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Chimeric faces, visual field bias, and reaction time bias: Have we been missing a trick?

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The chimeric faces test is a frequently used behavioural test of lateralisation for cognitive processing. Performance on this task is typically quantified in terms of bias towards selecting faces where positive facial emotion is expressed in the viewer's left visual field, indicating right hemisphere dominance for the task. This paper examines an alternative measure that may be extracted from responses to the chimeric faces test: reaction time bias. There was a strong positive correlation between the two asymmetry measures, which remained even after controlling for sex and handedness. The possible uses of reaction time bias in the measurement of cerebral lateralisation are discussed.

The chimeric faces test has become a widely used behavioural test of cerebral lateralisation for face processing. In the chimeric faces test, participants are presented with vertically split chimeric faces. The most common form of the chimeric faces test uses faces in which one half expresses a positive emotion and one half expresses a neutral expression. Participants are presented with two chimeric faces, the original and its mirror image, one placed above the other (see Figure 1). They are then asked to decide which face looks "happier". Selecting the face in which the positive expression is in the viewer's left visual field is interpreted as right hemisphere dominance for the task. Conversely, selecting the face in which the positive expression is in the viewer's right visual field is interpreted as left hemisphere dominance for the task.

One of the earliest uses of chimeric face stimuli was with split brain patients (Levy, Trevarthen, & Sperry, 1972). In this study many forms of chimeric stimuli were used, including photographic images of faces, line drawings of objects, geometric patterns, and unfamiliar visual stimuli. Reliable differences were found when comparing responses to left visual field and right visual field chimeric stimuli, which was interpreted as

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Figure 1. Example of chimeric face stimuli. Here the top face is expressing positive emotion in the left visual field and the bottom face is expressing positive emotion in the right visual field.

reflecting a distinction between left and right hemispheric processing of stimuli. In terms of the chimeric face stimuli, participants were shown stimuli where each half face depicted a previously learned face and they then had to identify the person's face. Responses were dominated by the face represented in the left visual field. This asymmetric response bias was interpreted as reflecting the right hemisphere superiority for processing faces. Chimeric faces were subsequently used with non-clinical participants

(Levy, Heller, Banich, & Burton, 1983; Milner & Dunne, 1977) with a left visual field bias for chimeric face stimuli being replicated. The chimeric faces test has now become a widely used behavioural test of lateralisation for processing faces. The test has been used in a wide range of samples including participants ranging in age from 5 to 80 (Levine & Levy, 1986), various clinical populations (e.g., Ashwin, Wheelwright, & Baron-Cohen, 2005; Bava, Ballantyne, May, & Trauner, 2005; Gooding & Tallent, 2002) and across different cultures and reading habits (e.g., Heath, Rouhana, & Ghanem, 2005).

Studies using the chimeric faces test reliably find a left visual field bias, which is interpreted as right hemisphere dominance for processing positive facial emotion. The use of the chimeric faces test as an estimator of right hemisphere function has been validated in a study comparing performance of non-clinical control participants with patients who had suffered either unilateral left hemisphere or unilateral right hemisphere lesions (Kucharska-Pietura & David, 2003). Both non-clinical participants and patients with unilateral left hemisphere lesions showed a significant left visual field bias when inspecting chimeric face stimuli (which indicates right hemisphere dominance). In contrast, patients with unilateral right hemisphere lesions showed a significantly reduced left visual field bias, with performance actually showing a slight, although not significant, rightward bias. This finding has also been replicated in children with congenital unilateral brain damage (Bava et al., 2005), although this study also found that larger lesions were associated with more pronounced reduction in the "typical" left visual field (right hemisphere) bias. The pattern of right hemispheric dominance for a facial emotion processing task is consistent with the selective right hemisphere activation found when using functional neuroimaging techniques (e.g., Nakamura et al., 1999; Narumoto et al., 2001). A left visual field/right hemisphere bias has also been identified with alternative versions of the chimeric faces test that have used negative facial emotion and judgements of sex, age, and attractiveness (e.g., Burt & Perrett, 1997; Chiang, Ballantyne, & Trauner, 2000; Christman & Hackworth, 1993).

The chimeric faces test is typically scored according to the number of times the face chosen as "happier" was expressing the positive emotion in the viewers left visual field. Some studies analyse this measure of bias either in terms of the number or the percentage of left visual field responses (e.g., Bava et al., 2005; Burt & Perrett, 1997; Chiang et al, 2000). Other studies have calculated a laterality quotient from participants' responses (e.g., Bourne, 2005; Failla, Sheppard, & Bradshaw, 2003; Levine & Levy, 1986). The laterality quotient produces a score that ranges from -1 to $+1$. Negative scores represent a preference for faces in which positive emotion is expressed in the viewer's right visual field, therefore suggesting left hemisphere dominance for the task. Positive scores represent a preference for faces in which positive emotion is expressed in the viewer's left visual field, therefore suggesting right hemisphere dominance for the task. However, given that the laterality quotient is calculated from the number of left visual field responses, the two measures are perfectly correlated.

While a great many interesting findings have been made using the chimeric faces test, it is interesting that all analyses seem to be based on visual field response bias measures. It appears that no study to date has examined participants' reaction times to chimeric face stimuli. This is likely to be, at least in part, due to the tendency to administer the chimeric faces test in booklet format (e.g., Bava et al., 2005; Chiang et al., 2000; Failla et al., 2003). By adapting the chimeric faces test into a computerised form, it is possible to record both responses and reaction times to the chimeric face stimuli. Is the frequently observed left visual field advantage in response bias also evident in a reaction time bias?

It is possible that the reaction time bias measure may provide rather different results to the response bias. These two measures may be seen as analogous to reaction time and accuracy measures in many other experimental settings. Studies using behavioural measures of lateralisation, such as divided visual field and dichotic listening, have found lateralised effects for reaction times, but not necessarily accuracy (e.g., Bourne & Hole, 2006; Welsh & Elliott, 2001). Therefore, it is important to examine the possible contribution of a reaction time measure to the understanding of lateralised processing using the chimeric faces test. In many areas of psychology speed–accuracy trade offs have been reported. It is possible that when completing the chimeric faces test a similar contingency for responding may be adopted by participants (although none has been reported or examined). If this were the case, differences in reaction time and response bias might be expected. It may be that there will be a strong relationship between the two variables, with participants responding faster to decisions initiated by the dominant hemisphere. An alternative outcome is that there will be no relationship between the two measures; that people respond just as quickly to decisions initiated by their dominant hemisphere as to decisions initiated by their non-dominant hemisphere.

METHOD

A total of 81 participants took part in this study. Both left- and right-handers were included. Of these participants, 33 (41%) were left-handed (14 males, 19 females) and 48 (59%) were right-handed (23 males, 23 females). The mean age of participants was 23 years (18–59 years, $SD = 6.8$).

Handedness was recorded according to self-report. All participants completed a 14-item handedness questionnaire (adapted from Dorthe, Blumenthal, Jason, & Lantz, 1995). Each item was marked on a 7-point Likert scale from -3 (always with left hand) to $+3$ (always with right hand). Handedness scores were calculated by summing the item scores giving a final scale of -42 (strongly left-handed) to $+42$ (strongly right-handed). Left-handed participants had a mean handedness score of -20 ($SD = 17$). Right-handed participants had a mean handedness score of $+33$ ($SD = 7$). The handedness scores of the two handedness groups differed significantly, $t(79) = 20.9$, $p < .001$.

All participants completed a computerised version of the chimeric faces test (Levy et al., 1983). The chimeric faces were created by taking two photographs of an individual, one showing a neutral expression and the other showing a positive emotion (i.e., smiling). These images were then split vertically and a chimeric face formed where one half showed neutral emotion and the other half showed positive emotion. In each trial, participants were presented with two faces, one above the other. One face expressed positive emotion in the left visual field and the other expressed positive emotion in the right visual field (see Figure 1). The placement of the faces was randomised and counterbalanced across the experiment. Each participant completed 60 trials.

Participants were seated centrally to a laptop computer. For each trial they had to decide which face they thought looked "happier", either the top face or the bottom face. They were asked to respond intuitively and as soon as one face appeared to be happier than the other. Faces were presented in free vision and remained on screen until a response was made. Responses were made using the buttons on a laptop mouse pad. If participants thought the top face looked happier they clicked the left button, if they thought the bottom face looked happier they clicked the right button. Superlab 2.01 was used to control stimulus presentation and for recording participant responses. For each trial two measures were recorded: visual field of the face chosen as being "happier" (i.e., left visual field or right visual field) and reaction time in ms.

Two measures of lateralised bias were calculated. First, laterality quotients were calculated from the number of left visual field responses made providing scores ranging from -1 (always picking the face in the right visual field, which indicates left hemisphere dominance) to $+1$ (always picking the face in the left visual field, which indicates right hemisphere dominance). Second, mean reaction times were calculated for left visual field responses and right visual field responses separately. The difference between these two means was calculated to give a mean reaction time bias. A negative value represents a faster response for right visual field (left hemisphere) decisions, whereas a positive value represents a faster response for left visual field (right hemisphere) decisions. Hence, for both the laterality quotient measure and the reaction time bias measure, negative values indicate left hemisphere dominance for the task and positive values indicate right hemisphere dominance for the task.

RESULTS

Initial analysis examined the correlation between the laterality quotient and reaction time bias (see Table 1). There was a significant positive correlation between the two measures ($r = .389$, $p < .001$; see Figure 2). This indicates that participants who are right hemisphere dominant for the chimeric faces test, according to the laterality quotient, also make faster responses to left visual field (right hemisphere) decisions. This analysis suggests that both laterality measures provide concordant asymmetry results. Partial correlation between the two measures, controlling for sex and strength of handedness, revealed an even larger correlation ($r = .432$, $p < .001$).

While a relationship between the two laterality measures has been identified, a more detailed analysis of this relationship is necessary. This was achieved by means of regression analysis. First main effects were considered by entering laterality quotient, handedness score, and sex into the model as possible predictors of reaction time bias. Second, two interactions were entered into the model: laterality quotient by sex and handedness score by sex.

Laterality quotient was a significant predictor of reaction time bias ($\beta = 1087.5$, $t = 4.3$, $p < .001$). This result confirms and is consistent with the simple correlation analysis and Figure 2 showing that both measures provide concordant results. Sex was not a significant predictor of reaction time bias ($\beta = -217.8$, $t = -1.0$, $p = .333$) nor was handedness ($\beta = -2.2$, $t = -.6$, $p = .564$).

The interaction between sex and laterality quotient was not a significant predictor of reaction time bias ($\beta = 1.6$, $t = 0.1$, $p = .997$), nor was the

TABLE 1
Means (*SD*) for reaction times (ms) to left visual field (LVF) and right visual field (RVF) decisions, reaction time bias, laterality quotients, and handedness quotients

	Males		*Females*		
	Left-handed	*Right-handed*	*Left-handed*	*Right-handed*	*Total*
N	14	23	19	23	81
LVF reaction time	2240.29 (728)	2228.91 (1210)	3286.00 (1504)	2988.61 (1347)	2713.31 (1323)
RVF reaction time	2853.23 (1953)	2364.50 (1530)	3195.52 (1203)	3001.56 (1555)	2840.52 (1555)
Reaction time bias	612.93 (1694)	135.58 (563)	−90.48 (1226)	12.95 (885)	127.21 (1088)
Laterality quotient	−.04 (.3)	−.01 (.5)	.16 (.5)	.13 (.5)	.07 (.4)
Handedness score	−24.6 (12)	33.5 (6)	−18.0 (20)	33.0 (9)	11.2 (29)

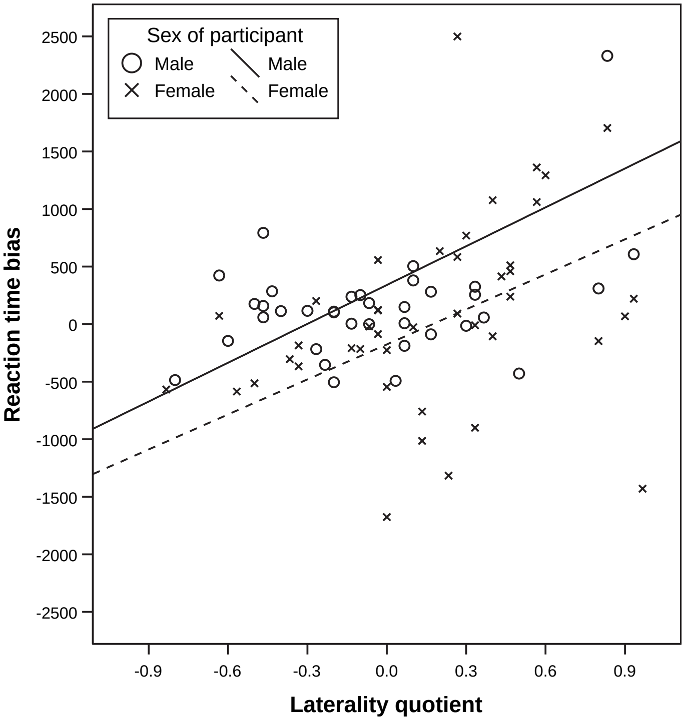

Figure 2. Scatterplot with best fit regression lines showing the relationship between reaction time bias and laterality quotient for males ($R^2 = .195$) and females ($R^2 = .179$) separately.

interaction between sex and handedness ($\beta = 10.6$, $t = 1.4$, $p = .173$). This suggests that the relationship between the two laterality measures is consistent across both sexes and regardless of strength of handedness.

DISCUSSION

This study has found that two measures of asymmetric bias in the chimeric faces test—response bias and reaction time bias—are significantly correlated. Whereas a left visual field advantage has been shown a great many times using various response bias measures, this is the first study to show a comparable bias in reaction times. Participants who showed a bias towards selecting chimeric faces with the positive expression in their left visual field as "happier" also made these decisions faster than right visual field decisions.

Sex was not a significant predictor of reaction time bias. Given that previous research has shown that males are more strongly lateralised than females using the chimeric faces test laterality quotient (Bourne, 2005), this is perhaps an unexpected finding. It is possible that this difference is due to the rather smaller sample size in this study than in the Bourne (2005) paper. However, inspection of the mean reaction time biases for males and females separately reveal a pattern that is consistent with the previously reported sex difference. Males had a mean reaction time bias that showed right hemisphere dominance which differed significantly from no bias (mean = 316.2, $SD = 1134.1$); $t(36) = 1.7$, $p = .050$. In contrast females showed no significant bias (mean = -31.7, $SD = 1034.6$); $t(43) = -0.4$, $p = .667$. Therefore, while the regression analyses did not show a significant sex effect, it appears that the data do show a trend in the predicted direction. This provides some validation that the bias is indeed measuring lateralised processes in the brain.

Handedness was not found to influence the chimeric faces test reaction time bias, either as a main effect or as an interaction with sex. This suggests that the chimeric faces test reaction time lateralisation measure does not vary according to handedness. Previous research measuring response bias from the chimeric faces test has compared responses from left- and right-handed participants. These studies have typically shown a reduced leftward response bias in non-right-handers (David, 1989; Harris, Almerigi, Carbary, & Fogel, 2001; Hellige et al., 1994; Luh, 1995). It might therefore have been predicted that the response time bias would reduce as a function of strength of handedness; however this was not apparent in the analyses. There are two possible sources of this discrepancy. First this study uses a reaction time bias measure of asymmetry whereas the previous studies all used response bias measures. Second this study used a continuous measure of handedness preference rather than dividing participants into discrete handedness groups.

While previous research has typically divided participants into subgroups (often two or three groups), in this study handedness was measured on a continuum. While this may provide some benefits, the simple summing of handedness item scores is not without disadvantages. Take, for example, a handedness score of 21. This score may represent two very different patterns of handedness. This score could be achieved with extreme right-handed (+3) scores on seven items and no preference (0) score on the remaining seven items. The same score could be achieved by the very different pattern of seven midpoint right-handed (+2) scores and seven weak right-handed (+1) scores. The use of a summed handedness score does not accurately reflect variability/consistency in handedness. There is no obvious way to account for this within the analysis; however analysis of subgroups of handedness types would not be subject to the same problem. Reanalysis of the regression using handedness groups (left- and right-handed participants) revealed the same relationship between the chimeric faces test reaction time and response bias, and there was no significant relationship between handedness group (either on its own or interacting with sex) and the reaction time bias measure.

The finding reported here suggests that both response bias and reaction time measures can provide a valid estimate of lateralisation on the chimeric faces test. It is interesting to consider how this finding about dependent variable measurement in the chimeric faces test might relate to alternative behavioural measures of lateralisation. While research using the chimeric faces test has been dominated by response bias measurement, studies using alternative behavioural measures of lateralisation typically consider both response (accuracy) and reaction time measures. Indeed, many have found speed of processing advantages for the dominant hemisphere in the absence of response bias (e.g., Bourne & Hole, 2006; Welsh & Elliott, 2001). As such, it may be suggested that consideration of both response and reaction time biases when using the chimeric faces test would bring the use of this paradigm into closer alignment with other behavioural measures, such as the divided visual field paradigm. Further, given that other behavioural measures of lateralisation have had a tendency to show effects in reaction time but not accuracy, it may be that the use of reaction time bias in the chimeric face test could reveal effects that are not apparent with response bias alone. While the data collected in this study do not allow for this possibility to be empirically tested, it is possible that the reaction time bias might provide further insights into lateralisation of the brain than could be achieved by response bias alone.

This study suggests that participants respond faster to stimuli presented in the left visual field than to those presented in the right visual field. This bias is consistent with there being a left visual field/right hemisphere dominance for processing positive facial emotion (e.g., Bourne, 2005). Although the data collected in this study cannot provide a definitive answer, the following question might be considered: Why might people respond faster when using their dominant hemisphere for a particular task? There are two possible interpretations of the increased reaction times when responding with the non-dominant hemisphere. First, it may be that the non-dominant hemisphere takes longer to process the face. Second, it may be that interhemispheric cooperation occurs, with information being transferred from the dominant hemisphere to aid processing and decision making. While it is impossible to distinguish between these possibilities with the current data set, there is evidence for interhemispheric cooperation when recognising familiar faces using the non-dominant hemisphere (Bourne & Hole, 2006). However, there is evidence that interhemispheric cooperation does not occur when processing unfamiliar faces (Mohr, Landgrebe, & Schweinberger, 2002), such as those presented in this experiment. There is also conflicting evidence regarding whether interhemispheric cooperation occurs when processing emotional face stimuli (compare Schweinberger, Baird, Blumler, Kaufmann, & Mohr, 2003; Tamietto, Corazzini, de Gelder, & Geminiani, 2006).

It is also interesting to consider alternative accounts of what the bias found in the chimeric faces test actually represents. Butler et al. (2005) conducted a study where participants examined single chimeric face stimuli while having their eye movements recorded. Butler et al. found a bias for looking at the left side of the chimeric face stimuli. This bias would mean that most of the face would be seen in the right visual field, and consequently projected to the left hemisphere. They suggest that this casts doubt on the right hemisphere dominance explanation for the left visual field bias in the chimeric faces test. While the eye movement patterns may have some influence on performance while completing the chimeric faces test, given the strong clinical evidence for the involvement of the right hemisphere in the perception of chimeric face stimuli (Bava et al., 2005; Kucharska-Pietura & David, 2003) it is unlikely that it provides a complete explanation. The leftward bias found in the chimeric faces test may also be explained in terms of leftward scanning biases that arise from experience reading script from left to right. Heath et al. (2005) examined directional bias on the chimeric faces test in participants who have only experienced left-to-right script (Roman script), who have only experienced right-to-left script (Arabic script), who have experience of both Roman and Arabic scripts, and in illiterate participants (i.e., no experience with directional script). Heath et al. concluded that, while script directionality can influence the magnitude of the leftward bias in the CFT, the leftward bias primarily reflects right hemisphere mechanisms. Therefore, it is unlikely that the reading and leftward scanning bias can entirely account for the leftward bias found in the chimeric faces test.

This paper examined a new measure of lateralisation using the chimeric faces test: a reaction time bias. This measure was found to be significantly correlated with the more typical response bias and it is concluded that both might be used to reflect asymmetries in processing positive facial emotion.

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