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Authors

Waguri, Emika
McLaren, R.P.
McLaren, IPL
et al.

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Using prototype-defined checkerboards to investigate the mechanisms contributing to the Composite Face Effect

Emika Waguri (ew518@exeter.ac.uk)
School of Psychology, College of Life and Environmental Sciences,
University of Exeter, UK
R. McLaren (r.p.mclaren@exeter.ac.uk)
School of Psychology, College of Life and Environmental Sciences,
University of Exeter, UK
I.P.L. McLaren (i.p.l.mclaren@exeter.ac.uk)
School of Psychology, College of Life and Environmental Sciences,
University of Exeter, UK
Ciro Civile (c.civile@exeter.ac.uk)
School of Psychology, College of Life and Environmental Sciences,
University of Exeter, UK

Abstract

We report the results from two experiments (n=192) examining the congruency effect (better performance for congruent vs incongruent stimuli) for prototype-defined checkerboard composites. We used a complete matching task design as that used to study a robust index of face recognition i.e., the composite face effect. The results from both experiments reveal an effect of order of presentation for congruent and incongruent trials. Critically, participants presented with incongruent first and then congruent trials revealed a significant congruency effect. In contrast, participants presented with congruent first and then incongruent trials showed no congruency effect. These results contribute to the composite effect literature by reporting the first evidence of a congruency effect for artificial non-face stimuli which do not have a predefined orientation. Also, they provide evidence in support of test order as a determining factor potentially modulating the composite effect.

Keywords: Composite effect, Congruency effect, Face recognition

Introduction

Recognition performance for a set of stimuli generated from the same prototype-defined category can be enhanced if we have prolonged exposure to, or experience with these stimuli. As one example, if we pre-expose someone to a set of checkerboards, all of which are produced by imposing random variation on one original prototype, then this will have the effect of making them better able to distinguish between exemplars generated in this way. They will now be able to tell two similar checkerboards apart where once they might have found it difficult to do so, and this pre-exposure improves their ability to identify checkerboards they have been asked to memorise in a subsequent recognition test. This phenomenon is called perceptual learning and has been suggested as one of the mechanisms that contribute to our face recognition skills. McLaren (1997), McLaren and Civile (2011), Civile, Zhao et al (2014) used prototype-defined checkerboards to investigate an analogue of one of the most robust phenomena in the face recognition literature; the face inversion effect (FIE, Yin, 1969; Civile et al., 2014; Civile et al., 2016; Civile et al., 2011)

The inversion effect refers to impaired performance at recognizing upside down faces, as opposed to when presented in their usual upright orientation. The initial discovery of this was interpreted as a marker for “specificity” of face processing, as the effect was found to be larger for faces compared to other images of objects (Yovel & Kanwisher, 2005). However, first Diamond and Carey (1986)’s finding of a robust inversion effect for dog images when participants were dog breeders (i.e., “dog experts”) and then Gauthier and Tarr (1997)’s finding of an inversion effect for mono-orientated artificial objects named Greebles after participants had become familiar with them, suggested that “expertise” plays a key role in determining the face inversion effect.

Perhaps the strongest evidence emerged from the perceptual learning approach begun by McLaren (1997). Civile, Zhao et al (2014) used an old/new recognition task typically employed to study the inversion effect. They first engaged participants in a categorization task (the pre-exposure phase) where they were asked to sort a set of checkerboards created from two prototype-defined categories. Following this, participants were asked to memorise new checkerboards drawn from one of the two familiar categories previously seen (in the categorization task) and from a novel category not seen previously. Half of the checkerboards were presented the orientation familiarized during the categorization task i.e., upright, and half were rotated by 180 degrees i.e., inverted. The checkerboards used are non-mono-orientated (do not have a predefined orientation) for those drawn from a novel category, so here the participants had no sense of an upright or inverted orientation. Hence, they served as a baseline for the inversion effect obtained for exemplars drawn from the familiar category. In the final recognition task, the “old” exemplars (seen in the study phase) were intermixed with “new” ones split by the same conditions, familiar upright/ inverted, novel upright/inverted, and the participants were asked to recognize the exemplars, they had or had not seen previously in the study phase. The results showed a robust inversion effect for checkerboards from the familiar category vs that for the novel category, partly due to an increased performance for upright checkerboards from the familiar category.

Importantly, recent research based on using a particular transcranial tDCS procedure has provided evidence that the inversion effect for checkerboards and that for faces share at least some of the same causal mechanisms. In 2016, Civile, Verbruggen et al (2016) showed that anodal tDCS (for 10 mins at 1.5mA) delivered over the left dorsolateral prefrontal cortex at prefrontal area Fp3 during the same old/new recognition task used by Civile, Zhao et al (2014) reduces the behavioral checkerboard inversion effect for familiar checkerboards. This was due to a reduction in recognition performance for upright checkerboards compared to sham. The specific tDCS montage was selected based on previous studies that used this montage to modulate performance during a checkerboard category learning task (Ambrus et al., 2011; McLaren et al., 2016). Critically, Civile et al (2018), Civile et al (2019), Civile, Cooke et al (2020), Civile, Waguri et al (2020), Civile, McLaren et al (2020) and Civile, Quaglia et al (2021) extended the tDCS procedure to an old/new recognition task this time testing the face inversion effect and found a reduction (compared to sham) of the face inversion effect after anodal stimulation, in this case also due to an impaired recognition performance for upright faces. The results from the studies reviewed here suggest that expertise plays a key role in face recognition and that a robust phenomenon such as the inversion effect can be obtained with checkerboards which are artificial stimuli that share no similarities with faces and critically do not have a predefined orientation. Thus, with these stimuli the development of expertise can be fully controlled. The current study examines further the analogy between the effects obtained face vs checkerboards stimuli.

Several authors have attributed face recognition skills to configural/holistic processing which relies on the small differences in the relationship between face components across the entire face (for a review about different types of configural processing see Maurer et al., 2002). One of the most convincing demonstrations of this is the *composite face effect*. People are less accurate at recognising the top half of one face presented in composite with the bottom half of another face when the composite is upright and aligned than when the two halves are offset laterally (misalignment, a manipulation that disrupts configural processing). This effect suggests that when upright faces are processed, the internal features are so strongly integrated that it becomes difficult to separate the face into isolated components, leading the composite to be perceived as a "new" face (for a review see Murphy et al., 2017). As for the case of the inversion effect, some authors have suggested the composite effect as an index of face specificity. Hence, when composite faces are aligned and shown upright the presence of the intact facial arrangement may therefore permit access to face-specific processing, responsible for the effect (Tsao & Livingstone, 2008). In contrast some authors argue that the composite effect may reflect a form of processing recruited by objects of expertise. Consistent with this, a few studies have reported a composite effect for non-face objects including cars (Bukach et al., 2010), words (Wong et al., 2010) and Chinese characters (Wong et al., 2012). A composite effect was also found for mono-orientated artificial stimuli (e.g., Greebles or Ziggerins) after participants were trained with them (Gauthier & Tarr 2002; Wong et al., 2009) and for images of bodies with expressive postures (Willems et al., 2014). In contrast, other authors have failed to obtain a composite effect with dog images (Robbins & McKone, 2007), Greebles (Gauthier et al., 1998) and with neutral bodies (Soria et al., 2011) opening the debate about the characteristics of the design and the specific stimuli (including the emotional valence) used across studies that have and have not obtained a composite effect with non-face stimuli.

In the two experiments reported here we made a first step towards the investigation of a composite effect for checkerboards. We adopted the same complete design as used in studies that have obtained a composite effect for artificial non-face stimuli (Gauthier & Tarr 2002; Wong et al., 2009). A key difference between complete and partial/original designs is in the *congruency effect* which is a key component determining the composite effect. In the complete design composites can be congruent or incongruent “same” and “different”. Congruent trials occur when the top half and bottom half of a composite are such as to facilitate the required response to the top half. In the “same” condition target and test composites are identical whereas in the “different” condition the test composite is made by two completely different (from the target composite) halves. Incongruent trials occur when the bottom half of the composite promotes the opposite response to the top half. In the “same” condition target and test composites have matching top halves but different bottom halves whereas in the “different” condition target and test composites have mismatching top halves and matching bottom halves. In line with previous literature, a significant congruency effect (higher performance for congruent vs incongruent stimuli) is found in aligned composites. However, this effect is reduced for misaligned composites. The difference between the congruency effect in aligned vs misaligned composites constitutes the composite effect. Here, as a first step, we aimed to investigate the congruency effect in aligned checkerboard composites.

Method

Participants

Experiment1a. 96 naïve students from the University of Exeter (mean age = 20.5, age range = 18-58) were recruited through the university online recruitment SONA system. They were compensated with course credits. The sample size was determined from earlier studies using the same checkerboard stimuli (Civile, Zhao et al., 2014), and studies on perceptual learning in the composite face effect (Civile, Milton et al., 2021).

Experiment 1b. 96 naïve participants (mean age = 23.8, age range = 18-38) were recruited via Prolific. They had an approval rating of at least 90% from participation in other studies and received monetary compensation adhering to the fair pay policies of Prolific Academic. We conducted a post-hoc power analysis for our sample size in Experiment 1a using G*Power software, based on the effect size (η^2_p=.025) recorded from the overall 2 x 2 x 2 interaction. This analysis revealed a statistical power of .87 (Effect size *f* = 0.16, 2 groups [*Congruent-Incongruent*, *Incongruent-Congruent*], 2 measurements [*Congruency*, *Familiarity*]). The same analysis for Experiment 1b (η^2_p=.029) revealed a statistical power of .91 (Effect size *f* = 0.39, 2 groups, 2 measurements).

Materials

Both **Experiment 1a** and **1b** used 4 prototype-defined categories of checkerboards (A, B, C, D) previously used in Civile, Zhao et al (2014, Experiment 1a). Category prototypes (16 x 16) were randomly generated with the constraint that they shared 50% of their squares with each of the other prototypes and were 50% black squares and 50% white. Exemplars were generated from these prototypes by randomly changing forty-eight squares thus, on average, 24 squares would be expected to alter from black to white or white to black. Composite checkerboards were presented at the resolution of 256 x 256 pixels on a grey background. The composites consisted of top and bottom halves of different checkerboards (each containing 16 x 16 squares) drawn from the same prototype-defined category (e.g., A65 Top, A73 Bottom). Both experiments were programmed and run using the Gorilla online platform.

The Behavioral Task

Experiment 1a. The study comprised of a categorization phase (pre-exposure phase), a training phase, a test phase (checkerboard-matching task).

Categorization phase. Upon providing consent, participants were shown instructions for the categorization phase (Civile, Zhao et al., 2014). They would be shown exemplar checkerboards from categories A and C one at a time in a random order. They were instructed to sort these exemplars into two categories (A-C) through trial-and-error, by pressing one of the two keys on the keyboard. They were given immediate feedback on whether their response was correct or incorrect. If they did not respond within 4 seconds, they were timed out. A fixation cross preceded each stimulus presentation in the center of the screen for 1 second. Participants saw 64 exemplars drawn from each of category A and category C (total of 128 stimuli)

Training phase. The aim of this task was for the participants to associate the response keys "x" and "." With one of the words SAME and DIFFERENT, according to the counterbalanced condition they were allocated to. 48 trials (24 SAME, 24 DIFFERENT) were presented randomly, one at a time for <1 second after a fixation cross (1s). Participants were instructed to press the "x" or "." as quickly as possible when classifying them as either SAME or DIFFERENT. They received feedback on each response as correct or incorrect.

Checkerboard-Matching task. This phase involved a matching-task with composite checkerboards (128 trials). Each trial commenced with a fixation cross (1s), followed by a TARGET composite checkerboard stimulus (1s), an interstimulus interval (1.5s), and a TEST composite checkerboard stimulus (≤2s). Participants were to press either the 'x' key or '.' key to identify the top halves of the TARGET and TEST stimulus as same or different (using the response keys from the previous training phase). Participants were randomly assigned to either one of the two groups. Half of the participants were first engaged with the *congruent* trials and following this the *incongruent* trials. The other half of the participants had the reverse order. This was particularly important considering that this was the first study in the literature to investigate the congruence effect on non mono-orientated artificial stimuli. Within congruent and incongruent trials, the familiar and novel composites were presented at random.

In the congruent familiar trials, participants first saw a TARGET composite checkerboard created by selecting the top and bottom halves of two different new (not seen in the categorization task) exemplars selected from the familiar categories (A-C) previously seen in the categorization phase (e.g., top-half of exemplar A65 and bottom-half of A73 or top-half of exemplar C65 and bottom-half of C73). In the TEST trial, they would either see the "same" composite or a "different" one created by selecting the top and bottom halves of two different exemplars within the same categories (e.g., top-half of A89 and bottom-half of A81 or top-half of exemplar C89 and bottom-half of C81). Overall, 32-A and 32-C composites were presented (16 same, 16 different) in a random order. An A-TARGET composite would correspond to an A-TEST composite, and a C-TARGET composite would correspond to a C-TEST composite.

The congruent novel trials TARGET and TEST "same" or "different" composites were also created by selecting the top and bottom halves of exemplars drawn from prototype-defined checkerboard categories (B and D in this case, 32 each, 16 same and 16 different) not seen during the categorization task. As in the case of familiar composites, the novel composites were also created from exemplars drawn from the same novel category (either B or D). So that a B-TARGET composite would always be followed by a B-TEST composite, and to a D-TARGET composite would always be followed by a D-TEST composite.

Incongruent familiar and novel trials utilized a different combination of the composites from the congruent trials. Here, the TARGET and TEST would be considered 'same' if the top halves of the composites were the same, but both would have different bottom halves (e.g., TARGET: A65/81; TEST: A65/A73). The converse was for different, wherein the top halves of the TARGET and TEST are different, but have the same bottom halves (e.g., TARGET: A89/A73; TEST: A65/A73) (Figure 1). Participants saw 128 trials (64 "same", 64 "different") split by four stimulus conditions: 32 familiar congruent

(16 A and 16 C), 32 novel congruent (16 B and 16 D), 32 familiar incongruent (16 A and 16 C) and 32 novel incongruent (16 B and 16 D).

Experiment 1b. The only difference from Experiment 1a was that the 4 categories of checkerboards were fully counterbalanced. Across all participants in the categorization and test phases, categories A-C and B-D were presented equal number of times as familiar or novel stimulus' conditions. Furthermore, after a careful examination of the stimuli used in Experiment 1a, we found imprecisions in the way that 12 novel composites had been made. Experiment 1b fixed that.

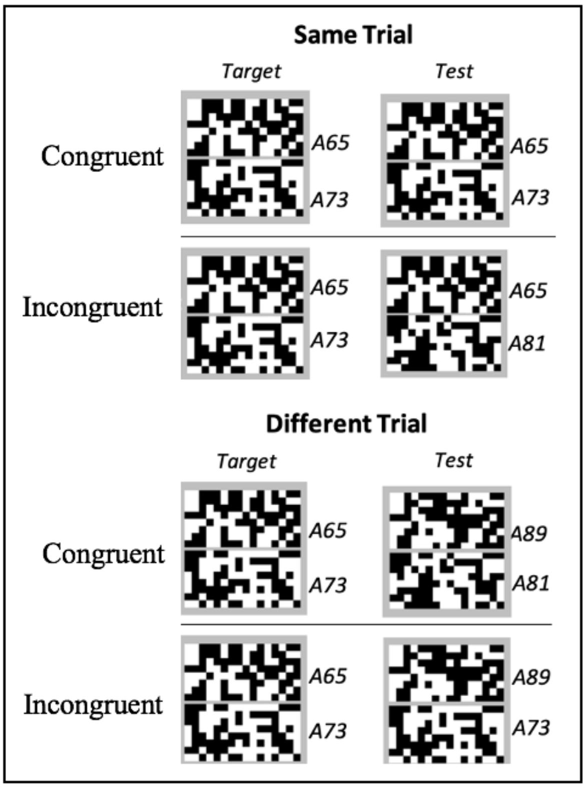

Figure 1 illustrates the study design. In each checkerboard pair, the first composite is the target, and the second one is the test. In the congruent condition, the target and the test composite halves are either both the *same* or are both *different*. In the incongruent condition, the bottom halves of the target and test composites have the opposite relationship to that in the top halves.

Results

In both experiments the primary measure was the accuracy data from all participants in a given experimental condition which we used to compute a *d'* sensitivity measure (Stanislaw & Todorov, 1999) for the matching task (same and different stimuli for each stimulus type) where a *d'* of 0 indicates chance-level performance. To calculate *d'*, we used subjects' hit rate (H), the proportion of SAME trials to which the participant responded SAME, and false alarm rate (F), the proportion of DIFFERENT trials to which the participant responded SAME. We assessed performance against chance to show that stimulus' conditions were recognized significantly above chance (for all four conditions we found *p* <.001). We analyzed the reaction time data to check for any speed-accuracy trade-off. We do not report these analyses here because they do not add anything to the interpretation of our results.

Experiment 1a. In the categorization phase, the mean percentage correct was 58%. We then computed a 2 x 2 x 2 mixed model design using as within-subjects factors, *Congruency* (congruent or incongruent), *Familiarity* (familiar or novel) and the between-subjects factor *Order of Trials* (congruent-incongruent or incongruent-congruent) for our matching data. Analysis of Variance (ANOVA) showed no significant main effect of *Congruency* *F*(1, 94) = .932, *p* = .337, η^2_p = .010, nor of *Familiarity* *F*(1, 94) = 2.62, *p* = .108, η^2_p = .027, nor of *Order of Trials* *F*(1, 94) = .709, *p* = .402, η^2_p < .01. The three-way interaction was not significant, *F*(1, 94) = 2.44, *p* = .121, η^2_p = .025, nor was the interaction between Congruency x Familiarity, *F*(1, 94) = 1.04, *p* = .308, η^2_p = .011. We did find a significant *Congruency* x *Order of Trials* interaction, *F*(1, 94) = 5.63, *p* = .020, η^2_p = .057, and a significant *Familiarity* x *Order of Trials* interaction, *F*(1, 94) = 5.14, *p* = .026, η^2_p = .052.

To further explore these interactions with *Order of Trials* we conducted some additional analyses. A paired-sample t-test between performance for Congruent (M= 1.84, SE=.14) vs Incongruent (M= 1.96, SE=.15) stimuli in the group where congruent trials were presented before incongruent trials, revealed no significant differences, *t*(47) = 1.38, *p* = .174, η^2_p = .038. A paired-sample t-test this time comparing Congruent (M= 1.89, SE=.13) vs Incongruent (M= 1.60, SE=.16) stimuli in the group where incongruent trials were presented before congruent trials, revealed a trend towards a significant difference, *t*(47) = 1.94, *p* = .058, η^2_p = .073 (Figure 2a) with an advantage for congruent trials, the opposite effect (numerically) to that with the other trial order.

We conducted a paired t-test between performance across Familiar (M= 1.88, SE=.15) vs Novel (M= 1.91, SE=.13) stimuli in the group where congruent trials were presented before incongruent trials, which revealed no significant differences, *t*(47) = .510, *p* = .612, η^2_p < .01. The same analysis across Familiar (M= 1.85, SE=.13) vs Novel (M= 1.64, SE=.12) stimuli in the group where incongruent trials were presented before congruent trials, revealed a significant difference, *t*(47) = 2.51, *p* = .016, η^2_p = .117 with an advantage for familiar stimuli.

Experiment 1b. In the categorization phase, the mean percentage correct was 63%. Analysis of Variance (ANOVA) revealed no significant main effect of *Congruency* *F*(1, 94) = 2.27, *p* = .135, η^2_p = .024, nor of *Familiarity* *F*(1, 94) = 1.62, *p* = .206, η^2_p = .017, nor of *Order of Trials* *F*(1, 94) = .017, *p* = .897, η^2_p < .01. The overall three-way interaction (Congruency x Familiarity x Order of Trials) was not significant, *F*(1, 94) = 2.77, *p* = .099, η^2_p = .029, nor was the interaction Congruency x Familiarity, *F*(1, 94) = .754, *p* = .388, η^2_p < .01. We found a significant *Congruency* x *Order of Trials* interaction again, *F*(1, 94) = 7.58, *p* = .007, η^2_p = .075, and a significant *Familiarity* x *Order of Trials* interaction, *F*(1, 94) = 5.28, *p* = .024, η^2_p = .053.

To further explore these effects of *Order of Trials* we conducted the same additional analyses. A paired-sample t-test between performance for Congruent (M= 1.65, SE=.15) vs Incongruent (M= 1.79, SE=.16) stimuli in the group where congruent trials were presented before incongruent trials, revealed no significant differences, *t*(47) = .943, *p* = .350, η^2_p = .018. A paired-sample t-test this time comparing Congruent (M= 1.97, SE=.12) vs Incongruent (M= 1.52, SE=.16) stimuli in the group where incongruent trials were presented before congruent trials, revealed a significant difference, *t*(47) = 2.83, *p* = .007, η^2_p = .146 (Figure 2b) showing an advantage for congruent trials. We conducted a Bayes analysis on the significant difference between the d' values for Congruent and Incongruent stimuli in Experiment 1b when incongruent trials were presented before congruent trials. We used as the *priors* the difference found in Experiment 1a setting the standard deviation of p (population value | theory) to the mean for the difference between the Congruent vs Incongruent stimuli (0.29). We used the standard error (0.15) and mean difference (0.45) between the Congruent vs Incongruent stimuli in Experiment 1b. This gave a Bayes factor of 31.80, which is very strong evidence (greater than 10) that these results are in line with what shown in Experiment 1a i.e., a better performance for Congruent vs Incongruent composites when incongruent trials were presented before the congruent trials.

Finally, a paired-sample t-test between performance across Familiar (M= 1.62, SE=.14) vs Novel (M= 1.82, SE=.15) stimuli in the group where congruent trials were presented before incongruent trials, which revealed a significant difference, *t*(47) = 2.38, *p* = .021, η^2_p = .108 with familiar trials worse. The same analysis across Familiar (M= 1.77, SE=.12) vs Novel (M= 1.72, SE=.13) stimuli in the group where incongruent trials were presented before congruent trials, was not significant, *t*(47) = .773, *p* = .443, η^2_p = .012.

Discussion

In the two experiments reported here we investigated one of the main contributors to the robust composite face effect often used as an index of configural processing. Specifically, we focussed on the congruency effect which consists of better performance at detecting the top half of a face when in the congruent condition compared to when presented in the incongruent condition. In order to further extend our understanding of the role of perceptual learning in face recognition, we used sets of artificial non mono-orientated stimuli previously used in the inversion effect research (Civile, Zhao et al., 2014). We have succeeded in finding an effect of congruency for our checkerboard composites, but we have also uncovered other effects that may call into question previous demonstrations of such an effect.

Only two previous studies reported a composite effect for non-face artificial stimuli after participants had been trained with them in the lab. One study used Greebles and the other used Ziggerins (Gauthier & Tarr 2002; Wong et al., 2009). Both studies used a complete design which allows the composite effect to be calculated by subtracting the congruency effect (better performance for congruent vs incongruent composites) in response to misaligned stimuli from the large congruency effect obtained with aligned composites. In contrast, Gauthier et al (1998) did not find a composite effect for Greebles when a partial/original design was used. Hence, the way the congruency effect is extracted plays a main factor in the final composite effect. Critically, studies have shown that composite effects calculated using the complete and partial/original designs do not correlate (Richler & Gauthier, 2014). Despite many authors arguing that the partial design may be influenced by differences in responses in response bias the debate remains still open. Our results contribute to the previous literature showing that using a complete design we can obtain a congruency effect for non mono-oriented composite checkerboards after participants received a brief pre-exposure to them. The critical result is that the effect of congruency is only found in participants that were first presented with incongruent trials and followed by congruent ones. In both experiments the order of presentation of the trials had a significant impact on the congruency effect.

On one hand our results now set the scene for a full extension to the aligned vs misaligned composites version of the study testing the composite effect as defined according to the complete design. Hence, future studies should investigate how misaligning the composite checkerboards may modulate the congruency effect found for the aligned checkerboards. Specifically, if similarly, to Greebles and Ziggerins the composite effect can be obtained with checkerboards, we would then expect a reduced congruency effect for misaligned composite vs that for aligned composites.

On the other hand, these results also reveal a new pattern of effects specifically related to the order based on which the composite checkerboards were presented. This is the first evidence in the literature where the order of the congruent and incongruent trials revealed to be modulating the congruency effect. A potential explanation could be based on the effects that generalization from the categorization phase may have when congruent trials are presented before incongruent trials. This seems to be primarily affecting familiar stimuli on congruent trials which may lead the order effects found for both familiarity and congruency. This is because for congruent trials the generalization leads to the different stimuli to seem more recent in the familiar category case. This would result in a decreased d-prime for congruent familiar composites vs to novel ones if those trials come first, but not if they come second where the "normal" effect of expertise (bigger d-prime for familiar stimuli) are seen. In each experiment numerical reduced d-prime for congruent familiar composites can be seen if comparing performance when congruent trials are presented first vs when presented second. Importantly, when the data from the two experiments are pooled together, that difference is significant [p=.01] suggesting how overall the order of presentation for congruent and incongruent trials would seem to modulate performance in response to congruent familiar composites. Future work should investigate this further.

Critically, to our knowledge this is the first series of experiments where the order of presentation for the congruent and incongruent trials has been systematically investigated using a between-subjects experimental design. This finding could contribute to one of the main debates in the composite effect literature. Hence, while research has addressed differences in individuals' susceptibility to the composite effect, less research has examined other factors. While it has been found for example that some facial composites induce a stronger composite effect than others, little explanation has been offered for these differences. Some of the variability may be due to the low-level image differences including image scale, spatial frequency and colour. Differences in shape and texture variation may also be important (Murhpy et al., 2017). Our findings suggest that also the order of trials, at least for non mono-orientated composites, has an effect. Future studies should systematically investigate the order effect in the traditional composite face effect hence to determine whether it is found only for artificial non-face stimuli. More in general, our results contribute to the perceptual learning and face recognition research showing how a congruency effect (key contributor to the composite effect) can be obtained with prototype-defined categories of checkerboards previously used in the literature to study the inversion effect.

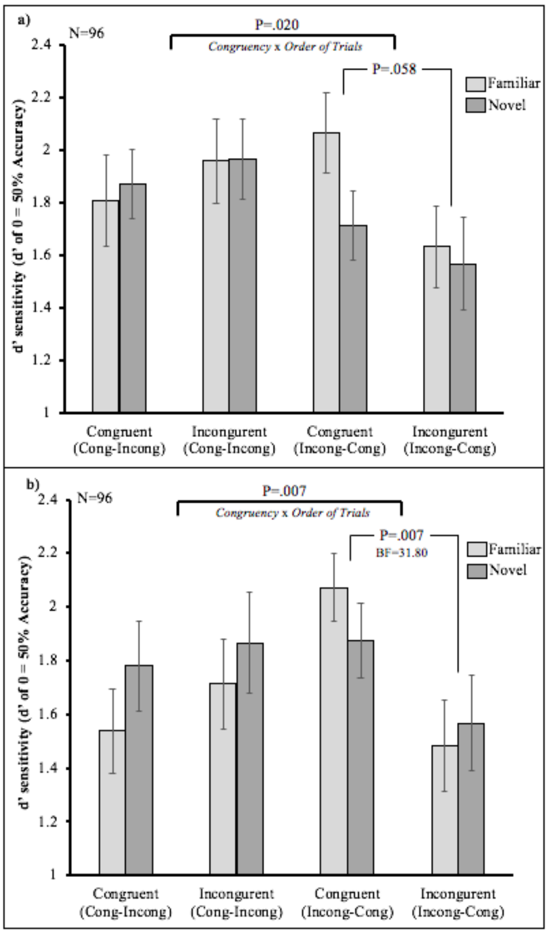

Figure 2. Panel a reports the results from Experiment 1a. **Panel b** reports the results from Experiment 1b. In both panels, the *x*-axis shows the stimulus conditions, the *y*-axis shows d'. Error bars represent s.e.m.

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