parts same, or both parts different); on incongruent trials, the irrelevant and cued halves were associated with different responses (e.g., one part same, the other part different). On misaligned trials, only the test face was misaligned (see Richler et al., 2009; Richler, Wong, & Gauthier, 2011).

There were 10 trials for each combination of Congruency (congruent/incongruent), Alignment (aligned/misaligned), Cued part (top/bottom) and Correct response (same/different) for a total of 160 trials. Cued part was blocked, with order counterbalanced across subjects. All other factors were randomized.

Holistic processing is indexed by a Congruency × Alignment interaction: the congruency effect (better performance on congruent vs. incongruent trials, calculated as a difference score) is reduced by misalignment (e.g., Cheung, Richler, Palmeri, & Gauthier, 2008; Richler, Tanaka, Brown, & Gauthier, 2008). The magnitude of this interaction is calculated by taking the congruency effect on aligned trials and subtracting the congruency effect on misaligned trials. A congruency effect that is not sensitive to misalignment is generally not considered evidence of holistic processing (Richler & Gauthier, 2013; Richler et al., 2009; Rossion, 2013).

Results

Individuation training and discrimination performance. Subjects in all groups improved in accuracy and reaction time (RT) across the three training sessions (Supplemental Figure 1). A comparison of pre- and posttraining discrimination performance revealed that subjects in all groups improved in accuracy and/or RT (Supplemental Figure 2).

Composite task. Data from two subjects (one from the Both group, one from the Bottom Group) were removed because of below chance performance.

First, to test for a role of experience in holistic processing of Lunaris, we compared the Both and Control groups in a Group (Both/Control) × Cued Part (top/bottom) × Congruency (congruent/incongruent) × Alignment (aligned/misaligned) analysis of variance (ANOVA) on d' (Figure 2). There was a significant Congruency × Alignment interaction, $F(1, 48) = 25.1$, $p < .0001$, $\eta_p^2 = .34$, that was not modulated by an interaction with Group, $F(1, 48) = 0.01$, $p = .92$, $\eta_p^2 = .00$, suggesting that both groups processed Lunari faces holistically and to the same extent. In that sense, even subjects without any previous exposure to Lunaris (Control Group) processed them holistically. However, the groups did differ, as suggested by a Group × Congruency × Cued Part interaction, $F(1, 48) = 4.99$, $p = .03$, $\eta_p^2 = .09$. Separate ANOVAs for each group revealed a Cued Part × Congruency interaction for

Table 1
Trial and Block Configuration for Individuation Training in Experiment 1

Phase	Faces	Training trials/block	Test trials/block	Day 1	Day 2	Day 3
1	4 named 6 unnamed	8	24	4 blocks	3 blocks	4 blocks
2	8 named 12 unnamed	16	48	4 blocks	3 blocks	4 blocks
3	12 named 18 unnamed	24	72	4 blocks	10 blocks	4 blocks
Total trials				576	936	576

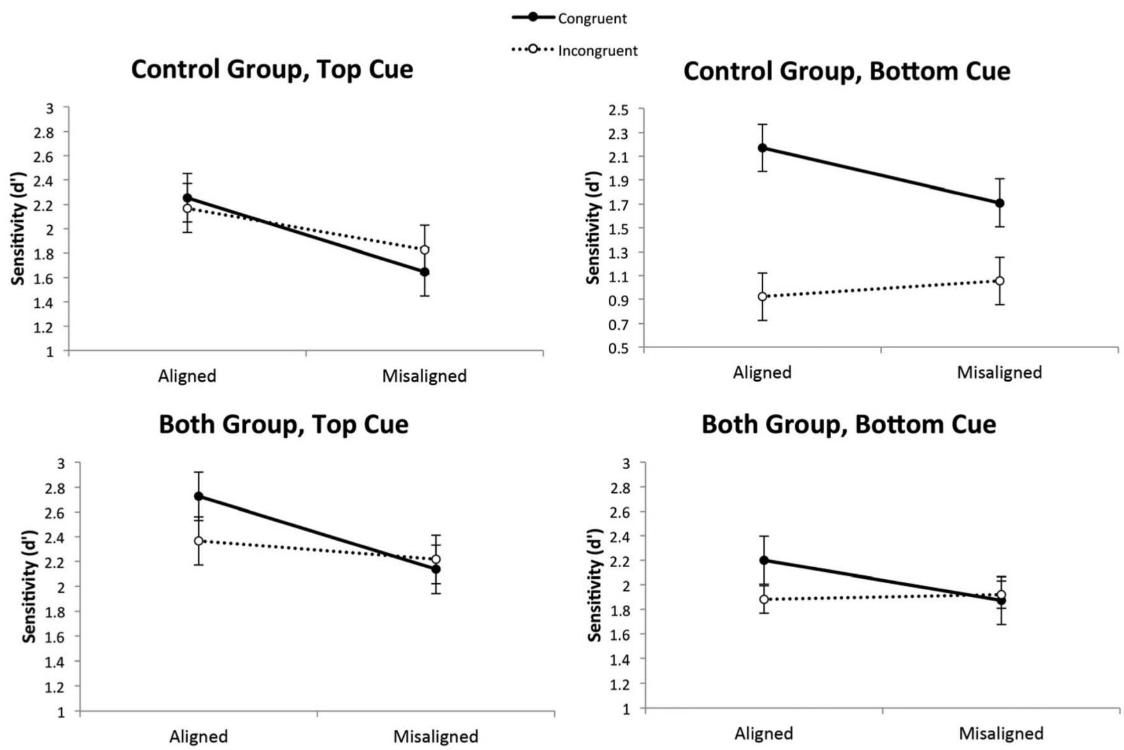

Figure 2. Sensitivity (d') as a function of alignment, congruency, and cued part for the Both and Control Groups in Experiment 1.

the Control group, $F(1, 25) = 7.2$, $p = .01$, $\eta_p^2 = .22$, with a larger congruency effect for bottom compared with top trials. The same Cued Part × Congruency interaction was clearly absent for the Both group, $F(1, 23) = 0.00$, $p = .98$, $\eta_p^2 = .00$. Individuation training changed a pattern that is not consistent with processing of standard faces—failures of selective attention for only one face part—to a pattern that reflects the expected failure of selective attention for both face halves.

Next, we tested whether asymmetric holistic processing was obtained as a function of the diagnostic face part during training by conducting a similar ANOVA with the Top and Bottom groups (Figure 3). We found no significant Group × Congruency × Alignment interaction, $F(1, 47) = 0.60$, $p = .44$, $\eta_p^2 = .012$, suggesting that the magnitude of holistic processing did not differ between the groups. There was a significant Cued Part × Alignment × Group interaction, $F(1, 47) = 6.34$, $p = .01$, $\eta_p^2 = .12$. Performance was better for aligned than misaligned trials for top trials in the Top Group, and for bottom trials in the Bottom Group. There were no other significant effects involving Group or Cued Part.

Critically, separate ANOVAs for each group revealed no evidence of holistic processing: the Congruency × Alignment interaction was not significant for either the Top group, $F(1, 24) = 0.0004$, $p = .98$, $\eta_p^2 = .00$, nor the Bottom group, $F(1, 23) = 1.82$, $p = .19$, $\eta_p^2 = .07$. This suggests that even individuation that led to improved discrimination of new Lunari exemplars was not sufficient to yield holistic processing. Because the Cued Part × Congruency × Alignment × Group interaction was not significant, $F(1, 47) = .01$, *ns*, there is no evidence that holistic processing was obtained only for the parts that were attended during training. Rather, subjects who were trained with Lunaris that could be individuated mainly based on one part had no difficulty selectively attending to either face part later on. Surprisingly, this was true of both diagnostic and nondiagnostic parts.

The magnitude of holistic processing (Congruency × Alignment interaction) for each group is shown in Figure 4. We combined the Top and Bottom groups (who did not differ in holistic processing) into a Diagnostic Part group, and we compared them to the Both and Control groups (combined into a Whole group because they also did not differ in the magnitude of holistic processing). A Group (Whole/Diagnostic Part) × Congruency (congruent/incongruent) × Alignment (aligned/misaligned) ANOVA revealed a significant Group × Congruency × Alignment interaction, $F(1, 91) = 4.41$, $p = .04$, $\eta_p^2 = .05$, such that there was less holistic processing for the Diagnostic Parts group versus the Whole group. We also compared the Diagnostic Parts group to the Both group only (because the Control group showed asymmetrical holistic processing), and found the same three-way interaction: $F(1, 71) = 4.63$, $p = .03$, $\eta_p^2 = .06$. In sum, while learning that both Lunari face parts are diagnostic led to the sort of holistic processing generally observed with normal faces, learning that Lunaris can be individuated based on a single part virtually abolished typical holistic processing for these faces.

Experiment 2

Experience with Lunaris when both top and bottom halves were diagnostic was necessary to support holistic processing. All three

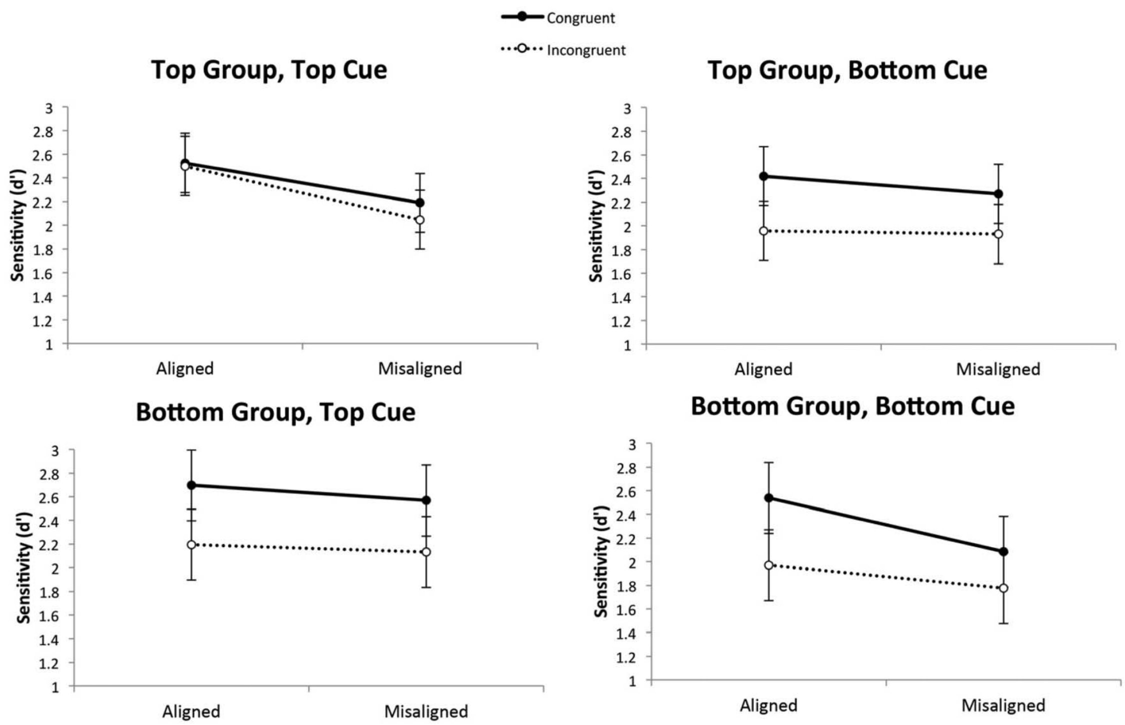

Figure 3. Sensitivity (d') as a function of alignment, congruency, and cued part for the Top and Bottom Groups in Experiment 1.

training groups learned to individuate Lunaris and showed transfer to new Lunaris. However, subjects trained to mainly attend to the top or bottom did not process Lunaris holistically, regardless of whether the parts had been diagnostic during training or not. This suggests that attention to both parts is critical for the development of holistic processing measured in the composite paradigm.

However, it is unclear whether all parts must be experienced simultaneously or whether learning that top and bottom halves are diagnostic can occur independently. In other words, can holistic processing arise for diagnostic face parts that are never seen together? For Experiment 2, we created a second race of faces, Taiyos. Subjects individuated both Taiyos and Lunaris, but the diagnostic information for each race was in complementary face parts (e.g., Taiyo tops were diagnostic, and Lunari bottoms were diagnostic, or vice versa). After training, we measured holistic processing with two different kinds of Taiyo-Lunari mixed composites, made from new parts (unseen during training): composites made from diagnostic parts, and composites made from nondiagnostic parts. It is important that Taiyo and Lunari parts were never seen together during training. If holistic processing does not require that diagnostic parts be experienced together, then diagnostic composites should be processed more holistically than nondiagnostic composites.

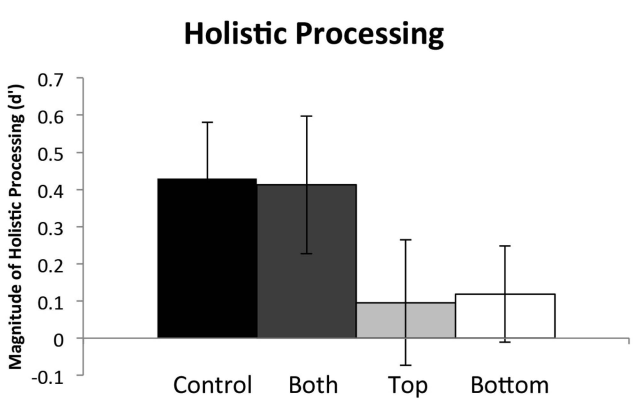

Figure 4. Magnitude of holistic processing calculated as the congruency effect (congruent minus incongruent) on aligned trials minus the congruency effect on misaligned trials (d') in Experiment 1 collapsed over cued part. Error bars are *SEM*.

Method

Subjects. An a priori power analysis (G●Power software) based on the effect size of the Group × Congruency × Alignment interaction in Experiment 1 indicated that 94 subjects would be required to obtain an effect of this size with .95 power and α = .05.[1] Thus, we included 100 subjects in Experiment 2. Subjects were randomly assigned to the TaiyoTop/LunariBottom (31 women, 19 men, mean age = 21.4) or TaiyoBottom/LunariTop (35 women, 15 men, mean age = 22.8) conditions. Group assignment dictated which part was diagnostic for each race during individu-

[1] Although Experiment 2 is within-subjects, the Congruency × Alignment interaction often shows poor reliability (e.g., .3 split-test reliability in a training study with novel objects, Wong et al., 2009). Therefore, there is little statistical benefit to a within-subjects design in this task.

ation training. Subjects received $12/hr for participation. The study was approved by the Vanderbilt University Institutional Review Board.

Stimuli. Lunari faces were the same as in Experiment 1. Taiyos were created by altering a set of Caucasian male faces using Adobe Photoshop. Specifically, the nose was copied three times, inverted, rotated, and darkened to create the forehead markings. The eyes were given a crescent shape. The bottom edges of the mouth were copied and inverted to create the mouth folds. The nose was stretched down toward the mouth and the nostrils were enlarged. Finally, the chin was manipulated such that it had three impressions, two on the left and one in the middle. The fact that one Lunaris were created from FaceGen models and the Taiyos were modified out of photographs added an qualitative image difference to the two races was consistent with our goal of distinguishing the two races so that different attentional weights would be learned for each one.

Procedure. There were three training sessions (~45 min each) completed on different days spaced within a week. On the third day, subjects completed the composite task after individuation training.

Individuation training. Individuation training (Table 2) was identical to Experiment 1, except that subjects learned names for eight faces of each race. Taiyos and Lunaris were trained in alternating blocks.

Composite task. The trial structure of the composite task was identical to Experiment 1. For half of the trials, composites were made from Taiyo tops and Lunari bottoms, and for the other half, composites were made from Taiyo bottoms and Lunari tops. Depending on group assignment during individuation training, these corresponded to diagnostic or nondiagnostic composites (Figure 5).

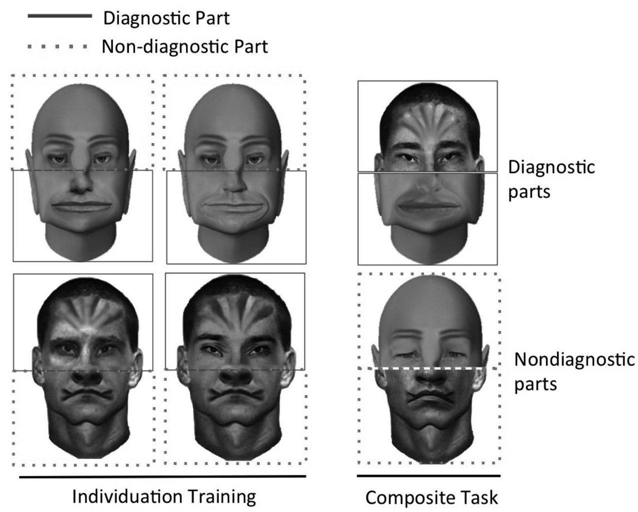

Figure 5. Example of the faces seen in the Lunari Bottom/Taiyo Top condition. For this group, the Lunari Bottoms and Taiyo Top parts are diagnostic during individuation. During the composite task, composites are created from either diagnostic or nondiagnostic parts.

There were 10 trials for each combination of Composite Type (diagnostic/nondiagnostic), Congruency (congruent/incongruent), Alignment (aligned/misaligned), Cued Part (top/bottom) and Correct Response (same/different) for a total of 320 trials. Cued Part was blocked, and order was counterbalanced across participants. All other factors were randomized.

Results

Individuation training. Subjects in all groups improved in accuracy and RT across training sessions (Supplemental Figure 3).

Composite task. Data from three subjects were removed for below chance performance. Trials with RTs <100 ms or >2000 ms were discarded (1.31% of total trials). The critical analysis concerns differences in holistic processing between composite faces composed of parts similar to those that were diagnostic versus nondiagnostic during training (Figure 6). A Composite Type (diagnostic/nondiagnostic) × Congruency (congruent/incongruent) × Alignment (aligned/misaligned) ANOVA revealed a significant interaction between Composite Type, Congruency, and Alignment, $F(1, 96) = 4.21$, $p = .04$, $\eta_p^2 = .04$. The four-way interaction with Cued Part was not significant, $F(1, 96) = 0.14$, *ns*, although there was a 3-way interaction between Composite Type, Alignment and Cued Part, $F(1, 96) = 5.89$, $p = .02$, $\eta_p^2 = .04$. This was because of better performance on Top than Bottom trials for nondiagnostic than diagnostic composites when they were aligned, while misaligned composites showed no such interaction. This interaction, which was not part of our predictions, does not affect the interpretation of the critical three-way interaction between Composite Type, Congruency and Alignment. Following-up on this three-way interaction, separate analyses for each Composite Type found a significant Congruency × Alignment interaction for diagnostic composites, $F(1, 96) = 8.64$, $p < .005$, $\eta_p^2 = .08$, but not for nondiagnostic composites, $F(1, 96) = 0.043$, $p = .83$, $\eta_p^2 = .00$.

Discussion

Prior work with novel objects revealed that individuation training results in holistic processing, while other equally demanding training tasks do not (Wong et al., 2009). Here, we asked whether individuation training is sufficient to produce holistic processing,

Table 2
Training Structure for Individuation Training in Experiment 2

Phase	Faces	Training trials/block	Test trials/block	Day 1	Day 2	Day 3
1	4 named 6 unnamed	8	21	2 blocks	—	2 blocks
2	6 named 14 unnamed	12	42	2 blocks	—	2 blocks
3	8 named 22 unnamed	24	63	6 blocks	10 blocks	6 blocks
Total trials				1,008	1,260	1,008

Note. The listed structure is for one race, but both Lunaris and Taiyos were trained in the same way.

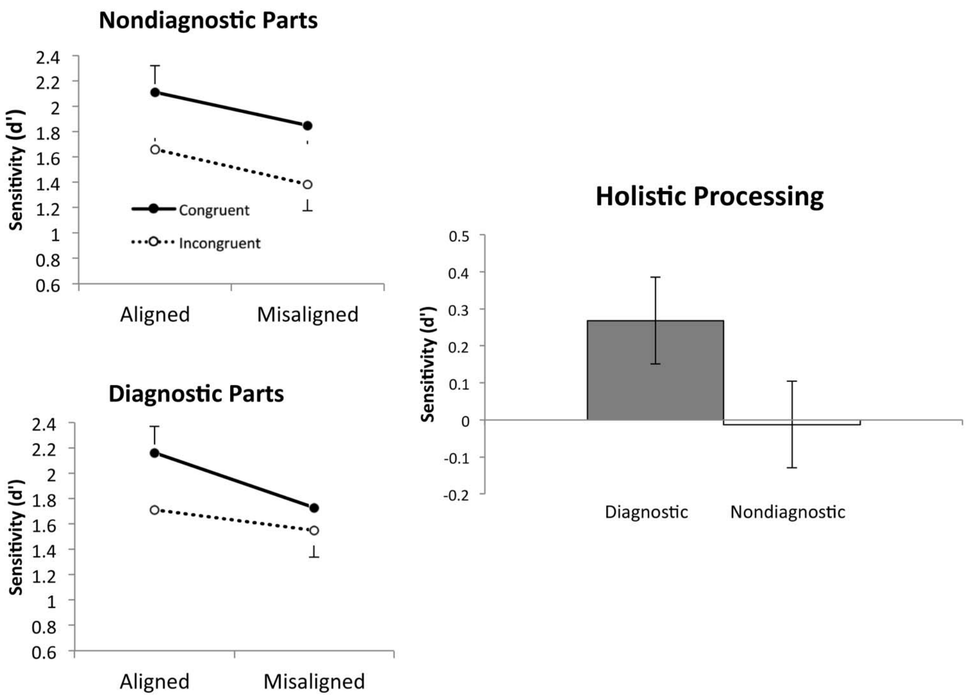

Figure 6. Left Panel: Sensitivity (d') in Experiment 2 as a function of congruency and alignment for composites made from diagnostic (top) and nondiagnostic (bottom) face parts. Right Panel: The magnitude of holistic processing is calculated as the congruency effect (congruent minus incongruent) on aligned trials minus the congruency effect on misaligned trials (d') for composites made from diagnostic and nondiagnostic face parts. Error bars are 95% confidence intervals.

and if not, whether attention to diagnostic parts may drive this hallmark of face processing.

We examined how learning to pay attention to different face parts affects the development of holistic processing. In Experiment 1, our analyses collapsed over both parts suggested that subjects with no previous experience with Lunaris (Control group) processed them holistically, but in fact it was mainly Lunari top parts aligned with bottom parts that could not be ignored (Figure 2). In contrast, subjects who learned to individuate Lunaris that varied in both face halves showed holistic processing that was symmetrical across parts, as typically seen with normal faces. Experience attending to diagnostic information can override biases that may stem from feature saliency in novel categories. It is important that individuation training only resulted in holistic processing of Lunaris if subjects experienced training wherein *both* parts were diagnostic. Thus, holistic processing may be understood as "sticky" attentional weights transferred from individuation training to other Lunaris, but the ultimate holistic effect cannot simply reflect weights for individual parts, because when learning to attend only to the top, there is no difficulty ignoring the top.

The specific pattern of results in subjects trained to attend to parts, including a congruency effect that was not influenced by alignment, was also found for composites made of nondiagnostic parts in Experiment 2 and mirrors the pattern found in a group of autistic adolescents (Gauthier, Klaiman, & Schultz, 2009). Individuals with autism look more to the mouth than the eyes (Klin, 2002), and thus a part-based attentional strategy (spontaneous rather than elicited by differential diagnosticity) seems to broadly result in failures of selective attention that are not sensitive to configuration. Our subjects, just like those individuals with autism, showed a congruency effect even in conditions where they showed no holistic processing (no interaction with alignment). While there has been speculation regarding the crucial role of eyes for holistic processing (e.g., Rossion, 2013), we found no difference between Top-diagnostic or Bottom-diagnostic training, suggesting that what is critical is learning to attend to *all* face parts, not just eyes. Moreover, our results illustrate that configuration of the attended face parts matters, revealing that failures of selective attention depend on alignment more when the two parts were diagnostic during training. One speculative account for the general congruency effect observed in the nondiagnostic condition of Experiment 2 and the parts-trained groups in Experiment 1 is that variability of parts during the composite task for parts that only varied minimally during training may attract attention regardless of alignment. This would suggest that the congruency effect in the aligned condition should not be interpreted as evidence of holistic processing when the same effect is observed for misaligned parts.

In Experiment 2, we found that diagnostic face parts that were never seen together were processed holistically when combined. It is interesting that subjects in Experiment 2 were trained just like the Top and Bottom groups in Experiment 1 who showed no holistic processing. Therefore, what yielded holistic processing in Experiment 2 was the combination of tops and bottoms that were *both* similar to parts that subjects had attended during training. Another way to describe our results would be that across both experiments, faces are processed holistically unless subjects learned to attend to parts of these faces—but strikingly, in Experiment 2, subjects were trained in the same way as subjects in the parts groups of Experiment 1 for both novel face races. When a test face is made of two halves that proved to be diagnostic individually, selective attention becomes very difficult, suggesting that selective attention may be sensitive to relative differences in such attention weights.

A related possibility is automatic attention to diagnostic parts facilitated grouping of these parts when they were presented together. This is consistent with recent work showing that grouping cues modulate holistic processing for faces (Curby et al., 2012). Although our current data cannot speak to whether failures of selective attention to diagnostic composites occurred because of attention weights assigned to diagnostic parts, or from facilitated grouping of parts that were automatically attended, both of these explanations are consistent with our general hypothesis that learned attention to diagnostic parts drives holistic processing of faces.

Together, our results provide support for the view that holistic processing arises through learned attentional strategies (Richler, Wong, & Gauthier, 2011; Curby et al., 2012). This is consistent with the literature on attentional control. Jacoby, Lindsay, and Hessels (2003) demonstrated that single items in a group of trials may trigger specific attentional sets, suggesting automatization of attentional filters attached to specific items (for review, see Bugg & Crump, 2012). Recently, Cañadas, Rodríguez-Bailón, Milliken, and Lupiáñez (2013) conducted a flanker task with faces as contextual cues. Face gender was associated with either a high or low proportion of congruent trials, and it was found to cue the allocation of attentional control, demonstrating that learned associations with faces can trigger attentional sets. Likewise, in our experiments, features that specify a Lunari or Taiyo may be acting as attentional cues, with diagnostic face parts cuing an attentional strategy that yields holistic processing. In the present case, the presence of diagnostic parts, only when aligned with other diagnostic parts, seems to trigger this attentional strategy. This may be because the diagnostic parts were learned in the context of other face parts, a hypothesis that could be tested by combining face parts that were individuated in isolation.

An attentional account of holistic processing is also consistent with the putative mechanisms of holistic processing of faces at the neuronal level. For instance, Freiwald, Tsao, and Livingstone (2009) demonstrated that individual cells showed more robust tuning and gain modulation when presented with a whole face rather than degraded face parts, similar to the gain modulation shown during selective attention to task-relevant features (Scolari & Serences, 2009).

One caveat to our interpretation is that it is unclear whether diagnosticity of the parts is critical, or whether other manipulations of attention could have the same effect. Evidence that individuals with autism show a pattern of results similar to our nondiagnostic training groups, even though they are surrounded by normal faces, suggests that attention itself may be the critical driving factor in holistic processing.

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