Behind the face of holistic perception: Holistic processing of Gestalt stimuli and faces recruit overlapping perceptual mechanisms

Kim M. Curby^{1,2} · Denise Moerel¹

Published online: 4 June 2019
© The Psychonomic Society, Inc. 2019

Abstract

Holistic processing, demonstrated by a failure of selective attention to individual parts within stimuli, is often considered a relatively unique feature of the processing of faces and objects of expertise. However, face-like holistic processing has been recently demonstrated for novel line stimuli with salient Gestalt perceptual grouping cues. Further, disrupting such cues within face stimuli disrupts holistic face perception. There is evidence that holistic processing of these gestalt stimuli and faces does not overlap mechanistically in the same way as does the processing of faces and objects of expertise. However, the relationship between these different manifestations of holistic processing is unclear. We developed a task to probe whether a holistic processing-specific overlap occurs at an earlier, perceptual level between the mechanisms supporting processing of faces and strong gestalt stimuli. Faces and gestalt line stimuli were overlaid, and participants made part judgments about either the faces (Experiment 1) or line stimuli (Experiment 2) in a composite task indexing holistic perception. The data revealed evidence of reciprocal interference between holistic processing of line and face stimuli, with indices of holistic processing of face and line stimuli reduced when the overlaid stimuli were also processed holistically (e.g., intact line/face stimuli) compared with when the overlaid stimuli did not commandeer holistic processing resources (e.g., misaligned line/face stimuli). This pattern is consistent with a mechanistic overlap between the holistic perception of faces and gestalt stimuli. Our results support a dual—stimulus-based and experienced-based—pathway model of holistic processing, with face stimuli using both.

Keywords Holistic perception · Perceptual grouping · Face perception

The processing of faces as holistic, perceptual units, rather than as collections of features, is often considered a defining, unique feature distinguishing the processing of faces from that of other objects (Farah, 1996; Tanaka & Farah, 1993). Subsequent findings of hallmarks of face-like holistic processing for objects of expertise suggest that this processing style may develop, in part, through extensive experience (e.g., Boggan, Bartlett, & Krawczyk, 2012; Curby & Gauthier, 2014; Gauthier & Tarr, 2002). However, the uniqueness of holistic processing and the importance of experience in establishing it, has been called into question by demonstrations of

face-like holistic processing for nonface, novel stimuli in the absence of perceptual expertise (Zhao, Bulthoff, & Bulthoff, 2016). Notably, these stimuli possessed strong, salient Gestalt grouping cues. It is unclear whether this holistic processing supported by strong gestalt grouping cues has the same mechanistic locus as that observed for face processing or whether it arises from mechanistically distinct sources. Here, we examine whether we can observe a trade-off in holistic processing indices for faces and gestalt stimuli in a task designed to tap an overlap in early perceptual processing stages supporting gestalt perception.

A robust paradigm indexing holistic perception is the composite task where participants make judgments about parts, typically the top or bottom half, of composite faces made from the tops and bottoms of different faces (Young, Hellawell, & Hay, 1987). Participants perform more poorly on part-matching judgments when the other, task-irrelevant part is inconsistent with the correct judgment. For example, participants experience more difficulty recognising that the bottom parts of two faces are the same when the top parts differ across

---

✉ Kim M. Curby
kim.curby@mq.edu.au

¹ Department of Psychology, Macquarie University, Sydney, NSW 2109, Australia

² Centre for Elite Performance, Expertise, & Training, Macquarie University, Sydney, Australia

the images, providing incongruent information, compared with when the tops are also the same, providing congruent information. One task version directly manipulates the congruency of the same–different relations between the task-relevant and task-irrelevant parts, with the effect of the congruency of the relationship between the parts providing an index of the failure of selective attention to the parts. This congruency effect is attenuated when the parts are misaligned, thereby no longer conforming to their typical configuration. This interaction between congruency and alignment is a hallmark of holistic processing (Richler & Gauthier, 2014).

Recent findings of face-like holistic processing of novel gestalt line patterns in the absence of expertise raise the possibility of the existence of multiple mechanistic pathways supporting holistic processing (Zhao et al., 2016). Using the composite task, the congruency effect for part judgements about these line patterns was shown to be attenuated when the parts were misaligned, demonstrating the same Congruency $\times$ Alignment interaction typically only present for faces and objects of expertise (Curby, Huang, & Moerel, 2019; Zhao et al., 2016). However, this similarity at the output level may mask underlying mechanistic differences. Thus, the relationship between the mechanisms supporting holistic processing of these novel gestalt stimuli and those for faces is unclear.

A functional overlap between holistic processing of strong gestalt stimuli and faces is consistent with studies demonstrating that disrupting gestalt cues also disrupts holistic face processing in the composite task (Curby, Entenman, & Fleming, 2016; Curby, Goldstein, & Blacker, 2013). Specifically, aligned face parts were processed less holistically when appearing on misaligned, differently coloured backgrounds than when appearing on aligned, uniformly coloured backgrounds. Notably, this contextual manipulation disrupted the perceptual grouping cues of similarity/common region (via different colours) and good continuation (via misalignment). Strikingly, this effect was reversed by pretask training that encouraged participants to perceive the bi-coloured/misaligned backgrounds as single novel polygon shapes (Curby et al., 2016). These findings are consistent with the potential importance of perceptual grouping cues in supporting holistic processing.

Other evidence suggests that holistic processing of these gestalt stimuli and faces do not overlap, at least not like the holistic processing of face and nonface objects of expertise. Specifically, concurrent processing of faces and gestalt stimuli failed to produce competitive interference in a task previously used to reveal the functional overlap between the processing of faces and objects of expertise (Curby et al., 2019). This task involved making two-back part judgments about composite faces and gestalt line patterns. However, the potential processing overlap tapped in this task is in visual working memory as the stimuli are presented serially, rather than simultaneously, with the overlap occurring via the requirement to

simultaneously hold a face and gestalt stimulus in working memory. Thus, this task is not ideal for detecting an overlap at earlier, more perceptual stages of processing, such as those underlying perceptual grouping.

Consistent with the possibility that there may be different mechanisms shared between the processing faces and gestalt stimuli than between faces and objects of expertise is the dual-route account of holistic processing (Zhao, Bulthoff, & Bulthoff, 2015, 2016). Note that while previous dual-route accounts in the face processing literature have included one holistic/configural route and one featural/part-based route (e.g., Bartlett & Searcy, 1993; Sergent, 1984), this account proposes two routes to holistic processing. These include a stimulus-based and an experience-based route. Thus, while the processing of faces and novel gestalt stimuli do not show evidence of a functional overlap in a task tapping experience-based contributions to holistic processing, an overlap may still be present, but in the mechanisms supporting stimulus-based contributions to holistic processing. An overlap of this type would be better tapped with a task where the locus of the overlap is at earlier, more perceptual processing stages. Thus, while holistic processing of faces and line patterns does not overlap in a similar manner as do face and nonface objects of expertise, it is still an open question as to whether there is an overlap at earlier, more perceptual processing stages that could support a stimulus-based contribution to holistic processing.

Experiment 1

If holistic processing of face and of non-face stimuli with strong, salient gestalt grouping cues recruits overlapping processing mechanisms, we should observe a trade-off in holistic processing when the two stimuli are processed simultaneously. That is, if these stimuli recruit capacity-limited overlapping processing mechanisms, the holistic processing of faces processed in the context of line patterns that are also processed holistically (intact line patterns) should be attenuated relative to when they are processed in the context of line patterns modified so that they are no longer processed holistically (part-misaligned line patterns).

Method

Participants

Thirty-two undergraduate students (26 female, $M_{\text{age}} = 22.25$ years, $SD = 7.57$) participated in this study for course credit.¹

¹ An a priori power analysis suggested that 25 participants were required to achieve our minimum desired power of .85, assuming a medium effect size. A larger sample was collected to ensure that power level was comfortably obtained, factoring in typical data loss due to poor performance.

All participants gave informed consent and reported normal or corrected-to-normal vision. The study was approved by the Macquarie University Ethics Committee.

Stimuli

Composite line patterns: 24 pairs of line stimuli, created by Zhao et al. (2016), were used. Each pair consisted of two top halves and two bottom halves, and each part was 7.3-cm wide $\times$ 3.6-cm high. Both top halves within a pair could be matched with both bottom halves, while keeping the gestalt information intact (e.g., the continuity of the lines). The line patterns were made transparent (transparency = 65%) and blue (RGB: 4, 59, 132) instead of grey, so they were visible when overlaid on the greyscale faces.

Composite faces: 48 Caucasian faces (24 males, 24 females; greyscale images) were selected from the Max Planck Institute for Biological Cybernetics face database (Troje & Bühlhoff, 1996). Images were cropped to remove hair and ears and divided into a top and bottom half, each 4.8-cm wide $\times$ 3.5-cm high. The 48 faces were divided into 24 pairs, with each pair consisted of two top halves and two bottom halves, from four different individuals. The images were made partially transparent (25%) to render them ambiguous as to which stimulus category was presented on top. Two additional stimulus pairs/category were created for use in the practice trials.

Design and procedure

Participants completed a composite task, with a total of 1,024 trials divided over 32 blocks, at a viewing distance of approximately 60 cm. The experiment used the Psychophysics Toolbox (PTB3) extensions for MATLAB software (Brainard, 1997; Kleiner, Brainard, & Pelli, 2007; Pelli, 1997). In each trial, face composite images were presented with line composite images overlaid on top. A 0.05-cm horizontal black line separated the top and bottom halves. Each trial proceeded as follows (see Fig. 1): fixation screen (500 ms, not shown in figure), first stimulus: face composite with line pattern composite overlaid (200 ms), pattern mask (500

ms), second stimulus: face composite with line pattern composite overlaid (200 ms). Participants were instructed to make same–different judgements on the bottom half of the face images while ignoring the top halves and the overlaid line patterns. Before starting the experiment, participants completed 32 or 64 practice trials.

The face and line stimuli parts were either aligned or misaligned by 1.8 cm, resulting in four stimulus conditions. The conditions were blocked, with eight blocks/condition, and block order was pseudorandomised for each participant so that all four conditions were shown in a cycle before repeating in a new order. The correct response to the bottom half of the face image (same/different) and the congruency of the relationship between the task-irrelevant top halves with the correct response were counterbalanced within a block. The congruency for the task-irrelevant line patterns was also counterbalanced with the congruency for the faces within each block.

Results and discussion

Data from four participants were discarded due to poor sensitivity (mean $d' < 0$). Mean response times were examined for outliers (mean RT > 2 standard deviations from group mean), but none were present. An additional participant was excluded because of completion of fewer than 75% of the study trials.

Sensitivity analysis

A 2 (congruency: congruent, incongruent) $\times$ 2 (face alignment: aligned, misaligned) $\times$ 2 (line alignment: aligned, misaligned) ANOVA performed on the sensitivity (d') scores revealed a main effect of congruency, $F(1, 26) = 30.37$, $p \leq .0001$, $\eta_p^2 = .54$, and face alignment, $F(1, 26) = 5.75$, $p = .024$, $\eta_p^2 = .18$. There was no main effect of, or two-way interaction with, line alignment (all $ps > .76$). However, there was an interaction between congruency and face alignment, $F(1, 26) = 35.9$, $p \leq .0001$, $\eta_p^2 = .58$, and a three-way interaction between congruency, face alignment, and line alignment, $F(1, 26) = 9.28$, $p = .0053$, $\eta_p^2 = .26$.

Fig. 1 Trial structure used for the modified composite face task. Composite face stimuli were presented overlaid with either (a) aligned or (b) misaligned line patterns. Participants made judgments on whether the bottom halves of the faces were the same or different

To probe the underlying source of the three-way interaction, the data from the trials where the lines were aligned and those where they were misaligned were analysed separately. Holistic processing is indicated by the presence of an interaction between face alignment and congruency, with a greater congruency effect for aligned than for misaligned faces. Thus, the presence or absence of this interaction indicates whether or not holistic processing of the faces is occurring. While a 2 (congruency) $\times$ 2 (face alignment) ANOVA of the misaligned line trials found no main effect of face alignment, $F(1, 26) = 2.14$, $p = .16$, $\eta_p^2 = .08$, there was a main effect of congruency, $F(1, 26) = 15.034$, $p = .0006$, $\eta_p^2 = .37$, and the typical interaction between congruency and face alignment, $F(1, 26) = 43.54$, $p \leq .0001$, $\eta_p^2 = .63$. Thus, faces in the presence of the misaligned lines showed evidence of being holistically processed (see Fig. 2b). In contrast, the 2 (congruency) $\times$ 2 (face alignment) ANOVA of the aligned line trials revealed a main effect of congruency, $F(1, 26) = 22.072$, $p \leq .0001$, $\eta_p^2 = .46$, but no main effect of, $F(1, 26) = 3.40$, $p = .077$, $\eta_p^2 = .12$, or interaction with face alignment $F(1, 26) = 1.546$, $p = .225$, $\eta_p^2 = .06$. Thus, while the key marker of holistic processing was present when faces were processed in the presence of misaligned line stimuli (see Fig. 2b), it was no longer present when they were processed in the context of the aligned line stimuli (see Fig. 2a).

Response-time analysis

Previous studies looking at holistic processing have found markers of holistic processing in RT, but not d' or vice versa. Thus, given the variability in the location of effects in this task, the RT data from this task was also analysed. Trials with a response time <200 ms or $>1,750$ ms ($<1\%$) were removed from the data. A 2 (congruency: congruent, incongruent) $\times$ 2 (face alignment: aligned, misaligned) $\times$ 2 (line alignment: aligned, misaligned) ANOVA was performed on the remaining RT data from correct trials. This analysis revealed no main effects or interactions between any of the variables (all $ps > .27$; see Fig. 2c–d).

Fig. 2 Mean sensitivity (d') for the congruent (blue circles) and incongruent (red diamonds) conditions, and the resulting index of holistic perception (congruency effect, filled bars, reflecting the difference between the congruency conditions) for the faces overlaid

with aligned (a) and misaligned (b) line stimuli in Experiment 1. The mean response time (ms) for accurate trials for the faces overlaid with aligned (c) and misaligned (d) line stimuli is also shown. Error bars represent standard error values. (Colour figure online)

In summary, the typically robust hallmark of holistic processing revealed in the composite task—that is, the reduced effect of congruency when face parts are misaligned—was attenuated when they were processed in the context of intact (holistically processed) line patterns, relative to when they were processed in the context of (nonholistically processed) misaligned line patterns. This result is consistent with a holistic processing-related functional overlap between the processing of faces and the line patterns developed by Zhao et al. (2016).

Experiment 2

If the processing of faces and stimuli strong in gestalt cues recruit overlapping resources, then the interference between the holistic processing of these stimuli should be reciprocal. To test this prediction, and further probe the interference between the processing of the face and line stimuli revealed in Experiment 1, Experiment 2 used the same overlay paradigm, but participants instead made part judgements about the line patterns, with the overlaid aligned and misaligned faces creating the high and low interference conditions, respectively. If the interference between the holistic processing of faces and line stimuli is reciprocal, the Congruency $\times$ Alignment interaction for line part judgements should be attenuated when aligned faces are overlaid (high-interference condition), relative to when misaligned faces are overlaid (low-interference condition).

Method

Participants

Thirty-five individuals participated for course credit (29 female, $M_{\text{age}} = 20.63$ years, $SD = 2.68$). All participants had normal or corrected-to-normal vision and provided informed consent, and none had participated in Experiment 1.

Design and procedure

The design and procedure were identical to Experiment 1, except that participants were instructed to make judgements about the line patterns instead of the faces.

Results and discussion

The same performance criteria were applied to the data as in Experiment 1. This resulted in data from three participants being discarded due to poor performance (mean $d' < 0$ or mean RT > 2 standard deviations from group mean). Data from one participant were excluded because of completion of fewer than 75% of the study trials.

Sensitivity Analysis

A 2 (congruency) $\times$ 2 (line alignment) $\times$ 2 (face alignment) ANOVA performed on the sensitivity (d') scores revealed a main effect of congruency, $F(1, 30) = 27.34$, $p \leq .0001$, $\eta_p^2 = .48$, but not of line, $F(1, 30) = 2.40$, $p = .13$, $\eta_p^2 = .07$, or face alignment, $F(1, 30) = .47$, $p = .50$, $\eta_p^2 = .02$. There was also a congruency by line alignment interaction, $F(1, 30) = 15.67$, $p = .0004$, $\eta_p^2 = .34$, with a congruency effect only present for aligned ($p < .0001$), but not misaligned stimuli ($p = .61$; see Fig. 3a–b). There was also a Line Alignment $\times$ Face Alignment interaction, $F(1, 30) = 6.32$, $p = .018$, $\eta_p^2 = .17$, with Scheffé test revealing an effect of line alignment when the overlaid faces were misaligned ($p = .007$; see Fig. 3b), but not when they were aligned ($p = .53$; see Fig. 3a). There was no three-way interaction between the variables, $F(1, 30) = 2.14$, $p = .15$, $\eta_p^2 = .07$.

Response-time analysis

A 2 (congruency) $\times$ 2 (face alignment) $\times$ 2 (line alignment) ANOVA performed on the RT data from correct trials² revealed main effects of line congruency, $F(1, 30) = 7.40$, $p \leq .011$, $\eta_p^2 = .20$, line alignment, $F(1, 30) = 6.42$, $p = .017$, $\eta_p^2 = .18$, and face alignment, $F(1, 30) = 5.55$, $p = .025$, $\eta_p^2 = .16$. There was also a two-way interaction between line alignment and face alignment, $F(1, 30) = 4.78$, $p = .037$, $\eta_p^2 = .14$, and a three-way interaction between line alignment, line congruency, and face alignment, $F(1, 30) = 6.29$, $p = .018$, $\eta_p^2 = .17$. No other interactions were present (all $ps > .09$).

To probe the basis of the three-way interaction, data from trials where the faces were aligned and those where they were misaligned were analysed separately. While a 2 (congruency) $\times$ 2 (line alignment) ANOVA of the misaligned face trials failed to find main effects of line alignment, $F(1, 30) = 1.78$, $p = .19$, $\eta_p^2 = .06$, or line congruency, $F(1, 30) = 3.48$, $p = .072$, $\eta_p^2 = .10$, there was an interaction between line congruency and line alignment, $F(1, 30) = 9.44$, $p = .0045$, $\eta_p^2 = .24$. Thus, lines in the presence of the misaligned faces still showed evidence of being holistically processed (see Fig. 3d). In contrast, while the 2 (congruency) $\times$ 2 (line alignment) ANOVA of the aligned face trials revealed main effects of line congruency, $F(1, 30) = 8.15$, $p = .0077$, $\eta_p^2 = .21$, and line alignment, $F(1, 30) = 7.84$, $p = .0088$, $\eta_p^2 = .21$, there was no interaction between these congruency and alignment effects, $F < 0.01$ (see Fig. 3c). This suggests that the previously documented holistic processing of lines did not occur when they were processed in the presence of the aligned faces.

In summary, consistent with previous findings, we found evidence of holistic processing of the novel line stimuli (Curby et al., 2019; Zhao et al., 2016). We also again found evidence of a trade-off between the holistic processing of the lines and faces.

² The same RT filtering applied in Experiment 1 was also applied in Experiment 2, resulting in the removal of $< 1\%$ of trials.

Fig. 3 Mean sensitivity (d') for the congruent (blue circles) and incongruent (red diamonds) conditions, and the resulting index of holistic perception (congruency effect, filled bars, reflecting the difference between the congruency conditions) for the line stimuli

overlaid with aligned (a) and misaligned (b) face stimuli in Experiment 2. The mean response time (ms) for accurate trials for the line stimuli overlaid with aligned (c) and misaligned (d) face stimuli is also shown. Error bars represent standard error values. (Colour figure online)

Specifically, line stimuli processing in the context of aligned faces failed to show hallmarks of being holistically processed, while those processed in the context of misaligned faces did. However, unlike Experiment 1, this trade-off emerged in RT, rather than d' . The lower sensitivity in Experiment 1, compared with Experiment 2, might account for this difference. Specifically, the lower accuracy in Experiment 1 resulted in substantial data loss from the RT analysis, as this analysis only included correct trials. Further, the reduced difficulty of the task in Experiment 2 may have also rendered RT a more sensitive measure. Notably, it is not unusual for effects in the composite task to be found in RT or d' or both (e.g., Curby et al., 2016). Importantly, there was no evidence of a speed–accuracy trade-off as the d' data showed the same general pattern.

General discussion

The present study aimed to investigate whether there is a functional overlap in the perceptual mechanisms underlying

holistic perception of faces and novel line pattern stimuli containing salient perceptual grouping cues. Across two experiments, we found evidence of reciprocal interference between the holistic processing of these stimuli. Faces were processed less holistically when an aligned, compared with a misaligned, line pattern was overlaid, and line patterns were processed less holistically when an aligned, compared to a misaligned, face was overlaid. Given that misalignment disrupts holistic perception of both faces and line patterns, this finding is consistent with a trade-off in holistic processing between the stimulus classes. That is, a reduction in holistic processing of the overlaid face or line stimulus frees up processing resources and thereby results in an increase in holistic processing of the other, concurrently processed stimulus. These findings suggest that the mechanisms supporting holistic perception of faces and novel gestalt stimuli are not independent.

Findings of interference between holistic processing of faces and stimuli strong in gestalt cues is somewhat surprising given that gestalt grouping is often assumed to occur preattentively and thus not be capacity limited. However,

one account of perceptual grouping suggests that, in addition to a preattentive parallel grouping process, there is a capacity-limited attentive process referred to as incremental grouping (Roelfsema & Houtkamp, 2011). This is thought to arise via the spread of attention across perceptual objects, with incremental grouping providing an account of object-based attention's role in perceptual grouping. Thus, incremental grouping may play a key role in the holistic perception of faces.

It is important to note that the interference between the processing of faces and gestalt line stimuli is specifically in terms of holistic processing as it is modulated by the degree to which the stimuli draw on holistic processing capacity—that is, the alignment of the stimuli. Thus, these results cannot be explained in terms of the general expected overlap between the processing of any visual stimuli. If this was true, the aligned and misaligned stimuli should have been equally effective in interfering with concurrent processing of stimuli from the other stimulus class.

Of note is that interference between holistic processing of line stimuli and faces is present even though the processing of only one of the stimuli is task relevant. This suggests that participants were obliged to process both stimuli, and potentially did so automatically. This provides further support for the locus of this interference being in early, rather than late, processing stages.

One possibility is that participants perceptually integrated the two stimuli, perceiving them as a meta-stimulus. This would suggest that the two stimuli did not interfere or compete with each other, but rather formed a new singular entity. However, we suggest that this is unlikely for a number of reasons. First, participants were readily able to adjust whether they made a response to the face (Experiment 1) or the line (Experiment 2) stimulus. Previous findings have also demonstrated the ease with which participants can parse overlaid stimuli, especially when they share few perceptual features (e.g., O'Craven, Downing, & Kanwisher, 1999). Further, misaligning the parts within faces and line patterns has been shown to robustly reduce holistic processing (Curby et al., 2019; Zhao et al., 2016). Therefore, misaligning some of the elements within an integrated metastimulus would be expected to result in *reduced*, rather than *increased*, holistic perception, compared with when all the elements in the metastimulus are aligned. Previous work also supports this expectation. For example, when aligned face parts are placed within a misaligned frame, holistic face processing is reduced (Curby & Entenmann, 2016). Thus, we suggest that our pattern of findings is more consistent with the non-task-relevant stimulus being concurrently processed, and thus competing or interfering with, holistic processing of the task-relevant stimulus.

While we provide evidence consistent with an overlap in the holistic processing of faces and the gestalt line stimuli,

when considered together with previous findings, these data suggest that this overlap is not complete. Rather, the findings reported here suggest that there are multiple factors that can support and foster holistic perception. Evidence of experience-based manifestations of holistic processing (e.g., amongst car experts compared with car novices; Curby & Gauthier, 2014; Gauthier, Curren, Curby, & Collins, 2003), and the use of the same stimuli in these previous comparisons, precludes a stimuli-based account of holistic effects for objects of expertise. Similarly, the novel nature of the line stimuli precludes an experience-based account of these holistic effects. Thus, taken together these results suggest that there are multiple paths to holistic perception.

One possibility is that, while the overlap in the processing of faces and stimuli strong in gestalt cues occurs via early, perceptual grouping contributions to holistic perception (Zhao et al., 2015, 2016), the overlap between the processing of face and nonface objects of expertise occurs via the mechanisms responsible for learned attentional strategies (Chua, Richler, & Gauthier, 2014, 2015). This account is consistent with the dual route account of holistic processing proposed by Zhao et al. (2015, 2016), where by a bottom-up (stimulus-based) and top-down (experience-based) route to holistic processing is proposed.

The results reported here are also consistent with prior evidence of the effect of contextual perceptual grouping cues on holistic processing of faces (Curby et al., 2016). While we report *interference* between the holistic perception of face and nonface stimuli strong in gestalt cues, previous research has also demonstrated that holistically, or globally, processed stimuli can prime holistic, or global, processing of other subsequently processed stimuli (e.g., Curby & Gauthier, 2014; Gao, Flevaris, Robertson, & Bentin, 2011; Weston & Perfect, 2005), with holistically processed stimuli *facilitating* the holistic perception of other stimuli. Notably, this pattern is the opposite to what is found when holistic perception is already quite strong for both stimuli, suggesting that facilitation of holistic perception can only occur when the system is not overtaxed.

In conclusion, we provide evidence of reciprocal interference between holistic processing of stimuli that have strong gestalt perceptual grouping cues and face stimuli, suggesting that the mechanisms supporting holistic perception of these novel nonface stimuli are not independent from those supporting holistic perception of faces. Together with previous studies demonstrating an experience-related overlap between holistic perception of face and nonface objects of expertise, these results suggest that there are multiple paths to holistic perception, one dependent on experience and the other on stimulus-level properties. Therefore, the relative strength and robustness of holistic face perception may arise from the ability of face stimuli to commandeer both paths. These findings have important implications for our understanding of face

perception and how it relates to the holistic perception of expert and nonexpert stimuli more generally.

Acknowledgements This research was support by a grant to KMC from the Australian Research Council.

Open practices statement All of the data and any material generated by the authors is available upon request to the corresponding author, providing it does not violate the approved ethics protocol. These experiments were not preregistered.

References

- Bartlett, J. C., & Searcy, J. (1993). Inversion and configuration of faces. *Cognitive Psychology*, 25(3), 281–316. doi:<https://doi.org/10.1006/cogp.1993.1007>
- Boggan, A. L., Bartlett, J. C., & Krawczyk, D. C. (2012). Chess masters show a hallmark of face processing with chess. *Journal of Experimental Psychology: General*, 141(1), 37–42. doi:<https://doi.org/10.1037/a0024236>
- Brainard, D. H. (1997). The Psychophysics Toolbox. *Spatial Vision*, 10, 433–436. doi:<https://doi.org/10.1163/156856897X00357>
- Chua, K. W., Richler, J. J., & Gauthier, I. (2014). Becoming a Lunari or Taiyo expert: Learned attention to parts drives holistic processing of faces. *Journal of Experimental Psychology: Human Perception and Performance*, 40(3), 1174–1182. doi:<https://doi.org/10.1037/a0035895>
- Chua, K. W., Richler, J. J., & Gauthier, I. (2015). Holistic processing from learned attention to parts. *Journal of Experimental Psychology General*, 144(4), 723–729. doi:<https://doi.org/10.1037/xge0000063>
- Curby, K. M., & Entenman, R. J. (2016). Framing faces: Frame alignment impacts holistic face perception. *Attention, Perception, & Psychophysics*, 78(8), 2569–2578. doi:<https://doi.org/10.3758/s13414-016-1194-4>
- Curby, K. M., & Gauthier, I. (2014). Interference between face and non-face domains of perceptual expertise: a replication and extension. *Frontiers in Psychology*, 5, 955. doi:<https://doi.org/10.3389/fpsyg.2014.00955>
- Curby, K. M., Goldstein, R. R., & Blacker, K. (2013). Disrupting perceptual grouping of face parts impairs holistic face processing. *Attention, Perception, & Psychophysics*, 75(1), 83–91. doi:<https://doi.org/10.3758/s13414-012-0386-9>
- Curby, K. M., Entenman, R. J., & Fleming, J. T. (2016). Holistic face perception is modulated by experience-dependent perceptual grouping. *Attention, Perception, & Psychophysics*, 78(5), 1392–1404. doi:<https://doi.org/10.3758/s13414-016-1077-8>
- Curby, K. M., Huang, M., & Moerel, D. (2019). Multiple paths to holistic processing: Holistic processing of gestalt stimuli do not overlap with holistic face processing in the same manner as do objects of expertise. *Attention, Perception, & Psychophysics* 81(3), 716–726. doi:<https://doi.org/10.3758/s13414-018-01643-x>
- Farah, M. J. (1996). Is face recognition “special”? Evidence from neuropsychology. *Behavioural Brain Research*, 76(1/2), 181–189. doi:[https://doi.org/10.1016/0166-4328\(95\)00198-0](https://doi.org/10.1016/0166-4328(95)00198-0)
- Gao, Z., Flevaris, A. V., Robertson, L. C., & Bentin, S. (2011). Priming of global and local processing of composite faces: revisiting the processing-bias effect on face perception. *Attention, Perception, & Psychophysics*, 73(5), 1477–1486. doi:<https://doi.org/10.3758/804s13414-011-0109-7>
- Gauthier, I., & Tarr, M. J. (2002). Unraveling mechanisms for expert object recognition: Bridging brain activity and behavior. *Journal of Experimental Psychology: Human Perception and Performance*, 28(2), 431–446. <https://doi.org/10.1037/0096-1523.28.2.431>
- Gauthier, I., Curran, T., Curby, K. M., & Collins, D. (2003). Perceptual interference supports a non-modular account of face processing. *Nature Neuroscience*, 6(4), 428–432.
- Kleiner, M., Brainard, D. H., & Pelli, D. (2007). What’s new in Psychtoolbox-3. *Perception*, 36. doi:<https://doi.org/10.1068/v070821>
- O’Craven, K. M., Downing, P. E., & Kanwisher, N. (1999). fMRI evidence for objects as the units of attentional selection. *Nature*, 401, 584–587. doi:<https://doi.org/10.1038/44134>
- Pelli, D. G. (1997). The VideoToolbox software for visual psychophysics: Transforming numbers into movies. *Spatial Vision*, 10, 437–442. doi:<https://doi.org/10.1163/156856897X00366>
- Richler, J. J., & Gauthier, I. (2014). A meta-analysis and review of holistic face processing. *Psychological Bulletin*, 140(5), 1281–1302. doi:<https://doi.org/10.1037/a0037004>
- Roelfsema, P. R., & Houtkamp, R. (2011). Incremental grouping of image elements in vision. *Attention, Perception, & Psychophysics*, 73(8), 2542–2572. doi:<https://doi.org/10.3758/s13414-011-0200-0>
- Sergent, J. (1984). An investigation into component and configural processes underlying face perception. *British Journal of Psychology*, 75(2), 221–242. doi:<https://doi.org/10.1111/j.2044-8295.1984.tb01895.x>
- Tanaka, J. W., & Farah, M. J. (1993). Parts and wholes in face recognition. *Quarterly Journal of Experimental Psychology A*, 46(2), 225–245. doi:<https://doi.org/10.1080/14640749308401045>
- Troje, N., & Bulthoff, H. H. (1996). Face recognition under varying pose: The role of texture and shape. *Vision Research*, 36(12), 1761–1771. doi:[https://doi.org/10.1016/0042-6989\(95\)00230-8](https://doi.org/10.1016/0042-6989(95)00230-8)
- Weston, N. J., & Perfect, T. J. (2005). Effects of processing bias on the recognition of composite face halves. *Psychonomic Bulletin & Review*, 12(6), 1038–1042. doi:<https://doi.org/10.3758/BF03206440>
- Young, A. W., Hellawell, D., & Hay, D. (1987). Configural information in face perception. *Perception*, 10, 747–759. doi:<https://doi.org/10.1068/p160747>
- Zhao, M., Bulthoff, H. H., & Bulthoff, I. (2015). A Shape-Based Account for Holistic Face Processing. *Journal of Experimental Psychology: Learning, Memory and Cognition*. doi:<https://doi.org/10.1037/xlm0000185>
- Zhao, M., Bulthoff, H. H., & Bulthoff, I. (2016). Beyond faces and expertise: Facelike holistic processing of nonface objects in the absence of expertise. *Psychological Science*, 27(2), 213–222. doi:<https://doi.org/10.1177/0956797615617779>

Publisher’s note Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.