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**Relationship status and sex differences in emotion lateralisation: An examination contrasting the processing of emotional infant and adult faces**

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**Abstract**

When processing facial emotion, most individuals are right hemisphere dominant; however there is variability in this pattern with males typically being more strongly lateralised than females. Relationship status has been found to influence the processing of facial stimuli in women, and therefore, in this research the lateralised processing of facial emotion is considered whilst taking into account the participant's relationship status and sex. Using the chimeric faces test, with both infant and adult facial stimuli, it was shown that partnered participants, but not single participants, were more strongly lateralised for the processing of adult stimuli than infant stimuli, and that partnered women did not show any hemispheric bias. These findings suggest that the neuropsychological processing of emotion may change dependent on an individual's relationship status, and are discussed in terms of the possible evolutionary significance of infant faces for individuals who are in a relationship and who wish to have children.

**Keywords:** Chimeric Face Test; infant faces; relationship status; emotion lateralisation; valence.

## 1. Introduction

Emotional face processing is typically lateralised, with the right hemisphere being dominant (Gazzaniga, 2000). However, there is some variation in this pattern. There is evidence for a sex difference with males being more lateralised than females (Bourne, 2005). However, this sex difference is not consistently reported in previous research. For example, it has been found that males are more lateralised to the right hemisphere only when emotions are displayed on male faces (Rahman & Anchassi, 2012). Psychological gender identity has also been linked to hemispheric specialisations for processing emotive faces, with masculinity being associated with stronger patterns of lateralisation, for males but not females (Bourne & Maxwell, 2010). Whilst there is accumulating evidence for males being more strongly lateralised than females, there are clearly other variables that may mediate this effect. In this study we consider whether relationship status might influence the magnitude of the sex difference.

Current relationship status may influence the processing of facial stimuli, particularly in women at certain phases across the menstrual cycle. Little et al. (2008) presented pairs of male faces, one of which was manipulated to look more masculine than the other, and asked partnered and single women to choose the face that they perceived to be more attractive. Although all women found more masculine male faces more attractive, women without a partner chose a similar percentage of masculine male faces during high and low fertility phases, whereas partnered women chose significantly more masculine male faces during the high fertility phase compared to low fertility phase. Little et al. suggested that, during the follicular phase, partnered women are at a higher risk of conception than single women, and therefore favour masculine features, which may be passed onto their offspring.

Conway et al. (2010) examined the influence of direct and indirect gaze in facial stimuli. They found that women preferred faces with a direct gaze, indicating social interest, but the results were more apparent for women who were not in a relationship when examining feminised male faces and judging them as a possible long-term partner. Such findings indicate that the way in which women process facial stimuli is influenced by their own relationship status. Additionally, Watkins (2012) found that the preference for masculine male faces was stronger for partnered women who had a greater desire to become pregnant, suggesting that being in a romantic relationship and thinking about future offspring modulates a woman's processing of facial stimuli. Whilst it is clear that a woman's relationship status can influence their processing of facial stimuli, it is unknown whether there is a neural basis to these effects, such as variability in brain lateralisation. One previous study has examined lateralisation for processing word stimuli in middle aged participants who were either married or not, and found no laterality effects (Fussell et al., 2012). However, to date there is no evidence for variability in lateralisation for processing emotive faces according to relationship status.

There are two main hypotheses regarding emotion lateralisation. According to the right hemisphere hypothesis, the processing of all emotions is lateralised to the right hemisphere (Borod, 1992). According to the valence hypothesis, negative emotions are processed in the right hemisphere while positive emotions are processed in the left hemisphere (Davidson, 1992). Emotion lateralisation is frequently measured with the chimeric faces test (Levy et al., 1983; Bourne, 2010). Participants are shown vertically split chimeric faces, with one half face expressing an emotion (e.g. anger) and the other half being neutral. Two chimeras are presented on top of each other. One of the chimeras expresses an emotion on the left side of the face and the other one expresses an emotion on the right side of the face. Participants have to decide which chimera looks more emotive. Typically participants show a bias towards faces expressing emotion in the left half face, reflecting the right hemisphere superiority for the processing of facial emotion (Bourne, 2010).

In previous research, chimeric faces stimuli are typically created using images of adult posers, such as the Ekman stimuli (Workman et al., 2006, Bourne, 2010) or the Levy stimuli (Levy et al., 1983). Little research has considered whether patterns of lateralisation might differ when processing emotional expressions of infant faces, and whether men and women might process infant and adult emotional expressions differently in the brain. A sex difference has been reported in an ERP study of the hemispheric processing of infant faces (Proverbio, Brignone, Matarazzo, Del Zotto, & Zani, 2006). Whilst the ERP response to infant faces tended to be earlier and larger for women, males had more asymmetric responses, showing the typical right hemisphere dominance (e.g., Bourne, 2005; Bourne & Maxwell, 2010). Barth, Boles, Giattina and Penn (2012) used facial stimuli from children aged between five and twelve years old, and adult participants had a significant right hemisphere bias for the processing of these stimuli, which was significantly correlated with the adult version that was developed by Levy et al (1983). However, both versions only used happy-neutral chimeras, and the facial stimuli were of children, not infants. Best and Queen (1989) developed a set of chimeric face stimuli from infants aged between seven and thirteen months. When asked to judge the intensity of the emotional expressions on single chimeric faces on infant faces, they found a right hemiface bias for smiling, but not for crying expressions. In a subsequent study, Best et al. (1994) used these stimuli to create a two face version of the chimeric faces test, where participants are asked to judge which of a pair of chimeric face stimuli is more emotive. They found a significant left hemiface (right hemisphere) bias for the infant stimuli, particularly for faces with a negative emotional expression. More recently, Proietti et al. (in press) formed chimeric faces from infants aged 3-4 days old with a neutral expression, and used these in a paradigm where individual unmanipulated target faces had to be matched for identity to one of two probe chimeric faces. In adult participants, they found a significant left visual field (right hemisphere) bias for both adult and infant faces, although the bias was significantly stronger for adult faces than for infant faces. In children, aged about five years old, these biases were reduced, and for the adult stimuli they were still significant, whereas for the infant stimuli there was no significant visual field bias.

Such findings indicate that the lateralised neuropsychological processing of infant emotive faces may differ according to the age of the poser in the stimuli and the sex of the viewer. The present study will additionally consider whether these biases vary according to relationship status. To date no research has considered whether the lateralised processing of infant faces may vary according to relationship status. However, there are sex differences in the lateralised processing of infant faces (e.g., Proverbio et al., 2006) and that partnered women process faces differently from single women (e.g., Watkins, 2012). It is therefore possible that patterns of lateralisation for the processing od emotive faces, and specifically infant faces, will differ between partnered women, single women, and men.

A sex difference is often observed in emotion lateralisation with males being more strongly lateralised to the right hemisphere than females (Bourne, 2005; Bourne & Maxwell, 2010). Females are often found to be more accurate with processing emotional faces than males (e.g., Hampson et al., 2006; McClure, 2000), however the reason for this is unclear. These differences may result from neuropsychological differences in the lateralised processing of facial emotion between males and females (e.g., Bourne, 2005; Bourne & Maxwell, 2010). The current study aims to further examine the sex difference in emotion lateralisation by considering whether relationship status influences emotion hemispheric lateralisation. Since partnered women have been found to process faces differently to single women (Little et al, 2008; Watkins, 2012), it is predicted that relationship status will influence emotion lateralisation with the typical patterns of hemispheric asymmetry being exaggerated in individuals who are in a relationship. It is also possible that the sex difference may be influenced by whether infant or adult faces are being processed.

## 2. Methods

### *2.1. Participants*

A sample of 200 people (99 males, 101 females) participated in the study. Participants were undergraduate or postgraduate students and were recruited through opportunity sampling. None had any children. Mean age was 21.5 years old (SD=3.1, range 18-40). All participants reported being right-handed and this was confirmed with a handedness questionnaire (Dorthe, Blumenthal, Jason & Lantz, 1995). The questionnaire contained 14 items about hand preference for various tasks and each item was scored on a seven-point Likert scale from -3 (always with left hand) to +3 (always with right hand), giving a total score between -42 (strongly left handed) and +42 (strongly right handed). Mean handedness score in the sample was 31.1 (SD=7.1, range 11-42). None of the participants reported having any head injuries, neurological or clinical disorders, as assessed by means of a self-report questionnaire. Vision was either normal or corrected to normal. Power calculations gave a minimum total sample size of 52 with a medium effect size, power of .95 and estimated correlations of .5 between repeated measures.Ethical approval was granted by the Departmental Ethics Committee.

### *2.2. Adult and Infant Chimeric Face Tasks (CFT)*

The adult trials in the chimeric faces test used the stimuli developed by Workman and colleagues and using the Ekman emotional face stimuli (Ekman, 1993; Workman et al., 2000). Male and female emotional faces expressing happiness (positive valence) or sadness (negative valence) were used to create adult chimeric stimuli. Infant chimeric faces were created from infant face stimuli used elsewhere (Kringelbach et al., 2008; Parsons et al., 2011) and had either positively or negatively valenced emotional expressions. Chimeric faces of both ages were created and presented in the same way.

Emotional faces were vertically split and paired with a neutral half face from the same poser. Thus, one side of the face expressed an emotion while the other side remained neutral. Two mirror images of the face, one with an emotional right hemiface and one with an emotional left hemiface, were presented simultaneously one above the other (see Figure One). The order of placement (i.e., left hemiface top or bottom) was counterbalanced and randomised across trials. Faces subtended 4.5° horizontally and 7° vertically at a viewing distance of 52 cm and were presented in greyscale on a white background in the middle of the computer screen.

[Insert Figure One about here]

Participants completed 24 trials for each emotional valence for infant and adult faces. Each of the four blocks (adult positive and negative, infant positive and negative) was presented in a randomised order that differed across participants. In each trial, participants were asked to make intuitive decisions of which face looked more emotive (e.g. happier). On the keyboard, an arrow up was pressed for top faces and an arrow down was pressed for bottom faces. The faces remained on the screen until the decision was made. Chimeric face laterality quotients (Bourne, 2008) were calculated for each of the four conditions, with possible scores between -1 and +1. Positive scores indicated a right hemisphere (left visual field) bias while negative scores showed a left hemisphere (right visual field) bias.

### *2.3. Relationship status*

Relationship status was determined by means of a self-report questionnaire. Participants who were married, co-habiting or classed themselves as being in a relationship were placed into the "partnered" group. All participants who responded that they were single were in the "single" group. Female participants were also asked about their menstrual cycle and whether they were taking the contraceptive pill, however the numbers within each group were too low for and reasonable analyses to be conducted.

### *2.4. Design and analysis*

Initial analyses used one-sample t tests to compare laterality quotients to 0 (i.e., no hemispheric bias). The main analysis used a 2 (valence: positive or negative, repeated measures) x 2 (face age: adult or infant, repeated measures) x 2 (sex: male or female, independent measures) x 2 (relationship status: single or partnered, independent measures). Any significant interactions were broken down using planned simple contrasts that controlled for familywise error.

## *3.* **Results**

### *3.1. Initial analyses*

One-sample t tests (see Table One) showed a significant right hemisphere bias for all four conditions for all participants, and for both male and female single participants. Partnered males also had a significant sight hemisphere bias across all four conditions, but partnered females did not. Laterality quotients were significantly and positively correlated (all r's $\geq$ .573, all p's $<$ .001).

*3.2. Primary ANOVA analysis*

There was a significant main effect of valence ($F(1, 196) = 4.7$, $p = .016$, partial $\eta^2 = .024$), with a stronger right hemisphere bias for negative stimuli (M = .24, SE = .04) than for positive stimuli (M = .19, SE = .04). There was no significant main effect of face age ($F(1, 196) = 1.6$, $p = .103$, partial $\eta^2 = .008$), sex ($F(1, 196) = 1.4$, $p = .117$, partial $\eta^2 = .007$) or relationship status ($F(1, 196) = 1.3$, $p = .126$, partial $\eta^2 = .024$).

There was a significant two-way interaction between valence and sex ($F(1, 196) = 3.0$, $p = .043$, partial $\eta^2 = .015$). For males there was a significant difference (p = .005), with negative emotions more right hemisphere lateralised (M = .30, SE = .05) than positive emotions (M = .21, SE = .05). For females there was no significant difference (p = .369; positive: M = .17, SE = .05; negative: M = .18, SE = .05).

The two-way interaction between face age and relationship status was significant ($F(1, 196) = 4.5$, $p = .018$, partial $\eta^2 = .023$; see Figure Two left). For participants not in a relationship, there was no significant difference between infant and adult stimuli (p = .242). For partnered participants, laterality quotients indicated a significantly stronger right hemisphere bias for adult faces than for infant faces (p = .017).

There was also a significant two-way interaction between relationship status and sex ($F(1, 196) = 3.2$, $p = .025$, partial $\eta^2 = .020$; see Figure Two right). For single participants there was no significant sex difference ($p = .259$), whereas for those in a relationship, males were more strongly lateralised to the right hemisphere than females ($p = .024$).

There were no significant two-way interactions between valence and relationship status ($F(1, 196) = 0.2$, $p = .311$, partial $\eta^2 = .001$), stimuli age and sex ($F(1, 196) = 1.8$, $p = .089$, partial $\eta^2 = .009$) or between stimuli age and valence ($F(1, 196) = 0.1$, $p = .394$, partial $\eta^2 = .001$). None of the three-way interactions were significant: valence * relationship status * sex ($F(1, 196) = 0.8$, $p = .184$, partial $\eta^2 = .004$), stimuli age * relationship status * sex ($F(1, 196) = 0.3$, $p = .283$, partial $\eta^2 = .002$), valence * stimuli age * relationship status ($F(1, 196) = 0.6$, $p = .226$, partial $\eta^2 = .003$), valence * stimuli age * sex ($F(1, 196) = 0.3$, $p = .286$, partial $\eta^2 = .002$). Finally, the four-way interaction between valence, stimuli age, relationship status and sex was not significant ($F(1, 196) = 0.5$, $p = .252$, partial $\eta^2 = .002$).

## 4. Discussion

This study replicated the findings that the processing of facial emotion is more strongly lateralised to the right hemisphere for males than for females (e.g., Bourne, 2005; Bourne & Maxwell, 2010), however only for participants in a relationship. For individuals who were single, there was no significant sex difference in strength of lateralisation for the processing of emotive faces.

Additionally, the processing of emotive adult faces was significantly more strongly lateralised to the right hemisphere than infant faces, but only for participants in a relationship.

The finding that emotion lateralisation differs according to both sex and relationship status suggests that the sex difference may not be as simple as a clear dichotomisation. Indeed, it has been shown that the sex difference is mediated by psychological masculinity in males (Bourne & Maxwell, 2010), and therefore a complex mix of variables may influence whether the sex difference is either enhanced or reduced. If the sex difference in lateralisation results numerous underlying factors, this may explain the lack of consistency in previous work (cf. Bourne, 2005; Hirnstein et al., 2013). Perhaps in the future, researchers should attempt to move beyond the simple dichotomisation of sex differences, and instead consider a wider range of variables.

One possible explanation for the relationship status dependent sex differences might be that males and females differentially engage with these stimuli according to whether they are in a relationship or not, and therefore there are differences in lateralised processing. It has been suggested that the human brain has evolved to be hypersensitive to stimuli that have a high degree of biological relevance. Brosch, Sander and Scherer (2007) showed participants positively and negatively valenced facial stimuli using a dot probe task to assess attentional biases. Participants were shown two stimuli, one in each visual field, and then asked to report whether an unrelated target dot was then shown in the left or right of the screen. They found that attentional capture was greater for baby faces than for adult faces when the face stimuli were presented to the left visual field, suggesting right hemisphere sensitivity to biologically relevant stimuli. They did not find any sex differences in this hemispheric attentional bias, and they provide no clear explanation for this. However, our study suggests a sex difference in this hemispheric bias, but only for individuals in a relationship. It may therefore be the case that females are predisposed towards prioritising the neuropsychological processing of biologically relevant stimuli, such as a distressed infant. Such an argument suggests that a females neuropsychological processing of infant faces and emotive stimuli is adapted to confer an advantage for child rearing. In our sample none of the participants had children, and this possibility could be examined further in future research.

In this study, the different patterns of lateralisation according to the valence of the emotional expression differed for males and females. A difference between laterality quotients for processing positive and negative facial expressions was only found for males. Whilst the finding of a valence dependent effect might appear to lend support for the valence hypothesis (Davidson, 1992) of emotion processing, the laterality quotients tend to provide strong support for the right hemisphere hypothesis (Borod, 1992). When looking at all participants together, there were significant left visual field biases for all four versions. When broken down according to the sex and relationship status of the participants, the bias was significant for all males and for females who were single. However, none of the laterality quotients in any condition were negative, and therefore do not reflect a left hemisphere advantage for any version. These findings do suggest that there is some variability in strength of lateralisation for processing different emotions depending on the expression, and this is not inconsistent with the previous research using the chimeric faces test (Bourne, 2010). However, the findings are still markedly more consistent with the predictions of the right hemisphere hypothesis than the valence hypothesis.

There was a significant interaction between face age and the participant's relationship status, for those not in a relationship, there was no difference in hemispheric bias between adult and infant chimeras, whereas for those in a relationship, they were significantly more right hemisphere dominant for the processing of adult stimuli than infant stimuli. This may suggest that the neuropsychological processing of adult and infant faces differs in people who are in a relationship, possibly due to children being of greater evolutionary significance to partnered individuals. Such a finding is consistent with previous research that has shown menstrual cycle effects on the processing of facial masculinity in partnered women only (Little et al., 2008). Further the bias towards preferring masculine faces is greater in partnered women who wish to become pregnant (Watkins, 2012). Our findings suggest that there may be a neuropsychological basis to the changes in face processing in single and partnered individuals. Interestingly, we did not find that face age interacted with the sex of the participant, suggesting that both males and females may experience the same changes in the processing of faces when single or in a relationship.

Whilst this study has shown that the lateralised processing of facial stimuli may differ according to relationship status, it is interesting to consider why this might be the case. There is a wide range of evidence for functional lateralisation fluctuating across time, rather than being a fixed functional process. For example, hemispheric superiority varies according to hormonal variations (Hwang et al., 2009) and levels of depression (Bourne & Vladeanu, 2013; Fu et al., 2008). Our findings suggest that strength of lateralisation for the processing of emotive faces may also fluctuate according to an individual's relationship status, however the mechanism by which this occurs is still unclear.

This study considered patterns of lateralisation for the processing of positive and negative emotional expressions on infant and adult facial stimuli, whilst also taking into account possible sex differences and relationship status. We found that partnered participants, but not single participants, were more strongly lateralised for the processing of adult stimuli than infant stimuli, and that partnered women did not show any hemispheric bias. These findings suggest that the neuropsychological processing of emotional stimuli may vary according to an individual's relationship status, which may have an evolutionary significance with regards to possible child rearing. In future research, it may be interesting to consider the individual's desire to have a child, in addition to their relationship status.

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**Figure 1:** Example stimuli from the infant version of the chimeric faces test. The left pair shows an infant expressing a positive emotional expression in the left half face in the top stimuli. The right pair shows an infant expressing a negative emotional expression in the left half face in the bottom stimuli. For examples of the adult stimuli used, please see Bourne (2010).

**Figure Two:** Interactions between relationship status and age of stimuli (left) and between relationship status and sex (right). Error bars represent ± 1 standard error.

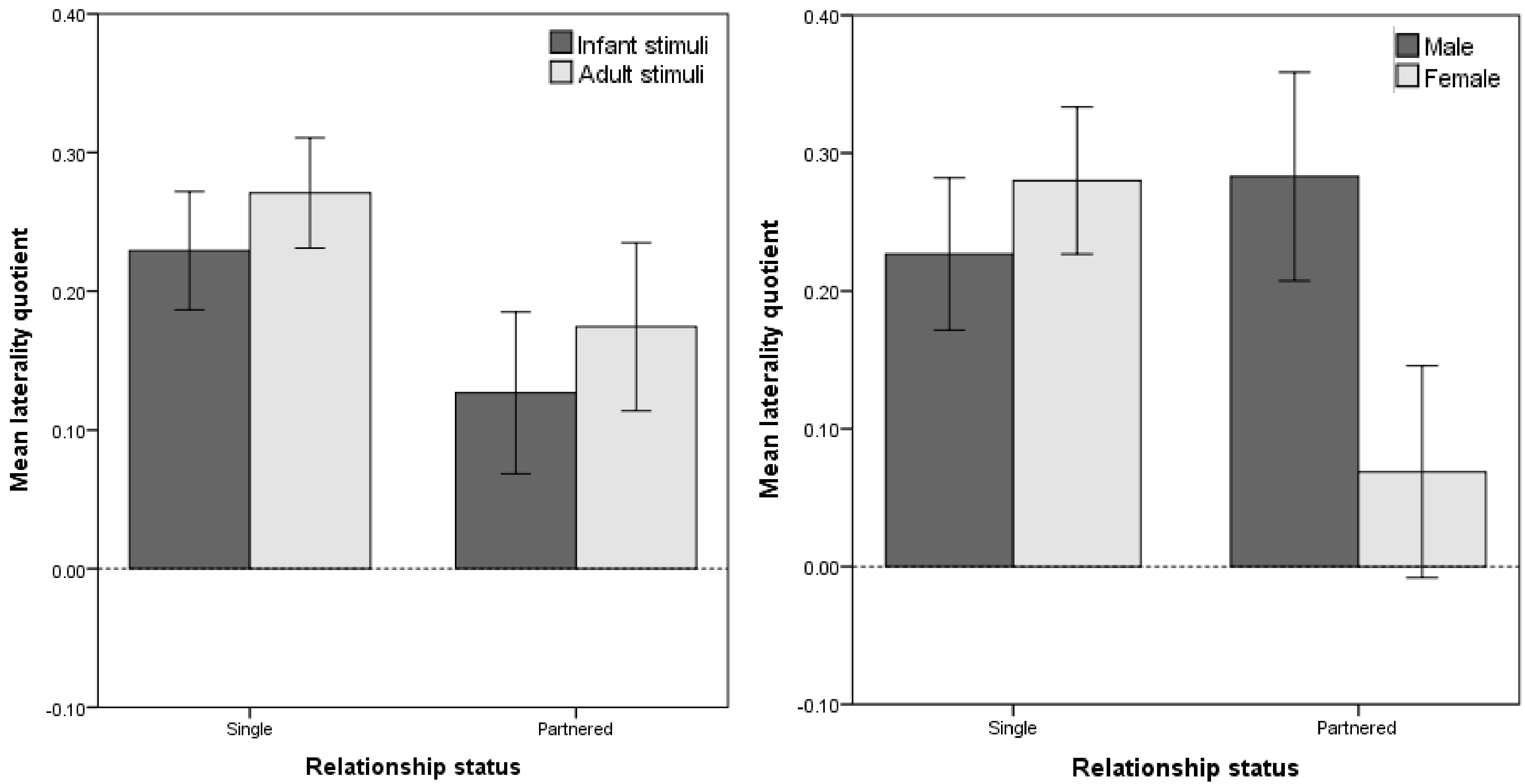

**Table One:** Descriptive statistics, one-sample t tests and independent measures t tests for laterality quotients.

| | Infant | | | | Adult | | | |
|---|---|---|---|---|---|---|---|---|
| | Positive | | Negative | | Positive | | Negative | |
| | M (SD) | t | M (SD) | t | M (SD) | t | M (SD) | t |
| All participants (N = 200) | .18 (.55) | 4.6*** | .20 (.53) | 5.4*** | .23 (.60) | 5.4*** | .24 (.47) | 7.2*** |
| Single participants (N = 124) | .23 (.53) | 4.9*** | .22 (.52) | 4.8*** | .30 (.57) | 5.8*** | .25 (.45) | 6.1*** |
| Partnered participants (N = 76) | .08 (.57) | 1.3 | .17 (.54) | 2.8** | .12 (.65) | 1.6 | .23 (.50) | 4.0*** |
| Male participants (N = 88) | .22 (.54) | 4.1*** | .19 ( .54) | 3.4** | .30 (.58) | 5.1*** | .27 ( .45) | 6.0*** |
| Male single participants (N = 70) | .24 (.57) | 3.5** | .16 (.57) | 2.3** | .29 (.59) | 4.2*** | .22 (.44) | 4.2*** |
| Male partnered participants (N = 29) | .19 (.45) | 3.5** | .25 (.44) | 5.1*** | .30 (.58) | 4.0*** | .39 (.45) | 4.4*** |
| Female participants (N = 88) | .13 (.56) | 2.4** | .22 (.53) | 4.2*** | .16 (.62) | 2.6** | .21 (.49) | 4.3*** |
| Female single participants (N = 54) | .23 (.48) | 2.3* | .31 (.45) | 3.1** | .30 (.55) | 2.8** | .28 (.46) | 4.7*** |
| Female partnered participants (N = 47) | .02 (.62) | 0.2 | .12 (.59) | 1.4 | .01 (.66) | 0.1 | .13 (.52) | 1.8 |