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Association between frontal EEG asymmetries and emotional intelligence among adults

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ABSTRACT

This study aimed at investigating the brain correlates of trait emotional intelligence. Trait emotional intelligence (trait EI) is a constellation of emotion-related traits, capturing the extent to which people experience, attend to, identify, understand, regulate, and utilize their emotions and those of others. As previous studies have provided converging evidence that frontal asymmetries were one of the determinants of emotion dispositions and behaviors, and as observations on individuals with a high level of emotional intelligence parallel those on people with a left-sided frontal cortical asymmetry in nearly every respect, we hypothesized that the level of emotional intelligence might be associated with differential frontal activation. Results supported the hypothesis: the pattern of resting electroencephalographic (EEG) activation recorded in the frontal areas was significantly associated with emotional intelligence. Individuals with higher trait EI evidence greater resting left frontal activation.

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1. Introduction

The concept of emotional intelligence aims to capture the individual differences in the extent to which people experience, attend to, identify, understand, regulate, and utilize their emotions and those of others. While EI was originally conceived as a set of *abilities* forming a new form of intelligence (Mayer & Salovey, 1993), other authors emphasized that EI was conceptually (inversely) related to the personality dimensions of neuroticism and alexithymia – among others – and was therefore best conceived as a set of affect-related *traits* (Petrides & Furnham, 2000, 2003).

Thus, trait emotional intelligence (trait EI) is a constellation of emotion-related dispositions located at the lower levels of personality hierarchies (Petrides, Pita, & Kokkinaki, 2007). The Appendix A presents the constituent elements of the sampling domain of trait EI, which have been derived by means of a content analysis of salient EI models and cognate constructs (Petrides & Furnham, 2003). In trait EI models, emotion-related self-perceptions have been repeatedly shown to form four interrelated factors (Freudenthaler, Neubauer, Gabler, Scherl, & Rindermann, 2008; Mikolajczak, Luminet, Leroy, & Roy, 2007; Petrides et al., 2007): *well-being* (traits pertaining to dispositional mood), *self-control* (traits pertaining to the regulation of emotions and impulses), *emotionality* (traits pertaining to the perception and expression of emotions) and *sociability* (traits pertaining to the interpersonal utilization and management of emotions).

In spite of the growing interest in EI, the neurobiological correlates of the psychometric construct have been largely overlooked. The present paper aims to address this gap and test whether trait EI may be associated with the differential relative activation of the right and left frontal cortices. The reason why we anticipated that frontal asymmetries could be one of the neuroendocrine correlates of EI is that previous studies have provided converging evidence that frontal asymmetries were one of the determinants of emotion dispositions and behaviors (e.g., Allen, Harmon-Jones, & Cavender, 2001, see Davidson, 2004 and Harmon-Jones, 2004, for reviews). For instance, subjects with increased relative left frontal activation experience more positive and less negative trait affectivity (Tomarken, Davidson, Wheeler, & Doss, 1992), recover faster following a negative event (Jackson et al., 2003), and exhibit lower levels of cortisol (e.g., Buss et al., 2003) as well as higher levels of immune responses (NK cells activity) at baseline and in response to challenge (Davidson, Coe, Dolski, & Donzella, 1999) than subjects with increased relative right frontal activation. In the same vein, hypoactivation of the left frontal cortex or hyperactivation of the right frontal cortex is associated with mood disorders (see Thibodeau, Jorgensen, & Kim, 2006 for a meta-analysis). Experimentally-induced asymmetry (through biofeedback or transcranial magnetic stimulation) has the same effects, thereby suggesting that prefrontal asymmetry is causally involved in emotion-related dispositions and behaviors (e.g., Allen et al., 2001).

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The foregoing suggests that it would be sensible to expect a relationship between frontal asymmetries and trait EI-a construct precisely aimed at capturing emotion-related individual differences. This is especially true as there is a stringent parallel between the EI asymmetries. Higher trait EI scores have indeed been associated with more positive and less negative state affectivity (Mikolajczak, Nelis, Hansenne, & Quoidbach, 2008; Mikolajczak et al., 2007), increased subjective resistance to stress or negative conditions (e.g., Ciarrochi, Deane, & Anderson, 2002; Mikolajczak & Luminet, 2008), and lower cortisol secretion amidst stress (Mikolajczak, Roy, Luminet, Fillée, & de Timary, 2007). Higher trait EI scores have also been associated with a lower risk for mental disorders such as depression and anxiety (for a meta-analysis, see Schutte, Malouff, Thorsteinsson, Bhullar, & Rooke, 2007).

The remarkable similarity among the findings observed in the EI and frontal EEG asymmetries studies (i.e., high emotional intelligence and greater relative left activation seem to be associated with the same outcomes) have recently led two research teams to hypothesize that higher levels of EI might be associated with a left-sided frontal EEG asymmetry. Kemp et al. (2005) conducted the first study and found a significant relationship between EI and EEG asymmetries among adults: higher relative left activation was associated with higher trait EI. Santesso, Becker, Schmidt, and Segalowitz (2006) aimed at replicating those findings on children one year later but could not find any significant relationship between trait EI and EEG asymmetries in Children. It is difficult to favor one conclusion over the other because both studies had shortcomings: Santesso et al. (2006) used a small sample of children ($n = 40$) who were not pre-screened to remove average scores. High and low emotionally intelligent children could therefore not be contrasted and it cannot be excluded that non-significant results are the result of an opaque average trend in both EI and EEG asymmetries. By contrast, Kemp et al. used a sufficiently large sample ($n = 597$) but failed to use a previously validated measure of EI. Moreover, it cannot be excluded that the large sample size is responsible for the significance of results that would be otherwise trivial. Thus, despite the many reasons to expect a significant relationship between EI and frontal asymmetries, the jury seems still out on that matter. The current study aimed at determining whether a relationship between EI and the level of left-frontal asymmetry could be found in a small sample of adults prescreened on the level of trait EI.

2. Method

2.1. Participants and procedure

Thirty-one healthy subjects (25 women and six men) preselected on the level of trait EI (mean ± minimum 0.5 SD) participated in the study in exchange for 10 EUR (15 USD). The mean age of the sample was 22.4 years (SD = 3.8 years). All subjects gave informed consent to participate and APA ethical guidelines were followed in the conduct of the study.

2.2. Measures

2.2.1. Trait emotional intelligence

Trait EI was measured through the French version of the Trait Emotional Intelligence Questionnaire (TEIQue; Petrides & Furnham, 2003; French adaptation by Mikolajczak & Luminet et al., 2007). The TEIQue consists of 153 items responded to on a 7-point scale. It provides a global score as well as scores for 15 subscales, four factors (*well-being*, *self-control*, *emotionality*, and *sociability*; see Appendix A for details and sample items). The reliability of the global score is .93 (reliabilities at the factor level are .90, .84, .84 and .80 for the well-being, self-control, emotionality and sociability factors, respectively). There are several good measures of trait EI. We chose the TEIQue for three specific reasons. First, it provides comprehensive coverage of the trait EI sampling domain; second, it has demonstrated discriminant validity in relation to personality (Petrides et al., 2007); third, its factor structure is stable across studies and languages (Mikolajczak & Luminet et al., 2007).

2.2.2. EEG asymmetries

The EEG was recorded using the program EEmagine and 10 frontal electrodes positioned according to the 10/20 International System (Fp1, Fp2, F7, F8, F3, F4, FC5, FC6, FC1 and FC2). The ground electrode was attached to the forehead and linked earlobs were used as the reference. Electrode impedance was generally below 5 kOhms and always below 10 kOhms. EEG was recorded during eight 1-min trials, four eyes open and four eyes closed (in counterbalanced order). Eyes-open/eyes-closed trials were taken together in the analysis. EEG was amplified (60 Hz notch filter), bandpass filtered (.1–100 Hz) and digitized at 500 Hz. The EEG data were visually inspected for artefact (±50 μV) due to eye blinks or eye movements (horizontal and vertical eye movements were recorded around the left eye to facilitate artefact correction).

After artefacts removal, epochs 2 s in duration with a 0, 5 s overlap were extracted (i.e., on average 957 epochs by subject) and Fast-Fourier transformed (Hamming window). Alpha power (8–12 Hz) was used as it is the frequency band generally used in frontal asymmetry and emotion research. Asymmetry indexes were created for each of the five electrodes pairs by subtracting the natural logarithm of the right site from the natural logarithm of the left homologous site. A mean frontal asymmetry index was then created by averaging asymmetries across the five electrode pairs. Because alpha power is inversely related to cortical activity, higher scores denote greater relative left than right activity. Because all hypotheses were directional and theory-driven, correlations were performed using a one-tailed criterion of significance.

3. Results

Descriptive statistics are reported in Table 1 (means and SDs of the variables under study), Table 2 (correlations between EEG sites) and Table 3 (correlations between trait EI factors). Continuous frontal asymmetry scores ranged from −0.15 to 0.81 (mean = 0.08, SD = 0.19). Comparison of above the mean and below the mean trait EI people revealed that, as expected, the former had significantly higher left-sided mean frontal asymmetry scores than the latter ($F_{1;30} = 4.35$, $p \leqslant .05$). As shown in Fig. 1, this result was mainly explained by the factor sociability ($F_{1;30} = 6.99$, $p \leqslant .01$) and to a lesser extent by factors self-control ($F_{1;29} = 3.49$, $p \leqslant .10$) and well-being ($F_{1;30} = 3.22$, $p \leqslant .10$). Differences between people scoring above and below the mean on emotionality were non-significant ($F_{1;30} = 1.47$, $p = .23$).

Table 1
Means and standard deviations of the variables under study.

Variable	Mean	Standard deviations
Global trait EI	4.72	0.86
Well-being	5.05	1.26
Self-control	4.27	0.99
Emotionality	4.97	0.88
Sociability	4.54	0.99
Mean frontal asymmetry	0.08	0.19
Fp1–Fp2	0.025	0.08
F7–F8	−0.04	0.27
F3–F4	0.15	0.34
FC5–FC6	0.13	0.28
FC1–FC2	0.16	0.36

Table 2
Pearson correlations between EEG sites.

	Mean frontal asymmetry	Fp1–Fp2	F7–F8	F3–F4	FC5–FC6	FC1–FC2
Mean frontal asymmetry	–					
Fp1–Fp2	.31	–				
F7–F8	.70***	.34	–			
F3–F4	.89***	.25	.43*	–		
FC5–FC6	.88***	.28	.73***	.70***	–	
FC1–FC2	.86***	.09	.37*	.89***	.62***	–

Table 3
Pearson correlations between Trait EI Factors.

	Global Trait EI	Well-being	Self-control	Emotionality	Sociability
Global Trait EI	–				
Well-being	.93***	–			
Self-control	.78***	.65***	–		
Emotionality	.77***	.71***	.30	–	
Sociability	.88***	.78***	.55***	.73***	–

If we adopt a continuous perspective (see Fig. 1), Pearson correlations performed between trait EI continuous scores and frontal asymmetry scores revealed that higher trait EI scores were associated with greater relative left frontal activation ($r = 0.38$, $p < .05$). This association was mainly attributable to the factors *sociability* ($r = 0.43$, $p < .01$) and *self-control* ($r = 0.38$, $p < .05$) and, to a lesser extent, to the factors *emotionality* ($r = 0.24$, $p < .10$) and *well-being* ($r = 0.21$, $p < .15$).

A multiple regression analysis revealed that, when the weight of the other TEIQue factors are controlled, the most significant predictors were sociability ($\beta = .62$, $p < .05$), well-being ($\beta = -.61$, $p < .07$) and self-control ($\beta = 0.40$, $p < .10$). Emotionality was no longer significant or marginally significant ($\beta = 0.10$, ns). Surprisingly, the direction of the correlation reverses for the factor *Well-being* when the other predictors are partially out.

4. Discussion

In line with our hypothesis, higher trait EI scores were associated with a greater relative left-sided frontal activation. The effect size *d* for the global score is 0.82, which is considered to be a large effect according to Cohen's norms for the social sciences. As far as the factors are concerned, the strongest relationships were obtained with the factors "sociability" and "self-control". Our results regarding *sociability* are consistent with a series of studies showing that greater relative left activation is associated with higher extraversion and social competence (e.g., Schmidtke & Heller, 2004). Namely, individuals with greater left-frontal asymmetry are less shy and initiate more contacts (e.g., Schmidt, 1999; Schmidt & Fox, 1994). The results regarding *self-control* are also in line with those of the numerous studies showing an association between a left-sided asymmetry and enhanced emotion regulation abilities (see Davidson, 2004 for a review). They may help explain why individuals with high trait EI are more prone to use problem-focused rather than avoidant coping strategies (Petrides et al., 2007). Findings about sociability and self-control probably interact and reinforce each other, as suggested by a study showing that that highly sociable children displaying greater relative right frontal EEG asymmetry were more likely to have externalizing problems than sociable children exhibiting greater relative left frontal EEG asymmetry. Conversely, shy children with greater relative right frontal EEG asymmetry were more likely to have internalizing problems than shy children exhibiting left frontal EEG asymmetry (Fox, Schmidt, Calkins, Rubin, & Coplan, 1996).

The relationship with the factor *emotional sensitivity* reached only marginal significance but is in accordance with studies (e.g., Aftanas & Varlamov, 2004) showing that a greater relative right frontal activation was associated with alexithymia, a psychoemotional disorder associated with difficulties in identifying and describing feelings (Vermeulen & Luminet, 2009). Finally, the relationship between EEG frontal asymmetries and the factor *well-being* did not reach significance, which is consistent with past results showing that the relationships between the asymmetry and dispositional positive and negative affect are usually not significant when examined in participants who were not selected for extreme left- or right-anterior alpha asymmetry (e.g., Harmon-Jones & Allen, 1998).

In view of the foregoing, it seems that the construct of trait emotional intelligence might be particularly well-suited to capture the socio-emotional dispositions affected by frontal EEG asymmetries. This is all the more remarkable as trait EI is measured via self-reports, which some have claimed to constitute unreliable measures of EI.

These results are of interest to both EI and frontal EEG asymmetries fields. Regarding trait EI, the present results first provide an insight into the neurobiological correlates of the psychometric construct. They also help explain some results never understood thus far, such as the fact that emotional intelligence had strong

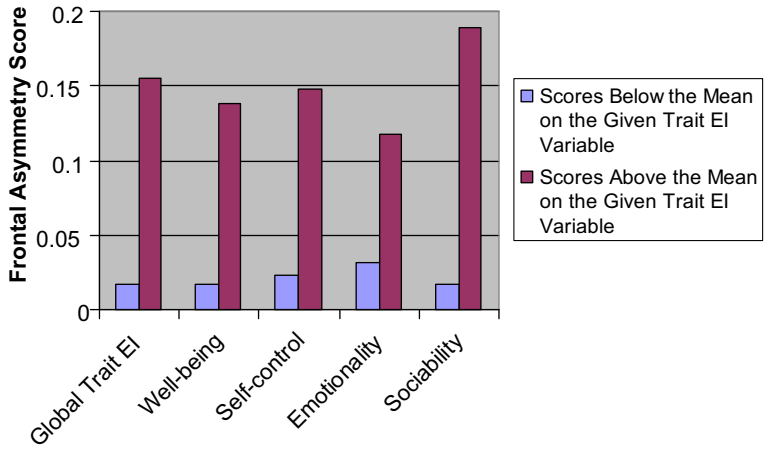

Fig. 1. Mean frontal asymmetry score (left-sided) by Trait EI Levels. *Note:* the pairs of sites responsible for the differences pictured in this Figure are FC5–FC6 and FC1–FC2 for the global trait EI score, FC5–FC6 for self-control and F7–F8, FC5-FC6 and FC1–FC2 for sociability.

negative relationships with sadness, stress and fear, but no significant relationship with anger (e.g., Mikolajczak et al., 2008). This is now interpretable, since frontal brain asymmetries have been found to increase anger in certain contexts (see e.g., Harmon-Jones, Sigelman, Bohlig, & Harmon-Jones, 2003). Regarding frontal EEG asymmetries, it is the first time that the effect of frontal asymmetries is examined *simultaneously* on various socio-emotional dimensions. The fact that frontal asymmetries had the largest impact on *sociability* suggests that future investigation would benefit from examining the relationship between asymmetries and other biological factors known to be involved in social behavior, such as oxytocin.

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Appendix A

The15 key emotional dispositions comprised in the TEIQue

Factors and subscales	High scores reflect...	Sample item
Well-being		
Self-esteem	...a positive view of oneself and one's achievements	*I'm not able to do things as well as most people (R)*
Trait happiness	... a general state of well-being, expressed by a cheerful mood and a general satisfaction with one's life	*I frequently have happy thoughts*
Trait optimism	...a propensity to look for the bright side of life, and to see the glass as half-full rather than half-empty	*I tend to see the glass as half-empty rather than half-full (R)*
Self-control		
Emotion regulation	...an aptitude and tendency to regulate one's emotions when they are not appropriate	*I usually find it difficult to regulate my emotions (R)*
Stress management	...a tendency to choose efficient coping strategies in stressful situations	*I try to regulate pressures in order to control my stress levels*
Impulsiveness (low)	...a tendency to manage one's urges, to think before acting, to weigh the pros and cons before deciding,	*I often indulge without considering all the consequences (R)*
Emotionality		
Emotion perception(self and others)	...a tendency to perceive and identify one's emotions as well as others'	*Just by looking at somebody, I can understand what s/he feels*
Emotion expression	...a tendency to express one's feelings to others	*Others tell me that I rarely speak about how I feel (R)*
Relationship skills	...a tendency to initiate and maintain deep and rich relationships with others, to listen to them and to care about them	*I really don't like listening to my friends' problems (R)*
Empathy	...a tendency to put oneself in others' shoes	*Imagining myself in someone else's position is not a problem for me*
Sociability		
Social competence	... an easy-going way of being... a tendency to express oneself clearly and to negotiate efficiently	*I'm generally good at social chit-chat*
Emotion management (others)	...an ease to influence others' emotions	*Generally, I'm not good at consoling others when they feel bad (R)*
Assertiveness	...a tendency to be forthright and frank, to express one's needs in a clear but nevertheless non-violent manner.	*On the whole, I would describe myself as assertive*
Adaptability[a]	...an ease to adapt to new environments	*I don't mind frequently changing my daily routine*
Self-motivation[a]	...a tendency to be intrinsically rather than extrinsically motivated	*Generally, I need a lot of incentives in order to do my best (R)*

[a]These subscales contribute directly to the global trait EI score.

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