Does Response Interference Contribute to Face Composite Effects?

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Abstract

Holistic processing of faces can be measured as a failure of selective attention to one face half under instructions to ignore the other face half in a naming or same/different matching task. But is interference from the irrelevant half due to response interference rather than to holistic processing? Here, participants learned to name two faces "Fred" and two "Bob". At test, composites were created from top and bottom halves of different learned faces or of a novel face, and composites were either aligned or misaligned. Naming was slower when the irrelevant half was from a different face vs. the same face, regardless of whether it was associated with the same name, a different name, or no name, suggesting holistic processing. Interference was eliminated when composite halves were misaligned. These results suggest that, unlike Stroop effects, composite effects are not due to response interference.

All faces share the same basic features (eyes, nose, mouth) in the same general, or "first-order", configuration. For this reason, the individuation of faces relies on the processing of "second-order" configural differences that include spatial relations between face parts (Diamond & Carey, 1986; Maurer et al., 2002). It has been suggested that attention to small metric differences between distant face parts encourages the use of a holistic processing strategy. Indeed, a considerable amount of work suggests that faces are not processed in terms of individual features, but as wholes (Farah et al., 1998; Le Grand et al., 2004; Mondloch et al., 2002; Tanaka & Farah, 1993).

Holistic processing of faces is robust in a variety of conditions, such that participants are unable to selectively attend to a face part even when explicitly instructed to do so and when holistic processing is disadvantageous to performance. Such holistic effects are often demonstrated in a composite paradigm in which stimuli are made by combining the top half of one face with the bottom half of another face. In the original study using the composite task (Young et al., 1987), parts of famous faces were used to create stimuli. Participants had to name half of a composite face and ignore the identity of the irrelevant half. For example, the target part might have belonged to Brad Pitt but the irrelevant part might have belonged to Matt Damon. The inconsistency of the two parts led to slower RTs in identifying the relevant part.

Interference in this task is assumed to reflect holistic processing – the irrelevant part affects performance because the face is automatically processed as a whole. However, an alternative possibility is that the different responses associated with the target and irrelevant face halves ("Brad Pitt" vs. "Matt Damon") compete, resulting in response interference

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analogous to classic Stroop effects, where, for example, the response to the word interferes with the response to the ink colour (MacLeod, 1991). Response interference in Stroop paradigms is thought to arise when features that are processed in parallel lead to conflicting outputs (Cohen et al., 1990) or activate competing motor programs (Singer et al., 1975). To what extent is the composite effect due to competing responses for the target and irrelevant face halves, rather than to holistic processing, where interference arises because face parts are not processed independently?

Since the original demonstration of the composite effect with famous faces, variants of the composite task have used unfamiliar faces in simultaneous matching (Hole, 1994) and sequential matching paradigms (e.g., Cheung et al., in press; Farah et al., 1998; Gauthier et al., 2003; Goffaux & Rossion, 2006; Le Grand et al., 2004; Michel et al., 2006; Richler et al., in press B). In these cases, participants judge whether one half of a test face is the same or different as the study face, and are told to ignore the other face half. Holistic processing is inferred from better performance on congruent trials (both parts same/both parts different) compared with incongruent trials (one part same, one part different; congruency effect; e.g., Cheung et al., in press; Gauthier et al., 2003; Richler et al., 2008). Response interference could also contribute in such a task: although the face halves do not have names, the response for the irrelevant part may still be different from the response for the target part (e.g., if the response to the target part is "same" when the irrelevant part is different). Indeed, it has been argued that the congruency effect in the matching composite task measures Stroop-like response interference rather than true holistic processing (Robbins & McKone, 2007). However, the extent to which interference in the composite task is analogous to Stroop interference has never been addressed and this is the goal of the present study.

To this end, participants learned to associate names with four composite faces. The names were randomly assigned: two faces were named "Bob" and two others were named "Fred". In this way, we could create composites at test where the irrelevant part could be from a different studied face, but the response associated with the irrelevant part could be the same or different as the target part. For example, the top of Bob-1 could be paired with the bottom of Bob-2, in which case any interference would be due to holistic processing, because the irrelevant part belongs to a different identity, but not to response interference, because the target and irrelevant part would elicit the same response ("Bob"). Alternatively, the top of Bob-1 could be paired with the bottom of Fred-1, in which case we could observe response interference because the target and irrelevant parts are associated with different responses that may compete ("Bob" vs. "Fred") in addition to interference related to holistic processing. In addition to the four learned faces, parts from a fifth composite face that was not learned were also used. Thus, there were four types of irrelevant parts that could be paired with the target part to create composites at test (see Table 1): same face with the same name as the target part (SFSN); different face with the same name (DFSN); different face with a different name (DFDN); an unfamiliar face not used during training (UF).

Each of these conditions was compared to a baseline where the target part had to be named when shown in isolation, so there was no irrelevant part that could interfere with (or facilitate) performance. Consistent with the idea that the composite task measures holistic processing, we expect to find some degree of interference in all conditions where the irrelevant face half is from a different face than the target part, regardless of whether the irrelevant part is from a face that was previously studied (DFSN and DFDN) or unfamiliar (UF) – performance should be impaired when the irrelevant half contains information that is inconsistent with the target part.

More interestingly, we compared performance between the three conditions in which we expect interference (DFSN/DFDN/UF), to determine if response interference contributes to the amount of interference observed. If there is more interference when the irrelevant part is associated with a different name than the target part vs. when the irrelevant part is associated with the same name as the target part or when it has no name (DFDN vs. DFSN/UF), this would suggest a contribution of response interference.

Young et al. (1987) inferred holistic processing by comparing naming of face parts between aligned and misaligned composites (alignment effect). However, it was impossible to assess if there was any remaining interference when face halves were misaligned because there was no baseline (see Gauthier & Bukach, 2007; Cheung et al., in press, for further discussion of the limitations of the alignment effect in measuring holistic processing). In fact, a recent study that measured holistic processing in terms of a congruency effect for both aligned and misaligned composite trials individually found that although holistic processing was reduced when face halves were misaligned, it was not always eliminated (Richler et al., in press B).

Observing interference even after face parts have been misaligned may occur because misalignment reduces holistic processing (e.g., Goffaux & Rossion, 2006; Robbins & McKone, 2007; Young et al., 1987) but does not affect response interference. For example, even if misalignment reduces holistic processing because of an unfamiliar configuration of parts, the mere presence of the irrelevant face half, regardless of the arrangement of parts, may trigger its associated response. Indeed, in classic Stroop tasks, separating the colour patch and colour name in space reduces, but does not eliminate, response interference (Gatti & Egeth, 1978; Macleod, 1991). Thus, we also test whether holistic processing, response interference or both, are attenuated by misalignment by comparing performance on the misaligned conditions to baseline. For completeness we also report analyses on the alignment effect (difference between aligned and misaligned trials).

Method

Participants

Participants were 29 members of the Vanderbilt University community (13 male; mean age: 24.16 years; normal/corrected-to-normal vision) who provided informed consent and were compensated with $12.

Stimuli

Five face-tops and five face-bottoms were selected from the Max-Planck Institute face database (Troje & Bülthoff, 1996) and randomly combined into five composite faces. For each participant, two of these composites were assigned the name "Bob" and two composites were named "Fred". Parts from the fifth composite were not assigned a name and were only used during testing. Name assignment was counterbalanced across participants.

Faces were approximately 5×6.5cm and a white line 2mm thick separated top and bottom halves. When only one face half was presented, the region either above or below the white line was all gray. Faces were presented in the middle of a gray rectangle (17.6×16.8cm) positioned centrally on a white background.

Misaligned composites were created by moving the top half of the composite leftward and the bottom half rightward, such that the edge of one face half fell in the center of the other face half.

Procedure

The experiment was conducted on iMac computers with a 640 ×480 pixel resolution. There were three phases in the experiment.

In phase 1 (whole-face training), participants learned the names of four whole composite faces. First, all four faces and their assigned names were displayed on the screen for participants to study for as long as they liked. Once participants terminated the study phase, training trials began. On each training trial, a fixation cross was presented (500ms) followed by a face. Participants were instructed to press "1" if the face was assigned the name "Bob", and "2" if the face was assigned the name "Fred". All participants completed three blocks of 40 trials. After the third block, participants were informed of their response time and accuracy. If accuracy was 95% or higher with RTs less than 1000ms, participants moved on to Phase 2. Otherwise, participants completed another block of 40 trials until this criterion was achieved, to a maximum of three additional blocks.

In phase 2 (part-naming training), participants practiced naming face halves presented in isolation. Training was identical to Phase 1, with the exception that a single face half was presented on each trial. Participants named top-halves until criterion was reached, and repeated the training procedure with bottom-halves. Phase 2 was included to ensure that names were strongly associated with each learned part. If anything, it should only serve to reduce holistic processing and enhance response interference because of practice with isolated parts.

Phase 3 was the test phase. First, the four faces were again presented on the screen with their assigned names. On the test trials, a fixation was shown (500ms) followed by a composite face. Composites were created by pairing a target part with one of four possible irrelevant parts with respect to the target part (see Table 1). Irrelevant part conditions were randomized during the experiment. Participants were instructed to indicate the name of the target face half (top or bottom) as accurately as possible using the same response keys as during training, while ignoring the irrelevant face half. Face composites were either aligned or misaligned. Alignment was blocked within-subjects because previous work has shown that aligned faces can induce holistic effects for subsequently presented stimuli where they would otherwise not be observed (Richler et al., in press A). Order was counterbalanced, such that 15 participants were tested on aligned composites first, and 14 participants were tested on misaligned composites first. Baseline trials showing only the target face half were included among both the aligned and misaligned test blocks and we calculated a separate baseline for the aligned and misaligned conditions.

Participants were instructed at the beginning of each block which face part (top or bottom) was the target, and on each trial four dots surrounding the target half also provided a reminder. There were five blocks of top-naming trials and five-blocks of bottom-naming trials that were alternated within each of the alignment blocks. In total, there were 480 trials.

Results

Performance for Phases 1 and 2 (learning phases) is reported in Table 2. Mean correct RTs and accuracy for Phase 3 are shown in the figure. Trials for which RTs were beyond three standard deviations of the mean were discarded (0.6% of trials).

RT

A 2 ×5 repeated-measures ANOVA with factors alignment (aligned/misaligned) and condition (baseline/SFSN/DFSN/DFDN/UF) revealed a main effect of alignment, with longer RTs for aligned than misaligned composites ($F_{1, 28} = 12.01$, $p < .01$). There was also

a main effect of condition ($F_{4, 112} = 9.83$, $p < .0001$) that was modulated by an interaction with alignment ($F_{4, 112} = 4.26$, $p < .01$). Scheffé's tests revealed that for aligned composites, performance for DFSN, DFDN and UF was significantly slower than baseline (p's $< .01$) and there was no significant difference between these conditions (p's $> .5$). For misaligned composites, no condition was significantly slower than baseline (p's $> .6$).

Accuracy

A 2×5 repeated measures ANOVA with factors alignment (aligned/misaligned) and condition (baseline/SFSN/DFSN/DFDN/UF) showed no significant main effects. There was a trend toward a significant alignment×condition interaction ($F_{4, 112} = 2.39$, $p = .055$). Scheffé's tests revealed that for aligned composites, only performance for DFDN was significantly worse than baseline ($p < .05$). However, there was no significant difference between DFDN, DFSN and UF (p's $> .6$). When composites were misaligned, no condition was significantly worse the baseline (p's $> .7$).

Alignment Effect

For each condition (baseline/SFSN/DFSN/DFDN/UF), we calculated an aligned-misaligned difference score and conducted a one-way repeated measures ANOVA on those values. In RT, there was a main effect of condition ($F_{4, 112} = 4.26$, $p < .01$). Scheffé's tests revealed that the alignment effect for DFDN was significantly larger than baseline ($p < .05$), and the difference between UF and baseline approached significance ($p = .06$). Importantly, there was no significant difference between the alignment effect for the DFSN, DFDN and UF conditions (p's $> .4$). Analysis of the alignment effect in accuracy revealed no significant effects.

Discussion

For aligned composites, interference, as revealed by longer RTs relative to baseline, was observed in all conditions in which a different face half (either novel or previously studied) was paired with the target half. In accuracy, performance was only significantly worse than baseline for the DFDN condition, suggestive of response interference – interference was only observed when the irrelevant part was associated with a different response than the target part. Moreover, the alignment effect was only significantly larger than baseline for the DFDN condition. However, we hesitate to interpret this as evidence of response interference for the following reasons. First, performance was significantly worse than baseline for all three interference conditions (DFSN/DFDN/UF) in RT, and the differences between DFDN and either DFSN or UF were not significant in either RT, accuracy or the alignment effect. Second, the accuracy data must be interpreted with caution due to potential ceiling effects. Finally, all interference effects (in RT and accuracy) were attenuated when composite face halves are misaligned. In sum, our results suggest that the congruency effect measured in the composite task reflects holistic processing, with very little if any contribution of response interference.

According to a model by Cohen and colleagues (1990), the Stroop effect arises when stimulus features that are processed in parallel share a common mechanism. In the classic case of colour naming and reading, the first shared resource is the response mechanism, so colour-word Stroop effects arise due to response interference. However, interference in this model can arise at any stage of processing where the target and irrelevant features rely on common mechanisms. Thus, in the composite task, Stroop-like interference that is not response interference could occur, since, unlike reading and colour naming, face-tops and face-bottoms likely share processing resources prior to the response stage. However, according to the Cohen et al. model, interference arises because of more practice with one

task (e.g., reading) compared to the other (e.g., colour naming), resulting in one processing pathway that is stronger and faster than the other. As such, the feature with which participants have more practice interferes with the less experienced feature, and not the other way around (Cohen et al., 1990;McLeod & Dunbar, 1988). Indeed, in bilingual participants the Stroop effect is larger in their most proficient language because of a stronger association between the stimulus and response (Magiste, 1984). Thus, from a Stroop perspective, an untrained irrelevant face half should not lead to inference for a trained target face half, since in this case participants have practice with the target half but not the irrelevant half. However, our data do not show less interference for untrained vs. trained irrelevant halves, suggesting that interference in the composite task does not arise from competition between outputs associated with target and irrelevant face parts.

In contrast to Stroop stimuli where participants have mostly independent experience with the target and irrelevant stimulus features (e.g., most of the time we read the words "red" or "blue" printed in black), participants typically experience co-variation between face parts. Outside of the lab, face parts change together. As Brad Pitt's mouth is replaced on the screen by that of Matt Damon's, the rest of the face can be assumed to change in the same way. Interference may arise with composite faces because they violate learned expectations that face parts change together. The idea that composite effects arise due to experience is supported by work with car experts (Gauthier et al., 2003) and with laboratory-trained experts with novel objects (Gauthier & Tarr, 2002; Wong, Palmeri & Gauthier, submitted), showing that both the congruency effect and its sensitivity to alignment increase with expertise.

Importantly, face parts may be processed together at either a perceptual level or decisional level (Richler et al., 2008). For example, holistic processing may arise due to the encoding of holistic representations in which face parts are not represented independently (Tanaka & Farah, 1993). Alternatively, holistic processing might arise because, even though face parts are encoded and stored independently, they are not treated independently when decisions are made about them (Richler et al., 2008; Wenger & Ingvalson, 2002). Although our data suggest that interference indicative of holistic processing arises because face parts are processed together (rather than due to response or Stroop-like interference), they do not distinguish between perceptual vs. decisional holism. To address this question requires an analytical framework that defines perceptual and decisional loci for interactions between dimensions, such as the General Recognition Theory (Ashby & Townsend, 1986). This is beyond the scope of this work. However, recent evidence suggests an important decisional contribution to holistic processing of faces (see Richler et al., 2008; Wenger & Ingvalson, 2002).

Critically, response interference due to competition between response labels or motor programs is distinct from holistic processing, be it perceptual or decisional. Even if, as the decisional account of holism holds, face halves are represented independently but the decisions made about the parts are dependent, this does not necessarily imply responses for each face half that compete with each other. For example, holism might arise as decisional processes acting on the representations of each face part interact prior to response selection or the initiation of motor programs. Thus, finding no influence of response interference in the composite task should not be taken as evidence against the role of decisional factors in holistic processing of faces.

Conclusion

The composite face paradigm is similar in many ways to classic Stroop tasks: performance is affected by irrelevant information in the stimulus, despite instructions to selectively attend

to another dimension. In face composite experiments, we treat the top and bottom halves of faces as independent dimensions, and often construct stimuli in such a way that they are completely uncorrelated. Yet, the visual system does not appear to treat face parts independently, either because they are not independently represented or because of experience in making judgments about one part which takes another part into consideration.

Our results demonstrate that interference measured in the composite task does not depend on experience with the irrelevant part and rejects an account of the composite effect whereby the response from the target half competes with the response from the irrelevant part, analogous to the Stroop effect. Instead, interference appears to arise because target and irrelevant face parts are not processed independently, prior to response selection and execution.

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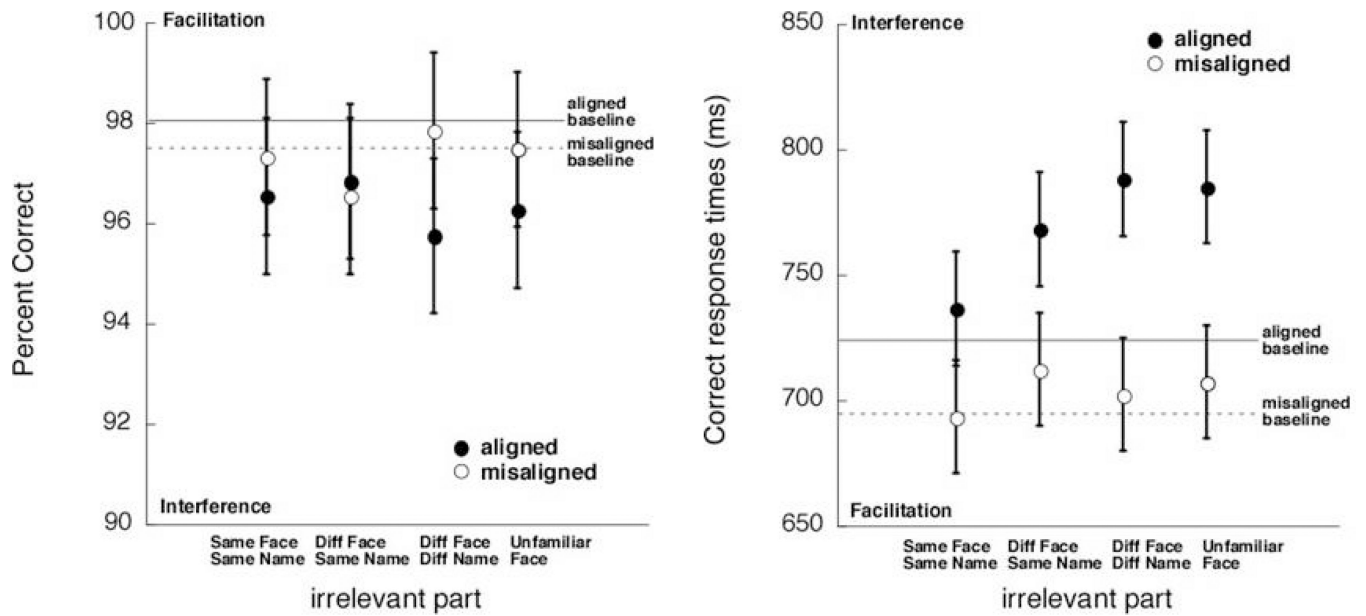
Figure 1.
Accuracy (percent correct; left panel) and reaction times (ms; right panel) for naming the
target half of aligned and misaligned composites as a function of the type of irrelevant part
(SFSN/DFSN/DFDN/UF). Interference is determined by a significant difference in
performance compared to the isolated baseline trials (solid line: aligned baseline; dotted
line: misaligned baseline). Error bars show 95% confidence intervals of within-subjects
effects.

Table 1

Four types of irrelevant parts that could be paired with the target part to create composites during Phase 3 and predictions for each condition.

Condition	Description	Predictions
same-face/same-name (SFSN)	Both the target and irrelevant part were from the same studied face.	Congruent trials, no interference expected.
different-face/same-name (DFSN)	The irrelevant part was from a different face that shared the same name with the target part.	Interference due to holistic processing with a familiar face part.
different-face/different-name (DFDN)	The irrelevant part was from a different face that was assigned a different name than the target part.	Interference due to holistic processing with familiar face part plus response interference.
unfamiliar face (UF)	The irrelevant half was from the unfamiliar face not named or studied during training.	Interference due to holistic processing with an unfamiliar face part.

Table 2

Average number of blocks to reach learning criterion and average accuracy and RT in the last block of Phase 1 (whole-training) and Phase 2 (part-training).

Learning Condition	# blocks to criterion	Accuracy (% correct)	RT (ms)
Whole	3.41	97.72	688.03
Part	3.45	96.83	637.79