Electrophysiological Correlates and Callous-Unemotional Traits as Predictors of Cognitive Impairments in Children and Adolescents

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Abstract

Fear recognition and working memory (WM) may be impaired in children and adolescents with callous-unemotional (CU) traits. Moreover, a mediating role in this cognitive impairment may be suggested for baseline automatic nervous system (ANS) measures, such as heart rate (HR) and skin conductance response (SCR). The present thesis examined fear recognition and WM performance in relation to CU traits and investigated a possible mediating involvement of ANS measures in this relationship. By utilizing a pooled sample cases (oppositional defiant disorder or conduct disorder) and controls aged eight to 17 years (n = 49), the predicting relationship of CU trait level on WM and fear recognition was examined. Furthermore, the mediating influence of HR, SCR and heart rate variability (HRV) on the relationship between CU traits and WM as well as fear recognition was investigated. Outcomes supported the hypothesis that higher CU traits were significantly related to lower WM functioning. Also, a preliminary significant effect was found for the predicting role of higher CU traits on poorer fear recognition. The assumption of a mediating link of ANS measures on the relationship between CU traits and WM as well as fear recognition function, however, could not be demonstrated. The findings challenge the idea of a mediating involvement of ANS measures in the relationship between CU traits and impairments in WM and fear recognition. The strengths, limitations and implications for research and clinical practice of the current study are discussed and suggest the need for future research to gain a better insight into the cognitive and behavioral components of CU traits in general and improve interventions for individuals with antisocial behavior.

Keywords: callous-unemotional traits, working memory, fear recognition, autonomic nervous system

Electrophysiological Correlates and Callous-Unemotional Traits as Predictors of Cognitive Impairments in Children and Adolescents

Disruptive behavioral disorders (DBDs) such as conduct disorder (CD) and oppositional defiant disorder (ODD) contribute a great deal to different behavioral and cognitive problems in children and adolescents such as aggressive behavior or impairments in emotion processing (Burke et al., 2002). Prevalence rates range from two to four percent and DBDs are thus, one of the most frequently diagnosed disorders in the youth population (Polanczyk et al., 2015; Loeber et al., 2015). Often, these disruptive behaviors affect a wide range of societal as well as individual concerns, such as academic, social, and/or emotional impairments, as well as criminality in adulthood (Kimonis & Frick, 2011). Whereas ODD can be characterized by irritability and defiance towards authorities like parents or teachers, CD involves the general violation of social standards and the personal rights of others (American Psychiatric Association, 2013). Yet, ODD is often viewed as a precursor of CD (Moffitt et al., 2008). The clinical representation of disruptive behavior, however, varies a lot among individuals and due to this heterogenous nature of DBDs, research focused on subtyping approaches to identify differences within disruptive behaviors and to gain a better understanding of DBDs in general (Frick & Nigg, 2012). Some of the subtyping approaches have focused on distinguishing between reactive and proactive forms of aggression (Frick et al., 1993), age of onset (Moffin et al., 2008) or the presence of comorbidities, such as attention- deficit/hyperactivity disorder (ADHD; Frick & Nigg, 2012).

The currently most accepted approach, however, is the assessment of callous-unemotional (CU) traits (Frick & Nigg, 2012), which can be defined as a lack of empathy and remorse, emotional dysregulation, as well as an unconcernedness about the own performance (Frick et al., 2104a). It has been conceptualized that CU traits are a “downward extension” of the callousness element in adult psychopathy (Salekin, 2017), and more importantly, they are considered a developmental risk factor for psychopathy (Lynam et al., 2007). Furthermore, the fifth edition of the Diagnostic and Statistical Manual of Mental Disorders (DSM-5; APA, 2013) included CU traits as a specifier of a CD diagnosis, i.e. “with limited prosocial emotions”. Elevated CU traits have been linked to more severe delinquency, violent acts towards others and consequently, the experience of many interpersonal problems (Frick, et al., 2003). Broadly speaking, individuals with high levels of CU traits (HCU) tend to show a distinct temperamental profile compared to those with low levels of CU traits (LCU; Blaire et al, 2014). Typically, those with DBDs and LCU can be associated with poor executive functions (EFs), such as inhibitory control problems, resulting in emotion regulation deficits and the expression of reactive aggression (RA; Cruz et al., 2020). RA is considered a rather impulsive form of aggression, usually in response to provocation (Miller & Lynam, 2006). Furthermore, individuals with DBDs and HCU traits have been demonstrated to show impairments in emotion recognition, especially fear recognition, and the accumulation of proactive aggressive behavior (Frick et al., 2014). Proactive aggression (PA) refers to planned and goal-directed behavior and is highly correlated with CU traits (Miller & Lynam, 2006). Additionally, children with DBDs and HCU traits have been associated with a high need of sensation seeking and lowered fearlessness, combined with a diminished susceptibility to punishment cues (Blaire et al., 2006; Frick et al., 2014).

Those unique cognitive impairments, such as executive dysfunctions or fear recognition problems, in individuals with DBDs and HCU traits differences imply that different treatment approaches may be required to successful target impairments in individuals with elevated CU traits. However, mixed evidence exists and various studies did not support associations between CU trait level and EFs in samples with disruptive individuals, including forensic (Pardini, 2012) and community samples (Fanti et al., 2018). These null findings may be explained by existing gaps in the literature. Firstly, it has to be noted that several studies on CU traits have been restricted by the use of EF tasks that assess combined domains of EFs (Fanti & Kimonis, 2017; Hadjicharalambous & Fanti, 2018). EFs can be defined as several goal-oriented and higher-order cognitive processes (Platje et al., 2018). CU traits, however, may be more strongly related to very specific EF tests, such as working memory tests (WM; Rydell & Brocki, 2019). Moreover, many studies utilized a case versus control group approach, which only compares the extreme ends of these populations (i.e. high versus low; Dotterer et al., 2021). However, there is cumulating evidence that CU traits may be better understood by a dimensional approach (Blonigen et al., 2006). Thus, these null findings indicate the further need of research to clarify whether CU traits can be linked to impairments in more specific EFs, such as WM, following a dimensional design.

WM is a very crucial component in integrating social information, such as interpreting others' emotions or intentions (Hillebrandt & Barclay, 2017). For successfully managing the social environment, in terms of appropriately reacting in social situations, individuals constantly need to adjust and maintain social information in their WM to further process it (Herman et al., 2007). Impairments in WM have been observed in individuals with DBDs and it seems very reasonable to assume that those impairments might lead to interpersonal problems (Platje et al., 2018). Therefore, early identification of WM impairments is of great concern to better understand cognitive processes of children and adolescents with DBDs and consequently, increase the development of intervention programs. It has been found that adult violent offenders demonstrate poorer WM functioning compared to healthy controls (Hoaken et al., 2007). However, most research so far has been conducted in the adult population only and specifically WM memory functioning in youth samples with CU traits has been extremely understudied.

Contrary to WM, emotion recognition has been widely investigated in samples with CU traits, using both a dimensional as well as a categorical framework (Aggensteiner et al., 2020, Oldenhof et al., 2019). In typically developing children, emotion recognition abilities are well developed by the age of eight and children are then able to integrate relational and contextual information to engage in prosocial behavior with others (Pons et al., 2004). As already indicated, children and youth with CU traits, however, seem to have a deficit in emotion recognition (Marsh & Blaire, 2008). As noted above, specifically, an impairment to recognize facial expressions of fear is a well-established finding in children and adolescents with elevated CU traits (Dawel et al., 2012). This deficit has been suggested to be one explanation why individuals with DBDs may behave negatively towards others (Munoz, 2009) since successful social communication requires intact facial emotion recognition (Andrew, 1963). Blair (2001) suggested that the failure to correctly recognize the expression of fear in others will result in non-inhibition of the own behavior. Thus, affected individuals are more likely to take advantage of others and consequently, engage regularly in antisocial behaviors (Blair, 2001).

An explanation for the frequent engagement in antisocial actions has been found within the framework of the low arousal theory (Portnoy & Farrington, 2015). Following this theory, individuals with DBDs and elevated CU traits, can be associated with lower physiological arousal, expressed as low heart rate (HR) or skin conductance (SC), compared to typically developing controls (Portnoy & Farrington, 2015). According to the sensation seeking theory (Raine, 2002), it has been suggested that individuals with low basal arousal seek sensation in order to boost their own arousal to an optimal level (usually through risky actions) to compensate for their rather uncomfortable physiological condition (Beauchaine, 2012). Furthermore, the fearlessness theory (Raine, 2002) assumes that low levels of physiological measures are associated with fearlessness and the failure to avoid harm (Raine, 1993). Being fearless is linked to a generally lower evaluation of possible negative consequences of antisocial behavior as well as an insensitivity to punishment, which usually leads to a flawed capability to learn from punishment (Fanti, 2018). Although the low arousal theory has been consistently replicated in the adult population, many mixed results were obtained in studies investigating children or adolescents (MacDougall et al., 2019, Kavish et al., 2017).

Research has also been suggested that antisocial/aggressive behavior can be linked to differences in electrophysiological measures that reflect the individual's emotional arousal (Raine et al., 2014). As explained above, the autonomic nervous system (ANS) plays an important role in regulating physiological responses to challenges in the environment and is therefore, crucial for behavioral as well as emotional regulation (Beauchaine & Thayer, 2015). Electrophysiological measures reflecting ANS activity include, amongst others, HR and skin conductance response (SCR; Raine et al., 2014). The SCR is primarily associated with the sympathetic path of the ANS. The sympathetic nervous system (SNS) is responsible for mediating functions such as alertness, arousal, or mobilization and stimulates the body's own resources to cope with elevated metabolic demands during arousing situations (Sapolsky, 1998). SCR resembles fast and phasic alterations in electrical conductivity (MacDougall et al., 2019).

HR, on the other hand, results both from activity of the SNS and parasympathetic nervous system (PNS; MacDougall et al., 2019). The PNS deals with the maintenance of organ function during resting or minimal activity as well as with the preservation of general energy and is sometimes called the rest and digest system (Stern et al., 2000; Dietrich, 2007). Next to HR, research focused on an additional ANS measurement that identifies the individual differences in autonomic activity (Fanti, 2018). The so-called heart rate variability (HRV), which can be described as the individual's distinctive time span between sequential heart beats, is also considered a reliable indicator of ANS activity (Acharya et al., 2006). Whereas heart beat accelerations are proposed to be the result of increased SNS or decreased

PNS activity, heart beat decelerations are usually the result from decreased SNS or increased PNS activity (Hansen et al., 2007). Moreover, HRV is recognized as a marker of emotion regulation, with higher HRV being associated with successful emotion regulation and lower HRV being associated with impairments in emotion regulation, reflecting the modulating role of cardiac activity to favorably handle novel/changing situations (Acharya et al., 2006). Measuring HR, HRV and SCR at rest, reflects the individual's autonomic activity without any external stimulation (Fanti, 2018) and it has been suggested that individual variations in baseline ANS functioning might explain why some are more prone to psychopathological impairments, whereas others are not (McLaughlin et al., 2014).

Following the low arousal theory, it has been repeatedly demonstrated that children and adolescents with CU traits display differences in basal ANS measures compared to typically developing children (Portnoy & Farrington, 2015). While children with DBDs and low CU traits usually show hyper-arousal of baseline HR and SC measures (i.e., high HR and SCR), children with DBDs and low CU traits are characterized with a hypo-arousal of those baseline measures (i.e., low HR and SCR; Frick & Elli's, 1999). Nevertheless, findings have been inconsistent, multiple studies did not find lower levels of basal physiological arousal in children and adolescents demonstrating antisocial behavior and high? CU traits when compared to typically developing children or even found higher levels of arousal (Schoorl et al., 2016; Scott & Weems, 2014). Furthermore, most studies investigating ANS measures and antisocial behavior in children focused on the general population, displaying various forms and levels of subclinical antisocial problems, thereby neglecting the approach of focusing on subtypes of antisocial behavior (Oldenhof et al., 2019).

It has also been suggested that cognitive impairments in individuals with high CU traits might be a result of differences in ANS functioning, i.e. lower ANS activity (Raine et al., 2014). Generally, cognitive functioning is thought to worsen when ANS measures deviate (lower/higher) from what is considered normal (Thayer et al., 2010). More specifically, a relationship between ANS measures, CU traits and fear recognition has been indicated (Aggensteiner et al., 2020). Aggensteiner and colleagues (2020) linked skin conductance (SC) hypo-activation to negative emotions (i.e. fear) in a sample of individuals with DBDs and additionally, found that higher CU traits can be associated with lower SCR. Others, however, found a SC over-activation in antisocial samples in response to negative emotions (i.e. fearful stimuli; Fanti, 2018). Emotion recognition deficits have also been investigated with regard to HR and HRV (Quintana et al., 2012). In typically developing individuals, higher HRV has been related to more accurate emotion recognition (Quintana et al., 2012). In antisocial populations, more mixed results have been found (Fanti, 2018). Some report a link between higher HR and emotion recognition deficits (Fanti, 2018), whereas others connected lower HR measures with deficits in emotion recognition (Fanti, 2018).

These inconsistent findings indicate the further need to clarify the role of variability in ANS measures of children and adolescents with CU traits and whether these differences can be linked reliably to cognitive impairments. Since consequences of antisocial behavior can be costly and the earlier cognitive impairments are detected, the better, those far-reaching consequences can be prevented.

Due to the limited and inconsistent research in children and adolescents with CU traits in combination with ANS measures and cognitive impairments, the current thesis has two aims:

Firstly, to replicate previous findings, whether CU traits can predict impairment in WM or fear recognition in children and adolescents. Following a dimensional approach of CU traits and based on the above presented research, Hypothesis I and Hypothesis II were developed:

Hypothesis I: Children and adolescents with higher CU traits show poorer WM functioning compared to those with lower CU traits.

Hypothesis II: Children and adolescents with higher CU traits, show poorer fear recognition compared to those with lower CU traits.

Moreover, the thesis intends to investigate a possible mediating link of baseline ANS measures on the relationship between CU traits and WM or fear recognition in children and adolescents and following, Hypothesis III was formulated:

Hypothesis III: The relationship between CU traits and both independent outcome measures WM and fear recognition functioning cannot be explained by a direct effect alone, but more strongly through an indirect effect of lower resting ANS measures.

In summary, the thesis aims at answering the research question: Do higher CU traits in children and adolescents predict poorer WM or fear recognition functioning and is this relationship mediated by baseline electrophysiological correlates, i.e. HR, HRV, and SCR?

Method

Sample and Procedure

The current sample consisted of 49 participants, of which 10 were female and 39 were male. The participant`s average age was 12.10 years (*SD* = 2.61), ranging from 8.02 years to 17.93 years. The average IQ was calculated with 105.55 points (*SD* = 11.28).

Participants who were considered "cases" ($N = 35$; $M_{age} = 11.80$ years, *SD* = 2.50) from which $N = 30$ were male, were diagnosed with CD and/or ODD which was based on the structured diagnostic parent-child interviews of the Kiddie Schedule for Affective Disorders and Schizophrenia (K-SADS; Kaufman et al., 1997) or if they scored above a cut-off value (*T* value ≥ 70) on the Child Behavior Checklist filled in by parents, teachers or youths themselves (CBCL/TRF/YSR; Achenbach et al., 1991). Participants were assigned to the control group (*N* = 14; M_{age} = 12.85, *SD* = 2.83; N_{male} = 9) if the K-SADS, the CBCL, TRF, or YSR allowed for an exclusion of a DSM axis I disorder. Generally, exclusion criteria in both groups were a previous diagnosis of a psychosis, bipolar disorder, anxiety disorder, and/or major depression according to DSM-5 criteria or an IQ < 80, assessed with four subtests (vocabulary, similarities, block design, and picture completion/matrix reasoning) of the Wechsler Intelligence Scale for Children-IV (Wechsler, 2003). Cases were recruited via institutions for child and adolescent mental health facilities and controls via advertisements in school.

The sample and data collection were part of a larger multicenter cross-sectional study (joined EU-Aggressotype and EU-MATRICS projects; see http://www.matrics-project.eu; http://www.aggressotype.eu/ for more information) in which nine different research locations in Europe were involved. The variables of interest for the current study, however, were only available from participants recruited in Germany (n = 30) and Switzerland (n = 19). The main objectives of the original study were to compare characteristics of children and adolescents diagnosed with ODD and/or CD with typically developing controls. Additionally, the study aimed to investigate subtypes of aggression from a behavioral, cognitive, neural, neurobiological, and genetic point of view.

Ethical approval for conducting the study was given from local ethics committees for each site separately. All participants and their (guardian) parents provided informed consent.

Materials

CU trait Assessment

To assess the level of the participants' CU traits, the parents/guardians of the participants were asked to rate their child's/guardian child's CU trait level by filling in the Inventory of Callous-Unemotional traits (ICU; Kimonis et al., 2008). The ICU is considered a valid and reliable measurement of CU traits with good reliability and external validity

(Cardinale & Marsh, 2020). It consists of 24 items distributed over three subscales, which can be defined as: uncaring, callousness, and unemotional. The rating scale of the ICU ranges from *"0 = not at all", "1 = somewhat true", "2 = very true", to "3 = definitely true",* with a maximal score of 72. An example item is "Does not care who he/she hurts to get what he/she wants". The higher the total score of the ICU, the more pronounced the child's CU traits. Some of the items needed to be reverse-scored. In total, the assessment of the ICU took approximately five minutes per (guardian) parent.

Working Memory Assessment

For assessing WM memory accuracy, participants were asked to complete the Delayed Matching to Sample Task of the Cambridge Automated Neuropsychological Test Battery (CANTAB; Cambridge Cognition, 2019). In this task, an abstract visual (target) pattern was presented to the participants and, followed by a short delay, four similar patterns were presented. The participants were asked to select the option that matched the pattern. After three practice trials, participants were asked to complete 20 counterbalanced test trials. In five trials, the choice patterns were presented simultaneously with the original pattern and in five trials each after, the matching options presentations were shown after zero, four, and 12 seconds. The outcome measure was the average response accuracy of all trials measured in percentage correct. The whole assessment took approximately seven minutes per participant. Generally, the CANTAB was shown to have high internal consistency coefficients ranging from .73 to .95 and having food validity (Luciana, 2003).

Emotion Recognition Assessment

For the assessment of emotion recognition, participants were asked to complete the Emotion Recognition task of the CANTAB (Cambridge Cognition, 2019). Different facial expressions were shown for 200ms to the participants, which were then asked to identify the emotion as either happy, sad, fear, anger, disgust, or surprise. However, for the current thesis, only the fear recognition data was considered. In total, participants completed two blocks with each 90 trials consisting of 15 stimuli for each emotion. The outcome measure was the participant's response accuracy in percentage, indicating emotion recognition. The assessment took approximately six to ten minutes per participant. As described above, the CANTAB can be considered a reliable and valid measurement (Luciana, 2003).

Heart rate and Heart rate variability

Resting HR in beats per minute (bpm) was derived from a finger clip pulse oximeter sensor (Nonin Medical, Inc., Plymouth, USA) of the participant's second finger. The analysis of HR data was performed in a Brain Vision analyzer (Brain Products, Gliching, Germany). HR data was bandpass filtered by a low cut-off of 5Hz and a high cut-off of 15Hz. The R-waves time series were extracted from the HR data by a semi-automatic solution of Brain Vision Analyzer and inspected manually for missed or incorrect R-peak registration. Eventually, the correctly recorded R-peaks were utilized to calculate HR as well as HRV as a time domain measure, which is the varying time between sequential heart beats, with an in house matLab script in milliseconds (ms).

Skin conductance response

SCR was measured inside a functional magnetic resonance imaging (fMRI) scanner, using Ag/AgCl electrodes in combination with an electrode paste containing 0.5% saline. The electrodes were located at the distal phalanges of the participants' index and middle finger of the non-dominant hand. The collected data were downsampled to 10Hz and further processed with the 3.4.9. version of Ledalab (www.ledlab.de) by applying a continuous decomposition analysis and extracting a specific time integral for future analyses. The decomposition into continuous tonic and phasic activity during this method is considered fast and robust against artifacts (Benedeck & Kaernbach, 2010). Outcome measures are indicated in microSiemens (μS).

Control variables

Covariates of interest in all analyses were age, sex and IQ. Those variables have been associated to influence ANS measures and cognitive functioning. Additionally, IQ has been linked to CU trait level (Cruz et al., 2020).

Statistical analysis

All statistical analyses were performed with the 26th version of the IBM SPSS Statistics software, using an alpha level of .05, unless otherwise stated.

Preparatory analysis

The study employs a cross-sectional design. Demographic differences between cases and controls in age and IQ were tested with an independent-samples T test. Sex differences between cases and controls were tested with Fisher's exact test.

Outcome measure of the two CANTAB tasks, i.e. Emotion Recognition task and Delayed Matching to Sample task were screened for outliers, which indicated insufficient task involvement. Exclusion of participants was done, when z-scores were $\geq |3.0|$ on at least one outcome measure of the tasks.

Due to a skewed distribution of SCR measures within the sample, this variable was log-transformed with 1+log SCR for the further analysis.

Group differences (n_{cases} = 35 versus controls $n_{controls}$ = 14) of the outcome measures of the CANTAB tasks were investigated with an independent-samples T test.

To explore the relationship between ANS measures, i.e. HR, HRV and SCR, and all other included variables, univariate correlational analyses were conducted employing Pearson's correlation and considering $r \leq .10$ as a small effect, $r \leq .30$ as a medium effect and $r \geq .50$ as a large effect (Cohen, 1988). Also, group differences (cases versus controls) of ANS measures, i.e. HR, HRV and SCR, were investigated with an independent T test or Mann-Whitney U test, where appropriate.

Hypothesis Testing

Linear regression analysis was performed investigating the contribution of CU traits to WM functioning. Initially, only the covariates age, sex and IQ were added (Model 1). In a next step, CU traits were entered as a predictor (Model 2). Following the same procedure, a separate linear regression analysis was performed to examine the predictive role of CU traits on fear recognition. Firstly, only the covariates were included in the model (Model 1), followed by entering CU traits as a predictor of fear recognition functioning (Model 2). Effect sizes were indicated by R^2.

Further, the mediating role of ANS measures on the relationship between CU traits and fear recognition and WM functioning was investigated. The PROCESS Macro function (Hayes, 2013) to perform a moderated mediation, following a dimensional approach, was used. Individual models were specified for each ANS correlate, i.e. HR, HRV and SCR, and each cognitive domain, i.e. fear recognition and WM accuracy, respectively. For testing significance, the PROCESS Macro function (Hayes, 2013) procedure uses a bootstrapping approach of indirect effects of the variables at various levels of the moderators (Hayes, 2013). Significance of the indirect effect was accepted when the 95% confidence interval (CI) did not contain zero (Preacher & Hayes, 2004). Acceptance of the hypothesis implies that within the specific mediation model, (1) CU traits predict WM and fear recognition functioning, i.e. higher CU traits predict poorer WM and fear recognition, (2) CU traits predict baseline ANS measures, i.e. higher CU traits predict lower ANS measures, (3) baseline ANS measures predict WM and fear recognition functioning i.e. lower ANS measures predict poorer WM and fear recognition, and (4) the relationship between CU traits and WM and fear recognition function is smaller when ANS measures are integrated in the model.

Results

Preliminary analyses

Before running the main analyses, the assumptions for linear regression analysis were tested. Almost all assumptions (i.e. linearity, absence of multicollinearity, and homogeneity) were met. SCR did not show a normal distribution. Overall, 10.2% (n = 5) of the data was missing.

Table 1 presents the descriptive information of the proposed variables. Overall differences between cases and controls in age, sex, IQ, CU trait score, WM and fear recognition response accuracy as well as ANS correlates (HR, HRV, SCR) were calculated using an independent-samples T test. Chi-square results of sex differences between cases and controls were not confirmed with Fisher's exact test (two-tailed p = .12).

Table 1

Mean, Standard Deviation and Correlations of the Proposed Variables Within the Pooled Sample

	M	*SD*	Fear Recognition	WM	CU traits	HR	HRV	SCR	Age	Sex	IQ
Fear Recognition	35.69	20.13	-								
WM	77.95	15.69	.42**	-							
CU traits	29.86	10.22	-.34*	-.25	-						
HR	82.27	15.75	.02	-.26	.08	-					
HRV	.77	.14	-.02	.25	-.03	-.77**	-				
SCR	6.92	4.77	-.24	-.02	.03	.01	-.01	-			
Age	12.1	2.61	-.15	.33*	.16	-.33*	.28	-.90	-		
Sex	-	-	-.30*	-.31*	.11	-.01	.03	.14	-.20	-	
IQ	105.55	11.28	.05	.12	.06	-.09	.11	.34*	-.01	-.02	-

Note. N = 49. Intercorrelations are presented below the diagonal.

M = Mean; *SD* = Standard Deviation; Fear recognition = measured in % correct (Emotion Recognition task of CANTAB Cambridge Cognition, 2015); WM = Working Memory in % (Delayed Matching to Sample task of CANTAB Cambridge Cognition, 2015); CU = Callous-unemotional traits measured with the Inventory of Callous-Unemotional traits; HR = Heart rate in beats per minute; HRV = Heart rate variability in milliseconds; SCR = Skin conductance response in microSiemens.

Sex: 1 = male, 0 = female.

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

Table 2

Independent Samples T Test Comparing Autonomic Nervous System Measures and Cognitive Test Performance between cases and controls

	Cases *n* = 35		Controls *n* = 14				
	M	*SD*	*M*	*SD*	*t*	*df*	*p* (two-tailed)
HR	85.68	16.23	74.17	7.94	2.52	46	.02
HRV	.75	.14	.81	.09	-1.70	46	.10
CU traits	34.31	9.98	21.93	5.85	4.34	47	.00
WM	75.55	14.86	88.1	13.88	-3.36	46	.00
Fear Recognition	32.74	17.92	39.76	24.58	-1.10	45	.28

Note. $N = 49$.

M = Mean; *SD* = Standard Deviation; WM = Working Memory in % (Delayed Matching to Sample task of CANTAB Cambridge Cognition, 2015); Fear recognition = measured in % correct (Emotion Recognition task of CANTAB Cambridge Cognition, 2015); CU = Callous-unemotional traits measured with the Inventory of Callous-Unemotional traits; HR = Heart Rate in beats per minute; HRV = Heart Rate variability in milliseconds; SCR = Skin Conductance Response in microSiemens.

Table 2 shows group comparison between cases and controls of ANS measures, WM and fear recognition. The independent T test comparison revealed significant higher measures of HR ($M = 85.68$, $SD = 16.23$, $t(46) = 2.52$, $p = .015$) in cases than controls. The outcome of the independent samples T test for HRV and the Mann-Whitney U test for SCR did not show significant differences between both groups. WM accuracy performance was significantly lower in cases than controls (*M* = 75.55, *SD* = 14.86, *t*(46) = 4.33, *p* = .002). Fear recognition did not show significant differences between cases and controls.

The intercorrelations between all included variables are also shown in Table 1. Not all variables were significantly correlated. Fear recognition accuracy did not show significant correlations with ANS measures, i.e. HR (*r* = .02, *p* = .88), HRV (*r* = -.02, *p* = .91) and SCR (*r* = -.24, *p* = .11); however, it was significantly negatively correlated to CU traits (*r* = -.34, *p* = .02), that is, that children with higher CU traits show poorer fear recognition. WM performance was not significantly correlated with HR (*r* = -.26, *p* = .08), HRV (*r* = .25, *p* = .09), SCR (*r* = -.02, *p* = .87) or CU traits (*r* = -.25, *p* = .09) either. CU traits also did not show significant correlations with HR (*r* = .08, *p* = .60), HRV (*r* = -.03, *p* =.85) or SCR (*r* = .03, *p* = .87). In terms of the covariates, i.e. age, sex, and IQ, some of the intercorrelations with the proposed variables were significant at α = .05 level. Fear recognition accuracy was significantly correlated to sex (*r* = -.30, *p* = .03), that is females performed better in fear recognition accuracy. This finding can be considered a medium effect WM performance was significantly correlated to age (*r* = .33, *p* = .02) and sex (*r* = -.31, *p* = .02), that is older children and females performed better in WM functioning. The effect of this finding can be considered medium. SCR was significantly correlated to IQ (*r* = .34, *p* = .02). This medium effect explains that children with a higher IQ showed higher SCR. CU traits were not significantly correlated to the covariates. Lastly, fear recognition and WM performance are significantly correlated (*r* = .42, *p* = .00) on a α = .01 level, that is that better WM performance is related to better fear recognition accuracy.

Hypotheses testing

Table 3 shows the results of testing hypothesis I, whether CU traits predict WM functioning. Regression analysis revealed a significant association for CU trait level related to WM function (*b* = -.45, *SE* = .21, *p* = .04, R^2 = .26). This negative coefficient indicates that the increase of one unit in CU traits, measured with the ICU, corresponds with a decrease of .45 units in percent of the WM accuracy performance. Hence, higher CU traits predict poorer WM performance. CU traits as an individual predictor explained 6% ($R^2 = 0.06$) of the variability in WM accuracy performance ($F(1,46) = 3.00$). The whole model explained 26.1% of the variability in WM accuracy performance ($F(4,43) = 3.80$).

Table 4 shows the outcomes for testing hypothesis II. It was assumed that CU traits negatively predict fear recognition accuracy. The analysis revealed a marginally significant negative coefficient for CU traits related to fear recognition ($b = -.53$, $SE = .26$, $p = .05$, $R^2 = .21$). The negative coefficient can be interpreted as that an increase of one unit in CU traits, measured with the ICU, corresponds with a decrease of .53 units in percent of the fear recognition performance. Thus, the higher the CU traits, the less accurate is the child's fear recognition. CU traits as an individual predictor explained 12% of the variability in fear recognition performance ($F(1,45) = 5.90$). The whole model explained 21.2% of the variance in fear recognition task performance (F(4,42) = 2.80).

Table 3

Results of Linear Regression Investigating Working Memory Test Performance on the Delayed Matching to Sample Task Predicted by Callous-Unemotional Traits

Predictor	*B*	*SE*	*p*
Constant	53.54	23.30	.03*
Age	20.4	.83	.02*
Sex	-8.28	5.333	.13
IQ	.18	.19	.34
CU traits	-.45	.21	.04*
R^2		.26	
F		3.80	

Note. $N = 47$.

a. Dependent Variable: Working memory test performance in % correct (Delayed Matching to Sample task of CANTAB Cambridge Cognition, 2015).

CU = Callous-unemotional traits measured with the Inventory of callous-unemotional traits.
* p < 0.05.

Table 4

Results of Linear Regression Investigating Fear Recognition Test Performance Predicted by Callous-Unemotional Traits

Predictor	*B*	*SE*	*p*
Constant	67.57	31.48	.04*
Age	-1-21	1.10	.28
Gender	-14.39	6.86	.04*
IQ	.09	.25	.72
CU traits	-.53	.26	.05
R2		.21	
F		2.80	

Note. $N = 47$.
a. Dependent Variable: Fear Recognition in % correct (Emotion Recognition task of CANTAB Cambridge Cognition, 2015).
CU = Callous-unemotional traits measured with the Inventory of callous-unemotional traits.
* p < 0.05.

Mediation Analysis

For the further analysis of hypothesis III, whether ANS measures play a mediating role in the relationship between CU traits and WM as well as fear recognition, respectively, the PROCESS Macro function to perform mediation analysis within the whole sample was used (Hayes, 2013). In total, six distinct analyses were performed. In all these six models, age, sex, and IQ were included as covariates of non-interest. All tables regarding the mediation analysis can be found in the appendix.

Working Memory. In the first model, CU traits were entered as the predictor of WM performance and HR was added as the mediator. The simple regression of HR predicted from CU traits shows a non-significant outcome ($b = .23$, $t = 1.07$, $p = .29$) with $R^2 = .15$. Besides that, the regression of WM functioning predicted from both CU traits and HR also shows a non-significant outcome with *b* = -.36, *t* = -1.71, *p* = .09 for CU traits and *b* = -.13, *t* = -.87, *p* = .39 for HR with R^2 = .27. A non-significant indirect effect of CU traits on WM performance was obtained, *b* = -.03, *95% CI* [-.18, .12]. Table 5 shows the outcome. Thus, CU trait level does not have a predicting influence on WM or HR in this model. Moreover, HR does not predict WM accuracy performance.

In model two, CU traits were added as the predictor of WM performance and HRV was simultaneously entered as the mediator. Table 6 represents the outcomes. The simple regression of the predicting relationship of CU traits on HRV shows a non-significant outcome (*b* = .00, *t* = -.57, *p* = .57) with R^2 = .11. The regression of WM predicted from both CU traits and HRV also shows a non-significant outcome with *b* = -.37, *t* = -1.79, *p* = .08 for CU traits and *b* = 18.11, *t* = 1.10, *p* = .29 for HR with R^2 = .28. A non-significant indirect effect of CU traits on WM performance was found, *b* = -.02, *95% CI* [-.14, .12]. Hence, CU traits do not predict WM or HRV and HRV does not predict WM accuracy performance.

Model three consisted of the variable CU traits as the predictor of WM accuracy as well as SCR as the mediator. The association between CU traits predicting SCR shows a non-significant outcome (*b* = .00, *t* = -.20, *p* = .84) with R^2 = .18. The regression of WM predicted from both CU traits and SCR shows a significant outcome for CU traits (*b* = -.45, *t* = -2.15, *p* = .04) and a non-significant outcome for SCR (*b* = -5.18, *t* = -.46, *p* = .65) with R^2 = .26. For this model, a non-significant indirect effect of CU traits on WM performance was found, *b* = .00, *95% CI* [-.05, .10]. Therefore, higher CU traits do predict poorer WM performance in this model but do not predict SCR. Moreover, SCR does not predict WM accuracy performance. Table 7 displays the outcome.

Fear recognition. In the fourth model, CU traits were entered as a predictor of fear recognition performance and simultaneously, HR was added as a mediator. The results are displayed in Table 8. The simple regression of HR predicted from CU traits shows a non-significant outcome (*b* = .20, *t* = .95, *p* = .35) with R^2 = .16. The regression of fear recognition predicted from both CU traits and HR also shows a non-significant outcome with *b* = .54, *t* = -1.92, *p* = .06 for CU traits and *b* = -.01, *t* = -.06, *p* = .95 for HR with R^2 = .21. There was a non-significant indirect effect of CU traits on fear recognition, *b* = -.0025, *95% CI* [-.12, .20]. Concluding, CU traits do not predict fear recognition accuracy or HR and HR does not predict fear recognition accuracy.

In the fifth model, CU traits were entered as the predictor of fear recognition and HRV was added as the mediating variable. The results are shown in Table 9. The simple regression of HRV predicted from CU traits shows a non-significant outcome (*b* = -1.05, *t* = -.55, *p* = .58) with R^2 = .11. Likewise, the regression of fear recognition predicted from both CU traits and HRV shows a non-significant outcome with *b* = -.53, *t* = -1.93, *p* = .06 for CU traits and *b* = .00, *t* = .16, *p* = .88 for HRV with R^2 = .21. No significant indirect effect of CU traits on fear recognition was obtained, *b* = -.0037, *95% CI* [-.1, .16]. Hence, within this model, fear recognition cannot be predicted by CU trait level or HRV. Moreover, CU traits do not predict HRV.

The last model consisted of the predictor CU traits, fear recognition as the dependent variable, and SCR as the mediating variable. Table 10 displays the outcomes. The simple regression of SCR predicted from CU traits shows a non-significant outcome (*b* = .00, *t* = .04, *p* = .97) with R^2 = .20. The regression of fear recognition predicted from both CU traits and HR, however; shows a significant outcome for CU traits (*b* = -.53, *t* = -2.06, *p* = .045). SCR did not reach significance (*b* = -26.05, *t* = -1.85, *p* = .07). The model explained 27% of the variance in fear recognition functioning. In general, the model revealed a non-significant indirect effect of CU traits on fear recognition (*b* = -.003 *95% CI* [-.17, .16]). Thus, within this model, higher CU traits are associated with lower fear recognition accuracy. However, CU traits do not predict SCR, and SCR does not predict fear recognition accuracy.

Taken together, the results of all six analyses did not provide evidence for Hypothesis III, that ANS measures mediate the relationship between CU traits and WM/fear recognition.

Discussion

The present master thesis addressed CU traits as a predictor of impairments in working memory and fear recognition in a pooled sample of cases with an ODD and/or CD diagnosis and controls. Following a dimensional approach, the aim was to find support for the assumption that higher CU traits predict impairments in these two cognitive domains and whether this relationship may be explained by a mediating indirect effect of lowered resting ANS correlates. Regression analysis confirmed the hypothesis that higher CU traits predict poorer WM functioning. Results of the predictive relationship of higher CU traits on poorer fear recognition performance can preliminary be accepted. ANS measures did not correlate with CU traits or performance in WM or fear recognition and a mediated relationship of ANS correlates (i.e. HR, HRV, and SCR) between CU traits WM/fear recognition functioning, could not be confirmed.

In line with previous findings, the present thesis found poorer WM functioning in individuals with ODD or CD compared to controls (Ogilvie et al., 2011; Kleine-Deters et al., 2020). Additionally, higher CU traits were, as expected, found to be associated with WM impairments in the present sample. These results replicate previous findings of a relationship of CU traits on WM (Platje et al., 2018). Importantly, the effect remained stable when controlling for age, sex and IQ in the current sample. Since WM is very crucial for social interactions, these findings support the idea that individuals with CU traits may have problems to successfully manage the social environment due to an impairment in adjusting and maintaining social information in their WM (Herman et al., 2007). Those impairments may thus, lead to interpersonal problems and disruptive behavior (Platje et al., 2018).

Even though others have been demonstrated that fear recognition seems to be impaired in individuals with DBDs (Kleine-Deters et al., 2020), no significant difference in fear recognition comparing cases and controls has been found in the present investigation. Yet, in the current examination, CU traits were found to be preliminary predictive of fear recognition impairments within the pooled sample. However, due to the small sample size and the high beta value, the outcome can be considered significant in the present investigation. This finding builds on existing evidence that children and adolescents with CU traits show impaired fear recognition (Dawel et al., 2012), and correspondingly, will not inhibit their own behavior, resulting in antisocial actions (Blair, 2001). It is noteworthy, that the effect of the current investigation remained stable when controlling for age, gender and IQ in the current sample.

Surprisingly, ANS measures were not correlated to CU traits, WM or fear recognition. These results do not fit with previous research that established a link between CU traits, ANS functioning and cognitive impairment (Raine et al., 2014). Moreover, contrary to expectations, current findings are not in line with the low arousal theory, which assumes that individuals with antisocial behavior show lower ANS measures than typically developing children (Portnoy & Farrington, 2015). This outcome, even though contrary to expectations, fits some of the mixed results of studies investigating the antisocial population and ANS measures (Fanti et al., 2018). Some studies linked higher ANS measures with CU traits (Scott & Weems, 2014). A few factors may explain these findings. Many studies investigating the low arousal theory included community samples only. However, these findings may be not applicable to clinical samples with higher levels of dysfunction in various aspects (Oldenhof et al., 2019). Moreover, it is very common that individuals with DBDs show co-occurring internalizing and externalizing behavior (27,28). Especially internalizing problems, such as anxiety or depression symptoms, have been reliably related to higher ANS measures (Dietrich et al., 2007). Besides that, Prätzlich and colleagues (2018) emphasize the inclusion of multiple covariates during the analysis of ANS measures since those functions are highly susceptible for bias. Previous investigations often did not include covariates, such as smoking, medication use, blood sugar level consistently. A meta-analysis revealed that only 26 of 115 studies that were included, incorporated relevant covariates (Portnoy & Farrington, 2015).

Lastly, the present investigation could therefore not confirm a mediating role of ANS measures in the relationship between CU traits and WM or fear recognition functioning. This is not in line with previous findings which suggested that cognitive impairments in individuals with CU traits may be a result of lower ANS measures (Raine et al., 2014).

A strength of this thesis was the utilization of a multi-site design which facilitates generalizability of findings. Also, investigating CU traits within a dimensional framework prevents the comparison of only the two most extreme forms of CU traits, i.e. high and low levels. Moreover, the present thesis examined WM as a specific function of EFs, compared to various other studies that utilized a joint EFs task design (Fanti & Kimonis, 2017). By exclusively investigating WM with the Delayed Matching to Sample task (Cambridge, 2015), a clearer and more specific picture of impairments in EFs has been made which adds to existing knowledge about WM functioning in individuals with CU traits. Another strength of the present thesis was the inclusion of multiple ANS measures, i.e. HR, HRV and SCR. Even though no significant outcomes regarding the ANS measures were obtained, this allowed for a sperate and thus, more precise investigation of the SNS as well as the combination of the SNS and PNS.

However, the present thesis shows several limitations which should be considered when interpreting and generalizing the findings. Specifically, in terms of generalizability of the outcomes, it has to be noted that next to a very small sample size (*n* = 49) and the utilization of a pooled sample (cases and controls), the majority of participants included was male (n = 39). Research on female samples with elevated CU traits and autonomic measures is scarce at this point, although preliminary study results indicate differences in ANS measures between males and females with DBDs and/or CU traits (Oldenhof et al., 2019; Bubier & Drabick, 2008). Besides that, the present investigation did not consider comorbidities due to the small sample size. In order to get a better understanding of the behavioral representation and neurocognitive profile of CU traits, a larger sample with great comorbidity variation would have been required. In addition, it has to be mentioned that the present study did only respect age, sex and IQ as covariates of non-interest. However, it has been suggested that ANS measures are specifically prone to bias since measures like HR or SCR are easily influenced by environmental factors (Oldenhof et al., 2019; Prätzlich et al., 2018). The consideration of additional covariates such as smoking or medication intake might have a hypothesis-supporting effect on the present results. Furthermore, CU trait level was assessed with the parent version of the ICU (Kimonis et al., 2008). Nonetheless, it has been reported that this way of assessment can result in an informant bias (Oldenhof, 2019), which in turn might have biased the present outcomes. Lastly, the present analysis only included resting ANS measures. This also might have biased the present outcome since previous findings suggest that differences in ANS measures are also evident in the assessment of ANS reactivity (Fairchild et al., 2008; Schoorl et al., 2016). Therefore, it is recommended to include reactivity assessment of ANS in future studies.

Future research may also focus on the fact that the neuropsychological profile of individuals with CU traits may be more closely described by integrating frequent neurodevelopmental comorbidities, such as ADHD or autism spectrum disorders, in the investigation. Additionally, multiple studies included other ANS measures than HR, HRV or

SCR. Measures such as respiration rate (RR) have been reliably associated with emotion processing deficits in antisocial samples (Fairchild et al., 2013). For that reason, it is recommended to include RR in future studies addressing emotion processing and antisocial behavior. Finally, it has been suggested that objective measures, such as ANS measures, may be extremely useful in in diagnostic, psychoeducation as well as intervention evaluation to increase patients' understanding and receptiveness of treatment (Oldenhof et al., 2019). However, more research is needed in terms of the development of adequate measurements of ANS correlates that can be easily, directly and practically implemented into clinical practice.

In conclusion, previous results of a link between higher CU traits and impairments in WM and fear recognition have been replicated in the present investigation. Unfortunately, the current thesis did not find support for a mediating relationship of ANS correlates on the relationship between higher CU traits and impairments in WM and fear recognition functioning. Due to the fact that disruptive behavior affects various aspects of societal and individual areas of life as a consequence of criminality and social or emotional impairments, the present incongruent findings underline the importance of gaining a better understanding of the behavioral as well as neurocognitive profile of individuals with CU traits in larger samples. By that, possible (bio)markers can be identified which facilitate the enhancement or the development of interventions for individuals displaying antisocial behavior.

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Appendix

Table 5

Outcome for Investigating the Mediating Role of Baseline Heart Rate on the Relationship Between Callous-Unemotional Traits and Working Memory Functioning

	Mediator Variable Model DV = HR					
Predictor	*B*	*SE*	*t*	*p*	*LLCI*	*ULCI*
Constant	118.52	23.95	4.95	.00*	70.18	166.86
CU traits	.23	.22	1.10	.29	-.21	.67

	Dependent Variable Model DV = WM					
Predictor	*B*	*SE*	*t*	*p*	*LLCI*	*ULCI*
Constant	66.57	29.20	2,28	.03*	7.59	125.55
CU traits	-.36	.21	-1.72	.09	-.79	.06
HR	-.13	.15	-.87	.39	-.43	.17

	Indirect Effects of CU traits on WM			
	Effect	*BootSE*	*BootLLCI*	*BootULCI*
HR	-.03	.07	-.18	.13

Note. N = 47.

CU = Callous-unemotional traits measured with the Inventory of callous-unemotional traits; HR = Heart rate in beats per minute; WM = Working memory in % correct (Delayed Matching to Sample Task of CANTAB Cambridge Cognition, 2015).

Control variables: age, gender, IQ.

* $p < 0.05$.

Table 6

Outcome for Investigating the Mediating Role of Baseline Heart Rate Variability on the Relationship Between Callous-Unemotional Traits and Working Memory Functioning

	Mediator Variable Model DV = HRV					
Predictor	*B*	*SE*	*t*	*p*	*LLCI*	*ULCI*
Constant	.43	.21	2.05	.05	.01	.86
CU traits	.00	.00	-.57	.57	-.01	.00

	Dependent Variable Model DV = WM					
Predictor	*B*	*SE*	*t*	*p*	*LLCI*	*ULCI*
Constant	43.21	24.23	1.78	.08	-5.71	92.14
CU traits	-.37	.21	-1.79	.08	-.80	.05
HRV	18.11	16.79	1.08	.29	-15.79	52.01

	Indirect Effects of CU traits on WM			
	Effect	*BootSE*	*BootLLCI*	*BootULCI*
HRV	-.02	.06	-.14	.12

Note. N = 47.

CU = Callous-unemotional traits measured with the Inventory of callous-unemotional traits; HRV = Heart rate variability in milliseconds; WM = Working memory in % correct (Delayed Matching to Sample Task of CANTAB Cambridge Cognition, 2015).

Control variables: age, gender, IQ.

Table 7

Outcome for Investigating the Mediating Role of Baseline Skin Conductance Response on the Relationship Between Callous-Unemotional Traits and Working Memory Functioning

	Mediator Variable Model DV = SCR					
Predictor	*B*	*SE*	*t*	*p*	*LLCI*	*ULCI*
Constant	.11	.32	.34	.73	-.53	.75
CU traits	.00	.00	-.20	.84	-.01	.01

	Dependent Variable Model DV = WM					
Predictor	*B*	*SE*	*t*	*P*	*LLCI*	*ULCI*
Constant	54.10	23.58	2.29	.03*	6.52	101.68
CU traits	-.45	.21	-2.15	.04*	-.87	-.03
SCR	-5.18	11.25	-.46	.65	-27.89	17.53

	Indirect Effects of CU traits on WM			
	Effect	*BootSE*	*BootLLCI*	*BootULCI*
SCR	.00	.04	-.05	.10

Note. N = 48.

CU = Callous-unemotional traits measured with the Inventory of callous-unemotional traits; SCR = Skin conductance response in microSiemens; WM = Working memory in % correct of CANTAB Cambridge Cognition, 2015).

Control variables: age, gender, IQ.

* $p < 0.05$.

Table 8

Outcome for Investigating the Mediating Role of Baseline Heart Rate on the Relationship Between Callous-Unemotional Traits and Fear Recognition Accuracy

	Mediator Variable Model DV = HR					
Predictor	*B*	*SE*	*t*	*p*	*LLCI*	*ULCI*
Constant	123.14	25.14	4.90	.00*	72.36	173.91
CU traits	.20	.21	.95	.34	-.23	.63

	Dependent Variable Model DV = Fear Recognition					
Predictor	*B*	*SE*	*t*	*p*	*LLCI*	*ULCI*
Constant	69.21	40.70	1.70	.10	-13.04	151.47
CU traits	-.53	.28	-1.92	.06	-1.09	.03
HR	-.01	.20	-.06	.95	-.42	.39

	Indirect Effects of CU traits on Fear Recognition			
	Effect	*BootSE*	*BootLLCI*	*BootULCI*
HR	-.003	.07	-.12	.19

Note. N = 46.

CU = Callous-unemotional traits measured with the Inventory of callous-unemotional traits; HR = Heart Rate in beats per minute; Fear recognition measured in % correct (Emotion Recognition task of CANTAB Cambridge Cognition, 2015).

Control variables: age, gender, IQ.

* $p < 0.05$

Table 9

Outcome for Investigating the Mediating Role of Baseline Heart Rate Variability on the Relationship Between Callous-Unemotional Traits and Fear Recognition Accuracy

	Mediator Variable Model DV = HRV					
Predictor	*B*	*SE*	*t*	*p*	*LLCI*	*ULCI*
Constant	413.40	223.93	1.85	.07	-38.84	865.64
CU traits	-1.05	1.90	-.55	.58	-4.89	2.79

	Dependent Variable Model DV = Fear Recognition					
Predictor	*B*	*SE*	*t*	*p*	*LLCI*	*ULCI*
Constant	66.27	33.63	1.97	.06	-1.71	134.24
CU traits	-.53	.28	-1.93	.06	-1.10	.02
HRV	.00	.02	.16	.87	-.04	.05

	Indirect Effects of CU traits on Fear Recognition			
	Effect	*BootSE*	*BootLLCI*	*BootULCI*
HRV	-.00	.06	-.10	.16

Note. $N = 47$.

CU = Callous-unemotional traits measured with the Inventory of callous-unemotional traits.

HRV = Heart rate variability in milliseconds; Fear Recognition measured in % correct (Emotion Recognition task of CANTAB Cambridge Cognition, 2015).

Control variables: age, gender, IQ.

Table 10

Outcome for Investigating the Mediating Role of Baseline Skin Conductance Response on the Relationship Between Callous-Unemotional Traits and Fear Recognition Accuracy

	Mediator Variable Model DV = SCR					
Predictor	*B*	*SE*	*t*	*p*	*LLCI*	*ULCI*
Constant	-.01	.33	-.01	.99	-.68	.67
CU traits	.00	.00	.04	.97	-.01	.01

	Dependent Variable Model DV = Fear Recognition					
Predictor	*B*	*SE*	*t*	*p*	*LLCI*	*ULCI*
Constant	67.45	30.61	2,2	.03*	5.63	129.28
CU traits	-.53	.26	-2.06	.045*	-1.05	-.01
SCR	-26.05	14.11	-1.85	.07	-54.55	2.45

	Indirect Effects of CU traits on Fear Recognition			
	Effect	*BootSE*	*BootLLCI*	*BootULCI*
SCR	-.003	.08	-.16	.16

Note. $N = 47$.

CU = Callous-unemotional traits measured with the Inventory of callous-unemotional traits; SCR = Skin conductance response in microSiemens Fear Recognition measured in % correct (Emotion Recognition task of CANTAB Cambridge Cognition, 2015).

Control variables: age, gender, IQ.

* $p < 0.05$.