Reduced anterior cingulate activation in aggressive children and adolescents during affective stimulation: Association with temperament traits

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Abstract

Objective: The risk for conduct disorder (CD) is markedly increased in children with specific temperament dimensions. Here, we investigated whether adverse temperament factors might contribute to an impairment in neural mechanisms underlying the regulation of aggressive behaviour.

Method: Functional magnetic resonance imaging was performed in 13 male adolescents with CD aged 9 to 14 years and in 14 healthy age and sex-matched control subjects at 1.5 T. During scanning, subjects looked at pictures from the International Affective Picture System with neutral or strong negative emotional valence. Temperament was assessed using the German version of the Junior Temperament and Character Inventory. In addition, behavioural control strategies (Wisconsin Card Sorting, Four Pack Card Playing Task) and sociomoral reasoning (Sociomoral Reflection Measure Short Form) were tested to behaviourally characterise the study groups.

Results: When comparing CD patients with healthy controls, we found reduced activation in the right anterior cingulate cortex (ACC) in response to negative affective pictures. The temperament dimension ‘novelty seeking’ was a significant predictor for ACC responsiveness to affective pictures as revealed by a stepwise multiple regression analysis ($\beta = -0.53$, $p < 0.01$). Moreover, individuals with high ‘novelty seeking’ scores chose more disadvantageous strategies in the Four Pack Card Playing Task ($p < 0.05$) and were characterised by a lower level of sociomoral reasoning ($p < 0.05$).

Conclusion: The results of this study provide a link between temperament factors and neural correlates of emotion processing in adolescents with conduct disorder.

Keywords: Aggression; Temperament; Functional magnetic resonance imaging; Anterior cingulate cortex; Emotion regulation

1. Introduction

In a previous functional magnetic resonance imaging (fMRI) study, we found that dorsal anterior cingulate cortex (ACC) activation during viewing of affective pictures was reduced in adolescents with conduct disorder (CD) compared to normal controls (Sterzer et al., 2005). The ACC plays an essential role in the regulation of cognitive and emotional behaviour (Posner, 1995; Casey et al., 1997; Bush et al., 2000). The dorsal part of the ACC is primarily involved in the cognitive control of behaviour, whereas its rostral-ventral part has been...
implicated in processing of emotional information (Bush et al., 2000). The focus of reduced activity in response to affective pictures in our previous study (Sterzer et al., 2005) was located in the cognitive subdivision of the ACC (Fig. 1).

In line with the notion of a reciprocal functional relationship between the cognitive and the affective subdivisions of the ACC (Bush et al., 2000; Drevets and Raichle, 1998), we speculated that this finding might indicate an impaired cognitive control of emotional behaviour in patients with CD.

It has been proposed that the ability to cognitively control behaviour and emotions is determined by various temperament factors (Cloninger, 1987; Cloninger et al., 1993). In Cloninger’s model, behavioural activation in response to novelty, reward, or relief of punishment is called ‘novelty seeking’. Behavioural inhibition in response to punishment or nonreward is called ‘harm avoidance’ and previously rewarded behaviour that is maintained without continued reinforcement ‘reward dependence’ and ‘persistence’ (Cloninger et al., 1993). Empirical evidence for a link between temperament factors and the efficiency of cognitive control strategies was provided by a recent study by Rothbart (2000). In this study, the temperament dimension ‘Inhibitory Control’ was positively correlated with the performance on neuropsychological tasks testing the ability to cognitively control behaviour, whereas ‘Impulsivity’ showed a negative correlation. These findings indicate that temperament might be an important factor for efficient control strategies, which in turn suggests an association between temperament and ACC function.

There is also a close association between temperament factors and the propensity for disruptive behaviour in children and adolescents. A number of studies have shown that the risk for the development of aggressive behaviour problems is markedly increased in children and adolescents with high novelty seeking (Tremblay et al., 1994; Ruchkin et al., 1998; Schmeck and Poustka, 2001) and to some extent in adolescents with low harm avoidance and low reward dependence (Sigvardsson et al., 1987).

Links between temperament and neural structures considered to be involved in cognitive and emotional processing, however, remain tenuous. Although a number of studies investigated the psychobiological foundations of Cloninger’s model (for an overview see Bond, 2001), direct evidence for a link between temperament dimensions – predisposing for aggression – and neural function is still lacking, especially in children. Although the relationship between temperament and psychopathology remains a controversial issue, most theories have conceptualised temperament as a construct distinct from psychopathology. Temperamental dimensions – viewed as inherited or constitutional, evident early in life and stable across development – are seen as predisposing vulnerabilities to develop a certain kind of psychopathology (see for example Frick, 2004).

The present study aimed to investigate whether specific temperament dimensions might be related to dorsal ACC function. We hence probed the relationship between temperament factors and the ACC activations in response to negative affective pictures that were observed in our previous fMRI study (Sterzer et al., 2005). Given the evidence for an important role of the ACC in the cognitive control of behaviour (Bush et al., 2000), we were also interested in the relationship between temperament factors and behavioural control strategies in our study population. Several instruments, each assessing different aspects of neuropsychological functioning, were used: The Four Pack Card Playing Test assessing decision making processes, the Wisconsin Card Sorting Test assessing the tendency to perseverate dominant responses and the Sociomoral Reflection Measure-Short Form were used. We hypothesised that high novelty seeking scores (i.e., an impulsive and quick tempered personality) might correlate with low ACC activity and impaired performance on neuropsychological tests that measure cognitive control strategies.
2. Methods

2.1. Subjects

Sixteen male adolescents with CD (age 9–15 years) recruited from the outpatient clinics of the Department of Child and Adolescent Psychiatry and 15 age-matched controls participated in the experiment. Written informed consent was given by all participants’ parents. Three patients received pharmacological treatment, two with Risperidone and one with Methylphenidate, which was paused for 36 and 24 h, respectively, prior to imaging. Two patients did not tolerate the scanning procedure, and the data of one patient and one control subject were discarded because of excessive motion during scanning. Thus, the imaging data of 13 patients and 14 controls were included in the analyses. All participants had normal or corrected-to-normal visual acuity and normal intellectual abilities (IQ > 80). None of the patients had a history of traumatic brain damage or other neurological diseases. None of the control subjects had a history of any psychiatric or neurological disease. The experimental protocol was approved by the local ethics committee.

2.2. Clinical assessment

All patients underwent a structured clinical interview and met the criteria for severe CD according to the Diagnostic and Statistical Manual of Mental Disorders (DSM-IV) (American Psychiatric Association, 1994) as diagnosed by a trained psychiatrist at the Department of Child and Adolescent Psychiatry. With the exception of one patient, all had CD of childhood-onset type. Eight patients (62%) also met the DSM-IV criteria for attention-deficit/hyperactivity disorder (ADHD). In addition to the clinical interview, the Child Behaviour Checklist (CBCL) (Achenbach, 1991) was used. The CBCL is a questionnaire to be completed by parents of 4- to 18-year olds and can be scored on 8 syndrome scales. Three of these scales – anxious/depressed, attention problems, and aggressive behaviour – were used to behaviourally characterise the study groups. Children’s temperament was assessed with the German version of the Junior Temperament and Character Inventory (JTCI 12–18, Schmeck et al., 2000) which has been well established previously (Schmeck et al., 2001). The JTCI consists of 84 statements assessing four temperament dimensions (novelty seeking, harm avoidance, reward dependence, persistence) and three character scales (self-directedness, cooperativeness, self-transcendence). This self-rating questionnaire was sent to all subjects within six months after fMRI scanning.

The culture fair test (CFT) was used to determine the intelligence quotient (IQ) of the participants (Weiss, 1987). The parental socio-economic status was assigned to one of three categories (unskilled/qualified worker, clerk/commercial occupation, and graduate occupation).

2.3. Neuropsychological assessment

The computerised Four Pack Card Playing Task (CPT, Bechara et al., 1994) was used to assess decision making processes. Subjects were confronted with four decks of cards (A, B, C and D) and instructed to select one card from the decks in a manner to win as much play money as possible. The winning and loosing schedules are preprogrammed in such a way that every time a card is selected from deck A or B, the subject gets $100, and every time a card is selected from C or D, the subject gets $50. We assessed the sum of selected cards of advantageous decks A and B (‘good’ decks) and of disadvantageous decks C and D (‘bad’ decks) as well as the monetary profit.

The computerised Wisconsin Card Sorting Test (WSCT) was used to assess cognitive flexibility and abstract reasoning. It uses stimulus and response cards displaying four shapes in different colours and numbers. The subjects are instructed to sort the cards according to colour, form, and number and to alter their approach as shifts in the sorting principle occur. Raw scores of perseveration errors were transformed into T scores (Heaton et al., 1993).

To assess the individuals’ developmental level of sociomoral reasoning, the German version of the Socio-moral Reflection Measure-Short Form (SRM-SF-D, Krettenauer and Becker, 2001), originally developed by Gibbs et al. (1992), was applied. The SRM-SF-D questionnaire is a reliable and valid measure of individuals’ level of sociomoral reasoning that is more economical than any interview procedure (Krettenauer and Becker, 2001). The SRM-SF-D follows Kohlberg’s definition of moral development, but yields only four stages of moral reasoning instead of six. The individuals’ written statements to eight moral themes, which were coded with the SRM-SF manual, provide two variables: Firstly, the mean of all coded items (SRMG) and secondly, a Global Stage which defines the individuals moral stage.

2.4. fMRI procedure

fMRI was performed at 1.5 T (Siemens Vision, gradient booster, standard head coil), acquiring echoplanar images (24 slices, 3.4 × 3.4 × 5.0 mm³ voxel size, TR = 3 s). During scanning, subjects looked at pictures from the International Affective Picture System (IAPS) with neutral or strong negative emotional valence balanced with respect to content complexity, luminance, colours, human beings, faces, and animals. 18 blocks of 6 either neutral or negatively valenced pictures were presented in alternation (6.5 s/picture, 1 block = 13
scans), interleaved with a rest condition (five scans) during which subjects fixated a black cross on a grey background. To ensure the subjects’ attention, they were asked to respond by right hand key presses to the short presentation of an abstract target picture (500 ms) randomly interspersed between the IAPS pictures. We chose a relatively easy task to not detract to much attention from the affective pictures.

### 2.5. Data analysis

The imaging data were analysed using statistical parametric mapping (SPM99, [www.fil.ion.ucl.ac.uk/spm](http://www.fil.ion.ucl.ac.uk/spm)). The statistical analysis was based on the contrast negative > neutral emotional valence and between-group differences were assessed using a random-effects analysis (for more details, see Sterzer et al., 2005). In brief, a fixed-effects analysis was applied separately to the preprocessed data of each subject using the general linear model implemented in SPM99. This model fits the data with a linear combination of regressors in a design matrix to produce 3D maps of parameter estimates ($\beta$ weights). Parameter estimates represent the contribution of a particular regressor to the data and can be transformed to percent BOLD signal change with respect to the average global signal across conditions and voxels. Individual maps of parameter estimates were subjected to second-level analyses to test for activation differences at the group level. Effect sizes used for regression analyses in the present study are differences between parameter estimates for the negative and those for the neutral condition. They were normalized to the mean across all subjects and averaged across the entire significant ($p < 0.001$, uncorrected) activation cluster in the dorsal ACC ($k = 72$ voxels).

A 2 (CD/control group) × 2 (negative/neutral condition) ANOVA was used to test for effects of study group and experimental condition on reaction times to the interspersed target picture.

Whenever IQ, age and socio-economic status had no significant influence on neuropsychological test data, $t$-tests for independent samples were used to test for significant mean differences in neuropsychological tests and moral reasoning. An analysis of covariance was used if a previous multiple regression analysis had revealed that IQ, age or socio-economic status significantly contributed to test performance.

We determined partial correlation coefficients for the relationships between JTCI temperament scores and decision making processes (good decks and bad decks in the Four Pack CPT), perseveration rate (WSCT) as well as moral development (SRMG), corrected for IQ differences.

Finally, a stepwise multiple regression analysis was performed to determine the influence of the temperament factors novelty seeking, harm avoidance, reward dependence and persistence on the ACC response to negative affective pictures. The response (negative > neutral) at the peak voxel in the ACC was used as the dependent variable and scores on the JTCI temperament scales as independent variables. Besides temperament dimensions, IQ, attention problems and aggression (CBCL scores) were used as independent variables.

### 3. Results

#### 3.1. Demographic and clinical characteristics

Characteristics of the patient and control groups are listed in Table 1. Significant differences between patients and control subjects were found for the three CBCL scales and for IQ ($p < 0.05$, unpaired Student’s $t$-test) as well as for parental socio-economic status ($p < 0.05$, Wilcoxon test).

#### 3.2. Behavioural data: Reaction times

The average response rates did not differ between the patient and control groups (98.3 ± 4.7% and 99.6 ± 0.5%, respectively, $p = 0.3$, Student’s $t$-test). There were no false-positive alarms. Reaction times did not differ between the two groups. Mean reaction times to targets presented during neutral and negative conditions were 545.4 ± 70.9 ms and 572 ± 88.8 ms, respectively, in the control group, and 551.5 ± 85.8 ms and 599.4 ± 103.6 ms, respectively, in the patient group. A two-way ANOVA did not show significant effects for group ($F(1,50) = 0.8$, $p = 0.4$), condition ($F(1,50) = 2.6$, $p = 0.1$), or the interaction of group and condition ($F(1,50) = 0.7$, $p = 0.4$).

#### 3.3. Temperament results

Mean scores for both the patient and control groups on the temperament and character dimensions are listed in Table 2. Significant group differences were found for novelty seeking and cooperativeness ($p < 0.01$).

<table>
<thead>
<tr>
<th>Demographic and behavioural characteristics of the study groups</th>
<th>Controls ($N = 14$)</th>
<th>Patients ($N = 13$)</th>
<th>$p$ value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>Mean</td>
<td>SD</td>
<td>Mean</td>
</tr>
<tr>
<td>IQ</td>
<td>117.36</td>
<td>11.50</td>
<td>97.54</td>
</tr>
<tr>
<td>Socio-economic state</td>
<td>2.64</td>
<td>0.50</td>
<td>1.69</td>
</tr>
<tr>
<td>Child behaviour check list (CBCL)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Anxious/depressed</td>
<td>53.43</td>
<td>4.99</td>
<td>62.54</td>
</tr>
<tr>
<td>Attention problems</td>
<td>52.29</td>
<td>5.12</td>
<td>63.85</td>
</tr>
<tr>
<td>Aggressive behaviour</td>
<td>53.64</td>
<td>5.53</td>
<td>75.23</td>
</tr>
</tbody>
</table>

* Student’s $t$-test.

b Wilcoxon test.
3.4. Neuropsychological results

In decision making processes as assessed with the Four Pack Card Playing Task, significant group differences were revealed for total monetary profit ($t = 2.21$, $p < 0.05$), showing that the patients’ strategy was less effective in gaining profit although the number of decisions made for good and bad card decks did not differ between the groups (Table 3).

Concerning cognitive flexibility, the analysis of covariance (Table 3) revealed a trend towards lower perseveration $T$-scores in the WSCT (=more perseveration errors) in patients with CD ($T = 43.19$, $SD = 3.11$) than in healthy controls ($T = 51.4$, $SD = 3.88$) ($F(1,27) = 2.96$, $p < 0.1$).

With respect to social moral reasoning, significant group differences were observed in SRMG, the mean of all coded items ($F(1,34) = 4.35$, $p < 0.05$). Furthermore, this test showed that patients tended to be on an immature moral level (Global Stage = 2.3). The patients’ moral reasoning was characterised by exchanging and instrumental judgments. In contrast, in controls prosocial statements predominated instrumental preferences ($F(1,34) = 3.31$, $p < 0.1$). Their Global Stage of 2.7 can be assigned to stage 3, the mature level of moral reasoning (Gibbs et al., 1992).

IQ significantly contributed to sociomoral reasoning in SRMG ($\beta = 0.73$, multiple regression analysis) and to performance in the WSCT ($\beta = -0.53$). Age and socio-economic status did not contribute to test performance in any of the neuropsychological tests including moral reasoning.

3.5. Temperament characteristics and their association with behavioural data and ACC activity

Relating neuropsychological functioning to temperament, we found that individuals with high novelty scores chose significantly more disadvantageous (‘bad’) decks ($r = 0.41$, $p < 0.05$) and less advantageous (‘good’) decks ($r = -0.51$, $p < 0.01$) in the Four Pack Card Playing Task. Harm avoidance, reward dependence and persistence were not related to decision making processes, only individuals with high persistence scores tended to choose more advantageous decks ($r = 0.35$, $p < 0.1$). None of the temperament factors was significantly associated with cognitive flexibility (perseveration errors in the WSCT).

Novelty seeking was negatively associated with sociomoral reasoning as assessed by the SRMG ($r = -0.41$, $p < 0.05$). Other temperament dimensions showed no influence on moral reasoning.

The stepwise multiple regression analysis, which was used to test the influence of temperament on ACC activity differences (Fig. 2), revealed a significant negative

Table 3: Neuropsychological functioning in patients and controls: descriptive statistics and test results

<table>
<thead>
<tr>
<th></th>
<th>Controls $(N = 14)$</th>
<th>Patients $(N = 13)$</th>
<th>$p$ value*</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>WSCT</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Perseveration rate*</td>
<td>51.47</td>
<td>43.19</td>
<td>$F = 2.96$</td>
</tr>
<tr>
<td>$T$</td>
<td>3.88</td>
<td>13.04</td>
<td></td>
</tr>
<tr>
<td>$SD$</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$M$</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$SD$</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Four Pack CPT</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bad decks (A + B)</td>
<td>45.6</td>
<td>51.7</td>
<td>$t = 1.23$</td>
</tr>
<tr>
<td>$SD$</td>
<td>9.9</td>
<td>14.3</td>
<td></td>
</tr>
<tr>
<td>Good decks (C + D)</td>
<td>54.4</td>
<td>462</td>
<td>$t = 1.57$</td>
</tr>
<tr>
<td>$SD$</td>
<td>9.9</td>
<td>15.4</td>
<td></td>
</tr>
<tr>
<td>Monetary profit</td>
<td>4033</td>
<td>3318</td>
<td>$t = 2.21$</td>
</tr>
<tr>
<td>$SD$</td>
<td>807</td>
<td>811</td>
<td></td>
</tr>
<tr>
<td><strong>SRM-SF-D</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SRMG</td>
<td>264.6</td>
<td>225.8</td>
<td>$F = 4.35$</td>
</tr>
<tr>
<td>$SD$</td>
<td>40.8</td>
<td>44.3</td>
<td></td>
</tr>
<tr>
<td>Global Stage</td>
<td>2.7</td>
<td>2.3</td>
<td>$F = 3.31$</td>
</tr>
<tr>
<td>$SD$</td>
<td>4.4</td>
<td>5.3</td>
<td></td>
</tr>
</tbody>
</table>

* Student’s $t$-test.

Note: WSCT, Wisconsin Card Sorting Test; $T$-scores are given; Four Pack CPT, Four Pack Card Playing Task; SRM-SF-D, Sociomoral Reflection Measure-Short Form; Raw scores are given.

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relationship between novelty seeking ($\beta = -0.53, p = 0.01$) and ACC response to negative affective pictures (Table 4). In other words, the reduction of ACC activity in response to negative affective pictures was greater in adolescents with higher novelty seeking scores. IQ was identified as another independent predictor ($\beta = 0.36, p = 0.03$) whereas the other predictors showed no significant contribution on ACC activation. In addition, we performed a voxel-wise analysis testing for brain regions that correlated with novelty seeking where IQ was included as a confounding variable. This analysis confirmed our finding of a significant correlation between novelty seeking and the dorsal ACC response to affective pictures ($p < 0.001$, uncorrected; $t = 3.51$). Strikingly, the coordinates of the peak voxel in the dorsal ACC ($x, y, z = 9, 42, 33$) were very similar to the coordinates of the voxel showing the greatest group difference in our previous study ($x, y, z = 6, 36, 33$).

Fig. 2. Regression plot showing the relationship between novelty seeking and the ACC response to negative affective pictures. ACC responses are expressed as percentage of the global brain signal across all voxels and conditions and represent differences between activations during viewing of negative and neutral pictures (for full details, see Section 2).

4. Discussion

In the present study, we investigated whether specific temperament dimensions were related to activity differences in the dorsal ACC that we had observed in a previous fMRI study when comparing responses in adolescent patients with conduct disorder with those in healthy controls (Sterzer et al., 2005). Furthermore, we investigated whether temperament was associated with behavioural control strategies which might be necessary for effectively controlling emotional processing. We found that novelty seeking, which comprises high impulsivity and a quick tempered personality, was associated with a reduced activation in the cognitive subdivision of the ACC in response to affective pictures. The result of this study indicates that the temperament dimension novelty seeking is more important in predicting the reduced ACC activation than the subject’s psychopathology (in terms of aggression and attention), when modelled in a joint statistical analysis. This may be due to the fact that temperament is the broader concept in which psychopathological behaviours are included. This result is in accordance with the hypothesis that individual differences in the temperament dimension of effortful control might be related to individual differences and developmental changes in ACC function (Rothbart, 2000). Whereas the latter assumption was based on neuropsychological data, our study provides direct support for an association between temperament and ACC function. It has been proposed that a suppression of neural activity in cognitive-processing areas might be the mechanism by which intense emotional states interfere with cognitive performance (Drevets and Raichle, 1998). Since the dorsal ACC has been implicated in cognitive processes such as monitoring of response conflicts and decision making (Bush et al., 2000), we hypothesised that the abnormal reduction of neural activation in this region during negative affect might result in a failure to cognitively control emotional behaviour (Sterzer et al., 2005). The behavioural results of the present study lend support to this assumption: In adolescents with conduct disorder, control strategies tended to be impaired in comparison with healthy controls. The patients failed to show normal learning of rules and strategies from repeated experience and feedback (Wisconsin Card Sorting Test). Furthermore, in the Four Pack Card Playing Task, patients gained significantly less monetary profit than controls, indicating impaired decision making in real-life situations when response options are variably associated with reward and punishment. Conduct disordered adolescents also tended to judge moral statements on an immature level, whereas healthy controls could be classified as belonging to the highest level with a mature moral using more prosocial than instrumental judgments. Although an impairment in social and moral behaviour has been
associated first and foremost with a deficient functioning of the prefrontal cortex (Anderson et al., 1999), one has to bear in mind that the cognitive subdivision of ACC maintains reciprocal connections with the prefrontal cortex. Kerns et al. (2004), for example, showed that behaviour control is associated with a positive correlation between prefrontal cortex and ACC activity.

Regarding the relation between temperament and neuropsychological functioning and moral development, we found a significant association between high novelty seeking and low social moral reasoning as well as disadvantageous decision making. These results are in line, for example, with the study of Le Bon et al. (2004) showing that consuming heroin, which is clearly a disadvantageous decision, is associated with increased novelty seeking. Heightened scores in novelty seeking are also found in patients with polysubstance addiction (Conway et al., 2003). On the other hand, good inhibitory control (i.e., low novelty seeking) is associated with the development of moral conduct and moral cognition in children (Kochanska et al., 1997).

In summary, the results of this study indicate that the suppressed ACC activation is associated with novelty seeking – a temperamental trait characterised by an impulsive and quick-tempered personality (Cloninger, 1987; Cloninger et al., 1993). In addition, our findings provide support for the hypothesis that the reduced affect-related dorsal ACC activation in CD patients might correspond to poor cognitive control strategies, as group differences in the assessed neuropsychological tests indicate. However, it has to be mentioned that in this study, cognitive control strategies were not directly assessed during the emotional processing task. Thus, the question whether there is a specific deficit in cognitive control strategies under emotional processing still needs to be explicitly addressed in future studies. To assess emotional processing and concomitant deficits in cognitive control, it seems helpful to use paradigms implying a cognitive task rather than passive viewing. Nevertheless, the finding that high novelty seeking scores are associated with reduced dorsal ACC responses to affective stimuli is likely to reflect dysfunctional cognitive processing in conflict situations. This is in support of the notion that novelty seeking plays a crucial role in the developmental psychopathology of aggressive behaviour. Our findings may therefore help to explain the well-established observation that difficult temperament in childhood and adolescence is one of the major risk factors for the development of later disruptive behaviour (Kingston and Prior, 1995; Schmeck and Poustka, 2001).

We conclude that a deficient activation in the dorsal ACC might be a linking factor between temperament, cognitive and emotional processing, and behavioural outcome. In that sense, a close relationship between high novelty seeking and an impaired capacity to cognitively control emotional behaviour might underly the predisposition for the development of disruptive behaviour disorders.

References


