in perception and/or attention for those with greater drawing skill relative to those with weaker drawing skill (Kozbelt, 2001, 2017). In support of this latter possibility, Chamberlain and Wagemans (2015) reported that those with stronger drawing skill were better able to switch attention between global and local visual information according to task demands. This suggests that greater drawing skill is associated with a stronger ability to deploy attention to task-relevant information rather than a general bias to attend to local over global visual information.

Second, the relationships between drawing skill and local processing biases have been mostly observed in correlational studies assessing the relationship between drawing skill and performance in non-drawing perceptual judgment tasks. What has not been researched well is how, or even if, drawing performance itself is affected by reduced global processing and/or stronger local processing. It could be that drawing performance generally benefits from the selective deployment of attention towards local visual information and away from global visual information. In contrast, and more in line with what is suggested by Chamberlain and Wagemans (2015), it could be that drawing performance is facilitated by reduced holistic processing only when an individual is focusing on drawing a local aspect of the model object (e.g., drawing the details of a small part of a larger object face such as a single eye within a face) but is not facilitated by reduced holistic processing when an individual is focusing on drawing a global aspect of the drawing (e.g., drawing the relative spatial positioning of two or more features contained within an object such as the vertical distance between the eyes and mouth in a face).

One way this discrepancy can be resolved is to conduct experimental studies that manipulate the presence vs absence of global, holistic processing towards a model object and determine how that affects individuals' ability to draw the model. Here, face inversion-based perceptual and drawing experiments are informative, as we have mentioned earlier that face inversion disrupts holistic, global processing of faces. With respect to faces, accurate perception of the spatial relationships between features (e.g., the vertical distance between the eyes and mouth) is strongly supported by holistic processing. An illustrative example comes from a study reported by Freire and co-workers (2000). Here, individuals were observed to be able to accurately discriminate two upright faces as being different when they only differed with respect to the vertical distance between the eyes and mouth and the horizontal distance between the two eyes. When the faces were presented upside down, however, individuals lost their ability to successfully make these discriminations. In contrast, individuals were able to accurately discriminate two faces, when presented both upright and upside down, when the two faces only differed with respect to individual features (e.g., when the two faces only differed with respect to the appearance of the eyes, nose and/or mouth). In addition to the same/different

long-range spatial relationships may be related to attentional biases as opposed to disrupted holistic perceptual processing. It has been previously established that individuals exhibit a bias to allocate attention more strongly to the upper than lower visual field in some studies (Feng and Spence, 2014; Quek and Finkbeiner, 2016; Zito, Cazzoli, Müri, Mosimann and Nef, 2016) and a bias to allocate attention more strongly to the lower than upper visual field in other studies (

horizontal gap (matched in color to the background) was included to separate the top and bottom halves of the faces for both aligned and misaligned face stimuli. In this way, there are two segregated regions of the face presented to participants in both the aligned and misaligned face models.

Face models were displayed against a white background on a computer monitor. As displayed on the computer monitor, each face was approximately 8.75 inches in height, and the horizontal gap in between the top and bottom halves of the face measured 0.13 inches in height.

Participants created each their drawings on a plain 8.5″ × 11″ white sheet of paper using a No. 2 pencil.

2.3.

image and not to include any features absent from the image. They were further instructed to include the gap that separated the top and bottom half of the face model in their drawings. Participants were given a 15-minute time limit to complete their drawing and were told that they were allowed to erase and modify any aspect of their drawing during this time period. Once any questions were addressed by the researcher, the participants began drawing.

After the 15-minute time limit expired (or the participants indicated that they had completed their drawing), the drawing was taken by the researcher and participants were provided a new sheet of paper for their second drawing. All participants created a second drawing of the same face model used during the first drawing. Here, participants were randomly assigned to either draw the aligned face model for a second time (this group of participants were labeled the *A -FaM D a G*) or to draw the misaligned face model (this group of participants were labeled the *M a -FaM D a G*). Within the latter group, participants were further randomly assigned to draw the model whose bottom half was misaligned to the left or right. Participants in the *A -FaM D a G* received an explanation that the reason they were being asked to draw the same model again was in order to assess the effect of practice on face drawing performance. Then, they were provided the same instructions as they received for their first drawing. Participants in the *M a -FaM D a G* received an explanation that the reason they were drawing the misaligned face was to assess the effects of practice and face misalignment on drawing performance. They then received the same instructions that were provided for the first face drawing, with the added instruction to draw the misaligned face as it appeared on the screen (or to depict a misaligned face as opposed to aligning the face in their drawing).

After the second drawings were complete and collected, the researcher debriefed the participants and encAfter the second dae,(ple)9(te and collected, t)ral BDC B

- D/A = vertical distance between the eyes and eyebrows relative to the height of the head
- E/A = vertical distance between the nose and mouth relative to the height of the head
- F/B = interocular distance relative to the width of the head

Table 1 displays the SRR values for each model and the mean and standard deviation SRR values of the drawings.

D aw E for each of the four SRRs were calculated using the following formula:

- Deviation of Drawing from Model % = | [(Drawing SRR – Model SRR) / Model SRR] | × 100

3. Results

The following analyses aimed to assess the effects of face misalignment on drawing errors for each of the four spatial relationships described above. Before the analyses were performed, we collapsed across (a) the drawings of the four different models and (b) the drawings of the leftward- and rightward-misaligned models. Table 2 displays the mean and standard deviation values of the drawing errors for each of the four SRR measures.

We performed four 2 (Drawing Order: First vs Second Drawing) × 2 (Group: Aligned vs Misaligned) ANOVAs that tested for effects on the drawing errors; one ANOVA was performed for each of the spatial relationships assessed in this experiment.

3.1.

Table 1.
Spatial Relation Ratio (SRR) values of models and mean (SD) SRR values of drawings.

Model/Group	**Eye–mouth distance (C/A)**		**Eye–eyebrow distance (D/A)**		**Nose–mouth distance (E/A)**		**Interocular distance (F/B)**	
	Drawing 1	**Drawing 2**	**Drawing 1**	**Drawing 2**	**Drawing 1**	**Drawing 2**	**Drawing 1**	**Drawing 2**
M 1 1	0.35		0.08		0.13		0.25	
Aligned	0.44 (0.07)	0.42 (0.03)	0.09 (0.03)	0.09 (0.02)	0.17 (0.03)	0.16 (0.02)	0.22 (0.05)	0.23 (0.05)
Misaligned	0.45 (0.03)	0.48 (0.06)	0.08 (0.01)	0.08 (0.01)	0.19 (0.03)	0.20 (0.04)	0.24 (0.04)	0.23 (0.05)
M 1 2	0.40		0.10		0.19		0.29	
Aligned	0.46 (0.05)	0.46 (0.04)	0.12 (0.02)	0.12 (0.01)	0.19 (0.03)	0.19 (0.04)	0.25 (0.06)	0.25 (0.06)
Misaligned	0.46 (0.04)	0.47 (0.03)	0.10 (0.02)	0.10 (0.02)	0.21 (0.03)	0.19 (0.04)	0.29 (0.05)	0.28 (0.05)
M 1 3	0.38		0.10		0.17		0.28	
Aligned	0.46 (0.06)	0.45 (0.05)	0.10 (0.02)	0.11 (0.01)	0.19 (0.02)	0.19 (0.02)	0.24 (0.08)	0.22 (0.04)
Misaligned	0.47 (0.06)							

as an extreme outlier (-score = +3.26). There were no significant main effects of Drawing Order, $F_{1,59} = 0.35$, $= 0.56$, $^{2} = 0.01$, or Group, $F_{1,59} = 2.45$, $= 0.12$, $^{2} = 0.04$. However, there was a significant interaction, $F_{1,59} = 5.22$, $= 0.03$, $^{2} = 0.08$. Simple main effect analyses indicated that the Aligned Drawing Group was significantly less accurate than the Misaligned Drawing Group when drawing the eye–eyebrow distance in their first drawing, $F_{1,59} = 5.72$, $= 0.02$, $^{2} = 0.09$. In contrast, there was no significant difference in drawing errors between the two groups with respect to their second drawings, $F_{1,59} = 0.02$, $= 0.89$, $^{2} < 0.01$.

3.3. E D a V M D a M b N a M (E/A)

There were no significant main effects of Drawing Order, $F_{1,60} = 0.55$, $= 0.46$, $^{2} = 0.01$, or Group, $F_{1,60} = 2.14$, $= 0.15$, $^{2} = 0.03$, nor was there a significant interaction between these two factors, $F_{1,60} = 0.19$, $= 0.66$, $^{2} < 0.01$.

3.4. E D a I M a D a M (F/B)

There were no significant main effects of Drawing Order, $F_{1,60} = 0.18$, $= 0.67$, $^{2} < 0.01$, or Group, $F_{1,60} = 0.22$, $= 0.64$, $^{2} < 0.01$, nor was there a significant interaction between these two factors, $F_{1,60} = 0.01$, $= 0.91$, $^{2} < 0.01$.

4. Discussion

To summarize the results described above, the horizontal misalignment of facthe *Aligned-Face Drawing Group* was significantly less accurate than the *Misaligned-Face Drawing Group*. Since the vertical distance between the eyes and eyebrows was a short-range spatial relationship, it was hypothesized that face misalignment would not affect the drawing of this spatial relationship. While the significant group difference in the accuracy of the first drawings is not ideal for the purposes of evaluating this hypothesis, there are two reasons that lead us to believe that this observation does not substantially weaken our claim that face misalignment has no effect on drawing this short-range spatial relationship. First, as mentioned in the Results section and with respect to the second drawings, there was no significant difference in accuracy between the drawings of the aligned and misaligned face. One may argue, however, that this is not a fair comparison as the groups differed in their initial baseline accuracy, potentially masking any drawing effects due to face misalignment as assessed by a group comparison of the second drawings. In order to resolve this, we ran a *post-hoc* within-group analysis testing for differences in accuracy between the first and second drawings produced by those in the *Misaligned-Face Drawing Group*. In this way, if the different baseline points in accuracy between the two groups is masking face misalignment-based group-based effects in the second drawings, we should see a significant difference in accuracy between the aligned and misaligned face drawings produced by the *Misaligned-Face Drawing Group*. In a statistically liberal analysis, this was not observed, $t(29) = 1.23$, $p = 0.11$. Thus, we maintain the claim that face misalignment has no effect on the drawing of the short-range spatial relationship between the eyes and eyebrows.

As a side-note relating to this issue, a reviewer pointed out that, with respect to the *Aligned-Face Drawing Group*, the errors for the first drawing were larger than those observed for the second drawing, indicating a potential practice effect that was not observed for the *Misaligned-Face Drawing Group*. The reviewer suggested that if such a practice effect existed, it may indicate an effect of disrupting holistic processing on eye–eyebrow distance drawing errors. Specifically, since the eye–eyebrow distance drawing errors were not observed to differ between the first and second drawings of the *Misaligned-Face Drawing Group*, a practice effect observed in the *Aligned-Face Drawing Group* could indicate that disrupting holistic processing prevents practice from reducing drawing errors. To clarify whether the potential practice effect observed in the *Aligned-Face Drawing Group* was statistically significant, we conducted a statistically liberal analysis comparing the eye–eyebrow distance drawing errors between the first and second drawings produced by the *Aligned-Face Drawing Group* and observed a non-significant difference in drawing errors, $t(30) = 1.98$, $p = 0.06$. Thus, we did not observe a significant practice effect pertaining to the *Aligned-Face Drawing Group* with respect to their eye–eyebrow distance drawing errors. In considering the total sum of

use of drawing grids. Drawing grids allow users to segment whole images into multiple cells, and create their drawing by focusing on reproducing the visual information one cell at a time. Presumably, this technique supports the users' ability to attend to local areas of the image and suppresses attention towards global aspects of the image. If the use of such grids is effective in increasing drawing accuracy (to date, no experimental validation of this technique has been attempted), then that would be convincing evidence that biasing visual attention towards local visual information is capable of facilitating drawing performance.

A final limitation to address relates to our conceptualization of the effects observed in this experiment (and in prior face inversion experiments discussed in this article) being due to the disruption of holistic processing. There is an unresolved debate in the face perception literature concerning the relationship between holistic and configural processing. Specifically, as Richler and Gauthier (2014) point out, the terms 'holistic processing' and 'configural processing' are often used as synonyms in the literature, assuming that they are the same perceptual process. They further point out that while holistic processing can facilitate configural processing, it does not necessarily indicate that configural processing is identical to holistic processing in terms of how they exert effects on face perception. In the current article, we adopted the perspective that face misalignment and face inversion disrupt holistic processing in such a way to affect the drawing of long-range as opposed to short-range spatial relationships. However, in light of the arguments provided by Richler and Gauthier (2014), this may not be an accurate conceptualization. While the results of the current experiment and past studies indicate that face inversion and misalignment detrimentally affect configural processing of long-range spatial relationships, this may not necessarily indicate that these effects are due to disrupted holistic processing. While this is an issue, we invite the readers to consider when interpreting the nature of the drawing-related effects of face misalignment and inversion, the current lack of consensus on this issue in the literature leads us to not take a strong position on this potential distinction.

4.2. C M T

In general, this study and discussion highlights the limitations of research that aims to determine the predictive relationship between drawing skill and performance biases that are observed in non-drawing tasks. Many studies that investigate such relationships assume, either explicitly or implicitly, that drawing is a general skill that is either associated or unassociated with the performance/biases that are measured using non-drawing tasks. This is evident by two common features of such studies: (1) drawing skill is commonly assessed using unitary measures of drawing performance and (2) the researchers select the type of object that serves as the model in a seemingly arbitrary fashion.

Such methodological strategies may mask the complexity of the relationship between drawing and non-drawing task performance for two reasons. First, drawing production is not a unidimensional behavior, as there are multiple components that must be successfully reproduced in order to produce a high-quality drawing (e.g., spatial proportions and positioning, line curvature, shading, appearance of individual features, linear perspective, etc.). It is by no means established that strong skill in reproducing one component of a model guarantees strong skill in reproducing other components (e.g., individuals may be able to successfully reproduce the relative spatial positioning of features, but may be less skilled in reproducing the appearance of individual features). Further, processes/biases observed in non-drawing tasks may be differentially associated with different components of drawing skill. Second, drawing skill may not generalize across different types of object categories within an individual. Individuals may be skilled in drawing one type of object, but less skilled in drawing other types of objects. For instance, Glazek (2012) observed differences in drawing skill for familiar vs unfamiliar object categories (e.g., a human eye vs a Chinese ideogram, respectively). Thus, when reporting that general drawing skill is associated with performance/biases observed in non-drawing tasks, it is unclear what specific components of drawing are associated with the non-drawing task performance of interest. Further, it is unclear if such associations generalize across the drawing of all types of model objects or only some types of model objects. We believe future research in this area would benefit from an attempt to specify which components of drawing and/or which categories of model objects are associated (vs non-associated) with performance/biases in non-drawing tasks.

Note

1. While outside of the scope of this article's focus, it is worth acknowledging the theoretical debate as to why this is the case. Some argue this holistic vs non-holistic difference is due to faces and non-faces being processed by distinct, domain-specific perceptual mechanisms (Kanwisher, 2000), whereas others argue that this difference is more generally related to different perceptual processing mechanisms existing for categories of objects individuals have vs do not have extensive experience in perceiving, with faces being an example of an object category most humans are 'experts' in perceiving (Bukach *a* .; Tarr, 2006).

References

Bukach, C. M., Gauthier, I. and Tarr, M. J. (2006). Beyond faces and modularity: the power of an expertise framework,m *T* *C* . *SM*, **10**, 159–166.

Chamberlain, R. and Wagemans, J. (2015). Visual arts training is linked to flexible attention to local and global levels of visual stimuli, *Acta Psychol.*, **161**, 185–197.

Chamberlain, R. and Wagemans, J. (2016). The genesis of errors in drawing, *Neurosci. Biobehav. Rev.*, **65**, 195–207.

Chamberlain, R., McManus, I. C., Riley, H., Rankin, Q. and Brunswick, N. (2013). Local processing enhancements associated with superior observational drawing are due to enhanced perceptual functioning, not weak central coherence, *Q. J. Exp. Psychol.*, **66**, 1448–1466.