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**Luman, M., Sergeant, J.A., Knol, D.L., & Oosterlaan, J. (In Press)**

Impaired Decision-making in ODD Mediated by Psychophysiological Responses to Reinforcement. *Biological Psychiatry*

[Abstract](#)

**Background.** When making decisions, children with oppositional defiant disorder (ODD) are thought to be focused on reward and ignore penalty. This is suggested to be associated with a state of low psychophysiological arousal. **Methods.** This study investigates decision-making in 18 children with ODD and 24 typically developing (TD) controls. Children were required to choose between three alternatives that carried either frequent small rewards and occasional small penalties (advantageous), frequent large rewards and increasing penalties (seductive), or frequent small rewards and increasing penalties (disadvantageous). Penalties in the seductive and disadvantageous alternatives increased either in frequency or magnitude in two conditions. Heart-rate (HR) and skin conductance (SC) responses to reinforcement were obtained. **Results.** In the magnitude condition children with ODD showed an increased preference for the seductive alternative (carrying large rewards); this was not observed in the frequency condition. Children with ODD, as compared to TD children, displayed greater HR reactivity to reward (more HR deceleration), and smaller HR reactivity to penalty. Correlation analyses showed that decreased HR responses to penalty were related to an increased preference for large rewards. No group differences were observed in SC responses to reward or penalty. **Conclusions.** The findings suggest that an increased preference for large rewards in children with ODD is related to a reduced cardiac reactivity to aversive stimuli. This confirms notions of impaired decision-making and altered reinforcement sensitivity in children with ODD and adds to the literature linking altered autonomic control to anti-social behavior.

**Luman, M., Tripp, G., & Scheres, A. (2009)**

Identifying the Neurobiology of Altered Reinforcement Sensitivity in ADHD: A Review and Research Agenda. *Neuroscience and Biobehavioral Reviews*

[Samenvatting in het Engels](#)

ADHD is associated with altered reinforcement sensitivity, despite a number of inconsistent findings. This review focuses on the overlap and differences between seven neurobiologically valid models and lists 15 predictions assessing reinforcement sensitivity in ADHD. When comparing the models it becomes clear that there are great differences in the level of explanation. For example, some models try to explain a single core deficit in terms of lower-level reinforcement systems, such as the dopamine transfer to reward back in time. Other models explain multiple deficits, by describing higher-level systems, such as impaired bottom-up prefrontal activation. When reviewing the available experimental evidence in support of the predictions, most experimental studies have been focusing on behavioral changes in the face of reward and response cost over no-reward, and on delay discounting. There is currently a lack of studies that focus on explaining underlying cognitive or neural mechanisms of altered reinforcement sensitivity in ADHD. Additionally, there is a lack of studies that try to understand what subgroup of children with ADHD shows alterations in reinforcement sensitivity. The scarcity of studies testing the neurobiological predictions is explained partly by a lack of knowledge how to test some of these predictions in humans. Nevertheless, we believe that these predictions can serve as a useful guide to the systematic evaluation of altered reinforcement sensitivity in ADHD.

**Luman, M., Van Meel, C. S., Oosterlaan, J., Sergeant, J. A., & Geurts, H. M. (2009)**

Is it reward frequency or magnitude that drives reinforcement learning in ADHD. *Psychiatry Research*, 168, 222-229.

[Reprint](#)

Children with attention-deficit/hyperactivity disorder (ADHD) show an impaired ability to use feedback in the context of learning. A stimulus-response learning task was used to investigate whether (1) children with ADHD displayed flatter learning curves, (2) reinforcement-learning in ADHD was sensitive to either reward frequency, magnitude, or both, and (3) altered sensitivity to reward was specific to ADHD or would co-occur in a group of children with autism spectrum disorder (ASD). Performance of 23 boys with ADHD was compared with that of 30 normal controls (NCs) and 21 boys with ASD, all aged 8–12. Rewards were delivered contingent on performance and varied both in frequency (low, high) and magnitude (small, large). The findings showed that, although learning rates were comparable across groups, both clinical groups committed more errors than NCs. In contrast to the NC boys, boys with ADHD were unaffected by frequency and magnitude of reward. The NC group and, to some extent, the

ASD group showed improved performance, when rewards were delivered infrequently versus frequently. Children with ADHD as well as children with ASD displayed difficulties in stimulus–response coupling that were independent of motivational modulations. Possibly, these deficits are related to abnormal reinforcement expectancy.

**Luman, M., Van Noesel, S.J.P., Papanikolau, A., Veugelers, D., Sergeant, J.A., & Oosterlaan, J. (2009)**

Inhibition, reinforcement sensitivity and temporal information processing in ADHD and ADHD+ODD: Evidence of a separate entity? *Journal of Abnormal Child Psychology*, 37, 1123-1135.

[Reprint](#)

This study compared children with ADHD-only, ADHD+ODD and normal controls (age 8–12) on three key neurocognitive functions: response inhibition, reinforcement sensitivity, and temporal information processing. The goal was twofold: (a) to investigate neurocognitive impairments in children with ADHD-only and children with ADHD+ODD, and (b) to test whether ADHD+ODD is a more severe form of ADHD in terms of Neurocognitive performance. In Experiment 1, inhibition abilities were measured using the Stop Task. In Experiment 2, reinforcement sensitivity and temporal information processing abilities were measured using a Timing Task with both a reward and penalty condition. Compared to controls, children with ADHD-only demonstrated impaired inhibitory control, showed more time underestimations, and showed performance deterioration in the face of reward and penalty. Children with ADHD+ODD performed in between children with ADHD-only and controls in terms of inhibitory controls and the tendency to underestimate time, but were more impaired than controls and children with ADHD-only in terms of timing variability. In the face of reward and penalty children with ADHD+ODD improved their performance compared to a neutral condition, in contrast to children with ADHD-only. In the face of reward, the performance improvement in the ADHD+ODD group was disproportionately larger than that of controls. Taken together the findings suggest that, in terms of Neurocognitive functioning, comorbid ADHD+ODD is a substantial different entity than ADHD-only.

**Luman, Marjolein (2009)**

Een afwijkende gevoeligheid voor beloning: een neurobiologische verklaring voor ADHD?. *Neuropraxis*, 13, 55-60.

[Reprint](#)

Elke ouder kent het gegeven dat zijn kind het ene moment heel druk is, terwijl het een ander moment rustig aan het spelen is. Bij kinderen met attention-deficit/hyperactivity disorder (adhd) zullen deze uitersten nog meer opvallen: veel kinderen kunnen niet stilzitten tijdens het eten, maar kunnen wel kalm in de bioscoop naar een film kijken. Deze variabiliteit in de ernst van adhd-symptomen is karakteristiek voor deze ontwikkelingsstoornis. Eén van de verklaringen is dat het gedrag van kinderen met adhd zeer afhankelijk lijkt van prikkels uit de omgeving. Verondersteld wordt dat als kinderen met adhd iets doen wat ze leuk vinden of wanneer ze aangemoedigd worden, ze beter gaan presteren en meer aandacht kunnen besteden aan hun werk.

**Geurts, H.M., Luman, M., & Van Meel, C.S. (2008)**

What's in a game: The effect of social motivation on cognitive control in boys with ADHD and ASD. *Journal of Child Psychology and Psychiatry*, 49(8), 848-857.

[Samenvatting in het Engels](#)

Background: Children with attention deficit hyperactivity disorder (ADHD) and with autism spectrum disorders (ASD) are known to have cognitive control deficits. Some studies suggest that such deficits may be reduced when motivation is increased through tangible reinforcers. Whether these deficits can also be modulated by non-tangible reinforcers has hardly been studied. Methods: Therefore, the effect of social motivation on the ability to suppress irrelevant information (i.e., interference control) was investigated in 22 ADHD boys, 22 ASD boys, and 33 typically developing (TD) boys. An adapted Eriksen Flanker task was administered under a motivational condition in which the boys were told that they were competing with peers, and under a neutral condition in which standard instructions were given. Results: In comparison with TD boys, boys with ADHD were impaired even when no interference was present, while this was not the case for the ASD boys. All groups benefited from the motivation manipulation, i.e., their performance increased when they thought they were competing with peers. Although the boys with ADHD were still slower than TD boys when motivated, they performed as accurately as TD boys. Children with ASD also improved slightly in accuracy and response speed, but this did not reach significance. Conclusion: Children with ADHD are able to exert sufficient cognitive control when they are motivated, which is in line with the current models of ADHD. However, motivation seems to have a general effect on performance and is not solely related to cognitive control abilities.

In contrast, this effect was not obtained in children with ASD.

**Luman, M., Oosterlaan, J., Knol, D. L., & Sergeant, J.A. (2008)**

Decision making in ADHD: Sensitive to frequency but blind to the magnitude of penalty?. *Journal of Child Psychology and Psychiatry*, 49, 712-722.

[Reprint](#)

Background: Decision-making and reinforcement sensitivity were investigated in 23 children with ADHD and 20 healthy controls using a gambling paradigm. Methods: Children were required to choose between three alternatives that carried (A) small rewards and small penalties (advantageous), (B) large rewards and increasing penalties and (C) small rewards and increasing penalties (both disadvantageous). Penalties increased either in frequency or magnitude in two independent conditions. Heart rate (HR) and skin conductance (SC) were measured to examine whether impaired decision-making was accompanied by autonomic abnormalities. Results: Children with ADHD showed a maladaptive response style compared to controls by demonstrating a smaller preference for the advantageous alternative, when penalties increased in magnitude. When penalties increased in frequency, children with ADHD performed like controls. Group differences in decision-making attenuated after the task was administered twice. Compared to controls, performance of children with ADHD in the magnitude condition was accompanied by increased HR acceleration following reward. In this condition, the post-selection SC of children with ADHD was larger for advantageous than for disadvantageous alternatives, in contrast to controls who showed an opposite SC pattern. Conclusions: The current findings suggest that during decision-making, children with ADHD may be sensitive to the frequency but blind to the magnitude of penalty.

**Luman, M., Oosterlaan, J., & Sergeant, J.A (2008)**

Affective modulation of response timing in ADHD: The impact of reinforcement valence and magnitude. *Journal of Abnormal Child psychology*, 36(3), 445-456.

[Samenvatting in het Engels](#)

The present study investigated the impact of reinforcement valence and magnitude on response timing in children with ADHD. Children were required to estimate a 1-s interval, and both the median response time (response tendency) and the intrasubject-variability (response stability) were investigated. In addition, heart rate and skin conductance were measured to examine the autonomic responses to reinforcement. Feedback-only trials were compared to low response cost trials (response cost for incorrect responses), low reward trials (reward for correct responses), high response cost and high reward trials. In feedback-only trials, children with ADHD underestimated more severely the interval and responded more variably than controls. Children with ADHD, unlike controls, were unaffected by the reinforcement conditions in terms of time underestimations. The variability of responding, on the other hand, decreased under conditions of reinforcement to a larger extent in children with ADHD than controls. There were no indications that children with ADHD were abnormally affected by the valence or magnitude of reinforcement. Furthermore, skin conductance responses increased when feedback was coupled with reinforcement, an effect which was larger in children with ADHD than controls. This could be interpreted as demonstrating that children with ADHD suffer from a diminished awareness of the significance of feedback in the feedback-only condition. The current study suggests that children with ADHD suffer from motivation problems when reinforcement was not available, at least when variability in responding was measured. Underestimations of time may reflect more stable deficits in ADHD.

**Luman, M., Oosterlaan, J., Van Meel, C. S, Hyde, C., & Sergeant, J.A. (2007)**

Heart rate and reinforcement sensitivity in ADHD. *Journal of Child Psychology and Psychiatry*, 48(9), 890-898.

[Reprint](#)

Background: Both theoretical and clinical accounts of attention-deficit/hyperactivity disorder (ADHD) implicate a dysfunctional reinforcement system. This study investigated heart rate parameters in response to feedback associated with reward and response cost in ADHD children and controls aged 8 to 12. Methods: Heart rate responses (HRRs) following feedback and heart rate variability (HRV) in the low frequency band (.04-.08 Hz), a measure of mental effort, were calculated during a time production paradigm. Performance was coupled to monetary gain, loss or feedback-only in a cross-over design. Results: Children with ADHD exhibited smaller HRRs to feedback compared to controls. HRV of children with ADHD decreased when performance was coupled to reward or response cost compared to feedback-only. HRV of controls was similar across conditions. Conclusions: Children with ADHD were characterised by (a) possible abnormalities in feedback monitoring and (b) motivational deficits, when no external reinforcement is present.