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Research report

Neural correlates of affective empathy and reinforcement learning in boys with conduct problems: fMRI evidence from a gambling task

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HIGHLIGHTS

- Conduct problems are discussed in association with aberrant learning processes such as reward dominance and insensitivity to punishment.
- Neural correlates were found for reward dominance as well as insensitivity to punishment.
- Observing others winning or losing evoked affect regulation and perspective taking in controls, but not in adolescents with conduct problems.
- Callous-unemotional traits were correlated with this underarousal as well as aberrant learning processes.
- Disorder-specific learning processes imply a focus on rewarding instead of punishing consequences in the behavioral treatment of conduct problems.

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ABSTRACT

Background: Conduct problems (CP) comprise abnormal behaviors associated with aberrant aspects of affective empathy as well as learning. However, behavioral measures for affective empathy are challenging, and previous results concerning learning in patients with CP are inconsistent.
Methods: Nineteen boys with CP and 24 typically developing (TD) boys aged 11–17 years (M = 14.34, SD = 1.93) participated in the study. An ultimatum-game was applied in order to elicit the feeling of like or dislike towards the opponent for a subsequent gambling task, which was played by the opponents (OTHER-condition) and by the participants themselves (SELF-condition). Functional MRI data were recorded throughout the experiment.
Results: In accordance with the model of insensitivity to punishment, hypo-activation of the left amygdala, left anterior insula, ventral medial prefrontal cortex (MPFC), and bilateral temporo-parietal junction (TPJ) was observed as a response to losing in participants with CP during the SELF-condition. Callous-unemotional (CU)-traits correlated negatively with activation of amygdala and right TPJ. During the OTHER-condition, TD participants showed activation in brain areas associated with theory of mind (right TPJ, left IFG), and affect regulation (right DLPFC) rather than areas associated with affective empathy. This pattern was not found in adolescents with CP. Moreover, and independently of individual characteristics of their opponents, adolescents with CP demonstrated reward-associated activation (ventral striatum) observing others win, which was positively correlated with CU-traits. This may be interpreted in line with the theory of reward dominance.
Conclusions: The current study provides support for the theory of abnormal learning processing in adolescents with CP which yields implications for further research as well as clinical practice. The gambling task did not activate affective empathy networks, but was specific for cognitive empathy, inhibition, and affect regulation.

1. Introduction

Conduct problems (CP; including conduct disorder and oppositional defiant disorder) in childhood and adolescence comprise a pattern of behaviours that violate social norms and the rights of others, angry mood, and defiance [4]. These behaviours can be regularly observed, irrespectively of negative consequences by the

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social environment [29]. Therefore, core deficits of this disorder are related to *reinforcement learning* on the one hand, and *empathy* on the other hand. However, studies on either concept yielded mixed results. One of the possible explanations for these inconsistencies is the inhomogeneity of the CP group. Some co-occurring personality traits, namely callous-unemotional (CU) traits, are present in about 50% of children and adolescents with CP and may have a differentiating impact on results [35]. CU traits are closely related to the concept of adult psychopathy [49] and encompass emotional and interpersonal characteristics, such as lack of empathy, generally low emotionality, lack of guilt or remorse, or the manipulative use of others for one's own gain. Despite of the high prevalence of CU traits in children and adolescents with CP, epidemiological studies indicated that these traits occur in typically adolescents, too, however with a frequency of only about 5% [13,22]. Therefore, CU traits should be considered as a dimensional construct.

1.1. Reinforcement learning

Reinforcement learning describes behavior modification in dependence of positive or negative outcomes of oneís actions. In general, positive outcomes increase the likelihood of an action to be conducted in the future, whereas negative outcomes decrease this likelihood. Reinforcement not only displays an important role in infant social learning but also with respect to therapeutic intervention.

It has been hypothesized that CP may be associated with abnormal reward and punishment processing [30]. In a study with children of varying CP and CU traits, children with high values on both conditions demonstrated a decreased sensitivity to punishment, while those with high values on CP only showed an increased sensitivity to punishment [25]. A behavioral study with a door-opening-paradigm found a response perseveration in participants with CP, which can be interpreted in line with insensitivity to punishment, respectively reward dominance [44]. In this study, children with CP continued to open doors in expectance of reward and irrespective of the negative outcome of previous actions. Neuroimaging studies on reward and punishment processing in adolescents with CP, especially the ones which take into account CU traits, are scarce and yield results that differ from what has been found in behavioural studies. In a rewarded continuous performance task [52], decreased activation in the right OFC was observed in children with pure CP as compared to children without CP [27,52]. A differing OFC activation in adolescents with CP was also discussed in the context of prediction errors in learning paradigms, i.e. unexpected punishment or absence of reward [8]. Here, typically developing (TD) participants showed decreased OFC activation.

Therefore, it can be concluded that previous studies indicate aberrant reinforcement learning in children and adolescents with CP. However, mixed results have been found with respect to the direction of this aberration. Here, a differentiation between reactions towards reward as well as punishment might bring light into the origin of inconsistencies. Furthermore, the results demonstrated so far indicate the importance of considering CU traits.

1.2. Empathy

Results of behavioral studies on empathy suggest that children with CP have limited affective empathy, which includes aspects of sharing another person's emotions without experiencing the same situational conditions. At the same time, their cognitive empathy, which comprises the ability to understand the emotions of others, was found to be rather intact [7,34,56]. While a number of convincing paradigms have been developed to assess cognitive empathy, affective empathy still poses a challenge for researchers and requires further investigation [10]. On the one hand, behavioral studies rely on variants of self-report measures which require verbal skills, introspective capacity, and openness, all of which are preconditions that might be compromised in patients with specific mental disorders [42]. On the other hand, peripheral physiological measures such as heart rate, pupil size, or skin conductance indicate only unspecific emotional arousal and do not allow drawing conclusions on the affective valence experienced by the participant.

Hence, neuroimaging studies have the potential to provide further insight into mechanisms of affective empathy [40]. During the past decade, specific as well as common neural correlates have been identified for cognitive and affective empathy in healthy adults. Results of a whole-brain based meta-analysis as well as different literature reviews indicated that affective empathy was exclusively associated with activation of the right anterior insula, while both kinds of empathy were attributed to activation of the left anterior insula [24,33,40,66]. Furthermore, a study with healthy adults revealed an association between stronger activation of the anterior insula, orbitofrontal cortex (OFC), amygdala, and ACC, and dominance of affective empathy [15]. A research paradigm frequently used to assess affective empathy in neuroimaging studies is the so called "gambling task" [32]. This task involves the own experience of positive or negative outcome of gambling as well as the response to another personís outcomes. Studies demonstrated a comparable event related potential (ERP) reaction in healthy adults to an own gain compared to the gain of the other person [31]. Furthermore, the empathetic reaction differed with respect to special features of the other person such as familiarity [41,58].

With respect to children with CP, hypo-responsivity of the amygdala has been discussed [10]. However, CU traits mediate the activation pattern in children with CP. Over-reactivity to negative stimuli has been found in children with low CU traits. At the same time, elevated CU traits were associated with reduced activity in the amygdala and dorsal ACC in two studies [60,64], and in a third study, these children did not differ from typically developing children [57]. A recent study in which fearful or angry facial expressions were shown to participants demonstrated decreased responses during an affective empathy task in the left IFG and AI in participants with CP and elevated CU traits [37]. Despite these promising findings, no studies have investigated neural correlates of affective empathy in adolescents with and without CP beyond reactions to facial expressions. Furthermore, the influence of likability of the opponent on the empathetic reaction of adolescents with CP and typically developing children has not been assessed so far.

1.3. Current study

The current study was designed to address the questions of neural mechanisms of reward processing in CP and to explore affective empathy as modulated by previous experience of fairness in opponents. For this purpose, we adopted a gambling task [32] which has been shown to elicit affective empathy in past studies with healthy adults. The gambling task was to be executed by study participants themselves (SELF condition). Moreover, they were asked to observe other adolescents (OTHER condition), of varying fairness, playing the game and losing or winning money [46].

We expected to find reward-associated activations in the ventral striatum in both groups during SELF-winning, with stronger activations in the CP group given their reward dominance [25,29,44]. Particularly, we expected CU traits to correlate positively with reward-associated activations in adolescents with CP. Furthermore, we hypothesized that there would be reduced activations in limbic and paralimbic regions during SELF-losing in the CP group, these being linked to the abnormal social-affective regulation and insensitivity to punishment as has been reported for these patients