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Interactions between the processing of gaze direction and facial expression

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Abstract

In this article, we explored the relationship between the processing of facial expression and the processing of gaze direction. In Experiment 1, participants were unable to ignore gaze while classifying expression—or to ignore expression while classifying gaze. This suggests that the processing of expression and the processing of gaze are interdependent. In Experiment 2, the faces were inverted to isolate configural from part-based contributions to this interdependence. Inversion had a striking effect on expression judgments, which could now be processed independently of gaze, but not on gaze judgments, which were still influenced by expression, even when photos that contained only the eye region of faces were presented (Experiment 4). In Experiment 3 the processing of expression was found to be sensitive to even small variations in the direction of gaze. These results suggest that the processing underlying judgments of expression is configural and entails an obligatory computation of gaze direction. Judgments of gaze direction, however, are carried out in a part-based manner using local features around the eyes and are insensitive to the configural aspects of facial processing.

Keywords: Face perception; Selective attention; Gaze discrimination; Facial expression; Image processing

1. Introduction

Judging the emotion expressed on other people's faces is a central aspect of our everyday social interactions. After all, it is the ability to interpret what other people feel that determines our success in both personal and professional relationships. It is probably for this reason that the processing of facial expression has received much more attention in psychological research over the last few decades than that of other socially relevant facial dimensions, such as sex (e.g., Goshen-Gottstein & Ganel, 2000; Henson et al., 2003) or the direction of gaze (Sinha, 2000).

In recent years, however, growing neurological and psychological research has focused on the processing of other facial dimensions, and in particular, on the processing of the direction of gaze. Computing the direction of gaze, like computing expression, is elementary to social interactions in that it provides information about where other people direct their attention. Because a person can express any particular emotion while looking at any point in space, it is logically possible that perceivers process expression and gaze direction independently of one another. Still, the social relevance of a person's facial expression can be completely understood only if we also know towards whom (or where) that expression is being directed. Therefore, it is reasonable to assume that it is the combined output from processing of expression and gaze that determines the way in which we interpret expression in its social context.

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Neurological studies have revealed that a large network of cortical and subcortical regions mediate the perception of gaze direction (Haxby, Hoffman, & Gobbini, 2000, 2002). These regions have been localized primarily in the superior temporal sulcus (STS) and in the amygdala, both of which are also thought to mediate the perception of expression (Vuilleumier, Armony, Driver, & Dolan, 2001). The finding of an overlap between the regions that mediate the perception of expression and gaze has led some researchers to propose that all social aspects of face perception are processed by the same network of brain regions (Haxby et al., 2000, Haxby, Hoffman, & Gobbini, 2002).

Furthermore, the overlap between the regions that process expression and gaze has been used to suggest that the processing of expression and the processing of gaze are functionally interdependent (Haxby et al., 2000). However, because the overlap in the regions that mediate expression and gaze has only been described using techniques with low temporal resolution (see Hernandez, Badre, Noll, & Jonides, 2002), it is possible that even though these facial dimensions are processed at the same cortical sites, they may be computed at different times and/or by different neuronal populations. In fact, using single-cell recordings, which have a relatively high temporal resolution, Sugase, Yamane, Ueno, and Kawano (1999) demonstrated in monkeys that even when the same brain cells respond to two different facial dimensions (i.e., identity and expression), those cells respond at different latencies to the two dimensions. Therefore, while an examination of the cortical sites may yield one prediction (that of functional dependence), additional evidence may yield a reverse prediction (that of functional independence). Likewise, the neuroanatomical evidence for an overlap in cortical sites of the processing of expression and gaze is insufficient to predict functional dependence between the two. More direct, behavioral evidence is required to support such a conclusion.

Indeed, in a recent paper, Adams and Kleck (2003) provided initial behavioral evidence for such a functional dependence of expression judgments on perceived gaze direction. In this study, expression judgments for different facial emotions (e.g., happiness, anger) were found to be differentially affected by whether the direction of gaze was directed towards or away from the observer. They did not examine, however, the effects of expression on judgments of gaze. Moreover, the effects they observed may be limited to situations in which gaze is directed towards the observer.

The present study was designed to provide a more direct exploration of the idea that a functional interdependence exists between the processing of facial expression and the processing of gaze direction. To test if the effects of gaze on expression judgments extend beyond situations in which gaze is directed towards the observer, we also included experimental conditions in which gaze was always directed away from the observer. Furthermore, in addition to examining the effects of gaze on expression, we also investigated whether or not there were possible effects of expression on judgments of gaze direction.

It is clear why the judgments of facial expression could be affected by the direction of gaze. It is less obvious, however, that judgments of gaze would be influenced by facial expression. As was discussed earlier, the processing of gaze direction helps us interpret facial expression—and as a consequence our social environment. Because the two processes are closely intertwined, it is possible that expression might influence judgments of gaze just as gaze affects judgments of expression. Alternatively, there may be no reciprocity here. It has been shown that judgments of expression depend on configural processing of the entire face, which would include the eyes (Calder, Young, Keane, & Dean, 2000), whereas judgments of gaze direction appear to be based entirely on information within the region of the eyes (Sinha, 2000, but see Jenkins & Langton, 2003). To examine this issue in the present study, we used Garner (1974) speeded-classification task, a paradigm that allowed us to test not only how judgments of facial expression are influenced by gaze, but also how judgments of gaze are influenced by facial expression.

Garner's task examines the ability to process one dimension of a visual stimulus, such as face, while ignoring another dimension of the same stimulus (e.g., Felfoldy, 1974; Ganel & Goodale, 2003; Ganel & Goshen-Gottstein, 2002, 2004; Schweinberger & Soukup, 1998). In the present experiments, participants were asked to make speeded classifications of either expression (i.e., smiling or angry) or direction of gaze (e.g., directed toward or averted away from observers). Two blocks of trials were used. In one block, the *baseline* block, only the relevant dimension was varied, while the irrelevant dimension was held at a constant value (e.g., all faces looked toward the same direction when expression was the relevant dimension or all faces were smiling when gaze was the relevant dimension). In the second block, the *filtering* block, both the relevant and the irrelevant dimension were randomly varied (i.e., all possible combinations of expression and gaze were used).

Equal performance in expression judgments (reaction times and accuracy) in the baseline and filtering blocks would indicate that expression can be processed independently of gaze (or, by the same token, for gaze judgments, that gaze can be processed independently of expression) because participants are able to process one dimension while completely ignoring variations in the other. Worse performance in expression judgments in the filtering block as compared to the baseline blocks would indicate that the processing of expression involves computing the direction of gaze (or, for gaze judgments, that the processing of gaze involves computing expression). Worse performance on the filtering blocks, called *Garner interference*, would support the notion that the processing of expression is dependent on the processing of gaze (or vice versa).

2. Experiment 1

Experiment 1 examined the relationship between the processing of expression and gaze using Garner's task. Two different expressions (smiling and angry, see Fig. 1) were used throughout the experiment. Two different gaze conditions were included, one in which gaze was always averted away from observers (on half of the trails to the left and on the other half to the right), and a second one in which gaze was directed toward observers on half the trials and to their right on the other half.

2.1. Method

2.1.1. Participants

Forty undergraduates from Tel-Aviv University received course credit for their participation in the experiment. Half the participants were randomly assigned to the directed-gaze condition and half to the averted-gaze condition.

2.1.2. Design and materials

Task (expression judgments, gaze judgments) and block (baseline, filtering) were manipulated within subject. Gaze direction (directed-gaze condition; averted-gaze condition) was manipulated between subjects.

The stimuli for the directed-gaze condition were created from a factorial combination of Expression (smiling, angry) × Direction of gaze (directed toward observers, directed 40° to their right). The stimuli for the averted-gaze condition were created in a similar manner, but with gaze directed either 40° to the left or 40° to the right of observers. In all other respects the directed- and averted-gaze conditions were identical. To prevent unwarranted effects of variations in identity, photos of the same person were presented to each participant. All photos were 16 cm long and 12 cm wide.

Fig. 1. Examples of stimuli that were presented in Experiment 1 (upright faces, see top row) and 2 (upright and inverted faces, top and bottom rows). Speeded classification of either facial expression or the direction of gaze was required in both experiments.

In the baseline blocks, the relevant dimension (expression or gaze) varied from trial to trial while the irrelevant dimension was held at a constant value (e.g., when expression was being judged, gaze was always directed toward observers; or when gaze was being judged, all faces were smiling). In the filtering blocks, the relevant dimension again varied, but now so did the irrelevant dimension (i.e., all possible combinations of expression and gaze were presented). Each photo was presented 14 times in random order in each block, resulting in a total of 28 presentations for each baseline block and 56 presentations for each filtering block. Order of blocks was counterbalanced across participants.

2.2. Procedure

In each block, participants were asked to classify expression (smiling or angry) or direction of gaze (directed to the right or to the center in the directed-gaze condition; directed to the left or to the right in the averted-gaze condition) by pressing one of two buttons on a response box (Cedrus-Corporation) as quickly as possible. For gaze judgments in the directed gaze condition, participants pressed the left key when the gaze was directed to the center or the right key when gaze was directed to the right. For gaze judgments in the averted gaze condition, participants pressed the left key when the gaze was directed to the left or the right key when gaze was directed to the right. For expression judgments, response keys assigned to smiling and angry judgments were counterbalanced across participants. Practice trials, four random repetitions of upcoming stimuli, were given before each block. One-minute breaks were given between blocks. On each trial, a 1-s blank white screen preceded the presentation of each face stimulus at the center of the screen. Each face remained on the screen until the subject responded. The next trial was initiated 2 s later.

2.3. Results and discussion

Mean reaction times (RT in ms) were calculated for each participant using only correct responses (outliers more than 2.5 standard deviations above the mean for each condition were eliminated). These means are shown in Fig. 2. The data were submitted to an analysis of variance (ANOVA), with task (expression judgments, gaze judgments) and block (baseline, filtering) as within-subject variables and gaze direction (directed gaze, averted gaze) as a between-subjects variable.

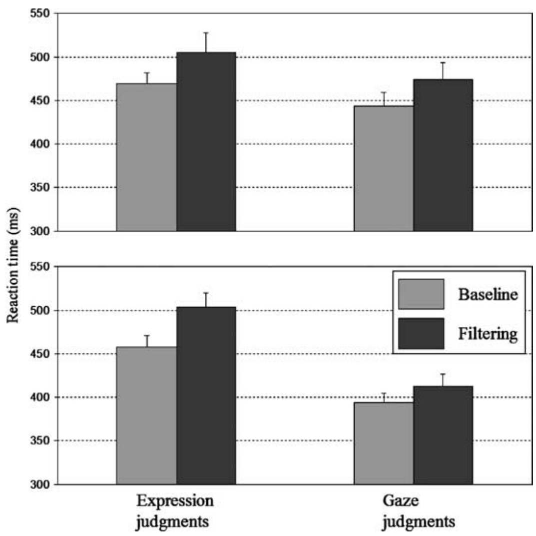

Fig. 2. Mean reaction times in the baseline and filtering blocks for speeded classification of expression and direction-of-gaze in the directed-gaze condition (top panel) and in the averted-gaze condition (bottom panel). Slower performance in filtering than baseline (Garner interference) is an indication that the relevant dimension cannot be processed without taking into account the irrelevant dimension. Error bars show standard error of the mean.

Examination of the data revealed an overall 33 ms Garner interference effect (filtering minus baseline). A main effect of block showed this effect to be significant, $F(1,38) = 29.26$, MSe = 1443, $p < .001$. Within each experimental condition, variations in gaze position produced a 41 ms Garner interference effect on judgments of expression, and, by the same token, variations in expression produced a 24 ms interference effect on judgments of gaze. The two way interaction between task and block revealed that the difference between these effects was not significant, $F(1,38) = 2.76$, MSe = 946, $p > .1$.

Importantly, specific comparisons between the baseline and the filtering blocks in all the four combinations of conditions and task, revealed significant Garner interference effects both in the directed-gaze condition (for expression judgments, 35 ms, $t(19) = 2.65$, $p < .05$; for gaze judgments, 30 ms, $t(19) = 2.75$, $p < .05$) and in the averted-gaze condition (for expression judgments, 46 ms, $t(19) = 4.12$, $p < .01$; for gaze judgments, 19 ms, $t(19) = 2.49$, $p < .05$). These results demonstrate that expression could not be processed independently of the direction of gaze and that the direction of gaze could not be processed independently of expression, both when gaze was directed toward the observers and when gaze was averted away from them. The bidirectional interference between expression and gaze establishes that the processing of each of these two dimensions is dependent on the processing of the other.

Further examination of the data revealed that expression judgments were 53 ms slower than gaze judgments, as indicated by a significant main effect of task, $F(1,38) = 56.57$, MSe = 1967, $p < .001$ (for a discussion about the theoretical aspects of performance differences in Garner's task, see Algom, Dekel, & Pansky, 1996). This difference was larger in the averted-gaze condition than in the directed-gaze condition, $F(1,38) = 12.37$, MSe = 1967, $p < .01$. Specific comparison revealed that the source of this interaction was the faster processing of gaze in the directed- than in the averted-gaze condition, $t(38) = 2.73$, $p < .01$, accompanied by equal performance in expression judgments in these two experimental conditions, $t(38) = 0.28$, $p > .1$.

Thus, the only difference found between the directed- and the averted-gaze conditions was that gaze judgments were faster in the directed-gaze condition. Other than that, the pattern and magnitude of Garner interference between expression and gaze was virtually identical in the two conditions.

Examination of the error data revealed that overall performance was highly accurate (97.9%). An ANOVA between task, block, and gaze direction showed that performance was 1.2% more accurate for gaze than for expression judgments, as revealed by a significant main effect of task, $F(1,38) = 12.65$, MSe = 0.00038, $p < .01$. All other main effects and interactions were not significant.

The results of Experiment 1 demonstrate that the processing of expression and gaze are dependent on one another. Furthermore, the processing of expression seems to be affected by gaze not only when observers are directly involved in the 'quasi-social' interaction (directed gaze), but with any change in the direction of gaze. The data so far suggest that gaze direction is computed in an obligatory way whenever we interpret facial expressions. The data also suggest that expression must be computed whenever we judge gaze direction. But as we will see in Experiment 2, the bi-directional nature of this interaction may be more apparent, than real.

3. Experiments 2A and 2B

In Experiment 1, we demonstrated that participants could not avoid computing gaze when processing expression and could not avoid computing expression when processing the direction of gaze. We used this Garner interference effect to argue that the processing of expression and gaze are interdependent. The purpose of Experiment 2 was to isolate configural from part-based contributions for this dependence.

To this end, we used inverted faces as well as upright faces. It has been argued that the processing of upright faces is configural while the processing of inverted faces is part-based (e.g., Yin, 1969). Most previous studies using inverted faces have explored the effect of this manipulation on judgments of single dimensions, such as identity or expression. Using the Garner paradigm in conjunction with inverted faces, however, allowed us to examine the effect of inversion on the interactions between the processing of at least two different facial dimensions (expression and gaze direction).

If, for example, the interference effect of gaze on expression in Experiment 1 was mediated by configural processing of the whole face (Calder et al., 2000), then inverting the faces should eliminate the interference effect that gaze processing has on judgments of expression. In other words, because the expression on an inverted face would have to be extracted using a part-based analysis (such as the shape of the mouth), it would not be affected by the obligatory configural processing of gaze direction. Moreover, we would also expect that such part-based categorizations would be much slower than those made with upright faces.

The design of Experiment 2 also allowed us to examine the relative contributions of configural as compared to part-based processing to the computation of gaze direction. It could be the case that the interference we observed from expression on gaze was truly configural. If so, then inverting the face should eliminate this interference as well as substantially decreasing overall performance. But it is also possible that the processing of gaze is quite local and part-based, and relies only on information within the eye region. If this is the case, then inverting the faces should have little effect on overall performance or on the magnitude of the Garner interference that was found for upright faces.

The effects of inversion on the relationship between the processing of expression and gaze were studied using two different experiments. In Experiment 2A, we presented the same stimuli that were used in Experiment 1, but now in an inverted manner. This allowed a direct comparison of performance in this experiment to that of Experiment 1. In Experiments 2B, inversion was again used but, to allow larger statistical power, inversion was now manipulated in a within-subject design which included both upright and inverted faces. In addition, to increase the external validity of our results, additional face photos, belonging to new two different individuals, were used in Experiment 2B.

3.1. Method

In all, 20 undergraduates from Tel-Aviv University participated in Experiment 2A, and 24 participants in Experiment 2B. Participants received course credit for their participation.

The method used in Experiment 2A was identical to that used in the directed-gaze condition of Experiment 1, but now all photos were rotated in 180°.

In Experiment 2B, a similar method was used to the one used in Experiments 1 and 2A, but now inversion was manipulated as a within-subject variable. In addition, photos of two additional men were used. Each participant was presented with photos of one of the two men throughout the experiment. To equate task demands for gaze judgments between upright and inverted faces, a photo of the man originally looking to the right was used in the inverted condition, so that in the inverted photo the man would appear as looking to the left (see Fig. 1). This way, gaze judgments were operationalized by speeded classifications to eyes directed to the center versus the left.

3.2. Results and discussion

3.2.1. Experiment 2A

The data were submitted to a two-way ANOVA with task (expression judgments, gaze judgments) and block (baseline, filtering) as within-subject variables. As can be seen in Fig. 3, RTs for expression judgments were 79 ms slower than RTs for gaze judgments. This difference was in the same direction as in Experiment 1 and was significant, as confirmed by a main effect of task, $F(1,19) = 26.68$, MSe = 4561, $p < .001$.

More important, Garner interference for gaze was significant (25 ms, $t(19) = 3.2$, $p < .01$) and was similar in magnitude to the interference found for upright faces in Experiment 1 (30 ms). The similar pattern of gaze

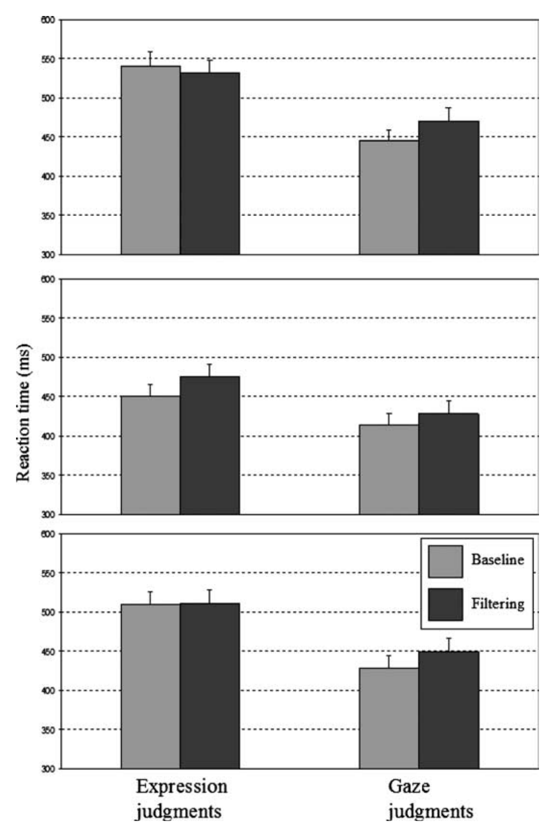

Fig. 3. Mean reaction times in the baseline and filtering blocks in Experiment 2A for inverted faces (top panel) and in Experiment 2B for upright faces (middle panel) and inverted faces (bottom panel). Error bars show standard error of the mean.

performance for upright and inverted faces suggests that the processing of gaze is part based, rather than configural. Furthermore, the fact that similar Garner interference effects were found for upright and inverted faces suggests that these interference effects were not the result of processing facial expression in its normal, configural manner.

Most importantly, unlike gaze judgments, which were influenced by irrelevant information from expression, expression judgments were not influenced by irrelevant information from gaze (−8 ms interference effect, $t(19) = 0.56$, $p > .1$). A significant interaction between task and block confirmed that the interference effects for expression and gaze were different, $F(1,19) = 4.94$, MSe = 1077, $p < .05$. This pattern of results suggests that unlike the processing of direction of gaze which was insensitive to the configural aspects that are part of the processing of expression, the processing of expression is configural in that it takes into account the direction of gaze.

Examination of the data revealed that errors occurred on 3.6% of the trials. These errors were equally distributed between the experimental conditions, as confirmed by the fact that an ANOVA revealed no significant main effects or interactions.

3.2.2. Experiment 2B

The data were submitted to a three-way ANOVA with inversion (upright faces, inverted faces), task (expression judgments, gaze judgments) and block (baseline, filtering) as within-subject variables. As in the previous experiments, RTs for expression judgments were slower than RTs for gaze judgments (57 ms difference). This difference was significant, as confirmed by a main effect of task, $F(1,23) = 21.47$, MSe = 7231, $p < .001$. A significant main effect of inversion showed that RTs were slower for inverted as compared to upright faces, $F(1,23) = 30.67$, MSe = 1707, $p < .001$.

More importantly, this effect was modulated by an interaction between inversion and task, which showed that expression judgments were slowed significantly more by inversion than gaze judgments, $F(1,23) = 8.22$, MSe = 1259, $p < .01$. The larger decrease in performance for expression, as compared to gaze judgments converges with the findings of Experiment 2A to suggest that expression and gaze are processed in a different manner. Whereas the processing of gaze direction was only slightly affected by inversion, the effect was far less than that seen for expression—again supporting the idea that gaze judgments are part-based while expression judgments are more configural.

Most importantly, we directly tested the effect of inversion on the pattern of interference effects between expression and gaze by specific comparisons between the baseline and filtering blocks for each task. These specific comparisons replicated the results of Experiment 2A. Specifically, for gaze judgments, interference effects from expression were found both for upright ($t(23) = 3.26$, $p < .01$) and for inverted faces ($t(23) = 2.48$, $p < .05$). On the other hand, for expression judgments, interference effects from gaze were found only for upright faces ($t(23) = 3.81$, $p < .001$), but not for inverted faces ($t(23) = 0.22$, $p > .1$). A significant three-way interaction between inversion, task, and block confirmed that the interference effect for expression was significantly smaller for inverted, as compared to upright faces, $F(1,23) = 5.31$, MSe = 421, $p < .05$.

Examination of the data showed that errors occurred on 3.4% of the trials. Again these errors were equally distributed between the experimental conditions. This was confirmed by an ANOVA that revealed no significant main effects or interactions.

In contrast to the results of Experiment 1, which emphasized the apparent similarities between the processing of expression and gaze by showing their processing is interdependent, the results of Experiments 2A and 2B highlight the differences between the processing of these two dimensions. In particular, the processing of expression seems to be based on configural analysis of the entire face, which includes computing the direction of gaze. The processing of the direction of gaze, however, seems to be based on part-based analysis, one that is probably based on the region of the eyes (see Experiment 4 for a direct support to this hypothesis).

4. Experiment 3

Our findings so far suggest that when processing facial expression, participants also compute the direction of gaze. The purpose of Experiment 3 was test how accurate these computations are. In previous experiments, the changes in the direction of gaze were quite large, with differences of 40° in visual angle between the center and the averted gaze positions (see Fig. 1). It is possible that our findings of Garner interference from gaze to expression are limited to situations in which only large differences in gaze are present. To test the idea that the processing facial expression can be affected by much smaller differences in gaze direction (20° in visual angle, see Fig. 4), we carried out a final experiment in which the computation of gaze direction was much more difficult than it was in previous experiments. The question we asked was this: Are judgments of expression sensitive to these small variations in gaze?

4.1. Method

Thirty-two undergraduates from the University of Western Ontario, 19 women and 13 men, received course credit for their participation in the experiment.

Fig. 4. Examples of stimuli that were presented in Experiments 3 and 4. Top and middle panels—full faces; speeded classification of either facial expression or the direction of gaze was required in Experiment 3. Bottom panel—eye region only; speeded classification of the direction of gaze for either upright (bottom row) or inverted (not presented in the figure) photos of the eye region of faces was required in Experiment 4.

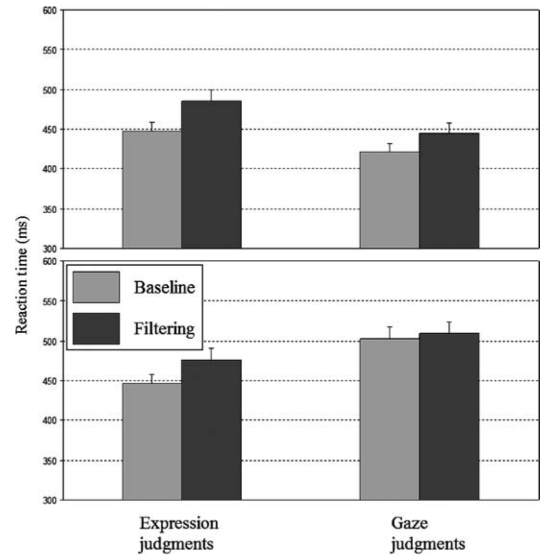

Fig. 5. Mean reaction times in the baseline and filtering blocks in Experiment 3 in the directed-gaze condition (top panel) and in the averted-gaze condition (bottom panel). Error bars show standard error of the mean.

The method was similar to the one used in Experiment 1, but now gaze was directed either 20° to the left, 40° to the left, or directly towards the observer (see Fig. 4). In this experiment, gaze direction was always a within-subject variable. In the directed gaze condition, photos of faces were presented with gaze directed toward the observer or 20° to the left. In the averted gaze condition, photos were presented with gaze directed 20° or 40° to the left. The order of the baseline and filtering blocks was counterbalanced in a similar manner to the one used in Experiment 2B.

4.2. Results and discussion

RT data was analyzed as in Experiment 1 and was submitted to a three-way ANOVA with gaze direction (directed gaze, averted gaze), task (expression judgments, gaze judgments) and block (baseline, filtering) as within-subject variables. Unlike in previous experiments, overall RTs for expression judgments did not differ from overall RTs for gaze judgments (see Fig. 5), as indicated by a non-significant main effect of task, $F(1,31) = 0.68$, MSe = 3259, $p > .1$. This main effect of task, however, was mediated by a significant interaction between task and gaze direction, $F(1,31) = 107.84$, MSe = 911, $p < .001$, which indicated that expression judgments were made faster than gaze judgments in the directed gaze condition, but were made slower than gaze judgments in the averted gaze condition.

A significant interaction between task and block showed that the overall Garner interference for expression judgments (34 ms) was larger than that for gaze judgments (15 ms), $F(1,31) = 7.11$, MSe = 782, $p < .05$. A main effect of gaze direction showed that performance in both tasks was significantly faster in the directed than in the averted gaze condition (34 ms difference, $F(1,31) = 28.01$, MSe = 2595, $p < .001$.

Most importantly, a main effect of block indicated that the overall Garner interference effect between expression and gaze was significant, $F(1,31) = 20.42$, MSe = 1855, $p < .001$. Specific comparisons confirmed that interference was significant for expression judgments both in the directed gaze condition, $t(31) = 4.13$, $p < .001$, and in the averted gaze condition, $t(31) = 3.89$, $p < .001$. These findings are important in that they show that the processing of expression includes computing even small variations in the direction of gaze. Yet more interesting is the fact that variations in gaze affected expression judgments even in the averted gaze condition, in which gaze judgments were actually slower that expression judgments. In other words, judgments of expression were modulated by gaze direction—even before the classifications of gaze direction had been completed. This finding emphasizes the configural nature of the processing of expression, and provides a strong support to the idea that that the processing of expression also involves computations of the direction of gaze.

The pattern of the interference from expression to gaze was quiet surprising; although as in the previous experiments, interference was again found in the directed gaze condition (23 ms, $t(31) = 2.99$, $p < .001$), no such interference effect was found in the averted gaze condition, $t(31) = 0.55$, $p > .1$. This lack of interference of expression on the processing of gaze may reflect the fact that the judgments of gaze direction can be made independently from expression when gaze is directed away from the observer.

Examination of the data revealed an overall error rate of 4.9%. An ANOVA between gaze direction, task, and block showed that performance in the directed gaze condition was more accurate than performance in the averted gaze condition (1.1% difference, $F(1,31) = 5.11$, MSe = 0.00164, $p < .05$). Similar to the pattern of results found for the RT data, a significant interaction between task and gaze direction showed that gaze judgments were more accurate than expression judgments in the directed gaze condition (1.9% difference), but less accurate than expression judgments in the averted gaze condition (1.4% difference), $F(1,31) = 11.25$, MSe = 0.00159, $p < .01$.

5. Experiment 4

The results of Experiments 1–3 provide strong support for the notion that the processing of expression is configural in that it was slowed down by irrelevant variations in the direction of gaze for upright faces (Experiments 1–3) but not for inverted faces (Experiment 2). The processing of the direction of gaze, however, showed similar interference effects for upright and inverted faces. It is unlikely, therefore, that the processing of facial expression (even in the case of upright faces where configural processing would presumably be used) was responsible for this interference. What, then, created this interference?

Examination of the stimuli (see Fig. 4) suggests one possible answer. As can be seen in Fig. 4, changes in facial expression not only affect the overall configuration of the face (i.e., the relative distance between facial features); they also affect the shape of local facial features, particularly in the region around the eyes. For example, 'smiling eyes' are different from 'angry eyes' in local attributes such as the pattern of muscle contractions around the eyes, their overall shape, or even their size. It is possible, therefore, that the interference effects found for expression on gaze were the result of these differences in the local features around the eyes.

To test this notion, we devised a new set of stimuli that showed only the region of the eyes cropped from the same set of facial stimuli used in Experiment 3 (see Fig. 4). If the interference effects of expression on gaze in previous experiments were the result of local variation within the region of the eye, then interference effects should also be observed with these stimuli. Furthermore, if these interference effects on judgments of gaze were the result of part-based but not configural analysis, then similar interference effects should be found for inverted photos of these same eye regions.

5.1. Method

Thirty-six undergraduates from the University of Western Ontario, half of them women, received $10 for their participation in the experiment.

The method was similar to the one used in Experiment 3, but now the stimuli were cropped using Adobe Photoshop 6 so that only the eye region of the faces was included (see Fig. 4, bottom row). Participants were asked to make speeded classification of the direction of gaze for upright and inverted eyes in a Garner speeded-classification task. The order of blocks was counterbalanced in a similar manner to the one used in Experiment 2B.

5.2. Results and discussion

The data were submitted to a two-way ANOVA with inversion (upright faces, inverted faces) and block (baseline, filtering) as within-subject variables. As in Experiment 2B, RTs for inverted stimuli were slower than RTs for upright stimuli (18 ms slower in Experiment 2B, 17 ms slower in the current experiment, see Fig. 6). This difference was significant, as confirmed by a main effect of inversion, $F(1,35) = 12.1$, MSe = 890, $p < .01$. Slower performance for inverted stimuli has been widely reported for many classes of stimuli, including stimuli that are known to engage part-based processing (for a review, see Tanaka & Farah, 2003). More direct evidence for part-based processing comes from the observation that variations in expression interfered with judgments of gaze ($F(1,35) = 10.2$, MSe = 579, $p < .01$), and this interference was independent of the orientation of the stimuli, as indicated by a non-significant interaction between inversion and block, $F(1,35) < 1$. The specific comparisons between the baseline and filtering blocks showed significant interference effects both in the upright ($t(35) = 2.46$, $p < .05$) and in the inverted ($t(35) = 2.28$, $p < .05$) condition.

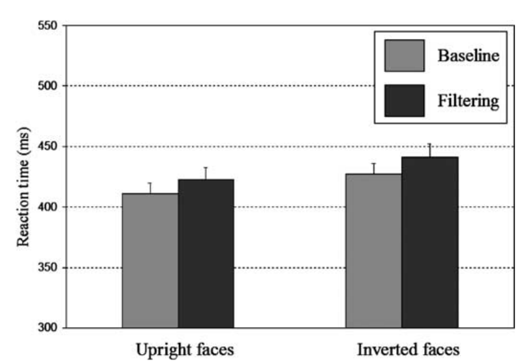

Fig. 6. Experiment 4: mean reaction times for speeded classification of the direction of gaze when only the eye region of faces was presented. Error bars show standard error of the mean.

Thus, the pattern of results observed in this experiment replicated the results of Experiment 2B, but now with stimuli that only allowed a part-based processing. Taken together, these findings support the notion that the processing of gaze is based on local information within the region of the eyes.

Examination of the data revealed an overall error rate of 3.3%. A two-way ANOVA with inversion and block as within-subject factors revealed a similar pattern to that found for RTs, with more accurate performance in the upright as compared to the inverted gaze condition (0.6% difference, $F(1, 35) = 4.27$, $MSe = 0.00027$, $p < .05$). The main effect of block and the interaction were not significant.

6. General discussion

The results of the four experiments described in this paper establish that computing the direction of gaze is an essential component of the processing of expression. When upright faces were presented, participants were unable to avoid computing the direction of gaze, even though expression was the relevant dimension. This evidence converges with recent behavioural (Adams & Kleck, 2003) and neurological (Adams, Gordon, Baird, Ambady, & Kleck, 2003) data to suggest that when judgments of expression are required, the processing of expression and the processing of gaze are mediated by a single system at both a functional and neuroanatomical level of description (see Haxby et al., 2000, 2002).

But even though the processing of expression appears to be intimately related to the processing of gaze, the evidence from our experiments with inverted faces (particularly Experiment 4, which used only stimuli limited to the eye region) shows that unlike explicit judgments of expression, explicit judgments of gaze appear to be mediated by systems that do not depend on the normal configural processing associated with upright face perception. Specifically, our findings show that such judgments of gaze rely primarily on part-based computations and are therefore not affected by manipulations that are known to affect configural processing.

Taken together, our findings suggest that the idea of a single system mediating the processing of expression and gaze may be oversimplified. Indeed, it is possible that because the processing of expression is configural, computations of gaze that are part of such processing would also be affected by the same configural manipulations, such as inversion. Therefore, it is possible that the idea of a single system mediating the processing of expression and gaze is true only in situations in which expression is being processed. On the other hand, the part-based computations that are required for explicit gaze judgments are probably not mediated by the same system that mediates the processing of expression. However, additional research will be required to reveal the neural correlates of the part-based computations that are involved in judgments of gaze—and how these substrates relate to the gaze processing that occurs during judgments of expression.

One possible explanation for why previous studies that have focused on the processing of expression and gaze did not find differences between the nature of processing of these two dimensions, is that these earlier studies focused only on explicit judgments of expression, and did not include conditions in which judgments of gaze were required. By including both these conditions in the current study, we were able to unpack to some extent the relationship between the processing of gaze and the processing of expression. Indeed, our experiments provide the first direct evidence for a dissociation between the part-based processing of the direction of gaze and the configural processing of facial expression.

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