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Individual Differences in Cognitive Performance Due to Right Hemisphere Arousal

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The purpose of this study was to investigate the relationship between individual differences in cognition and asymmetric patterns of cortical arousal in normal right-handed adults. Leftward asymmetry on a chimeric faces task was correlated with the ability to recognise faces and facial expression, and certain aspects of social skill. The correlation with face and emotional expression recognition was significant only for subjects who reported using a non-verbal strategy. These results further support the role of the right hemisphere in various aspects of social cognition, but also point to the need to consider individual differences in strategies employed during task performance.

INTRODUCTION

The role of the right cerebral hemisphere in recognising faces and facial expression is well-established. Damage to the right hemisphere (RH) leads to greater deficits in face recognition than damage to the left hemisphere (LH) (Etcoff, 1984; Hecaen & Angelergues, 1962; Warrington & James, 1967). Neuroimaging studies have shown activation of the occipito-temporal cortex and parahippocampal gyrus, with greater activation on the right, in normal subjects performing face recognition tasks (Gur et al., 1997; Gur, Skolnick, & Gur, 1994; Sergent, Ohta, & MacDonald, 1992). Normal subjects also show a left visual field (LVF) advantage in recognising tachistoscopically presented pictures of faces (Leehey & Cahn, 1979; Levine & Koch-Weser, 1982; Rizzolatti, Umilta, & Berlucchi, 1971; Suberi & McKeever, 1977). Other studies have shown that the ability to recognise emotional expression in faces is also dependent on the

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RH, and that the RH specialisation for recognising emotional expression may be dissociable from its role in recognising facial identity (Etcoff, 1984; Fried et al., 1982; Gur et al., 1994; Laurian, Bader, Lanares, & Oros, 1991; Suberi & McKeever, 1977).

It is also well established that when asked to judge which of two chimeric faces (faces with one side smiling and one side showing a neutral expression) is happier, most right-handers show a preference for the face with the smile to their (the viewer's) left (Banich, Elledge, & Stolar, 1992; Borod, Vingiano, & Cytryn, 1989; Christman & Hackworth, 1993; Heller, Nitschke, & Lindsay, 1997; Hellige, Bloch, & Taylor, 1988; Hoptman & Levy, 1988; Levy, Heller, Banich, & Burton, 1983a; Luh, Rueckert, & Levy, 1991; Moreno, Borod, Welkowitz, & Alpert, 1990; Wirsen, Klinteberg, Levander, & Schalling, 1990). This asymmetry can be found even when the faces are presented in free vision, and is believed to be due to the fact that performing an emotional expression task results in an increase in neural activity and blood flow in the RH. This RH arousal causes a bias of attention to the left side of space, which means that participants will pay more attention to the side of the face to their left (Levy et al., 1983a,b).

Although approximately 85% of all right-handed subjects show this leftward bias, there is substantial individual variation in the strength of the asymmetry. These individual differences do not seem to be due to random error variability; they are extremely reliable and consistent over time. Despite the reliability of these individual differences, very little is known about their functional significance. Levy and her colleagues (1983a) have hypothesised that individual differences in asymmetry on the chimeric faces test (CFT), and other lateralised tasks, may reflect stable differences in characteristic hemispheric arousal asymmetry. In other words, some people tend to utilise their RH more than their LH, or vice-versa. These individual differences are thought to be superimposed on asymmetries due to the nature of the task. In support of this hypothesis, several studies have reported positive correlations between asymmetry scores obtained on a wide variety of tasks, even when the tasks are lateralised to opposite hemispheres (Kim & Levine, 1991; Ki, Levine, & Kertesz, 1990; Levine, Banich, & Koch-Weser, 1984; Levy et al., 1983a). Thus, someone who exhibits a greater than average leftward bias on the CFT would be expected to show a smaller than average right visual field (RVF) advantage on a verbal task, suggesting that that person tends to differentially engage the RH more than the LH across all tasks. However, some studies have not found positive correlations between asymmetry scores (Hellige et al., 1988, 1994), suggesting that these individual differences in characteristic arousal asymmetry may be to some extent task-dependent. This is also supported by studies by Luh and her colleagues (Luh et al., 1991; Luh, Redl, & Levy, 1994) who administered several different types of chimeric tasks. Despite the fact that asymmetries on all tasks tended to correlate positively with each other, stimuli that were more similar to each other showed higher correlations, suggesting that arousal asymmetries elicited by these tests are to some extent task-specific. (For further discussion of this issue, see Boles, 1998.)

One obvious question is whether these individual differences in characteristic arousal asymmetry have implications for cognitive performance. One might expect that people with relatively greater RH arousal would show better performance on cognitive tasks involving RH processing, and perhaps worse performance on tasks requiring LH processing. Several studies have suggested that this may be the case. In a PET study, Gur and his colleagues (1994) found that subjects with greater right parietal activation (relative to left parietal) were better at discriminating sad faces, and subjects with greater left frontal activation were better at discriminating happy faces. In a follow-up, Gur et al. (1997) reported that subjects who showed greater rightward asymmetry in the parahippocampal gyrus during a face recognition task showed better performance on the task. Other studies have reported that subjects who show a greater than average leftward bias on the CFT require shorter exposure durations on a tachistoscopic face recognition task (Levine, Banich, & Koch-Weser, 1988), perform better on a separate non-lateralised test of face recognition (Banich et al., 1992), and show higher self-reported levels of arousal on the Profile of Mood States (Heller et al., 1997).

In addition to facial and emotional recognition, the RH has been implicated in other aspects of social communication. Despite the recent revival of interest in the measurement of social skills and "emotional intelligence" (Goleman, 1995; Mayer & Salovey, 1997; Rosenthal et al, 1977), the neuropsychology of social skills, beyond the measurement of face and prosody recognition, has received very little attention. Recently, several authors have identified a type of "non-verbal learning disability" in children that is characterised by poor visuo-spatial and social skills. These children typically show deficits in perceiving and/or expressing emotion through facial expression, prosody, and gesture. Most of these children show some sign of RH abnormality (Denckla & Rudel, 1978; Rourke, 1982, 1995; Semrud-Clikeman & Hynd, 1990; Voeller, 1986; Weintraub & Mesulam, 1983).

Furthermore, Lane, Kivley, DuBois, Shamasundara, and Scharz (1995) found a significant correlation between asymmetry on the CFT and the "level of emotional awareness". The task they used required participants to verbally describe the emotions that would be felt in certain situations. It involved a written description of various "scenes" involving two people. The participant was asked to report how he/she would feel in that situation, and how the other person would feel. Answers were scored according to the complexity of the emotions reported (e.g. the number of emotion words). They found that participants with a stronger leftward bias (reflecting greater arousal of the RH) on the CFT gave richer and more detailed descriptions of the emotions that would be felt.

Alexithymia is a disorder characterised by impaired ability to verbalise affect and a paucity of fantasy that is often associated with psychosomatic disorders and post-traumatic stress disorder (Sifneos, 1972; Taylor, 1984). Several authors have suggested that alexithymia may be associated with a disorder in RH processing. For example, Jessimer and Markham (1997) found that normal subjects who scored high on an alexithymia scale showed a reduced leftward bias on several chimeric tasks, and Berenbaum and Prince (1994) found that normal undergraduates who scored extremely high on an alexithymia scale showed diminished leftward biases on the CFT.

Together, the results of these studies suggest that strong leftward asymmetry on the CFT is associated with superior performance on tasks thought to be lateralised to the RH. However, most of the significant correlations reported have been for tasks involving either face recognition, or some type of emotional processing. According to the hypothesis proposed by Levy and her colleagues (1983a), RH arousal should also be associated with superior performance on other RH tasks, such as non-facial visuo-spatial processing, and with *inferior* performance on LH tasks. Here the evidence is not as straightforward. Kim and his colleagues (1990) found no correlation between RH arousal and performance on tests of digit span, mental rotation, face recognition, verbal fluency, and verbal analogy. Banich and her colleagues (1992) found a non-significant correlation in the expected direction between the CFT and tasks thought to involve the LH (reading comprehension and verbal fluency). They suggested that the CFT may more reliably predict the *difference* between performance on RH and LH tasks, as scores on either type of task alone would be likely to include some variation due to general intelligence, which is not thought to be related to lateral asymmetries.

Another factor that has not been addressed in previous studies, but may turn out to be important, is individual variability in strategies used during task performance. Many tasks, particularly those believed to rely on the RH, can actually be performed by either hemisphere. It is possible that even among normal, non-lesioned adults, some will choose a strategy that relies on the LH. If these individuals were utilising their RH for the CFT, but their LH for the other task in question, little, if any, correlation would be expected.

METHOD

Participants

A total of 100 right-handed participants (23 men and 77 women) were recruited from Northeastern Illinois University by flier, and were paid six dollars for participation. Initial phone interviews screened potential subjects for attention deficit hyperactivity disorder, dyslexia, epilepsy, stroke, head injury (involving a loss of consciousness longer than five minutes), and any other neurological disorders. Handedness was assessed with a 10-item questionnaire (Oldfield, 1971). Ages ranged from 18 to 56, with a mean of 28.42 years. Most participants were psychology majors.

Materials

All participants were administered the following tasks:

Levy Chimeric Faces Task. (Levy et al., 1983b.) All participants were given a modified version of the CFT. The original task consisted of 36 pairs of chimeric faces, with one pair arranged vertically on each page. The chimeras were constructed by taking two pictures of one person, one in which they were smiling and one in which their expression was neutral. Each picture was cut in half through the vertical midline, and chimeras were formed by joining one smiling half with one neutral half. A mirror image photo was then taken of each chimera. Each pair of faces consisted of one original chimera, paired with its mirror image. Half of the pairs had the chimera with the smile to the participants' left on the top and the one with the smile to the right on the bottom. The other half of the items had the smile-left chimera on the bottom. Participants were asked to indicate which chimera, the one at the top of the page or the one at the bottom, appeared happier. They were not allowed to indicate that the two chimeras were equally happy. Because pilot data suggested that the lateral bias for this task increases with number of items, the number was doubled to 72 (i.e. each pair from the original appeared twice).

Benton Faces Task. (Benton, Hamsher, Varney, & Spreen, 1983.) This task consists of 22 black-and-white photographs of target faces. For the first six, participants must choose one of six alternative photos that matches the target. For the other 16 photos, participants must choose three of six alternatives that match the target. The correct choices are not exact replicas of the target, but have been altered in perspective or shading. Performance on this task is especially impaired by damage to the posterior RH (Benton et al., 1983).

Sherman Test of Facial Affect Recognition. (Sherman, 1994.) This task was designed to measure the ability to recognise facial expression in the same way that the Benton measures the ability to recognise facial identity. It consists of 20 items. Like the Benton, for each item there is one black-and-white photograph of a face at the top, and six photographs below. For the first six items the participant is asked to indicate which of the six faces on the bottom is exhibiting the same emotional expression as the one on top. For items 7–20 the participant is asked to choose three photos from the bottom that match the expression of the photo on the top. The photos that make up the six alternatives are never of the same person as the one in the top photograph. The emotions depicted are happy, sad, angry, disgust, surprise, fear, and neutral. Due to unavailability of the test, it was only given to 74 participants.

This test was designed to measure the ability to match facial expression without using a verbal label. However, several subjects reported that they found it difficult to perform without giving a verbal label to the expression. Therefore, after the test was over, some of the subjects were asked to indicate the extent to which they used a verbal label to make the match (always, sometimes, or never).

Social Skills Inventory. The SSI is a 90-item self-report inventory developed by Riggio (1986) to measure social communication skills. It consists of six scales that measure communication skills on two levels—emotional and social. Both levels have three scales—expressivity, sensitivity, and control. *Emotional Expressivity* (EE) measures the skill with which individuals communicate non-verbally, particularly in sending emotional messages, but it also includes the non-verbal expression of attitudes, dominance, and interpersonal orientation. A representative item: "I have been told that I have expressive eyes". *Emotional Sensitivity* (ES) measures skill in receiving and interpreting the non-verbal communication of others. A representative item: "It is nearly impossible for others to hide their true feelings from me". *Emotional Control* (EC) measures ability to control and regulate emotional and non-verbal displays. A representative item: "I am easily able to make myself look happy one minute and sad the next". *Social Expressivity* (SE) assesses skill in verbal expression and the ability to engage others in social discourse. A representative item: "When telling a story, I usually use a lot of gestures to help get the point across". *Social Sensitivity* (SS) assesses ability to interpret the verbal communication of others. A representative item: "Sometimes I think that I can take things other people say to be too personally". *Social Control* (SC) assesses skill in role-playing and social self-presentation. A representative item: "I am usually very good at leading group discussions".

The inventory comprises 90 items (15 items per scale) to which the respondents answer by using a 5-point Likert scale, indicating the extent to which the description in the item applies to them. The scales are anchored at 1 = "Not at all like me" and 5 = "Exactly like me". Questions for the six scales are intermixed. The test is scored by adding up the numbers chosen for each item in a given scale. For 32 items, the scoring is reversed, such that a "not at all like me" choice is given a score of 5, etc.

Procedure

Testing was done individually or in groups of two or three subjects. Participants were randomly assigned to either Order 1 or Order 2. Order 1 participants were given the CFT, followed by the SSI, the Benton face recognition test, and then the Sherman test of facial affect recognition. Order 2 participants were given the CFT last. All other tests were administered in the same order as for Order 1.

RESULTS

Chimeric Faces Task

Laterality quotients (LQs) for the CFT were computed by subtracting the number of smile-left choices from the number of smile-right choices, and dividing by the total. Thus, a negative LQ indicates a leftward bias and a positive LQ indicates a rightward bias. There was a significant leftward bias, $M=-.220$, $t(99)=-4.4921$, $P<.00001$. To determine whether LQs differed between the group that received the CFT at the beginning of testing, and the group that received it in the end, an ANOVA was performed with LQ as the dependent variable. Half (first 36 items versus second 36 items) was a repeated measure, and sex and order (test given at the beginning or end), were between-subjects variables. There was a significant effect of half, $F(1,96)=5.24$, $P<.05$, due to a stronger leftward bias for the second half (first half $M=-.196$, second half $M=-.245$). The order of testing did not affect the scores. Reliabilities increased only slightly from the first to the second half of the test (first half=.913, second half=.936).

Benton and Sherman Tests

The overall mean score for the Benton test was 46.3 out of 54 (86%), which is in accordance with norms reported by Benton et al. (1983). The overall mean score for the Sherman test was 40.8 out of 48 (85%). The scores for men and women did not differ for either of these tests.

Social Skills Inventory

The dependent variable for this test is the score obtained for each of the six scales. Note that the maximum score differs for each scale, due to the reverse scoring of some items. An ANOVA was conducted with scale (EE, ES, EC, SE, SS, and SC) as a repeated measure. Sex was a between-subjects variable. There was a significant scale by sex interaction, $F(5,490)=4.73$, $P<.005$. Figure 1 shows that women scored higher on both expression and sensitivity scales, and men scored higher on both control scales. Simple effects post-hoc analyses showed that only the female advantages on ES ($P<.05$) and SS ($P<.01$) were significant.

Correlations Between Tasks

Correlations were examined between LQs for the CFT, the Benton face recognition score (proportion correct), the SSI subscales and overall score, and the Sherman facial affect score (proportion correct; 74 subjects only). Only the

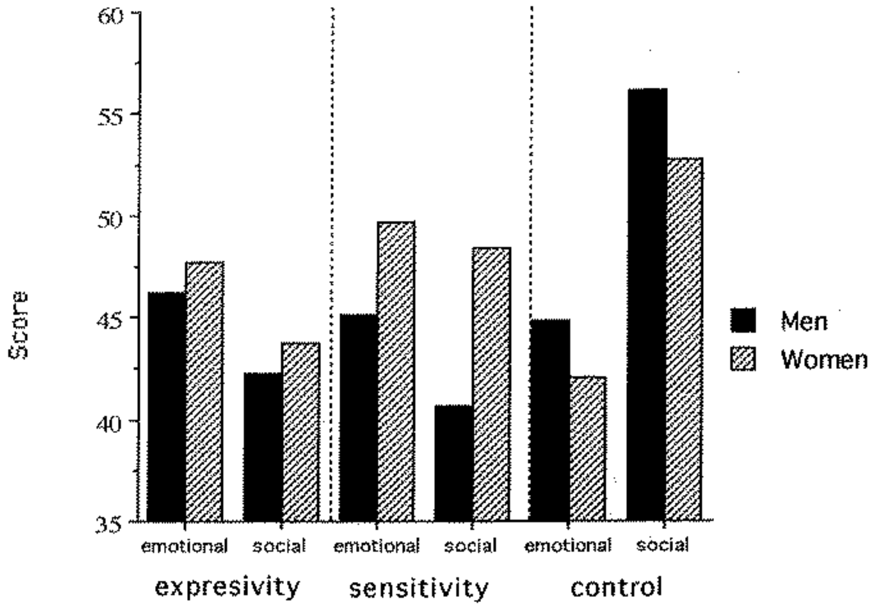

FIG. 1. Men's and women's scores on the Social Skills Inventory subscales.

EC and SC subscales of the SSI correlated significantly with the CFT (EC $r = -.238$, $P < .05$; SC $r = -.244$, $P < .05$). However, there was a trend in the expected direction for both the Benton ($r = -.168$) and the Sherman tests ($r = -.137$). Note that the negative correlations indicate that subjects with a greater leftward asymmetry on the CFT (more negative scores) obtained higher scores on the other tests.

The correlations between CFT and the Benton and Sherman tests were much lower than expected, given the results of previous studies. It is possible that some participants may have used a verbal strategy to perform these tests. Unfortunately, the participants were not asked about their strategy for the Benton. However, 65 were asked about the strategy used for the Sherman. Only 3 said they "never" used a verbal label for the face, and 33 said that they "always" used a verbal label. The other 29 said that they "sometimes" used a verbal label. Therefore, correlations were computed separately for the subjects who always used verbal labels, and for those who sometimes or never used verbal labels. For those who did not always use a verbal label, there was a trend towards a correlation between CFT asymmetry and scores on the Sherman test ($r = -.33$, $P < .07$). In contrast, there was no correlation ($r = .-01$) for those who always used a verbal label. Interestingly, the correlations between the CFT and scores on the Benton test were also much stronger for the subjects who did not always use a verbal label on the Sherman test, compared to those who did

($r=-.54$, $P<.01$, versus $r=-.16$, n.s.). The two groups did not differ in the correlations between the CFT and the SSI.

DISCUSSION

The results of this study confirm that asymmetries in cortical arousal, as measured by the CFT, correlate with performance on tasks involving the RH. The correlation between CFT asymmetry and ability to recognise faces on the Benton face test replicates results reported by others (Banich et al., 1992; Levine et al., 1988). However, this correlation was significant only for participants who did not report using a verbal strategy on the Sherman task. The results of this study supply limited support for the idea that RH arousal is associated with the ability to recognise facial expression. There was a trend towards a significant correlation only for participants who reported that they did not always use a verbal strategy. This suggests that the relationship between asymmetric patterns of arousal and ability is contingent on the strategy a participant uses on a particular task, and may explain the difficulty in obtaining significant correlations in some studies.

As the Sherman task required matching different people with different types of expression (i.e. open-versus closed-mouth expressions of anger), some participants may have found it necessary to generate a verbal label to make the match. These participants would have been forced to rely on their LH no matter what their characteristic arousal asymmetry was, thus eliminating any correlation with the CFT. On the other hand, the performance of those participants who employed a more flexible strategy (i.e. those who said they "sometimes" used a verbal label) would be more likely to be influenced by their characteristic arousal asymmetry.

Note that differences in strategy were not due to asymmetries in arousal. One might expect that participants with relatively greater LH arousal would be the ones who would be more likely to use a verbal strategy. However, the CFT scores of subjects who reported that they always used a verbal strategy did not differ from those who did not (−.188 versus −.184); it was only in the pattern of correlations between the CFT and Sherman scores that the two groups differed.

The sex differences found on the SSI, with men scoring higher on the EC and SC scales, and women scoring higher on the others, replicates results reported by Riggio (1986), and conforms with several studies showing higher level of emotional and social sensitivity in females (Hall, 1978; Magill-Evans, Koning, Cameron-Sadava, & Manyk, 1995; Rosenthal et al., 1977; Shanley, Walker, & Foley, 1971). Although speculation as to the origin of these sex differences is beyond the scope of this article, it is unlikely that they are due to differences in utilisation of the RH; CFT asymmetry scores for men and women did not differ and showed similar patterns of correlation with the SSI subscales.

The significant correlation between the CFT and SSI supports previous speculation that the RH may be differentially involved in social skills (Berenbaum & Prince, 1994; Denckla, 1978; Jessimer & Markham, 1997; Lane et al., 1995; Rourke, 1982; Semrud-Clikeman & Hynd, 1990; Voeller, 1986; Weintraub & Mesulam, 1983). It is interesting that this correlation was due mainly to the correlation with the EC and SC subscales. It might have been predicted that it would be ES and SS that would show the greatest correlation, as previous studies have shown that the RH is differentially sensitive to emotional expression in the face and voice (Borod, 1992; Etcoff, 1984; Fried et al., 1982; Gur et al., 1994; Heilman, Scholes, & Watson, 1975; Laurian et al. 1991; Ross, 1981; Suberi & McKeever, 1977). The EC and SC subscales measure skill in emotional and verbal self-presentation, and correlate highly with Snyder's (1974) self-monitoring scale (Riggio, 1986). Riggio (1986) has also shown that college students scoring high on these scales are more likely to have had acting or sales experience, and Riggio, Tucker, and Throckmorton (1988) showed that participants who scored high on the SC scale were rated by others as more believable, whether or not they were actually telling the truth. Thus, it appears that the RH may be involved in allowing a person to infer and to present the socially appropriate expression, rather than in emotional expression *per se.*

Of course, when interpreting these results it must be kept in mind that the SSI relies on self-report. It is possible that some people may not have an accurate perception of their own social skill. However, Riggio (1986) has shown that scores on the SSI do have predictive validity; participants with high scores were rated as more "likeable" by independent raters.

There was some evidence that experience with the CFT results in a greater leftward bias. More negative LQ scores were found for the second 36 items than for the first 36 items. This is congruent with results reported by Luh and her colleagues (1994), who used the original 36-item version of the CFT and found an increase in asymmetry scores from the first to the second half. This increase was most likely not due to an increase in reliability, as reliability increased only slightly. It is possible that as participants became more familiar with the faces, their processing strategy shifted slightly to a mode that involved the RH to a greater extent.

In summary, there is growing evidence for the importance of the RH in many aspects of emotional and social cognition. However, a great deal of work is still needed, particularly in terms of the cerebral basis of social skills other than recognition of emotional expression. It must be kept in mind that although the present study found significant correlations between RH arousal and performance on several tasks, the correlations were quite low, usually accounting for 5–9% of the total variability. This is to be expected when examining something as complex as social cognition, which undoubtedly involves the integration of numerous processes and regions of the brain. Future studies need to utilise a wider range of tasks, and to further explore individual differences in the employment of strategies on these tasks.

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