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BRIEF REPORT

Holistic processing does not require configural variability

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Abstract Using the Garner speeded classification task, Amishav and Kimchi (Psychonomic Bulletin & Review, 17, 743–748, 2010) found that participants could selectively attend to face features: Classifying faces based on the shape of the eyes was not influenced by task-irrelevant variation in the shape of the mouth, and vice versa. This result contrasts with a large body of work using another selective attention task, the composite task, in which participants are unable to selectively attend to face parts: Same/different judgments for one-half of a composite face are influenced by the same/different status of the task-irrelevant half of that composite face. In Amishav and Kimchi, faces all shared a common configuration of face features. By contrast, configuration is typically never controlled in the composite task. We asked whether failures of selective attention observed in the composite task are caused by faces varying in *both* features and configuration. In two experiments, we found that participants exhibited failures of selective attention to face parts in the composite task even when configuration was held constant, which is inconsistent with Amishav and Kimchi's conclusion that face features can be processed independently unless configuration varies. Although both measure failures of selective attention, the Garner task and composite task appear to measure different mechanisms involved in holistic face perception.

Keywords Face perception · Selective attention

Faces are processed differently from other objects. For one, faces are said to be processed as wholes—holistically—rather than as a collection of features. "Holistic processing" is used to describe several different phenomena that may or may not reflect the same underlying mechanism (Richler et al., 2012). Holistic processing could facilitate individuation of objects from a homogenous category (like faces) where all exemplars contain the same parts (eyes, nose, mouth) in the same general configuration. Indeed, one meaning of holistic processing is that it integrates processing of parts and their configurations (e.g., Cabeza & Kato, 2000; Searcy & Bartlett, 1996). Amishav and Kimchi (2010) used a variation of the classic Garner (1974) speeded classification task to test this notion.

In the Garner task, participants classify multidimensional stimuli on one relevant dimension. In the *control condition*, only the relevant dimension varies and the task-irrelevant dimension is constant. In the *filtering condition*, the relevant and irrelevant dimensions vary orthogonally, and participants have to ignore variation in the task-irrelevant dimension. Worse performance in the filtering versus control condition is called Garner interference: Variation in the task-irrelevant dimension interferes with performance on the task-relevant dimension. Selective attention is possible for stimuli with separable (e.g., size and color), but not integral (e.g., color hue and saturation), dimensions.

Amishav and Kimchi (2010) adapted this paradigm in two ways. In their Experiment 1, faces varied in their parts (different shapes of the eyes, nose, and mouth) and their configuration (variation in spacing between parts). Both when classifying faces based on parts regardless of configuration, and when classifying faces based on configuration regardless of parts, Garner interference was observed (see also Kimchi et al., 2012). This suggested that holistic processing reflects the integration of parts with their configuration. Indeed, in their Experiment 2, when face parts varied and configuration was constant, when classifying faces based on eye shape while ignoring variation in mouth shape and when classifying faces based on mouth shape while ignoring variation in eye shape, *no* Garner interference was observed. Their Experiment 2

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suggested that without configural variability, face parts can be attended and processed independently. Because perception of configural but not feature information is often disrupted by inversion (see McKone & Yovel, 2009, for a review), this may explain why some have argued that inverted faces are not processed holistically (see Rossion, 2008, for a review). However, this line of logic is incompatible with studies that find holistic processing for inverted faces (Richler et al., 2011; Susilo et al., 2013).

Moreover, the lack of interference between face parts in Experiment 2 of Amishav and Kimchi contrasts with considerable work using another selective attention paradigm, the composite task (Hole, 1994; Young et al., 1987), in which participants are unable to selectively attend to face parts (see Richler & Gauthier, 2014, for a review and meta-analysis). In the complete design of the composite task[1] (Fig. 1), participants must compare parts (e.g., top half) of two sequentially presented composite faces while ignoring the other parts (e.g., bottom half). On congruent trials, both the relevant and irrelevant face halves are associated with the same response (e.g., both same/both different); on incongruent trials, the relevant and irrelevant face halves are associated with different responses (e.g., one is the same, the other is different). For faces, a failure of selective attention is observed: Participants are influenced by the same/different status of the part they were instructed to ignore, and performance is better on congruent than incongruent trials. This congruency effect is reduced when face halves are misaligned, indicating that the effect is sensitive to changes in the global face configuration (e.g., DeGutis et al., 2013; Richler et al., 2011). Thus, holistic processing in the composite task is often indexed by a congruency × alignment interaction.

Although both tasks ostensibly measure failures of selective attention, the composite and Garner tasks differ in important ways. Most relevant here is that to test for Garner interference between face parts, Amishav and Kimchi held configuration constant. By contrast, composite faces are generally created by combining face halves that contain natural configural variability. Thus, when a face half is "different" between study and test, it differs in its parts *and* their configuration. Accordingly, it is possible that failures of selective attention to parts observed in the composite task depend on attention to features in the presence of variation in configuration. If so, these failures might be eliminated when configuration is held constant, as in Experiment 2 of Amishav and Kimchi (2010). We tested this possibility in two experiments. Specifically, we tested for the first time whether holistic processing is observed in the composite task when faces do not vary in configuration (SC: *same-configuration* group). If we fail to find holistic processing (congruency × alignment interaction) in the SC condition, this would support Amishav and Kimchi's conclusion that parts can be attended and processed independently when configuration is held constant, and the view that holistic processing reflects an integration of parts and their configuration (e.g., Cabeza & Kato, 2000; Searcy & Bartlett, 1996). By contrast, finding holistic processing in the SC condition would support alternative views, including one that suggests that holistic processing is the outcome of obligatory attention to all parts (e.g., Richler et al., 2012). For completeness, we included a condition where configuration varied (DC: *different-configuration* group); because this condition is similar to the standard composite task design, we expect the typical holistic processing (congruency × alignment interaction)[2].

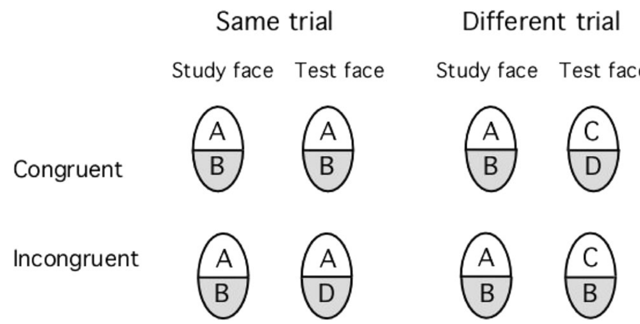

Fig. 1 Schematic representation of the trial types in the complete design of the composite task. The study face is always aligned. On misaligned trials, the test face is misaligned

Experiment 1

Method

Participants

An *a priori* power analysis indicated that 72 participants (36 per condition) would be required to obtain a congruency × alignment × configuration group interaction with $\eta_p^2 = .1$, alpha = .001, and 90 % power, assuming a correlation between measures of .3 (based on a meta-analysis; Richler & Gauthier, 2014). This sample size affords us 99 % power to detect holistic processing in each condition separately (based on the meta-analysis effect size for the congruency × alignment interaction of $\eta_p^2 = .32$; Richler & Gauthier, 2014). Seventy-four Vanderbilt University undergraduates participated in exchange for course credit.

[1] There are two versions of the composite task in the literature (*complete* and *partial* design), and debate over which is more appropriate. Here we use the complete design, which we have empirically demonstrated to be a more reliable and valid measure of holistic face processing (see Richler & Gauthier, 2014, for a review).

[2] Although we are manipulating one aspect of configural *information* between the DC and SC conditions to determine whether this influences holistic processing (i.e., ability to selectively attend to parts), this should not be interpreted as a manipulation of configural *processing* (i.e., sensitivity to spatial relations between features), which our experiments are not designed to measure.

Participants were randomly assigned to the DC (n = 38, 30 female, mean age = 19.39 years) or SC (n = 36, 34 female, mean age = 19.50 years) groups.

Stimuli

The faces in Experiment 2 of Amishav and Kimchi were made from two sets of features in two configurations. At minimum, the composite task has included five top and bottom parts (Ross et al., 2014). Therefore, stimuli were created by adapting stimuli from a different study (Kimchi & Amishav, 2010, Experiment 3) that included faces with four sets of features, two of which are identical to those used in Amishav and Kimchi, in two configurations. For different-configuration (DC) faces, the Kimchi and Amishav stimuli were modified so that there were four different inter-eye and nose-mouth distances (vs. two in the original stimuli). For same-configuration (SC) faces, faces were modified so that the inter-eye distance and nose-mouth distance was the same in all faces. Thus, the face features were identical in the SC and DC stimulus sets (Fig. 2a), but configuration was held constant (SC) or varied (DC).

Faces were cut in half to produce four face tops and bottoms (205 × 259 pixels) for each set. SC face halves were randomly combined to create composites for the SC group, and DC face halves were randomly combined to create composites for the DC group. A black line 3 pixels thick separated face halves. On misaligned trials, the top and bottom halves were moved 50 pixels leftward and rightward, respectively.

Procedure

Each trial (Fig. 2b) began with a fixation cross (200 ms), followed by a study composite (700 ms). A pattern mask was then presented (630 ms), followed by a square bracket indicating whether the top or bottom of the test face was the target (300 ms). The test composite was then presented until a response was made or for a maximum time of 3,000 ms. Time-out trials were excluded. Participants indicated by keypress whether the cued part was the same ('J') or different ('K') as in the study face. Sixteen practice trials were followed by 20 trials for each combination of congruency (congruent/incongruent), alignment (aligned/misaligned), cued part (top/bottom), and correct response (same/different) for a total of 320 trials (randomized for every subject). On misaligned trials, only the test composite was misaligned.

Results

The following data were discarded: eight participants (DC group) due to a programming error; eight participants (four per group) for failing to respond on more than 5 % of trials; one participant (SC group) for using incorrect keys. Thus, our final sample

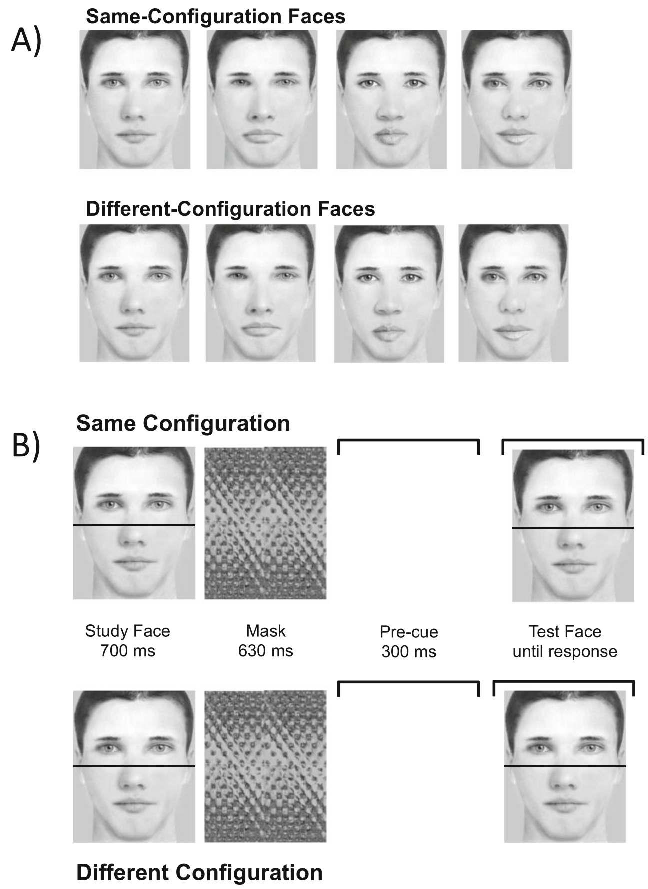

Fig. 2 (**a**) Same-configuration (SC) and different-configuration (DC) faces (adapted from Kimchi & Amishav, 2010, Experiment 3) used to make composite faces. Faces were cut in half to produce face tops and bottoms that were randomly combined within each set to create composites for SC and DC groups, respectively. (**b**) Example of top-same-incongruent trial in the SC and DC conditions. The correct response to the target part (top) is "same" and the irrelevant bottom half differs between study and test. In the SC condition the "different" bottom shows a different feature. In the DC condition, the "different" bottom shows a different feature in a different configuration (i.e., different nose-mouth distance)

included 57 participants (DC group = 26, SC group = 31), giving us .99 power to detect holistic processing (congruency × alignment interaction) in the SC group. In both experiments, we report all significant effects and theoretically important non-significant effects in d', the typical dependent measure in the composite task. The reaction time (RT) analyses are available upon request and generally yielded no significant effects.

Figure 3 displays the sensitivity (d') data. The signature of holistic processing in the composite task is the large congruency effect when face parts are aligned that is reduced or eliminated when face parts are misaligned. A 2 × 2 × 2 mixed ANOVA with alignment (aligned/misaligned) and congruency (congruent/incongruent) as within-subjects factors and configuration group (DC/SC) as a between-subjects factor revealed significant main effects of alignment ($F_{1,55}$ = 5.87, MSE = .12, p = .02, η^2_p = .01) and congruency ($F_{1,55}$ =

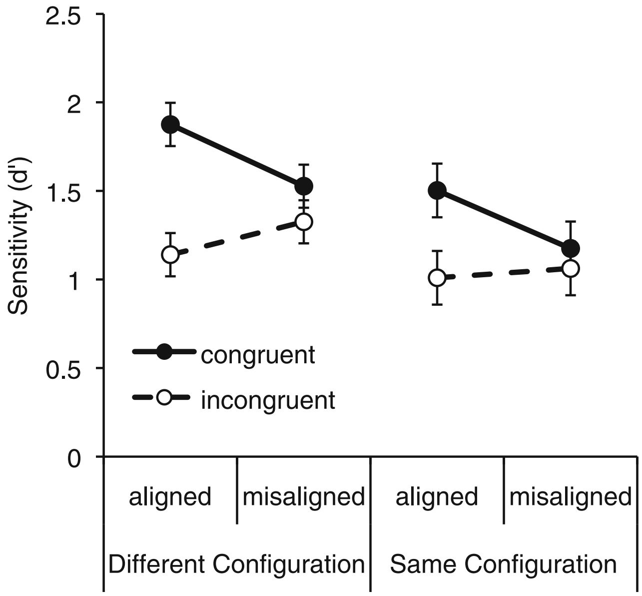

Fig. 3 Sensitivity (d') as a function of alignment and congruency for the different-configuration (DC) and same-configuration (SC) groups in Experiment 1. Error bars show 95 % confidence intervals of the within-subject effect, calculated separately for each configuration group

96.92, MSE = .09, p < .001, η^2_p = .64), and a significant congruency × alignment interaction, indicative of holistic processing ($F_{1,55}$ = 22.34, MSE = .13, p < .001, η^2_p = .29). There was a significant congruency × configuration group interaction, with larger congruency effects for the DC vs. SC group ($F_{1,55}$ = 4.45, MSE = .09, p = .039, η^2_p = .08).

Critically, both SC and DC faces were processed holistically (significant congruency × alignment interaction; SC: $F_{1,30}$ = 6.73, MSE = .17, p = .015, η^2_p = .18; DC: $F_{1,25}$ = 20.34, MSE = .09, p < .001, η^2_p = .45). The congruency × alignment × configuration group interaction was not significant ($F_{1,55}$ = .63, MSE = .13, p = .43, η^2_p = .01)[3].

Discussion

Holistic processing was observed when configuration was held constant (SC condition) in the composite face task. This differs from Amishav and Kimchi (2010, Experiment 2), where participants could selectively attend to features in faces without configural variability in a Garner task. The effect size of the difference in holistic processing between SC and DC groups (congruency × alignment × group interaction) was very small with no significant effect. While this null result supports the general conclusion regarding the (absent) role of configural variability in holistic processing, it is not the critical finding. What is most important is the congruency × alignment interaction in the SC condition, just like the one expected and obtained in the DC condition.

Of all the potential differences between the Garner and composite tasks, there is one particularly worth investigating. In Experiment 1, the target face part (top or bottom) was randomized on every trial, whereas the relevant face part is blocked in the Garner paradigm. Failures of selective attention could be observed in the composite task using randomized trial results because participants have to encode both parts of the study composite (the cue to the relevant face part only appeared after the study face). In Experiment 2, we tested whether we would still obtain holistic processing in the SC condition if we blocked the trials by relevant face half.

Experiment 2

Method

Participants

Ninety Vanderbilt University undergraduates and members of the community participated for either course credit or monetary compensation. Participants were randomly assigned to the DC (n = 44, 34 female, mean age = 20.68 years) or SC (n = 46, 34 female, mean age = 20.31 years) groups. These conditions were run as part of a larger experiment with two additional groups/conditions not reported here. We ran more participants in Experiment 2 to increase the likelihood that, after discarding participants because of errors or non-compliance, we would achieve our target of at least 36 participants per group.

Stimuli and procedure

The stimuli and procedure were identical to Experiment 1, with the following exceptions: The cued part (top/bottom) was blocked (two blocks of 80 trials per part). Top and bottom blocks alternated, and which block type was first was counterbalanced. The study composite was presented for 200 ms (instead of 700 ms)[4]. For comparison with conditions not reported here, the same face features from the previous

[3] The findings were qualitatively the same if all participants (except those discarded due to a programming error) were included in the analyses (SC holistic processing: p = .01, η^2_p = .17; DC holistic processing: p < .001, η^2_p = .45; congruency × alignment × configuration group: p = .28, η^2_p=.02;).

[4] We initially ran an experiment where target part was blocked using the same timing parameters as Experiment 1. The congruency × alignment × configuration interaction was not significant ($F_{1,64}$ = 1.72, MSE = .17, p = .20, η^2_p = .03). Holistic processing was significant for the DC (N = 33; p = .001, η^2_p = .28) but not SC (N = 33; p = .23, η^2_p = .04) group. However, these results were difficult to interpret due to a pronounced ceiling effect in the SC condition; blocking by cued part made the task easier because participants knew which part of the study face was relevant, and could (try to) devote all their attention to that part at study. Presentation time was reduced in Experiment 2 to resolve this issue, bringing performance off ceiling levels.

experiments were presented within one of eight different face/head outlines for each subject (counterbalanced).

Results

The following data were discarded: six participants (three per group) for failing to respond on more than 5 % of trials; three participants (DC group = 1, SC group = 2) due to a computer error; two participants (SC group) for below-chance performance. Thus, the analyses include data from 79 participants (DC group = 40, SC group = 39), giving us .91 power to detect holistic processing (congruency × alignment interaction) in the SC group based on the effect size obtained in Experiment 1.

Figure 4 displays the sensitivity (d') data. A 2 × 2 × 2 mixed ANOVA with alignment (aligned/misaligned) and congruency (congruent/incongruent) as within-subjects factors and configuration group (DC/SC) as a between-subjects factor was conducted. There were significant main effects of alignment ($F_{1,77}$ = 13.32, MSE = .16, p < .001, η^2_p = .15) and congruency ($F_{1,77}$ = 9.40, MSE = .16, p = .003, η^2_p = .11), and a significant congruency × alignment interaction, indicative of holistic processing ($F_{1,77}$ = 8.37, MSE = .10, p = .005, η^2_p = .10). There was also a significant main effect of configuration group ($F_{1,77}$ = 7.73, MSE = 1.81, p = .007, η^2_p = .09), with higher overall performance in the SC versus the DC group.

Critically, holistic processing (congruency × alignment interaction) was significant for the SC group ($F_{1,38}$ = 6.88, MSE = .09, p = .01, η^2_p = .15). Although holistic processing was not significant for the DC group ($F_{1,39}$ = .27, MSE = .12, p = .13, η^2_p = .06), the congruency × alignment × configuration group interaction was not significant either ($F_{1,77}$ = .39, MSE = .10, p = .54, η^2_p = .005)[5].

General Discussion

Using the classic Garner (1974) task, Amishav and Kimchi (2010, Experiment 2) found that participants could selectively attend to face parts when there was no configural variability. This finding does not generalize to the composite face task: we observed clear failures of selective attention to face parts even when configuration was held constant.

Many tasks can measure selective attention, but they may differ in kind. Garner interference has been argued to differ

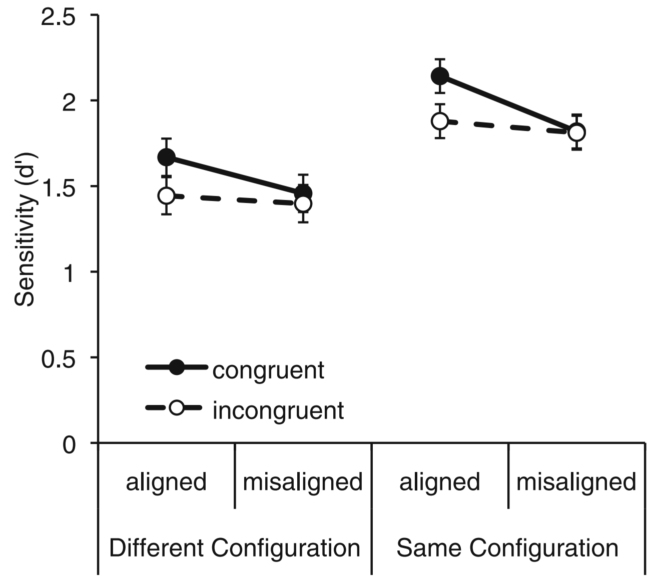

Fig. 4 Sensitivity (d') as a function of alignment and congruency for the different-configuration (DC) and same-configuration (SC) groups in Experiment 2. Error bars show 95 % confidence intervals of the within-subject effect, calculated separately for each configuration group

from Stroop interference (e.g., Pomerantz et al., 1989; van Leeuwen & Bakker, 1995), and although the Stroop and composite task both measure a congruency effect, there are important differences between the two. For example, failures of selective attention in the composite task are not driven by response interference like they are in Stroop tasks (Richler et al., 2009), and failures of selective attention in the composite task do not track differences in discriminability between dimensions like they do in Stroop tasks (e.g., Melara & Mounts, 1993).

While our experiments reveal that failures of selective attention to parts in the composite task do not operate in the same way as failures in the Garner paradigm, they cannot by themselves reveal the specific reasons for the difference. Our composite task instructed participants to attend to a face half (top or bottom) while the Amishav and Kimchi version of the Garner task instructed participants to attend to a face feature (eyes or mouth), and although we used stimuli very similar to Amishav and Kimchi (2010), we used four sets of face features whereas they used only two sets of features. Regardless of whether the difference between our findings and theirs is due to minor stimulus or task parameter differences, or simply to a core difference between interference observed in a Garner task versus a composite task, our results very clearly challenge the generality of their finding that face features are processed independently when the configuration of those features does not vary. Holistic processing of faces does not depend on the presence of configural variability in face parts.

We have noted previously that not all tasks aimed at measuring holistic face recognition address the same underlying construct (Richler et al., 2012). Failures of selective attention

[5] Holistic processing in the DC group did reach statistical significance when all participants (with the exception of those discarded due to a computer error) were included in the analyses (p = .04, η^2_p = .09). Including these data did not qualitatively change the other critical effects (SC holistic processing: p = .03, η^2_p = .10; alignment × congruency × configuration group interaction: p = .90, η^2_p < .00).

in the composite task are face-specific, or at least limited to domains of expertise. They are not observed for objects in novices (e.g., Farah et al., 1998; Richler et al., 2011). By contrast, Garner interference seems more general, as it is observed for objects in novices (e.g., Freud et al., 2013; Tanzer et al., 2013). While the composite task seems to tap into face-specific mechanisms tied to holistic processing, it is unclear whether the same is true for the Garner task.

Garner tasks are informative about general attentional processes in object perception. For example, congenital prosopagnosics do not show the same pattern of Garner interference as control subjects for faces and objects (Kimchi et al., 2012; Tanzer et al., 2013), suggesting a general impairment. But if Garner interference is not face-specific in the first place, more work is needed to link this general deficit in global processing to the face recognition impairments that characterize a particular patient group. One possibility is that a general deficit in attending to global information prevents acquisition of the automatic "attention to all parts" strategy for faces. Chua et al. (2014) showed that participants only processed novel-race faces holistically following training where both face halves in the novel race were diagnostic. Participants in "part training" groups, who were trained with faces for which all the diagnostic information was in only one part (either top or bottom), did not show evidence of holistic processing after training. Perhaps congenital prosopagnosics are similar to participants in these part training groups: they do not attend to the whole, and so do not develop a holistic processing strategy.

What is clear from our results is that holistic processing, operationalized as failures of selective attention in the composite task, is obtained even when there is no configural variation. Holistic processing is not simply the integration of features and configuration since it is manifest even when faces exhibit no configural variability. While both the Garner and composite task can be described as measuring failures of selective attention, they clearly measure different things. The composite task appears to measure a failure that is face-specific while the Garner task appears to measure a failure that may be more general.

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