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DEPARTMENT OF PSYCHOLOGY

CALLOUS UNEMOTIONAL AND AUTISTIC TRAITS: INVESTIGATING DIFFERENCES ON EMPATHY, PHYSIOLOGICAL MEASUREMENTS AND EMOTION RECOGNITION

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DECLARATION OF DOCTORAL CANDITATE

The present doctoral dissertation was submitted in partial fulfillment of the requirements for the degree of Doctor of Philosophy of the University of Cyprus. It is a product of original work of my own, unless otherwise mentioned through references, notes, or any other statements.

Georgios Georgiou

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ABSTRACT IN GREEK

Εισαγωγή: Σύμφωνα με προηγούμενες έρευνες, τόσο τα Χαρακτηριστικά Σκληρότητας (ΧΣ) όσο και τα αυτιστικά χαρακτηριστικά συνδέονται με προβλήματα στην ενσυναίσθηση και στην κοινωνική αλληλεπίδραση. Παρά τα εν λόγω επιφανειακά κοινά προβλήματα, διάφορα θεωρητικά μοντέλα προτείνουν πως μια εις βάθος κατανόηση των ελλειμμάτων ενσυναίσθησης μπορεί να οδηγήσει σε καλύτερη κατανόηση των δομικών και λειτουργικών διαφορών των δυο χαρακτηριστικών. Επιπρόσθετα, υπάρχουν ελάχιστες πληροφορίες αναφορικά με τις διαφορές των εν λόγων χαρακτηριστικών με άλλους παράγοντες συναισθηματικής επεξεργασίας και πιο συγκεκριμένα την ψυχοφυσιολογική διέγερση και την αναγνώριση συναισθημάτων. Αν και υπάρχουν ερευνητικά αποτελέσματα που προτείνουν την συνύπαρξη των δυο χαρακτηριστικών, εντούτοις ελάχιστες έρευνες έχουν εξετάσει την πιθανότητα αλληλεπίδρασης των δυο. Ως εκ τούτου, ο στόχος της παρούσας έρευνας είναι να μελετήσει την αλληλεπίδραση αλλά και την ξεχωριστή σχέση των ΧΣ και των αυτιστικών χαρακτηριστικών με την συναισθηματική και γνωστική ενσυναίσθηση, την ψυχοφυσιολογική διέγερση και την αναγνώριση συναισθημάτων. **Μεθοδολογία:** Από ένα αρχικό δείγμα 1652 παιδιών, ηλικίας 4 με 10 ετών, συλλέχθησαν δεδομένα αναφορικά με τα επίπεδα ενσυναίσθησης. Ακολούθως, παιδιά με χαμηλά και τυπικά επίπεδα ενσυναίσθησης επιλέγησαν για να συμμετάσχουν στο επόμενο στάδιο της έρευνας (163 παιδιά). Για το κάθε ένα, αξιολογήθηκαν τα ΧΣ, τα αυτιστικά χαρακτηριστικά και τα επίπεδα ενσυναίσθησης. Επιπρόσθετα καταγράφηκαν ψυχοφυσιολογικές μετρήσεις (καρδιακοί παλμοί, εφίδρωση, αντανακλαστικό αιφνιδιασμού), κατά την διάρκεια που τα παιδιά παρακολουθούσαν συναισθηματικές σκηνές κινουμένων σχεδίων και εικόνες, ενώ στην συνέχεια οι συμμετέχοντες κατέγραψαν το συναίσθημα του κεντρικού ήρωα της σκηνής των κινουμένων σχεδίων. **Αποτελέσματα:** Για την ενσυναίσθηση, η ανάλυση παλινδρόμησης έδειξε πως τα αυτιστικά χαρακτηριστικά συνδέονται αρνητικά με την γνωστική ενσυναίσθηση, ενώ τα ΧΣ αρνητικά και με την γνωστική και συναισθηματική ενσυναίσθηση. Επίδραση αλληλεπίδρασης βρέθηκε μόνο στα κορίτσια, αναφορικά με την σχέση τους με την συναισθηματική ενσυναίσθηση, όπου τα ψηλά επίπεδα αυτιστικών χαρακτηριστικών διαμεσολαβούν στην αρνητική σχέση μεταξύ ΧΣ και συναισθηματικής ενσυναίσθησης. Αναφορικά με τις ψυχοφυσιολογικές μετρήσεις, τα αποτελέσματα κατέδειξαν πως η εφίδρωση κατά την διάρκεια αρνητικών ερεθισμάτων μπορεί να αποτελεί δείκτη που διαφοροποιεί τα αγόρια με

ΧΣ και αυτιστικά χαρακτηριστικά. Επιπρόσθετα, παιδιά με ψηλά επίπεδα αυτιστικών χαρακτηριστικών συνδέονται με χαμηλό αντανακλαστικό αιφνιδιασμού τόσο σε θετικά ερεθίσματα όσο και σε ερεθίσματα δυσφορίας, ενώ τα ΧΣ με αυξημένο αντανακλαστικό σε θετικά ερεθίσματα. Τέλος, δεν καταγράφηκε καμία δυσκολία στην συναισθηματική αναγνώριση σε όλους τους συμμετέχοντες. **Συζήτηση:** Τα αποτελέσματα επιβεβαιώνουν την ύπαρξη διακριτών προφίλ ενσυναίσθησης και ψυχοφυσιολογίας μεταξύ ΧΣ και αυτιστικών χαρακτηριστικών, και την σημαντικότητα της διερεύνησης της αλληλεπίδρασης και των διαφορών μεταξύ των φύλων. Τα ευρήματα μπορούν να ενισχύσουν και να βελτιώσουν τις υφιστάμενες παρεμβάσεις, εστιάζοντας σε διαφορετικές τεχνικές ενσυναίσθησης, ανάλογα με το προφίλ του παιδιού, ενώ ταυτόχρονα γίνεται ξεκάθαρη η αναγκαιότητα του να λαμβάνεται υπόψη η ετερογένεια και οι διαφορές φύλου στις παρεμβάσεις που αναπτύσσονται για τα εν λόγω χαρακτηριστικά.

ABSTRACT

Introduction: Callous unemotional (CU) and autistic traits have both been associated with deficits in empathy and social interaction in previous studies. However, despite their superficial similarities, prior evidence suggests that a deeper understanding of their empathy deficits, can lead to a better understanding of their functional differences. Furthermore, there is a lack of evidence regarding differences of those traits in other components of emotional processing, and specifically physiological measurements and emotion recognition. In addition, despite evidence proposing that both traits can co-exist, few studies have investigated interactive effects. Thus, the aim of the current study is to investigate the unique and interactive association of CU and autistic traits with affective and cognitive empathy, physiological measurements and emotion recognition. **Methods:** Data on empathy was initially collected from a sample of 1652 children in early development, age 3-8, rated from their parents. Next, children with low and normative levels of empathy were selected to participate (n= 163). For each child, a package of questionnaires was provided assessing CU, autistic traits and empathy. In addition, physiological responses (heart rate, skin conductance, startle modulation) were recorded while children watched affective and neutral videos and pictures, while asking participants to rate the emotional state of the main character of the video assessed emotion recognition. **Results:** For empathy, regression analysis revealed that autistic traits were negatively correlated with cognitive empathy, while CU were negatively correlated with both empathy subcomponents. Interaction effect was revealed only for girls in predicting affective empathy, where high levels of autistic traits moderate the negative association between CU and affective empathy. Regarding physiological measurements, results suggested that skin conductance reactivity during negative stimuli can be used as a marker differentiating only boys with CU and autistic traits. Moreover, children with high levels of autistic traits showed low startle reactivity in both positive and distress stimuli, while CU traits startle potentiation during positive stimuli. No difficulties in emotion recognition ability were found in both traits. **Discussion:** Findings confirm the distinct empathy and physiological profile of both traits, and the importance of investigating CU and autistic traits interactive effects and gender differences. These results can inform and improve current prevention and intervention programs, including different empathy training to address CU and autistic traits, while also

highlighting the importance of taking into account heterogeneity and gender differences for more effective treatment outcomes.

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DETICATION

To the people who inspired me.

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FOREWORD

> **An empathic way of being can be learned from empathic persons. Perhaps the most important statement of all is that the ability to be accurately empathic is something, which can be developed by training. Therapists, parents and teachers can be helped to become empathic. This is especially likely to occur if their teachers and supervisors are themselves individuals of sensitive understanding.**
>
> - Carl Rogers

Empathy is one of the fundamental aspects of human behavior and personality. It is no coincidence that Carl Rogers, one of the founders of the humanistic approach in psychology, highlight the importance of empathy in human relationships, and the need of therapists to be empathic, and help others to become empathic. For over 250 years, there has been a long – standing debate over the notion of empathy, focusing on several topics like whether empathy is a learned behavior or people are born with it. Despite all these on-going discussions, philosophers, psychologists and other specialists agree on one thing: the multidimensional nature of this phenomenon. A conclusion, which lead to the assumption that difficulties in different dimensions of empathy can lead to different physiological profiles and traits.

The majority of theorists suggest that empathy has two subcomponents. First *affective empathy*, refers to the ability to share the emotional state of others – or the ability to experience what other people are feeling. The second subcomponent, *cognitive empathy*, is the ability to understand and recognize the emotional state of other people, without necessarily sharing the exact emotional experience. Following this model, Smith (2006), proposed that we could identify several empathy disorders, according to the combination of empathy deficits and abilities (high levels or low levels), experienced by the individual. For example, in the case where an individual experiences deficits only on cognitive empathy, this results in a different psychological and behavioral profile, compared to an individual with deficits in both empathy subcomponent. In addition, excessively high affective empathy can also lead to several behavioral and emotional difficulties and, as in the case of low levels, can also be related with abnormal developmental circumstances.

This project is focused on the study of two traits, which literature describes as low empathy traits or in some cases as empathy disorders. First, there are callous unemotional traits (CU), a specific profile characterized with difficulties in empathy, shallow emotion, and callous use of others. The second are autistic traits, characterized with an inability of understanding other people's emotions, difficulties in social interaction and engagement in stereotype behaviors. In both cases individuals exhibit empathy deficits, which are related to impairments in social interaction and engagement in disruptive behaviors. However, these similarities may mask specific functional differences, and not just a general notion of deficits in empathy construct and prosocial behaviors. The last ten years, several models explaining the emotional and behavioral development of individuals with these two profiles have been offered, with the empathy imbalance theory being the most prominent. According to this theory, individuals with autism or autistic traits exhibit difficulties on understanding others' mental state, namely perspective taking, but they show intact affective empathy. On the other hand, individuals high on CU traits show the exact different profile – deficits in the ability to share the emotional state, but not in understating emotions of others. Thus, in both cases different levels and deficits in empathy subcomponents, lead to a similar behavioral profile: engagement in disruptive behaviors.

Moreover, prior work on empathy deficits in CU and autistic traits populations has focused mainly on school-aged children and adolescents. However, this is problematic since empathy develops early in life, as early as 18 to 72 hours after birth. This information highlight the need for additional studies addressing this issue in children early in development because: 1) it will lead to better understanding the profile of individuals with high levels of these traits early in development, and 2) by identifying deficits and difficulties in such young age can lead to early preventions and more effective interventions.

Differences in empathy profiles (cognitive and affective) can also be related to different emotional processing mechanism in both traits. Two main components of emotional processing, related with empathy are: *physiological arousal*, related to emotional arousal, and *emotion recognition*, which is related with the ability of understanding other people's emotional state. Gradual differences in skin conductance and heart rate activity during exposure to aversive stimuli, compared to the activity during exposure to neutral situations, is a well validated method used for measuring physiological arousal and reactivity. High levels of both measures are related with high emotionality, while the exact different profile with low emotionality. In addition, startle reflex reactivity is a method commonly used for measuring defense motivation, and constitutes a clear index of amygdala activity, a brain area linked to fear. Specifically, low startle reactivity during exposure to negative aversive emotional situations is related with a fearless profile. Differences in specific functions and reactivity, which may be trait specific, are necessary for understanding the abnormalities of both psychological conditions. An in depth knowledge will shed more light in the "modus operandi" - the underlying mechanisms and the developmental procedure – of each trait, help in differentiating individuals showing symptoms of both CU and autism early in development. Focusing on these mechanisms will promote knowlegde that will eventually lead to the developing of suitable and effective interventions. Intervention which will focused and address specific traits mechanisms, despite surface similarities.

The overall purpose of the current project is to map the different empathy and emotional profile of these traits, and their interactions. The main assumption is, that despite both traits are characterized as low empathy traits, they have distinct empathy – since empathy is a multidimensional construct - and physiological profiles. Second assumption is derived from some recent findings proposing that both traits can co-exist, leading to a different profile. Thus, there is a need of an in depth comparison of both traits in order to fully understand the different underlying mechanisms in each psychological condition, and the effects of their interaction in case of co-occurrence. For this purpose, the current project is organized into two correlated but distinct studies, which have be designed to investigate different profiles of individuals with high or low levels of CU and autistic traits and also the profile of individuals in case of interaction of the two traits, within a sample of children in early development.

Study 1, takes into account theories proposing that despite the similarities in low empathy phenotype in both CU and autistic traits, deficits in different empathy subcomponents might explain the mechanisms underlying these traits. Thus, the aim is to investigate the unique and interactive associations between CU and autistic traits with cognitive and affective empathy. Participants of this study are 163 children early in development, who participated through parent-reports measuring CU, autistic traits and empathy.

Study 2, is an experimental study, investigating the unique and interactive effects of both traits in relation to emotional processing aspects - physiological arousal and emotion recognition, using the same sample as in study 1. This study is divided into 2 experiment phases. During experiment 1, we investigate how CU or autistic traits relate to heart rate, skin conductance and startle modulation during exposure to emotional cartoon videos, while we also assess their ability to understand other people emotions using the same video stimuli. In experiment 2, we investigate the same physiological reactions during exposure to static emotional pictures.

Taken together, both studies will help to understand the fundamental differences of the two traits in young children, which will eventually lead to more effective prevention and intervention programs. Programs, which will focus at the specific needs of each trait, taking into account heterogeneity and different emotional processing profiles.

Study 1

Distinct empathy profiles in callous unemotional and autistic traits: Investigating unique and interactive effects with affective and cognitive empathy.

Abstract

Decades of research on empathy lead to a multidimensional contrast, divided in *affective* and *cognitive* subcomponent. Moreover, it is proposed that empathy deficits are a hallmark sign of both callous-unemotional (CU) and autistic traits. However, prior evidence suggest that a deeper understanding of the relation of both traits with empathy deficits can lead to a better understanding of their functional differences. The aim of the current study was to investigate the association of affective and cognitive empathy, with CU and autistic traits, and also the interactive effect of these traits in predicting empathy subcomponents. The participants of the current study were selected from a sample of 1652 children. In order to include both high-risk and healthy community children in early development, participants with low levels of empathy (scoring -1 SD on GEM questionnaire; *n* = 78) and control individuals (*n* = 85) were both recruited. Overall, the sample consisted of 163 participants (*M*age= 7.30, *SD*=1.42, 44.2% girls). For each child, parents were provided with a battery of questionnaires assessing CU, autistic traits and empathy. Partial correlation and regression analysis revealed that autistic traits were negatively correlated only with cognitive empathy, while CU were negatively correlated with both cognitive and affective empathy. Moreover, an interaction effect of both traits was revealed only for girls in predicting affective empathy, where high levels of autistic traits moderate the negative association between CU traits and affective empathy. Our findings propose that both traits are related with cognitive empathy deficits, whereas CU traits are also associated with deficits in the affective empathy subcomponent. Moreover, this is the first study distinguishing empathy profiles in girls with CU traits, where impaired levels of affective empathy are evident only at the case of interaction with autistic traits.

Introduction

For many years, several psychologists and philosophers have discussed the notion of feeling and sharing other peoples' emotions, which is defined as empathy. Kohut (1977) for instance, highlights the importance of empathy in human behavior and personality by stating: "the empathic understanding of the experience of other human beings is as basic an endowment of man as is vision, hearing, touch, taste and smell" (p.144). A major question is what characterizes individuals who show deficits in this basic empathy understanding? Empathy deficits are a hallmark sing of two psychological conditions: callous-unemotional traits (CU: e.g., lack of empathy, lack of remorse, guilt), which represent a precursor of adult psychopathy, and autistic traits (e.g., impairments in communication, social interaction, engagement in stereotype behaviors), which are symptoms below the threshold of autism (Blair, 2005; Frick, Cornell, Barry, Bodin, & Dane, 2003; Frick Stickle, Dandreaux, Farrell, Kimonis, 2005; Jones, Happé, Gilbert, Burnett, & Viding, 2010). The last 10 years, studies focusing on the emotional and behavioral development of individuals with CU and autistic traits, gave raise to several models explaining the developmental trajectories of these two profiles, with the empathy imbalance theory (Smith, 2006) being the most prominent. Smith (2006) proposed that individuals with autistic traits exhibit deficits in perspective taking, but show intact emotional empathy. On the other hand, individuals high on CU traits show the exact opposite profile, since they mainly exhibit deficits in emotional empathy. However, empirical evidence testing this theory is limited, since the majority of prior studies investigate each trait individually or are focused either in a single (cognitive or affective) or overall component of empathy.

Empathy is defined as an individual's ability to feel or understand the actual or expected emotional state of others (Hoffman, 2008). According to Feshbach's (1989) model, empathy is a multidimensional construct involving two overlapping subcomponents: The first component is *cognitive empathy* referring to the ability to identify and assess emotions of another person, as well as the ability to recognize others' perspectives (e.g., why the other person is crying). The second component is *affective empathy* that involves vicarious affective sharing and resonating with others' specific emotional states; requiring not only to understand the emotional perspective of others, but to feel what others are feeling (i.e., physically experiencing others' pain; Baron-Cohen & Wheelwright, 2004; Blair, 2005; Davis, 1983; 1994; Decety & Jackson, 2004). The present study proposes that despite the similarities in low empathy phenotype and disruptive behaviors in both CU and autistic traits, deficits in different empathy subcomponents might explain the personality profile and emotional processing mechanisms underlying these traits. In addition to unique associations, it is possible that the interaction of both CU and autistic traits lead to a different empathy profile affecting empathy deficits in a larger degree.

Empathy and CU traits

CU traits refer to a group of characteristics related to callous use of others, lack of remorse or empathic concern, shallow or deficient emotions, and lack of concern about performance (Frick & Morris, 2004). The importance of these traits led to their inclusion in the latest version of the American Psychiatric Association's Diagnostic and Statistical Manual of Mental Disorders (DSM5; American Psychiatric Association, 2013) as a specifier for children fulfilling the criteria for Conduct Disorder (CD). The Limited Prosocial Emotion (LPE) specifier, or otherwise CU traits, refers to children diagnosed with CD exhibiting at least two of the following four symptoms for a period of at least 12 months in multiple settings: lack of remorse or guilt, lack of empathy, lack of concern about individual's performance in important activities, and shallow or deficient emotion. Evidence suggest that CU traits are related to severe and stable antisocial behavior, high levels of both proactive and reactive aggression, deficits in processing fear emotions, and diminished response to punishment cues (e.g., Fanti, Panayiotou, Lazarou, Michael, & Georgiou, 2016; Frick et al., 2003; Pardini, 2006). By definition, one of the major characteristics of individuals with CU traits is the impairment of empathy. However, researchers disagree over whether empathy deficits of individuals high on CU traits are in the affective or cognitive domain, or both (e.g., Georgiou, Kimonis, & Fanti, under review).

Arguing in favor for deficits in affective empathy as most relevant to CU, Blair (2005) proposed that CU traits are associated with deficits in affective empathy, whereas the ability to report on other people's emotion, namely cognitive empathy, remains intact among these individuals. In line with this assumption, Anastassiou-Hadjicharalambous and Warden (2008) found that children with high levels of CU traits and conduct problems (CP) report fewer emotional empathy responses when watching emotionally evocative movie scenes and score lower in affective empathy compared to controls. Similarly, Jones and colleagues (2010) revealed that male adolescents high on CU traits show affective empathy deficits and low scores of caring about the consequences of their aggressive act. Another line of research suggests that children scoring high on CU traits also exhibit deficits in recognizing others' emotions. For example, Chabrol and colleagues (2011) showed that CU traits are negatively associated with cognitive empathy and positively associated with self-centered thoughts and behaviors (e.g., blaming others distortions). Agreeing with these findings a recent study reported that cognitive, but not affective empathy, mediated the relation between CU traits and CP (Georgiou et al., under review). In line with these studies, Dadds and his colleagues (2009) found that females high on CU traits do not appear to exhibit deficits in affective empathy but merely in cognitive, while boys appear to exhibit deficits in both empathy components in childhood. However, it is suggested that boys overcome deficits in cognitive empathy as they enter puberty, through the development of formal verbal operation, regardless of their abnormalities in affective empathy.

Moreover, several studies report deficits in both affective and cognitive empathy. For example, Pardini, Lochman and Frick (2003) revealed that children and adolescents high on CU traits exhibit deficits in both forms of empathy. Similarly, Pasalich and colleagues (2014) proposed that among youth diagnosed with CD or oppositional defiant disorder (ODD), CU traits are associated with deficits in both cognitive and affective empathy, indicating impaired development of both subcomponents. In line with these findings, Ciucci and colleagues (2015) revealed a negative association between CU traits and both empathy subcomponents among young boys. Taken together, existing results are equivocal regarding whether affective or cognitive empathy deficits, or both, best characterize individuals with CU traits, which highlight the importance for additional research in this field. Testing these associations in combination with other traits associated with empathy deficits might shed light in understanding the emotional mechanisms underlying the phenotypic presentation of both CU and autistic traits.

Empathy and Autistic traits

Autism Spectrum Disorder (ASD) refers to a neurodevelopmental disorder characterized by impairments in communication, social interaction, and a tendency to engage in stereotype and repetitive behaviors (American Psychiatric Association, 2013). Profound impairments in social communication and interaction are believed to be the essential features of these disorders, while deficits in sharing thoughts, feelings and the ability of engaging with others (social-emotional reciprocity) are more evident in young children. The clinical presentation of ASD symptoms is heterogeneous and varies between individuals, suggesting the existence of a spectrum of autism with different levels of abilities, intelligence and severity (Hill & Firth, 2003). For example, Visser et al., (2017), revealed several groups of children with ASD symptoms, ranging from severe-stable to high improved group, highlighting the existence of different severity and stability levels in autistic traits. In addition, there is a shift on mental health research towards dimensional over categorical approach in psychopathology, suggesting the need of assessing traits that exist on a continuum rather categories (Cuthbert & Insel, 2013). In line with this theory and approach, recent studies indicate a broad range of severity of autistic symptoms, proposing that individuals may exhibit autistic traits below the threshold of the diagnosis of ASD, suggesting a continuous distribution (e.g., Constantino & Todd, 2003; Piven, Palmer, Jacobi, Childress, & Arndt, 1997). For example, it is well documented that parents of children with ASD share a similar profile with their children but to a milder degree, which does not place them to the diagnosis spectrum of ASD (for a review see: Hill & Frith, 2003).

Decades of research lead to the conclusion that impairments in the ability to understand others' minds (for a review see: Baron-Cohen, 2000) and empathy (e.g., Baron-Cohen & Wheelwright, 2004; Lombardo, Barnes, Wheelwright, & Baron-Cohen, 2007) are the core features of autism. The assumption is that individuals with ASD experience theory of mind deficits (ToM), referring to deficits in the understanding of others' mind and mental state, and a general dysfunction in the attribution of mental states to themselves and others (Baron-Cohen, 2000). As a result, it has been proposed that the majority of symptoms in autism can be explained by their ToM deficits, and these deficits have been the focus of the majority of previous studies investigating ASD. However, an important aspect, which is an integral part of ToM, is cognitive empathy. For example Johnson and his colleagues (2009) found evidence suggesting that both individuals with ASD and their parents exhibit lower level of empathy compared to non-ASD individuals. Based on this evidence, Baron-Cohen (2009) introduced the Empathising-Systemising (E-S) theory, suggesting that the autism deficits in social interaction and communication are related with empathy deficits, and particularly cognitive empathy deficits, which are directly related with ToM. In accordance with this theory, Blair (2008), highlights that among individuals with autism, cognitive empathy is profoundly impaired.

Similar, in his model, Smith (2006) proposes that individuals with autistic traits exhibit deficits in the cognitive empathy component, which then lead to deficits in social interaction.

Consistent with this notion and theoritical framework, the majority of studies proposed that autistic traits are related to problems in cognitive perspective taking, that is cognitive empathy, and not in resonating with others emotions, thus affective empathy (e.g., Lockwood, Bird, Bridge & Viding, 2013). Investigating this assumption, Pijper and colleagues (2016) found that young boys diagnosed with ODD or CD and high levels of autistic traits exhibit deficits in their cognitive empathy ability but they do not exhibit any significant difficulty with affective empathy. In line with these results, studies with young children and adolescents (Jones, Happe, Gilbert, Bunnet & Viding, 2010; Pasalich et al., 2014; Schwenck et al., 2012) proposed that individuals with high levels of autistic traits or ASD exhibit deficits in cognitive empathy, but no impairments in affective empathy. These results are in accord with the theoretical framework suggesting that autistic traits are characterized with deficits in understanding other people's emotions and perspective – an event that lead to their disruptive behavior as in the case of ODD and CD (Pijper et al., 2016). However, Mazza and her colleagues (2014) revealed that adolescents with ASD reported difficulties in understanding and interpreting the emotional and mental states of others, while they also exhibited deficits in affective empathy only when viewing stimuli with negative emotional valence. This study also revealed that individuals with ASD do not differ from typical youths in affective empathy when they are exposed to people expressing emotions with positive valence but they experience difficulties during negative valence. Thus, it is proposed that individuals with autistic traits exhibit deficits in both cognitive and affective empathy only in cases where they have to perceive negative emotions – suggesting low levels in an overall component of empathy in specific situations. In a recent review investigating the emotional and cognitive aspects of empathy in ASD and CD (Bons et al., 2013), it was proposed that cognitive empathy is impaired in ASD individuals, whereas among individuals with CD these deficits are observable only in negative emotions. Still, more studies are needed in investigating the relation of autism and autistic traits with cognitive and affective empathy, since the majority of previous studies were focused more on ToM tasks, and not empathy subcomponents, highlighting the importance for additional research in this field.

Interaction between CU and autistic traits

Although it appears that empathic dysfunction in children with CU traits is distinct from those in children with autistic traits, the majority of prior studies have investigated these deficits separately for each trait. Evidence that both CU and autistic traits can co-exist suggest that there is a need to extend prior work by testing the interaction effect of these traits in predicting empathy deficits (e.g., Lecavalier, 2006; Pasalich, Dadds, & Hawes, 2014). For example, Leno et al., (2015), revealed that more than half of their adolescent participants with ASD exhibited elevated levels of CU traits. In addition, findings revealing that there are cases where individuals with autistic traits can engage in disruptive behaviors, similar to CU traits individuals raised the question whether these behaviors and deficits are a result merely of their autistic profile, or an interaction between those two traits. Thus, whether autistic traits moderate the relation of CU and empathy. This will be important for improving the effectiveness of the prevention and intervention programs, since the behavior profile of the child may be a result of different mechanisms and interaction of traits, and in turn a need of addressing different psychological aspects.

There are very few previous studies which addressed the possibility of interactive effects of autistic and CU traits. First, Rogers and colleagues (2006) proposed that both CU and autistic traits can co-occur, but not as part of a single construct. This psychological condition is described as a "double-hit", where individuals characterized by both traits show poor moral convention, engage in an everyday severe antisocial behavior and exhibit deficits in recognizing sad facial expression. Similar, Pasalich and colleagues (2014), using a non-ASD clinical referred sample, found an interaction effect between CU and autistic traits, proposing that the combination of high CU and autistic traits is related with extremely low levels of affective empathy, lower than individuals exhibiting only high levels of CU traits. These results suggest that the negative relation of CU traits with empathy is moderated from medium or high levels of autistic traits, leading to severe deficits in affective but not cognitive empathy. In a recent study, Tye et al., (2017), found that in boys with ASD, high levels of CU traits were associated with intact executive function (EF) abilities, while low levels with EF difficulties. However, the lack of existing results regarding interactive effects between CU and autistic traits and some methodological issues (small sample size, mainly male sample), highlight the importance for additional research in this field, making the current study imperative.

The Importance of testing empathy association early in life

The majority of research linking empathy deficits with CU and autistic traits has been conducted with older children and adolescents (e.g., Anastassiou-Hadjicharalambous & Warden, 2008; Jones et al., 2010), which may be problematic for disentangling subcomponent effects. Empathic responding - precursors of affective empathy - can be identified as early as 18 to 72 hours after birth, in the form of "reactive crying", a phenomenon where newborns who are exposed to others' cry often and react with distress (for a review see McDonald & Messinger, 2011). At the age of 2, children have already developed both affective and cognitive capacities, and they can respond to others feeling with a number of comforting behaviors (Young, Fox, & Zahn-Waxler, 1999; Zahn-Waxler, Radke-Yarrow, Wagner, & Chapman, 1992). Moreover, at the age of 4 children are able to process the feelings evoked by a distressing situation, and respond appropriately to these emotions (Knafo et al., 2009). However, previous data proposed that despite empathy deficits, individuals in later development might develop new skills to compensate for their impairments – and more specifically in the case of CU traits. For example, it is proposed that individuals with high levels of CU traits develop a compensatory mechanism whereby they learn to describe what others feel (i.e., cognitive empathy) without experiencing those emotions themselves (i.e., affective empathy). Therefore, it is possible that they overcompensate for a lack of affective empathy with improved cognitive empathy as they develop (Mullins-Nelson, Salekin, & Leistico, 2006). Consistent with this hypothesis, Dadds and colleagues (2009) found that CU traits were related to both cognitive and affective empathy deficits in childhood, but only affective empathy deficits at later developmental stages. All in all, the importance of affective and cognitive empathy deficits in populations with increased CU and autistic traits needs to be explored early in development in order to identify the mechanism which favors the manifestation of these two different psychological conditions.

Current study

Despite the fact that individuals with either CU or autistic traits exhibit empathy deficits, which are related to impairments in social interaction and disruptive behaviors (Eisenberg, Eggum, & Giunta, 2010; Marshall & Marshall, 2011), it is not clear from prior work whether distinct cognitive and affective empathy processes underlie these traits. Providing evidence for distinct associations might lead to a better understanding of how the expression of empathy deficits might lead to maladaptive behaviors in both cases. Focusing on a more in depth study of these conditions, will be crucial for understanding and developing effective intervention and prevention programs for both psychological conditions. Unfortunately, there is limited number of studies focusing in the differences of these two profiles, and even less emphasizing on the interaction of both traits and possible moderation effects.

The main aim of the current study was to investigate the unique associations between CU and autistic traits with cognitive and affective empathy, within a sample of children aged 3 to 8 years old. It is hypothesized that children with autistic traits will primarily show deficits in cognitive empathy (e.g., Baron-Cohen, 2000), whereas children high on CU traits are expected to show deficits mainly in affective empathy. Based on findings from prior work (Georgiou et al., under review), it is also possible that individuals high on CU traits will exhibit deficits in cognitive empathy. In accordance with Rogers et al. (2006) and Pasalich et al., (2014) findings, it is assumed that the interaction between autistic and CU traits will predict deficits only in affective empathy. Specifically it is proposed that autistic traits will moderate the effects of CU traits on affective empathy, thus leading to more severe deficits in the specific empathy subcomponent.

In addition to the main focus of this study, we also investigated and control for sex differences in the relation of CU, autistic traits and their interaction with both empathy subcomponents. As far as we know, only Dadds et al. (2009) investigated sex differences on empathy subcomponents among young individuals with CU traits, revealing deficits only in cognitive empathy for girls and in both empathy components for boys. Regarding autistic traits, limited studies have reported that females with autistic traits exhibit higher levels of cognitive empathy compared to boys (Baron-Cohen, 2009; Goldenfeld, Baron-Cohen, & Wheelwright, 2005). These findings suggest a different empathy profile in girls with autistic and CU traits. Specifically, we assumed that girls with high levels of CU traits will score lower on cognitive empathy, while boys will show low levels in both empathy components. On the other hand, both boys and girls with autistic traits will exhibit deficits in cognitive empathy, although to a lesser degree in girls. Last, we controled for age, since our sample has a range of 3 to 8 years old. Despite that all participants are children in early development, there is a probability of being in different developmental stages. Thus, by controlling for age, we want to explore whether differences in development affect the relations between CU and autistic traits and empathy.

Method

Participants

Participants of the current study were selected for an in-depth assessment from a sample of 1652 kindergarten and primary school children living in the Republic of Cyprus whose parents completed a package of questionnaires during the screening phase of the study. There is evidence proposing that using both high-risk and mainstream sample, lead to larger and strongest effect sizes (Asscher et al., 2011; Kimonis et al., 2015). In order to include both high-risk and healthy community young children, participants with low levels of empathy (n = 78) and control individuals (n = 85) were recruited. Overall, the sample consisted of 163 participants, roughly equally divided between boys and girls (44.2% girls). Children ranged in age from 3-8 years (*M*age= 4.95, *SD*=.97), with 18% attending kindergarten and 80% grades 1-3 of elementary school. The majority of responders were mothers (89.8%), few fathers also participated (8.2%) and in 3 cases, both parents responded. For the 3 cases, scores were combined by taking the higher rating between raters at the item level, as done in prior work with this instrument (Wall, Frick, Fanti, Kimonis, & Lordos, 2016; Georgiou et al., under review). Thus, combined data from mothers, fathers and the combined scores of the 3 cases where used.

Procedure

Following approval of the study by the Centre of Educational Research and Assessment (CERE) of Cyprus, Pedagogical Institute, Ministry of Education and Culture, and Cyprus National Bioethics Committee, 47 private and public nursery schools, and 69 primary schools in three provinces (Nicosia, Larnaca and Limassol) were randomly selected for participation in the screening phase. Schools were contacted by telephone and informed about the aims of the study. School boards that were interested to participate in the study received details about the purpose and procedure via email or fax. Parents or guardians were informed about the nature of the study and 81% of them consented to their child's participation. During the screening phase, both fathers and mothers completed a package of questionnaires, which took approximately half an hour. Children with low (below -1 SD on GEM questionnaire) and normative (average to high scores) levels of empathy were selected to take part in the study. Results of the screening phase identified 141 children showing low levels of empathy. From them, 78 parents agreed to their child's participation. In addition, 85 individuals, exhibiting normal levels of empathy (scoring between average and +1 SD on GEM questionnaire) were randomly selected to participate. For each child, a new package of questionnaires was provided assessing the 3 main variables: CU traits, autistic traits and empathy.

Measures

Callous unemotional traits. CU traits were assessed with the parent-report version of the Inventory of Callous-Unemotional traits (ICU; Frick, 2004). ICU is a 24-items questionnaire, composed from 12 positively worded (e.g., "he/she express his/her feelings openly") and 12 negatively worded items (e.g., "he/she does not feel remorseful when he/she does something wrong"). Parents rated their children on a four point Likert scale (0 = Not at all true, 1 = Somewhat true, 2 = Very true, 3 = Definitely true) with total scores ranging from 0 to 72. The ICU captures three dimensions of CU traits: callousness (e.g., "He/she does not care who he hurts to get what he wants"), unemotional (e.g., "He/she does not show his emotions to others"), and uncaring (e.g., reverse scored items: "He/she feels bad or guilty when he/she does something wrong"). In the current study, only the total score of ICU was used. Previous studies have verified that ICU shows acceptable internal consistency using different translations (e.g., Ezpeleta et al., 2013; Kimonis et al., 2015), while several studies has verified the validity of ICU in community sample of Greek Cypriot children (e.g., Fanti, 2013; Fanti, Colins, Andershed, & Sikki, 2016). In the present study ICU demonstrated good internal consistency (α=.88).

Autistic Traits. Autistic traits were assessed using the school-age form of the Social Responsiveness Scale (SRS), a 65-item parent and/or teacher report (Constantino & Gruber, 2012). In the current study, SRS was used as a parent report. Parents rated their children on a four point Likert scale (1 = Not true, 2 = Sometimes true, 3 = Often true, 4 = Almost always true) with total scores range from 65 to 260, with higher scores indicating higher degrees of social impairment. Furthermore, SRS captures five domains – "Treatment Subscales" of autistic traits:

social ability, awareness, cognition, communication, motivation and mannerisms. In the current study, only the total score of SRS was used. Previous studies have verified that SRS shows high internal consistency (α=.91-.97) and acceptable inter-rater reliability (.76 and .95) (Bölte, Poustka, & Constantino, 2008; Constantino, Przybeck, Friesen & Todd, 2000; Constantino et al., 2003). In the present study total SRS score demonstrated excellent internal consistency (α=.92). SRS was used for measuring autistic traits in the current study, since it captures a continuous dimensional distribution of autistic symptoms, and not a categorization distribution using cut-off scores.

Empathy. Empathy was measured using the 23-item parent-report Griffith Empathy Measure (GEM; Dadds et al., 2008b). GEM except for an overall empathy score, captures the two subcomponents of empathy: cognitive and affective. It is composed with 6 items for cognitive empathy subscale (e.g., "My child has trouble understanding other people's feelings") and 9 items for affective empathy subscale (e.g., "Seeing another child sad makes my child feel sad"), rated on a 9-point Likert scale (rating from -4 = strongly disagree to 4 = strongly agree). Total scores range from -92 to 92, with higher scores indicating higher levels of empathy. Prior studies have demonstrated good test-retest reliability of scores over 1 week ($r > .89$) and 6 month intervals ($r > .69$), good internal consistencies, a stable factor structure across age and sex groups, inter-parental agreement ($r > .47$), and convergence with child reports ($r = .41$) (Dadds et al., 2008; 2008b). In the present study, both affective (α=.74) and cognitive empathy (α=.67) subscales showed adequate internal consistency. Several prior studies have used the Greek version of GEM in community samples of Greek Cypriot children (e.g., Georgiou et al., under review; Kimonis et al., 2015). Moreover, GEM captures both subcomponents of empathy but also an overall score of empathy, which are main variables for the study and the screening phase.

Plan of analysis

First, to test the unique association between affective and cognitive empathy and CU or autistic traits, while controlling for the other variable respectively, a partial correlation analysis was conducted in SPSS 21.0. Next, we performed a series of hierarchical multiple regression analyses with the predictors in each model being CU, autistic traits, sex and age and the interaction of the three first variables as done in prior work (Fanti, Panayiotou, Kyranides, & Avraamides, 2016b). Following the procedures recommended by Aiken and West (1991) and

Holmbeck (2002), CU and autistic traits were centered by subtracting the sample mean from each participant score, for facilitating the interpretation of the significant interactions. Depended variables were cognitive and affective empathy. In the first step, sex (0=males; 1=females), age, CU and autistic traits were entered. In the second step, the multiplicative interactions terms were entered to test the interaction between CU and autistic (moderator) traits, but also the interaction of each trait with sex: CU traits X sex, autistic traits X sex and CU traits X autistic traits. Last, in the third step, we entered the interaction between all independent variables: CU traits X autistic traits X sex. Next, the regression equation from the full sample is used to calculate the predicted values of the dependent variable at low (1 SD below the mean) and high levels (1 SD above the mean) of the predictors. In cases of interaction with sex, we moved to separate regression analysis for boys and girls.

Results

Descriptives and correlational analysis

Descriptive statistics and bivariate associations among the study variables are reported in Table 1. As shown, autistic traits were significantly negative correlated with cognitive (r=-.49, p<.001) but not with affective empathy (r=-.09, p= .32), whereas CU traits were significantly negative correlated with both cognitive (r=-.47, p<.001) and affective empathy (r=-.23, p<.01). Cognitive and affective empathy were not significantly correlated (r=.07, p=.39), while CU and autistic traits were significantly positively correlated (r=.60, p<.001). Age was positively correlated with both CU traits (r=.22; p<.001) and autistic traits (r= .28; p<.001). In addition, two partial correlations were run to determine first the relationship between CU traits and both affective and cognitive empathy whilst controlling for autistic traits, and second the relationship between autistic traits and empathy subcomponents whilst controlling for CU traits. For the first analysis, there was a negative partial correlation between CU and both affective (r=-.29, p<.001) and cognitive empathy (r=-.26, p<.01) whilst controlling for autistic traits. Thus, after taking into account the effects of autistic traits, CU traits were significantly negatively correlated with both cognitive and affective empathy. For the second analysis, there was a negative partial correlation between autistic traits with cognitive empathy (r=-.30, p<.001) but no partial correlation with affective empathy (r=.08, p=.39) whilst controlling for CU traits. That is, after taking into account the effects of CU, autistic traits were significantly, negatively correlated only with cognitive empathy.

Hierarchical multiple regression analysis

Hierarchical multiple regression analysis was performed to test the unique effect of, sex, CU, autistic traits, on cognitive and affective empathy. Also, during step 1 we investigate the effect of age. A 3 stage hierarchical multiple regression analysis was utilized with both empathy subcomponents as the dependent variables (see Table 2). Preliminary analyses were conducted to ensure no violation of the assumptions of normality, linearity, multicollinearity and homoscedasticity.

CU and autistic traits predicting cognitive empathy. In the first step, the regression analysis with cognitive empathy as the dependent variable revealed that sex and age was not a significant predictor, but both CU (β=-.28, p<.001) and autistic traits (β=-.33, p<.01) were significantly negatively associated with cognitive empathy, explaining 29% of the total variance. In the second step, after adding the interactions between the variables, no significant interaction effects were revealed between CU traits X sex, autistic traits X sex, and CU traits X autistic traits in predicting cognitive empathy. In the final step, the inclusion of the 3-way interaction effects between all independed variables in the model was non significant in explaining the variance of cognitive empathy.

CU and autistic traits predicting affective empathy. In the case of hierarchical regression analysis with affective empathy as the dependent variable, the first step revealed that sex, age and autistic traits were not significant predictors, but CU traits were negatively associated with affective empathy (β=-.27, p<.001), explaining 24% of the total variance. In the second step, no significant interaction effects were revealed between CU traits X sex, autistic traits X sex, and CU traits X autistic traits in predicting affective empathy. In the final step, there was a significant 3-way interaction between CU, autistic traits and sex (β=-.63, p<.01) explaining an additional 12% of the variance. The results of the 3-way interaction suggested that the interaction between CU and autistic traits was only significant for girls ($\beta_{\text{CU traits}}$ x $\beta_{\text{Autistic traits}}$= -.39, p<.01), but not boys ($\beta_{\text{CU traits}}$ x $\beta_{\text{Autistic traits}}$= -.52, p=.60). In boys, only CU traits were negatively related with affective empathy (β=-.38, p<.05), but not autistic traits (see figure 1). The significant interaction in girls is depicted in Figure 2. The high and low points of the graphs represent 1 SD, below and above the mean. According to the graph, among girls CU traits were associated with decreases in affective empathy only at high levels of autistic traits (β=-.73, p<.01), but not for low levels of autistic traits (β=.14, p=.31).

Discussion

The current study sought to investigate the unique associations between cognitive and affective empathy with CU and autistic traits, within a sample of children aged 3 to 8 years old. A further aim was to test the interaction of both autistic and CU traits with empathy subcomponents. Lastly, we aimed to investigate sex and age differences between our variables. First, similar to Leno et al., (2015) study, results indicated that both CU and autistic traits are positively associated suggesting that these traits share some behavioral and emotional similarities in their phenotype. Concerning the main focus of our study, consistent with previous findings (Dadds et al., 2009; Georgiou et al., under review) children high on CU traits exhibited low levels of both affective and cognitive empathy, while autistic traits were mainly associated with low levels of cognitive empathy (Jones et al., 2010; Pasalich et al., 2014). In addition, findings revealed an interaction between our variables, suggesting that high levels of autistic traits moderated the negative association between CU traits and affective empathy, but only for girls. No effect of age was revealed in the aforementioned relations.

Empathy impairments in children with CU

First, our hypothesis that high CU children in early development will show deficits in both empathy subcomponents was supported based on partial correlation and regression analyses. In line with work linking CU traits with deficits on affective empathy (e.g., Anastassiou-Hadjicharalambous & Warden, 2008; Muñoz, Qualter, & Padgett, 2011), we found that children with high levels of CU traits show reduced levels of affective empathy. Previous studies reported low physiological and emotional reactivity of individual high on CU traits (e.g., Blair, 2008; Fanti et al., 2016a; 2016b) and although physiological and emotional reactivity is not synonymous to affective empathy, it certainly contributes to deficits in this aspect. This result is consistent with previous studies showing that contrary to their counterparts, children with high levels of CU traits exhibit deficits in affective sharing and resonating with others' emotions (e.g., Muñoz et al., 2011; Pasalich et al., 2014).

Second, as predicted, we found that higher rates of CU traits in children are associated independently from autistic traits with lower levels of cognitive empathy. This suggests that diminished capacity of cognitive empathy in children with high levels of CU does not overlap with autistic traits, but is a core characteristic of these individuals. Findings of previous studies regarding empathy deficits in CU traits are mixed, with deficits only on affective (e.g., Muñoz et al., 2011) or both empathy subcomponents (e.g., Pardini et al., 2003) being reported. Our results, suggest that deficits in children early in development extend beyond affective sharing and resonating with others' emotions, as it is stated in several studies, but encompass deficits in the ability of understanding others' emotion. These findings highlight the importance of cognitive empathy in CU traits, suggesting that deficits in understanding other people emotions are equally important with affective empathy in children with CU traits. Moreover, current results are in accordance with recent findings proposing that cognitive empathy deficits mediate the positive association between CU traits and CP (Georgiou et al., under review).

Current findings are also in line with Moul, Hawes & Dadds empathy theory (2017), proposing that the interaction between neurocognitive capacities and personal experiences underly the development of empathy. According to this theory, deficits in the building blocks of empathy early in life may lead to impairments in affective empathy, which in turn affects the ability of developing normative levels of understanding others' emotional state, namely cognitive empathy. These findings are in contrast with currently accepted suggestions of CU traits structure, especially in adolescents and young children, proposing deficits only in the affective empathy. A possible explanation is derived from Dadds and colleagues (2009), which revealed that CU traits are related to both cognitive and affective empathy deficits in childhood, but only affective empathy deficits at later developmental stages. That is, in later development, individuals with empathy deficits may develop new skills to compensate for their impairments. All in all, the significant associations between both empathy subcomponents suggest deficits in both feeling and recognizing others' emotions in high CU young children.

Empathy impairments in children with autistic traits

Investigation of the relation between autistic traits and empathy subcomponents, confirmed our second hypothesis regarding autistic traits. Specifically, results revealed that autistic traits were related with deficits in cognitive empathy, whereas affective empathy remains intact. These findings suggest that autistic traits are not related neither with difficulties in resonating with emotions of others (Dziobek et al., 2008), nor with elevated levels of affective sharing (Capps, Kasari, Yirmiya, & Sigman, 1993), despite the fact that high levels of autistic traits are related with deficits in understanding others' emotion. No differences were revealed between boys and girls, pointing out that children high on autistic traits have deficits only on cognitive empathy regardless their sex. These results are in contrast with some studies proposing that females with autism perform better in both cognitive empathy tasks (reading the mind in the eyes task) and reports (Baron-Cohen, 2009; Goldenfeld, Baron-Cohen, & Wheelwright, 2005). However, to authors' knowledge there is a lack of studies regarding sex differences in autism in relation to empathy, thus until more studies investigate sex differences, we propose that boys and girls with autistic traits exhibit the same empathy deficits. Our results are in line with the majority of previous studies, which have consistently linked ASD and autistic traits with deficits in ToM, cognitive perspective taking and cognitive empathy (Baron-Cohen, 2000; Hill & Frith, 2003). Further, our findings are in accord with the Empathising-Systemising (E-S) theory (Baron-Cohen, 2009), and specifically with the empathising component, where low levels of cognitive empathy account for the social communication and interaction difficulties of those individuals. All in all, it is well documented that children with autistic traits exhibit difficulties in understanding other people's emotions but their ability of affective sharing remain intact.

Interaction and gender differences in empathy

The second aim of the current study was to expand the assessment of CU and autistic traits in relation to empathy subcomponents, by examining how autistic traits interact with CU traits in predicting affective and cognitive empathy in young children. First, no interaction effect and no gender differences were revealed for CU and autistic traits, and cognitive empathy. These findings point to unique associations of both traits with cognitive empathy deficits. However, results suggest that only in girls, high levels of autistic traits moderate the negative association between CU traits and affective empathy. In contrast, only CU traits explained the affective empathy deficits in boys. Only one previous study has investigated and reveled evidence of a potential moderation effect of autistic traits in the relation of CU with affective empathy impairments. Specifically, Pasalich et al. (2014) suggested a negative relation between CU and affective empathy at high and medium levels of autistic traits. However, there are some methodological differences between Pasalich et al. (2014) and the current study. The major differences are the behavioral features of the sample. In Pasalich's study; participants with CU and autistic traits were also diagnosed with Oppositional Defiant Disorder (ODD) or CD, while in the current study we had a community sample. Regarding gender, the majority of the participants in Pasalich study were boys, in contrast with the current study, where boys and girls were represented almost equally.

In the current study, our results propose the same relation, but only for girls. A possible explanation for this sex difference is derived from Dadds et al. (2009) work, suggesting that girls with CU traits do not exhibit deficits in affective empathy. It is proposed that in girls with high levels of CU, elevated levels of autistic traits may be the factor that leads to deficits in affective empathy, and not CU traits per se. Thus, it is the interaction effect of both traits that eventually lead to deficits in affective empathy in girls, and not CU traits alone, proposing that the interaction of both traits in girls, is related with the same empathy profile (low cognitive and affective empathy) as in high CU boys. However, there is a lack of studies investigating sex differences between CU and autistic traits, and even less in relation to their empathy ability. Thus, future studies should incorporate sex differences, since evidence suggest a possible differentiation in affective empathy, taking into account moderation effects.

Strengths and limitations

The current study has some strengths and limitations that should be noted. Among the strengths is the use of questionnaires developed to be appropriate for children in early development. Moreover, assessing interactions among the main study's variables is also strength, since there are only two prior studies investigating these effects. Third, similar to prior work (Georgiou et al., under review; Kimonis et al., 2015), both high-risk and control participants were used in order to maximize the validity in both CU and autistic traits. In terms of limitations, although the measure of empathy (GEM) has good empirical support (e.g., Dadds et al., 2008), there is possible methodological limitation, as it is stated in Murphy's' (2017) review, proposing that the GEM affective empathy scale measures mainly emotional contagion and not the overall affective sharing. Moreover, the assessment of empathy was based on parents' reports' – thus the perceptions of parents regarding their children empathic behavior and ability and no data were collected from teachers. Nevertheless, studies suggest that parents are considered to be a crucial source for reporting on their child behavior and abilities (De Los Reyes & Kazdin, 2005).

However, future studies may benefit for using multi-informant assessments – use of parents, teachers and even children self-reports regarding empathy and physiological responses of children during empathy experimental tasks. Finally, although a number of participants in our study were elevated in CU and autistic traits, we did not include participants meeting the criteria for ASD and Limited Prosocial Emotion, according to DSM-5. Thus, future studies will be benefited from the use of a clinical sample. All in all, future research is needed to replicate and extend these findings using different assessment methods (e.g., physiological measurements, empathy tasks) and clinical sample, in order to understand the integral role of empathy in CU and autistic traits, and the case of possible co-occurrence.

Conclusion

Within the context of these limitations, our findings clarify and build on previous studies examining the empathy profiles in CU and autistic traits. Our results suggest that high CU children in early development are impaired in both affective and cognitive empathy, while children high on autistic traits are primarily impaired in cognitive empathy. Findings regarding CU traits support a new perspective in the understanding of these traits, proposing that high CU children are equally impaired in both understanding and sharing others' emotions, even after accounting for autistic traits. Simultaneously, the study adds to the limited evidence in the interaction of both CU and autistic traits, indicating that in girls, the interaction of these two psychological conditions, leads to severe deficits in affective empathy. Future studies focusing on investigating different empathy profiles (deficits in different empathy subcomponents), and the interaction effect of both CU and autistic traits are clearly needed to enhance our understanding of the different empathy profile in CU and autism. This will help in improving the effectiveness of current prevention and interventions and developing new, focusing on the fundamental differences and not on grouping behaviors.

Investigating empathy and it's components, is debatable, since theorists are still trying to understand the origin of this notion, and how environmental factros and genetics affects its development. However, research findings have several clinical implication. For example, individuals high on autistic traits may benefit from emotion recognition interventions. Also, from interventions aiming to improve individual's ability to focus and direct their attention in specific cues, with the aim of improving their ability to decode and recognize emotions and emotional situations. On the other hand, in the case of CU traits, role-taking tasks and mindfulness techniques may improve the individuals' ability to recognize their own but also others emotional state, and introduce a level of emotional experience. The overall aim will be first to enhance individuals' ability of understanding other people's emotions and pay attention to their own thoughts (mind) and physiological reactions (body), while they are exposed to emotional stimuli. This will not necessary lead to the actual experience of emotion. However, it may provide individuals with skills, aiming to help them focus on their own and others' emotional experience, and use this information for pro-social behavior and better social interactions. Building on this evidence and implications, investigating emotion recognition and physiological arousal, will shed additional light in understanding the emotional processing and reactivity deficits delineating the development of empathy in CU and autistic traits, which is the main aim of Study 2.

Study 2

Emotional processing in children with high callous unemotional and autistic traits. Unique and interactive effects predicting physiological reactivity and emotion recognition.

Abstract

Empathy deficits are a hallmark sign of both callous-unemotional (CU) and autistic traits. However, despite surface similarities, prior evidence did not investigate differences of those traits in physiological reactions and emotion recognition ability, factors that are related with emotion processing. The current study adds to prior work by comparing physiological activity and emotion recognition ability, in children with high levels of CU, autistic traits and their interaction. Physiological activity was examined using a multi-method assessment, including two experimental tasks: video stimuli with 60s duration each, and pictures stimuli with 5s duration each. Participants were recruited from community children sample (*n*= 163; *M*age= 7.30, *SD*=1.42; 44.2% girls), using both high risk (low empathy) and mainstream (typical empathy) sample. Physiological responses (heart rate, skin conductance, startle modulation) were recorded while children watched affective and neutral videos and pictures, while asking participants to rate the emotional state of the main character of the video assessed emotion recognition. Findings suggested that skin conductance reactivity during negative stimuli can be used as a marker differentiating boys with CU (low reactivity) and autistic traits (high reactivity), but not in girls. Moreover, children with high levels of autistic traits showed low startle reactivity in both positive and distress stimuli, while CU traits with startle potentiation during positive stimuli. No difficulties in emotion recognition ability were found in both traits. These findings provide evidence for the distinct physiological profile of these physiological conditions, which can inform prevention and treatment programs.

Introduction

Callous unemotional (CU: e.g., lack of empathy, lack of remorse, guilt) and autistic traits have been associated with empathy deficits and difficulties in social interaction (for reviews see: Frick & Morris, 2004 for CU; Hill & Frith, 2003 for autism), with findings suggesting that low levels of empathy are related to maladaptive behaviors in CU traits (Georgiou et al., under review) and difficulties in social interaction in autism (Baron-Cohen, 2009). Moreover, as reported in study 1, different empathy profiles are revealed for each trait, with children high on autistic traits showing cognitive empathy deficits and boys high on CU displaying both cognitive and affective empathy deficits (see study 1). Also, a moderation effect of high autistic traits in the relation of CU traits and affective empathy was identified only for girls, where an interaction effect suggested that high levels of both traits lead to deficits in affective empathy. Additional work proposed that individuals with both traits exhibit deficits in emotion recognition, suggesting a role of amygdala dysfunction in recognizing basic (i.e. fear, anger, sadness etc) and social emotions (i.e. admiration, guilt) (Blair, 2008; Davis & Whalen, 2001).

Moreover, several studies highlight the role of physiological systems in emotional processing, including physiological reactivity during exposure to several emotional situations in individuals with high levels of autistic and CU traits (Bons et al., 2013; Fanti, 2016). For example, in a recent review, Fanti (2016) proposed that a personality profile of CU traits, fearlessness and insensitivity to punishment is related with physiological hypo-arousal and low Autonomic Nervous System (ANS) activity. On the other hand, Bons et al. (2013) suggest that high amygdala and emotional autonomic reactivity in individuals with autistic traits results to low attention to the eyes region, which in turn leads to empathy deficits. Recent studies investigating the emotional and behavioral development of these two traits, gave rise to several models explaining the developmental trajectories of these two profiles, suggesting different empathy profiles despite their surface similarities (e.g., Smith, 2006). However, there is a lack of studies investigating differences in the physiological profile and emotion recognition abilities between CU and autistic traits. Moreover, prior work focused on either autistic or CU traits separately and not in the case of interaction. The current study was designed to investigate the different emotional processing profile of those traits by: (a) studying physiological components of emotion in order to provide information regarding variability of emotional reaction in each trait, and (b) by assessing individuals ability of recognizing other people emotions. Testing the association between autistic and CU traits with physiological measures, including heart rate (HR), skin conductance (SC) and startle modulation, and emotion recognition in response to emotional stimuli of different valence (e.g., pleasant – happy, unpleasant - sad), can provide a better understanding of the underling etiology and individual differences in CU and autistic traits. Moreover, there is a lack of studies investigating in larger children sample.

Associations with physiological measurements

Emotions are important for understanding how individuals adapt in their environment, interact with others, and develop social relationships. A recent review of the literature proposes that several systems affect the interpretation of emotions (Fanti, 2016). Specifically, the way that humans interpret several emotions, differentiate on the levels of arousal (low – high) and valence (pleasant or unpleasant), in turn affects how individuals react in several emotional situations (for a review see: Fanti, 2016). For example, fearlessness (low levels of fear) is related with low levels of emotional distress and high risk for engagement in severe and chronic antisocial behavior, while high emotionality and low levels of emotion regulation with difficulties in social adaption, avoidance and internalizing problems (e.g., Fanti, Panayiotou, Lazarou, Michael & Georgiou, 2015; Wilmshurst, 2009). Physiological systems (e.g., HR, SC and startle modulation) provide information for emotional arousal and reactivity during exposure to emotional situations differentiated in terms of positive and negative valence. In addition, multiple theories regarding low or high emotionality have been developed based on investigating differences in physiological reactivity (for psychopathy: Blair, 2013; for autism: Bons et al., 2013; for antisocial behavior: Lorber, 2004). Specifically, a hyper-arousal profile with high levels of HR and SC on the one hand is associated with difficulties in emotion regulation and oversensitivity to fear and/or threatening stimuli, proposing high emotionality. On the other hand, a hypo-arousal profile (low SC and HR) associated with thrill seeking, temperamental fearlessness and insensitivity to punishment, might be related to low emotionality (Beauchaine, 2012; Fanti et al., 2015; Frick & Morris, 2004).

Since our aim was to investigate affective reactions of children with high levels of CU and autistic traits in response to emotional stimuli, in the current study we used physiological measurements. Collecting physiological data during exposure to emotional stimuli is a well-established method used in several studies investigating emotional arousal and valence. This is the case since it is less biased compared to questionnaires, and provide information regarding the immediate reaction of the individual (Anastassiou-Hadjicharalambous & Warden, 2008; Blair, Jones, Clark, & Smith, 1997; de Wied, van Boxtel, Matthys, & Meeus, 2012; Fanti, 2016; Fanti et al., 2017).

Heart Rate and Skin Conductance. Hear Rate (HR), derived from electrocardiogram activity (ECG) and Skin Conductance (SC) derived from electrodermal activity (EDA) are the most popular physiological measures used for assessing general emotional arousal and emotional empathy (Bons et al., 2013; Fanti, 2016). Specifically, Bons et al. proposed that measuring HR or SC response to distressing or threatening stimuli, can be reliable and objective measure of emotional empathy, although it is not synonymous. HR reflects both Parasympathetic Nervous System (PNS) and Sympathetic Nervous System (SNS) activity, while SC reflects primarily SNS activity. Gradual changes in both HR and SC levels after exposure to affective stimuli, compared to a measure during neutral conditions, are commonly used in analysis for measuring reactivity and arousal (Fanti et al., 2016; 2017; accepted). Hyper-arousal (high SC and HR) on the one hand is associated with difficulties in emotion regulation and an oversensitivity to negative stimuli, while hypo-arousal (low SC and HR) with thrill seeking, fearlessness and insensitivity to punishment (Beauchaine, 2012; Fanti et al., 2015; Frick & Morris, 2004). Several studies have investigated physiological arousal in children, adolescents and adults high on CU traits in response to stressful or aversive stimulus. In terms of autonomic activity, evidence indicates that individuals high on CU traits show physiological hypo-arousal, displaying low HR and SC reactivity (e.g., Anastassiou-Hadjicharalambous & Warden, 2008; Blair, Jones, Clark, & Smith, 1997; de Wied, van Boxtel, Matthys, & Meeus, 2012; Fanti, 2016). More specifically, low or high levels of CU traits may lead to different physiological profiles. For example, Anastassiou-Hadjicharalambous and Warden (2008) found that boys high on CU displayed reduced HR reactivity compared to children diagnosed with Conduct Disorder (CD) with low CU traits and control children, during exposure to emotionally evocative films. Similarly, de Wield et al. (2012) revealed that boys with high levels of CU exhibited lower HR reactivity while viewing a sad film compared to CD without CU traits and control boys. However, there are studies proposing that psychopathic traits are not associated with deficits on HR and SC in response to negative stimuli or point to hyper-arousal (e.g., Hansen et al., 2007; Pfabigan et al., 2014). Thus it is suggested that more studies are needed to understand the relation between CU traits and physiological reactivity.

In contrast, researchers have been unable to reach consensus regarding physiological activity in autistic traits, since there is a limited number of studies investigating physiological arousal in response to aversive stimuli in autism and autistic traits. In a recent review (Lydon et al., 2016), authors proposed that differences in physiological arousal are clearly present in autism and autistic traits, but varied across individuals who share same traits and symptoms. In favor of hyperarousal, Bal et al. (2010) found that children with ASD showed elevated HR baseline. Similar, in another study it was proposed that 2-years old preschoolers with autistic traits experience SC hyperactivity compared to same age typically developed preschoolers during play activities (Prince et al., 2017). However, Huber et al. (2009) revealed that adults with ASD did not exhibit differences in SC reactivity when they were exposed in emotional faces, indicating a lack of physiological arousal in such conditions. These findings were also replicated with high-functioning autistic children (Ben-Shalom et al., 2006). A possible explanation for this contradictory result is the use of different stimuli, since each type (video, images, sounds or activities) is composed from different components and time duration. For example Bal et al. (2010) used videos of emotional faces, Ben-Shalom and colleagues (2006) used general emotional pictures, while Prince et al. (2017) investigated reactions during play activities. In the current study, our aim is to focus on children physiological arousal during emotional stimuli, using both videos and images Due to the limited number of studies investigating physiological arousal in autism, especially during childhood, it remains unclear if these individuals exhibit deficits in their autonomic response, and how these deficits may affect or are linked with their emotional arousal. These limited contradictory findings, highlight the need to investigate the link between physiological measurements and autistic traits. The current study is the first attempt to investigate physiological arousal in big sample of children assessing traits that exist on a continuum rather than in categories.

Eye-blink startle reflex. Eye-blink startle reflex, derived from electromyography (EMG), is a well-established measure of defensive motivation, providing a direct index of amygdala activity (Vaidyanathan, Patrick, & Cuthbert, 2009; Vrana, Spence, & Lang, 1988). The startle reflex is a involuntary response to a sudden intense acoustic stimulus, and it’s amplitude is typically potentiated by negative affective contexts (i.e., fear, threat) in relation to neutral situations, while attenuated during positive stimulus. Reduced eye-blink startle reactivity– hypoactivity - during aversive negative stimuli have been associated with diminished amygdala activity and fearlessness (Fanti et al., 2015; Patrick 1994). On the other hand, high startle reactivity during the same stimulus is an indicator of fearfulness and high anxiety (e.g., Fanti et al., 2015).

A large number of studies indicate that antisocial individuals high on CU traits show reduced eye-blink startle reactivity during exposure to negative aversive or fearful stimului (e.g., Dackis, Rogosch, & Cicchetti, 2015; Fanti et al., 2015; Kyranides, Fanti, & Panayiotou, 2016). The most prominent model proposed that the presence of CU traits lead to different physiological profiles in antisocial individuals. For example, a study proposed that CP only adults exhibited higher levels of startle potentiation when they were exposed to violent films, compared to individuals with high levels of both CP and CU, who exhibited startle attenuation (Kyranidies, Fanti, & Panayiotou, 2016). In line with these results, Fanti et al. (2016) found that children high on CU exhibited diminish startle potentiation in fear imagery scenarios, compared to children with elevated levels of CP but without CU traits, who exhibited enhanced startle potentiation. Similar, Dackis, Rogosch and Cicchetti (2015) revealed that non-maltreated children high on CU traits, exhibit low levels of startle modulation to emotional stimuli. In accordance with these results, it was proposed that CU traits are related with a pattern of hypo-activity of amygdala during the exposure to aversive stimuli, which explains the poor fear conditioning of these individuals (Blair, 1999). However, prior work provided also some inconsistent findings. For example, Syngelaki, Fairchild, Moore, Savage and Van Goozen (2013) also revealed low startle modulation in adult offenders with psychopathic traits for both positive and negative emotions, pointing to general deficits in startle reactivity and not only in fear and sad stimulus. In addition, the majority of studies investigating startle modulation in CU individuals focused in adolescents and adults, with only very few exceptions trying to extend these results to children (e.g.,Dackis et al., 2015; Fanti et al, 2016; accepted). All in all, findings propose that CU traits are associated with startle hypoactivity and fearless temperament, but still there is a need of studies extending these results to young children, since it is unclear whether these deficits account also for this age. Importantly, no prior work investigated the difference between children with high levels of autistic and CU traits, on startle modulation

Similar to autonomic arousal, only a limited number of studies have investigated startle modulation among individuals with autistic traits. Existing findings suggest no impairments in startle modulation. Specifically, Bernier et al. (2005) found that participants with autism demonstrated similar startle potentiation during exposure to aversive stimulus with control individuals, possibly indicating that in contrast to those with CU traits, individuals with autistic traits might show intact amygdala functioning. Similar, Salmond and colleagues (2003) revealed no difference in startle response during exposure to either pleasant or unpleasant stimuli between individuals with autistic traits compared with a control group. However, in contrast with these findings, a third study revealed that individuals with autism show startle potentiation to both positive and negative stimulus in comparison with control individuals (Wilbarger, McIntosh, & Winkielman, 2009). According to Blair "fine cuts" approach (2008) it is suggested that in autism the use of stimulus-reinforcement association is intact, while social cognition aspects, which are involved in the affect-related response and judgment to emotional expressions, are impaired. The role of amygdala in the stimulus-reinforcement situation is clear. Specifically, amygdala is necessary for the formation of stimulus-reinforcement associations, which guide individuals to learn whether a new stimulus or situation is good or bad, and in turn to increase or decrease the likelihood of a specific response (e.g., Buchel & Dolan, 2000). However, we lack evidence regarding the relation of amygdala with social cognition in humans. Thus, it stills remain unclear whether startle potentiation is impaired in autism and autistic traits, and if so, how does this atypical potentiation occurred, with the hypothesis of intact startle modulation gaining ground. In addition, since prior studies propose that autistic and CU traits are differentially associated with startle reactivity, it is important to include both traits in investigating differences in this specific physiological measurement and not separately for each trait. This will help in understanding the different physiological profile of these two traits and the potential underlying mechanisms affecting their behavior and emotional processing. Further, despite previous studies suggesting the interaction and co-occurrence of both traits (e.g., Leno et al., 2015, Pasalich et al., 2014) no prior studies have investigated the interaction effects between autistic and CU traits in HR, SC and startle reflex. Findings from study 1 suggest a moderation effect of high autistic traits in the relation of CU with affective empathy in girls. Based in this evidence it is important to extend this results and investigate if autistic traits can also moderate physiological reactivity in high CU children, taking into account the possibility of gender differences.

Emotion recognition

The majority of previous studies propose that individuals with psychopathic and CU traits exhibit deficits in recognizing and responding to fearful and sad stimuli, as well as to others' distress cues (Blair, 2013, Frick & White, 2008). These results were replicated in community, forensic and clinical samples (e.g., Dolan & Fullam, 2006; Montagne et al., 2005). For instance, in two studies, Dadds et al. (2006; 2008) found that children and adolescents with high psychopathic traits exhibited deficits in recognizing fearful facial expressions. In line with these findings, Blair and Coles (2000) reported that children scoring high on the Psychopathy Screening Device (PSD) had difficulties in recognizing sad and fearful facial expressions, but not angry, disgusted, happy or surprised expressions. Similar, Montagne et al. (2005) found that participants high on psychopathic traits were less accurate in recognizing fearful facial expressions in comparison with individuals scoring low on those traits. These findings were also replicated in psychopathic offenders, proposing that they exhibited an overall lower accuracy in recognizing facial emotion expressions, with a specific deficit in recognition of sad facial expressions (Dolan & Fullam, 2006). Thus, based on empirical evidence, young children with high levels of CU traits exhibit deficits in recognizing fear and sad emotions, which remain stable through their life, and can be observed in both clinical and subclinical cases.

Agreeing with these findings, Marsh and Blair (2008) meta-analysis suggests a clear link between CU traits and deficits in recognizing primarily fear and sad emotions. It was suggested that difficulties in recognizing distress cues and especially fear and sad emotion is related with decreased amygdala function, with studies supporting the role of amygdala in processing fear expressions (see Blair, 2008; 2013; Viding et at al., 2012). Despite that deficits in recognizing negative and distress emotions supported consistently across the literature of CU traits, there are also some inconsistent results. For example, Leist and Dadds (2009) found that CU are associated with impairments in identifying only fear, while Woodworth and Waschbucsh (2008) revealed that high CU individuals are impaired only on identifying sad emotions. In addition, the majority of previous studies focus on recognizing facial emotional expressions. Thus, there is a need of more studies using emotional stimulus combining verbal, context and facial expression like video scenes, which are more close to real, every day scenarios.

In contrast to CU traits, there is a general belief that individuals with autism exhibit difficulties in recognizing multiple emotions (e.g., Humphreys, Minshew, Leonard, & Behrmann, 2007). However, despite the extended focus on emotion recognition abilities in autistic individuals, it is still unclear whether these individuals experience difficulties in recognizing specifically distress emotions or if their deficits are generalized to all basic emotions, or if they do not experience difficulties at all (for a review see Harms, Martin, & Wallace, 2010). For example, whereas one study found that children with Asperger's Syndrome (AS) exhibit difficulties in perceiving emotions through facial expression, prosody and verbal content compared to typically developing children (Linder & Rosen, 2006), another found that high functioning autistic adults exhibit difficulties only in recognizing negative emotional expressions compared to typically developed adults (Ashwin, Chapman, Colle & Baron-Cohen, 2006). In another study, it was revealed that adolescent males with high functioning autism, were less accurate in processing the emotions of anger, disgust and surprise (Law Smith et al., 2010), while on the other hand, Baron-Cohen, Splitz and Cross (1993) found that autistic children were impaired only on recognizing surprise. Yet other studies suggest that autistic individuals are unimpaired in emotion recognition. For example, Castelli (2005) found that children with autism were able to recognize all six basic emotion, showing no difference compared to control individuals. In another study, it was revealed that autistic children were as capable as typically development children in perceiving emotional expression in both human and cartoons (Rosset et al., 2007). Moreover, an interesting study examining basic emotion recognition in autistic individuals found that autistic children below 12 years old performed worst in recognizing emotion compared to autistic children over 12 years old (Kuusikko et al., 2009). According to Kuusikko et al.'s (2009) findings, difficulties in emotion recognition manifest at early development but children improved as they enter puberty. However they do not achieve the level of typically developing individuals, highlighting the need of teaching emotion recognition in individuals high on autistic traits, regardless of age.

Several reasons may account for the widely different findings in emotion recognition for individuals with autistic traits. An important factor mentioned by Blair (2008) and Harms et al. (2010) are the various demographic characteristics like age, number of sample, intensity and task demands and even differences in the mental age of children participating in these studies. Moreover, it is well documented that autistic traits and symptoms are heterogeneous and vary across each individuals, suggesting the existence of a spectrum of autism with different levels of abilities, intelligence and severity (Hill & Firth, 2003). Thus, using the dimensionality of autistic traits might be more effective in understanding differences in behavioral manifestation and severity than using a cut-off score approach. All these differences may account for the inconsistency of findings regarding emotion recognition in autism. Another concern is that the majority of the studies focus on the ability of autistic individuals to recognize emotional facial expressions, raising questions regarding the relation of autistic traits with recognizing emotions in every day situations and not only through facial expression.

Since prior studies point to both similarities and differences in emotion recognition in autistic and CU traits, it is important to include both traits in investigating emotion recognition deficits in order to identify unique associations. In addition, since findings from Study 1 and additional work (e.g., Pasalich, Dadds, & Hawes, 2014) propose an interaction effect between CU and autistic traits, there is a need to investigate if high autistic traits moderate the association of CU traits and emotion recognition. Since both traits seems to be associated with emotion recognition, and interaction of both traits may lead to more severe deficits in a broad range of emotions, and not only in negative ones. Moreover, this is the first study examining this topic using an emotion recognition task with children. This will help in better understanding the different emotion recognition deficits early in development and formulate prevention and intervention suggestions. All in all, individuals with autism or autistic traits appear to perceive and recognize emotion differently than typically developing individuals, but yet more research is needed to understand emotion recognition abilities in children with autistic traits.

Current study

Even though there is a growing body of research investigating physiological activity (HR, SC and startle reflex) in CU traits, there is a lack of studies investigating the same reaction in individuals high on autistic traits, during exposure to emotional stimuli. Moreover, to the authors knowledge, there are no studies investigating the interaction of both traits in relation to emotional processing (emotion recognition and physiological reactions). Regarding emotion recognition in CU and autistic traits, the majority of prior work focused in recognizing facial emotional expressions and not general emotions. In addition studies regarding autism and autistic traits are inconsistent. Since there are no prior studies investigating differences between CU and autistic traits on physiological measurements and emotion recognition, neither the interactive effect of these two traits, the current study aims to be the first to examine this topic. Moreover, it aims to fill the literature gap regarding relation of physiological measurements with autistic traits, extend findings of startle reactivity in high CU individuals to children with the same traits, and give more insight regarding emotion recognition abilities in both traits. To do so, the unique and interactive associations of differences of CU and autistic traits in levels of HR, SC and startle modulation, as well as emotion recognition ability will be examined.

In Study 1, we investigate how CU or autistic traits relate to HR, SC and startle modulation of children early in development, during exposure to emotional cartoon videos. We chose videos since they are more ecologically valid and include both optical and auditory stimuli. Moreover we assessed their ability to understand other peoples' emotions using angry, sad, fear, happy and neutral cartoon video stimuli. In Study 2, we investigate physiological reactions of the same sample during exposure to static emotional pictures, using distress, threatening, positive and neutral images. Our work advances prior investigations since we used a) two different emotional tasks in order to investigate physiological reactions in our participants and b) a broad range of emotions.

Based on previous studies, it is hypothesized that children with CU traits will exhibit difficulties in recognizing fearful and sad emotions, while individuals with autistic traits, due to their deficits on cognitive empathy are expected to exhibit general deficits in recognizing emotional stimuli. These findings can help inform previous contradictory results. Regarding physiological measurements, existing research suggests that CU traits are associated with under-arousal and physiological under-reactivity (Anastassiou-Hadjicharalambous & Warden, 2008; de Wied, van Boxtel, Matthys, & Meeus, 2012; Fanti et al., 2016). Thus, CU traits are expected to be associated with low HR, SC and startle response during distressing and threatening pictures, as well as emotional video scenes depicting fear and sadness. Previous studies using positive emotional stimuli did not find any association between physiological arousal measures and CU (Fanti et al., 2017). However, happy scenes and positive pictures are included to investigate if deficits in physiological responses will extend to positive stimulus or will be observed only in negative emotional cues. Regarding autistic traits, it is proposed that they will be associated with high reactivity of HR and SC during aversive stimulation, but intact startle modulation, since according to Blair (2008) the formation of stimulus-reinforcement ability, which is highly related to amygdala, in autism is intact.

In addition, this is the first study aiming to investigate the interaction of CU and autistic traits in relation to physiological measurements. Interactions will be assessed to investigate if autistic traits moderate the relation of CU traits with physiological measurements and emotion recognition. Based on prior studies suggesting that the interaction of CU and autistic traits is related with severe deficits in affective empathy, it is proposed that it will be also associated with low physiological measurement. Regarding emotion recognition, it is proposed that the interaction of both traits will lead to difficulties in recognizing a broad range of emotion and not only negative. Last, in addition to the main focus of this study, we also investigated and control for sex differences in both unique and interaction relations, and age for unique relations. As far as we know, no prior studies have investigated gender differences between these traits neither with physiological measurement, nor with emotion recognition. Thus, this analysis will be exploratory.

Study 1 Method

Participants

Participants were selected for an in-depth assessment based on a screening sample of 1652 children in early development, from schools in Cyprus, by selecting those who display low levels of empathy (*n* = 78) (below -1 SD on GEM questionnaire total empathy score) and control individuals (*n* = 85) (randomly selected from children scoring between -1 SD and +1 SD on GEM questionnaire total empathy score). From the initial identified sample we randomly selected 163 children (*M*age= 4.95, *SD*= .97; 44.2% girls), and approximately 90% (*n* =147) agreed to participate in the experimental phase of the study. Moreover, due to experimental errors and technical problems, not all data from the participants were available, which is common in physiological studies (e.g., Fanti et al., 2017). Final Ns based on tasks and measurements were as follows: heart rate, *n*= 110; skin conductance, *n*= 109; orbicularis oculi electromyography (startle modulation), *n*= 126; emotion recognition accuracy tasks, *n*= 142.

Procedure

Following approval of the study by the Centre of Educational Research and Assessment (CERE) of Cyprus, Pedagogical Institute, Ministry of Education and Culture and Cyprus National Bioethics Committee, 47 private and public nursery schools, and 69 primary schools in three provinces (Nicosia, Larnaca and Limassol) were randomly selected for participation in the screening phase. All schools were contacted by telephone and informed about the aims of the study. School boards that were interested to participate in the study received details about the purpose and procedure via email or fax. Parents or guardians were informed about the nature of the study and 81% of them consented to their child's participation. During the screening phase, both fathers and mothers completed a package of questionnaires, which took approximately half an hour. Children low on empathy (below -1 SD on GEM questionnaire) were selected to take part in the experimental phase.

For the experimental phase, the parents of the children selected to participate were conducted by a researcher and informed about the aims, procedures and the selection criteria of the study. Parents that agree to their child's participation scheduled an appointment at the Developmental Psychopathology Lab (DPL) at the premises of the Psychology Department in the University of Cyprus. Prior to the meeting, an email was sent to each family including: a) the contact details of the primary researcher in case they needed any further assistance, b) the University map and directions to the DPL, c) a reminder of their scheduled assessment and d) a link to an online questionnaire package using a secure internet-based platform (Survey Monkey) including the three main variables of CU traits, autistic traits and empathy.

Questionnaire Assessment

Callous unemotional traits. The parent version of the 24-items Inventory of Callous-Unemotional Traits (ICU: Frick, 2004) is comprised of 12 positively worded (e.g., "he/she express his/her feelings openly") and 12 negatively worded items (e.g., "he/she does not feel remorseful when he/she does something wrong") assessing CU traits. Parents rated their children on a four point Likert scale (0 = Not at all true, 1 = Somewhat true, 2 = Very true, 3 = Definitely true) with total scores ranging from 0 to 72. The ICU captures three dimensions of CU traits: callousness (e.g., "He/she does not care who he hurts to get what he wants"), unemotional (e.g., "He/she does not show his emotions to others"), and uncaring (e.g., reverse scored items:

"He/she feels bad or guilty when he/she does something wrong"). In the current study, only the total score of ICU was used. Previous studies have verified that the ICU shows acceptable internal consistency using different translations (e.g., Ezpeleta et al., 2013; Kimonis et al., 2015), while several studies has verified the validity of ICU in community sample of Greek Cypriot children (e.g., Fanti, 2013). In the present study ICU demonstrated good internal consistency (α=.88).

Autistic Traits. Autistic traits were assessed using the school-age form of the Social Responsiveness Scale (SRS), a 65-item parent and/or teacher report (Constantino & Gruber, 2012). In the current study, SRS was used as a parent report. Parents rated their children on a four point Likert scale (1 = Not true, 2 = Sometimes true, 3 = Often true, 4 = Almost always true) with total scores ranging from 65 to 260, with higher scores indicating higher degrees of social impairment. Furthermore, SRS captures five domains – "Treatment Subscales" of autistic traits: social ability, awareness, cognition, communication, motivation and mannerisms. In the current study, only the total score of SRS was used. Previous studies have verified that SRS shows high internal consistency (α=.91-.97) and acceptable inter-rater reliability (.76 and .95) (Bölte, Poustka, & Constantino, 2008; Constantino, Przybeck, Friesen & Todd, 2000; Constantino et al., 2003). In the present study, the total SRS score demonstrated excellent internal consistency (α=.92).

Screening Questionnaire

Empathy. Empathy was measured using the 23-item parental scale Griffith Empathy Measure (GEM; Dadds et al., 2008b). GEM except for an overall empathy score, captures the two subcomponents of empathy: cognitive and affective. It is composed with 6 items for cognitive empathy subscale (e.g., "My child has trouble understanding other people's feelings") and 9 items for affective empathy subscale (e.g., "Seeing another child sad makes my child feel sad"), rated on a 9-point Likert scale (rating from -4 = strongly disagree to 4 = strongly agree). Total scores range from -92 to 92, with higher scores indicating higher levels of empathy. Prior studies have demonstrated good test-retest reliability of scores over 1 week ($r > .89$) and 6 month intervals ($r > .69$), good internal consistencies, a stable factor structure across age and sex groups, inter-parental agreement ($r > .47$), and convergence with child reports ($r = .41$) (Dadds et al., 2008; 2008b). In the present study, both affective (α=.74) and cognitive empathy (α=.67) subscales showed adequate internal consistency.

Experimental procedures

To ensure that video clips indicate specific emotions, pilot data were collected form an independent sample of children (*n* = 45; *M* age = 6), matched for age with the experimental sample. Participants validated an initial pool of 33 films by categorizing the emotion expressed by each film main character to one out of four different emotions (happy, fear, sad, anger) and neutral expression. For rating, we used a scale made of clipart images of each emotion, which was age appropriate. Specifically, raking of the scenes was made according to valid-rate (e.g., a happy emotional state expressed by the main character is correctly categorized as happy), invalid-rate (e.g., an angry emotional state is not categorized as any of the four emotions). Based on children's ratings, 10 scenes of 1-minute duration were selected as the best representatives of each category from two classic Disney movies, "Bambi" (Disney Animation Studios, 1942) and "Aladdin" (Disney Animation, 1992). All the scenes were in Greek and included music and some dialogue or commentary of approximately equal duration.

Apparatus. For experimental phase**,** timing of the events, presentation of the visual and auditory emotional stimuli, and recording of participants' responses to the rating questions were controlled by an E-Prime 2.0 script (Schneider, Eschmann, & Zuccolotto, 2002). Auditory stimuli (i.e., films' soundtrack and white noise- startle probe) were presented binaurally with headphones in order to mask ambient noise. Visual stimuli (i.e., emotional video clips) were presented on a 22 inch (maximum resolution of 1680 x 1050 pixels) computer screen, placed 60 cm from the participant. All physiological signals were collected using BIOPAC MP150 for Windows bioamplifiers and transducers, running an Acq4.3 data acquisition software (Biopac Systems Inc, Santa Barbara, CA). Physiological measures were continuously monitored during the experiment.

Startle probes. Startle probes are white-noise stimuli use with the purpose of eliciting the blink startle reflex. Probes were created using the Audacity software package, and constituted of 50-ms bursts of 100-dB white noise. In order to reduce predictability, startle probes were presented at varying points during videos. Two of 10 scenes included 3 startle probes each, presented in the beginning (10s), middle (25s) and near the end (45s) of the video. Four scenes included two startles probes each, occurring either at the beginning and middle of the video, at the beginning and the end, or at the middle and end of the video. Finally, two scenes included only one startle probe, presented either at the beginning, middle, or end of the scene and the remaining scenes did not include any startle probe. Participants heard a total of 12 startle-probes, equally distributed across each emotional video category (3 per fear, sad, angry, happy) and 4 startle probes during neutral video clips.

Heart Rate (HR). HR data were acquired using the ECG module of Biopac system. For recording HR activity, two 11-mm disposable Ag/AgCl pre-gelled electrodes were placed on the left and right inner forearms of the participant. ECG signals amplified with a gain of 500, filtered using a Biopac ECG100C bioamplifier, sampled online at 1000Hz, and then converted offline to beats per minute values. In addition, during the conversion, a visual artifact inspection was conducted, and high proportions of artifacts and/or recordings that occurred during technical errors (detachment, touching or scratching the electrodes) removed by deleting the physiological data for the specific emotional task. A mean level of resting HR was calculated during a 60s baseline, preceding experiment onset (rest).Following the baseline, the video stimuli were presented and the mean level of HR during each affective and neutral scene was collected (i.e. HR activity).

Skin Conductance (SC). SC data acquired in microSiemens (μS) using the galvanic skin response (GSR) module of Biopac system. For measuring SC, two 11-mm disposable pre-gelled Ag/AgCl electrodes were placed adjacently on the hypothenar eminence of the palmar surface of the non-dominant hand. In order to reduce hand movement artifacts, participants were instructed to keep their hand facing palm-up. The signal was amplified with a gain of 10μS/V and sampled online at 250 Hz. Similar to HR, SC screening for artifacts, removing recordings occurred during technical errors. In addition, mean level of SC calculated during the 60s baseline period preceding experiment onset (rest), and during the presentation of each affective and neutral stimuli (i.e. SC activity).

Startle reflex. Startle reflex data acquired using the EMG module of Biobac system, recoding EMG signals for the orbicularis oculi (ORB). Those signals sampled at 1000 Hz using two miniature Ag/AgCl electrodes, filled with electrode gel and placed over the ORB muscle under the under the left eye, using the guidelines of Fridlund and Cacioppo (1986). Raw EMG was rectified and integrated using a 10-ms time constant. Startle amplitude was scored offline, by identifying peak EMG deflections, within a time of 20 – 120 ms, after each startle probe. Mean baseline of the ORB calculated for 2s prior to each startle probe, and subtracted from the peak amplitude occurring within the 20-120 ms scoring window. Similar to Fanti et al. (2016), in order to establish a common metric for all participants, the difference score was converted to T-scores units for each participant, by standardizing raw values across trials. T-scores were also averaged to represent startle magnitude values within each video category (happy, sad, fear, angry, neutral). Extreme outlier trials, at the level of each film segment were detected using a Boxplot-function (3 IQR from the median; Ashare, Hawk & Mazzullo, 2007) and excluded from further analyses.

Affective ratings. Following the presentation of each video, participants were provided with a multiple-choice question, asking them to identify the emotional state of the main character from the list of five different choices (1= happy, 2= sad, 3= angry, 4= fear, 5= neutral). Participants entered their ratings using a compact keyboard placed by their dominant hand. If the answer was correct then the accuracy rate of the current scene was 1, while in case of wrong answer the rate was 0.

Experimental procedure

Upon participants' arrival at the University a researcher greeted families, answered any questions that came up and explained the consent form in detail. Then participants were informed that during the experimental procedure they: (1) will be seated in a comfortable chair in front of a computer screen, (2) fitted with physiological sensors, (3) watch different cartoon videos, and (4) they will need to identify the main character's emotion (happy, sad, anger, fear and neutral) after watching each scene. Subsequently, parents (either mother or father, or both of them) signed the consent form and children were seated in a height-adjustable chair, adjusted to the point at which they were looking directly towards the computer screen. Next, they were fitted with the physiological sensors and instructed to relax in order to evaluate the effectiveness of the recordings. Baseline physiological activity was recorded for a 60s period, while participants viewed a blank computer screen. Following each video clip, participants entered their ratings regarding main character's emotion using a compact keyboard placed by their dominant hand.

The experiment took approximately 25 minutes to complete – 10 minutes for preparation and 15 minutes for the actual task. Once the experiment was completed, participants were debriefed.

Plan of Analysis

First, correlation analyses were conducted in SPSS 21.0, in order to investigate the association between CU and autistic traits with baseline HR and SC physiological measures as well as HR, SC, and startle reactivity after controlling for the neutral condition. Specifically, for physiological reactivity, difference scores were computed by subtracting activity during neutral scenes from activity during emotional scenes, a method used and verified by previous work (see Fanti et al., 2015; 2017). In addition, correlation analyses were conducted between CU and autistic traits with emotion recognition accuracy. Moreover, in order to test the unique association between CU and autistic traits with physiological measurements, two partial correlation analysis was conducted, whilst controlling for autistic and CU traits respectively. Next, we performed a series of hierarchical multiple regression analysis with the predictors in each model being CU, autistic traits, sex and the interaction of those variables. More over, we use age as predictor only in step 1. Dependent variables were physiological reactivity for each emotional video stimuli and emotion recognition accuracy. In step 1, sex (0=males; 1=females) CU and autistic traits were entered. In step 2, we entered the 2-way interactions: CU traits X sex, autistic traits X sex and CU traits X autistic traits. In step 3, we entered the 3-way interaction between all independent variables: CU traits X autistic traits X sex. The procedures followed for both 2-way and 3-way interactions are the same as the one described in method section of the first study (see plan of analysis of the first study).

Study 1 Results

Correlation analysis for physiological measurements

Zero-order correlations between CU and autistic traits with physiological measures and emotion recognition are reported in Table 1. As shown in the table, CU and autistic traits were moderately correlated ($r=.60$; $p<.001$), although the majority of bivariate associations with physiological measures were not statistically significant. Next, a partial correlation was run to determine the correlation between CU and physiological reactivity whilst controlling for autistic traits. Results revealed that CU traits were partially negatively correlated with SC reactivity during sad videos (r= -.29; $p<.01$). This points to a suppressor effect of autistic traits in the relation of CU traits with SC reactivity during sad stimuli, where autistic traits seem to suppress the relation between CU and physiological reactivity. Similar to previous analysis with CU traits, a partial correlation was run to determine the relation between autistic traits and physiological reactions whilst controlling for CU, revealing no significant relations.

Associations with Physiological Measures

Resting HR and SC. As shown in Table 1, neither CU and autistic traits did not show any negative zero order correlation with both HR and SC at baseline. However, regression analysis for these measures revealed that autistic traits was uniquely predictive of higher baseline HR (β=.26; $p<.05$) (see Table 2). No interactive effect, sex or age differences were found. The fact that correlations were non-significant at the zero order level for both traits, but increased and become significant within the joint regression model for autistic trait only, indicates that HR baseline is uniquely associated with autistic traits.

HR reactivity. As shown in Table 3, there was no direct association for CU and autistic traits with HR activity during the emotional scenes after controlling for the neutral condition. However, during exposure to fear videos, there was a significant two-way interaction between CU and autistic traits ($\beta_{\text{CU traits}}$ x $\beta_{\text{Autistic trait}}$=-.30, $p<.01$). The significant interaction is depicted in Figure 1. According to the graph, CU traits were associated with higher levels of HR during the fear scene at low levels of autistic traits (β=.33; $p<.05$) but not for high levels of autistic traits (β=-.26; p=.12). Also there was a positive significant relation between age and HR reactivity in both sad (β=.24; $p<.05$) and angry (β=.24; $p<.05$) emotional stimuli.

SC reactivity. Regarding SC reactivity there was a significant two-way interaction between CU and sex ($\beta_{\text{CU traits}}$ x β_{Sex}=.35, $p<.01$) predicting SC reactivity during sad videos (Table 4). Separate regression analysis for boys and girls revealed a significant negative relation of CU traits and SC for boys (β=-.76, $p<.001$) but not for girls (β=-.05, p=.81). These findings are depicted in Figure 2. Two significant two-way interactions between CU traits and sex ($\beta_{\text{CU traits}}$ x β_{Sex}= .43, $p<.05$) and between autistic traits and sex ($\beta_{\text{Autistic traits}}$ x β_{sex}= -.40, $p<.05$) were identified during the fear scene. As before, we performed two separate regression analysis for boys and girls. As shown in Figures 3 and 4, results revealed that in boys, CU traits negatively predicted SC reactivity during fear scenes (β=-.50; p<.01), although a positive association was found for autistic traits (β=.38; p<.05). Non-significant prediction was revealed in girls for both CU (β=.10, p=.59) and autistic traits (β=-.18, p=.31)

Startle reflex modulation. Analyses focusing on startle modulation scores (emotional videos minus neutral) revealed a significant two-way interaction between CU and sex only for emotional videos depicting fear ($\beta_{CU\ traits}$ x β_{Sex}= -.33, p<.05) (see Table 5). However, separate regression analysis for boys (β=-.28 p=.11) and girls (β=-05, p=.80) did not revealed any significant relation between startle and CU traits during fear emotional video. No associations with CU traits during happy and angry scenes were identified. Similar, autistic traits did not significantly predicted startle modulation during any emotional video.

Associations with Emotion Recognition

As shown in Table 1, significant zero order correlations between emotion recognition accuracy and, CU and autistic traits were evident only for the neutral scenes. Both autistic (r =-.24, p<.01) and CU traits (r =.-28, p<.01) were negatively correlated with emotion recognition during neutral scenes. Moreover, findings from the regression analysis did not indicate any relation between the independent variables and their interaction, and emotion recognition, suggesting that the association with neutral emotions was lost after controlling for the covariance of CU and autistic traits (Table 6). However, there were significant positive relations between age and emotion recognition of happy (β=.26; p<.05)., fear (β=.22; p<.05) and angry (β=.28; p<.05) emotional scenes.

Study 2 Methods

Participants

The same sample participated in the second task of the study. Again, due to experimental errors and technical problems, not all data from the participants were available. Final Ns based on physiological measurements were as follows: heart rate, n= 99; skin conductance, n= 99; orbicularis oculi electromyography (startle modulation), n= 98.

Experimental assessment and procedure

Participants' physiological activity in study 2 was assessed in the same lab with the same experimental materials and apparatus (please refer to Study 1 methods for more detailed descriptions of physiological measures and apparatus). Thus, as with Study 1, E-Prime 2.0 scripts was used for the presentation of pictures and BIOPAC MP150 for the collection of HR, SC and startle modulation physiological signals. No baseline measures were collected, since both HR and SC baseline physiological reactivity were reported in Study 1. After finishing the emotional video experimental task (see Study 1), participants remained seated with attached physiological sensors and were informed about the second experimental task. In the current study children viewed pictures of varied emotional content including distress (e.g., malnourished children), threat (e.g., angry dog ready to attack), positive (e.g. kids having fun in a park) and neutral (e.g., book) emotions. In order to follow a similar procedure as in study 1, the affective pictures (distress, threatening, positive) were computed and compared to neutral pictures. The task used in the current study was developed using pictures taken from the International Affective Picture System (IAPS; Lang, Bradley, & Cuthert, 1997). These pictures were selected because they have been used in previous studies with children aiming to investigate emotional processing and affective reactions during exposure to aversive stimulus (Kimonis et al., 2006; McManis, Bradley, Berg, Cuthbert, & Lang, 2001) (see Appendix A for the codes of pictures used). During the procedure, the participants were instructed to try to keep their movements to minimum level and watch the pictures the entire time they were on the screen. During the experimental procedure the participants were alone in the room.

The task consisted of 40 pictures, 10 corresponding to each emotion. Pictures were presented with a random order for duration of 5s each. Before the presentation of the picture an asterisk was appeared in the centered of the screen. Intertrial intervals varied from 3.5 to 10.5s. In order to elicit the blink startle reflex, a startle probe was delivered randomly between 1s and 4s into the viewing period of 32 pictures. Eight startle probes were delivered at each emotional stimulus, and also 8 probes were delivered between the pictures. The experiment took approximately 15 minutes to complete – 5 minutes for preparation and 10 minutes for the actual task. Once the experiment was completed, sensors were removed and participants were debriefed.

Plan of Analysis

Same analysis plan was followed as in Study 1 for physiological measurements. For all physiological measures, difference scores were computed by subtracting activity during neutral pictures from activity during emotional pictures. Initially, a correlation analysis was conducted to investigate the association between the main two variables with physiological measurements after controlling for neutral condition (HR, SC and startle modulation) for each emotion. Moreover, in order to test the unique association between CU and autistic traits, and physiological measurements, two partial correlation analysis was conducted, whilst controlling for autistic and CU traits respectively. Subsequently we conducted a series of hierarchical multiple regression analyses with the predictors in each model being CU, autistic traits, sex and age, and the interaction of the first three variables. Steps were the same as in the regression analysis for physiological measurements in study 1. Depended variables were the physiological difference scores for HR, SC and startle modulation for each emotional scene.

Results study 2

Correlation analysis for physiological measurements

Bivariate associations among the study variables are reported in Table 7 for physiological reactivity after controlling for the neutral condition. As shown, there was no significant zero order correlations between CU and autistic traits with physiological measurements. Interestingly, the majority of associations with physiological measures were in the opposite direction for CU compared to autistic traits. Next a partial correlation analysis was run to determine the correlation between CU traits and physiological measurements whilst controlling for autistic traits. Results revealed that CU traits were partially positively correlated with startle modulation during positive (r= .26; p<.05) and threatening (r= .23; p<.05) images. No significant results were revealed for the rest of the measures. Similar to previous analysis with CU, a partial correlation was run to determine the relation between autistic traits and physiological measurements whilst controlling for CU traits. Results revealed that autistic traits were partially negatively correlated with HR reactivity during threatening (r= -.22; p<.05) and startle modulation during positive (r= -.26; p<.05) pictures.

Associations with Physiological Measures

HR reactivity. As shown in Table 8, there was a significant negative relation between sex and HR reactivity (β=-.22; *p*<.05), suggesting that boys exhibit low levels of HR reactivity during exposure to positive emotional pictures compared to girls. In addition, a significant negative prediction of autistic traits during exposure to threatening pictures was also revealed for HR reactivity (β=-.29; *p*<.05). No significant predictions were revealed for CU, and HR reactivity in all emotional stimuli.

SC reactivity Relations between CU and autistic traits, and SC reactivity during emotional pictures are presented at Table 9. As shown, no significant unique association or interaction for both CU and autistic traits and SC reactivity was revealed during exposure to positive pictures. However, a negative significant two-way interaction was found between CU traits and sex ($\beta_{\text{CU traits}}$ x β_{Sex}=-.46, *p*<.05). Thus we conducted separate regression analyses for boys and girls. Significant predictions of CU traits in SC reactivity during distress pictures was revealed in boys (β=.43; *p*<.05) but not in girls (β=-.18; *p*=.35). Regarding threatening pictures, no significant predictions were revealed for both CU and autistic traits.

Startle reflex modulation. Analyses focusing on startle modulation scores, revealed a significant negative prediction of autistic traits (β=-.33; *p*<.05) but a significant startle potentiation in CU traits (β=.32; *p*<.05) during exposure to positive pictures (Table 10). In distress pictures, autistic traits significantly negatively predicted startle modulation (β=-.28; *p*<.05), while no significant relation was revealed for CU traits. Similar, no significant relation was revealed between both traits and startle modulation during threatening pictures. Moreover, in all emotional pictures, results did not reveal any significant interaction, sex differences or age effect.

Discussion

The current study set out to investigate the unique and interactive associations between CU and autistic traits in: (a) physiological measurements during exposure to emotional videos and pictures, and (b) emotion recognition after watching emotional video scenes, within a sample of children in early development. Angry, sad, fear and happy emotional stimuli were used in video task, while positive, threatening and distress stimuli in picture task. Regarding the first aim of the study several interesting findings were revealed for CU traits and physiological measurements. Specifically, results indicated no correlation between CU and autistic traits with physiological measurements in all emotions and emotional tasks. However, these results differentiated when we accounted for the covariance between these traits in regression analysis. For example, we found that CU traits were related with low SC reactivity during negative stimuli when we controlled for autistic traits. Regarding sex differences, we found that boys exhibited lower levels of HR reactivity when exposed to positive pictures compared to girls. However, these results were not replicated when participants exposed to happy emotional videos. Concerning our second aim, findings did not point out any association between CU and autistic traits, and emotion recognition accuracy, except in neutral videos, where both individuals with high levels of CU and autistic traits exhibit deficits in recognizing neutral emotional scenes.

Physiological arousal during rest

Findings regarding baseline physiological measurements revealed that children with high levels of autistic traits exhibit higher levels of HR activity but not SC during baseline. Several studies have reported anxiety symptoms for individuals with ASD and autistic traits (e.g., Kuusikko et al., 2008; MacNeil, Lopes, & Minnes, 2009), with published studies proposing a range of 20-80% comorbidity between autism spectrum and anxiety (see Vasa & Mazurek, 2015). Thus, a possible explanation of the elevated levels of HR activity during baseline is that children with high levels of autistic traits were experiencing higher levels of anxiety. This result is in accord with Bal et al. (2010) findings, proposing high levels of HR baseline for individuals with autistic traits. In addition, since baseline measurements are collected at the beginning of the experiment, there is a possibility that participants with high levels of autistic traits experience high levels of anxiety at the beginning of the experimental task, due to the procedure (use of sensors on their hands and under their eye) and the new environment that they were exposed. On the other hand, in line with prior studies (e.g., Fanti, et al., 2017; 2018) no differences in SC and HR baseline in children with high levels of CU traits were revealed, indicating that it is more important to investigate their reactivity during emotional stimuli.

Physiological reactivity in CU traits

First, findings propose that older children exhibited higher levels of HR reactivity during sad and angry emotional stimuli. This is an interesting finding, proposing that as children get older they exhibit higher levels of arousal during negative aversive stimuli. Since our study is not longitudinal, we cannot make a strong claim about these results. However, our findings can inform future work in terms of the need to take a developmental perspective. Our hypothesis that CU traits would be related with low levels of HR and SC during sad and fear videos, and threatening and distress pictures relative to neutral condition was partially supported. In line with our predictions, findings suggest that low SC arousal among young children with CU traits is evident during exposure to fear and sad emotional stimuli, but only for boys. The majority of prior work found low autonomic activity among high CU children after exposure to negative (e.g., violent) stimuli (e.g., Anastassiou-Hadjicharalambous & Warden, 2008), but, there is a lack of studies investigating sex differences among high CU individuals. Moreover, previous studies were based mainly on male samples (e.g., de Wield et al., 2012; Muñoz, Frick, Kimonis & Aucooin, 2008). Thus, these findings provide novel evidence that low SC is evident only in high CU boys but not in girls. A possible explanation is derived from Blair (2013) theory. According to Blair (2013) when an individual is exposed to distress cues of others (e.g., someone being fear or sad), this leads to an aversive physiological reaction (elevated levels of autonomic arousal), as a result of recognizing and sharing the emotional state of the other person. This reaction is related with stimuli-reinforcement deficits, which in turn will make high physiological arousal undesirable to the individual. Thus in CU traits, deficits in empathy are associated with individuals' inability of processing specific emotions but also hypo-arousal during exposure to negative cues. Thus, when boys are exposed to negative emotional situation, they do not exhibit elevated levels of physiological arousal but instead low levels.

According to Dadds et al. (2009) and to first study's results, in the case of CU traits, boys exhibit deficits in both sharing and understanding others emotions (affective and cognitive empathy) a result that may lead to low physiological reaction towards negative emotions, and thus low SC reactivity. However, since girls with high levels CU traits are able to share the emotional state of other, they may not exhibit deficits in autonomic arousal during emotional stimuli in the same degree with boys, and as a result they do not exhibit low SC reactivity. Another possible explanation can be derived from Fontaine et al. (2010) study, proposing sex differences in the contribution of genetic and environmental factors in the development of CU traits. Specifically, it was found that different etiologic factors lead to CU traits, where boys were primarily affected by genetic factors while girls by environmental. Thus, low autonomic arousal in children in early development might be a result of genetic etiologic processes and it is related mainly with boys and not with girls.

Findings did not replicate prior evidence for SC reactivity during exposure to distress pictures. Specifically we found that CU boys exhibit high levels of SC reactivity at these emotional cues compared to girls. This is also interesting, since our results regarding video stimuli revealed the exact opposite findings. A possible explanation can be derived from exposure time. In video task, participants were exposed for 60s while in the case of pictures for 5s. There is a possibility that initially, boys with high levels of CU traits exhibit the expected physiological arousal - thus high levels of SC reactivity, which however reduced quickly. Moreover, some researches proposed that CU traits are associated with sensation seeking (Essau, Sasagaw, et al., 2006), and for this reason they engaged in risking, high-sensation seeking behavior. Thus, initially those children acquire the typical reactivity or even high levels – an indicator of sensation seeking (Zuckerman, 1990), but they cannot maintain it.

Contrary to our expectations, results did not reveal any unique relation between CU traits and HR reactivity in negative emotional stimuli. Some prior studies have found results supporting no differences on HR reactivity in both children and adults with high levels of CU traits (e.g., Fanti et al., 2017; 2018) suggesting that elevated levels of HR are related with a more grandiose-manipulative profile and not with callous-unemotionality. However, while investigating for possible interactions, an interesting result was revealed. Specifically, we found that the relation of CU traits and HR reactivity during fear stimuli, was moderated by low levels of autistic traits, leading to elevated HR reactivity in children with high levels of CU traits. This finding is surprising, since it demonstrated the exact opposite relation of CU traits and HR reactivity during fear, and not the negative or absent relation as prior studies proposed (Anastassiou-Hadjicharalambous & Warden, 2008; Fanti et al., 2017). This result can be also associated with the sensation seeking profile of high CU traits, suggesting that children with high levels of CU traits exhibit high levels of HR reactivity during novel emotional stimuli as an indicator of their sensation seeking tendencies. Another explanation can be offered from studies investigating the heterogeneity of CU traits (Fanti et al., 2018). For example, in their recent work, Fanti and colleagues suggest that high CU traits individuals differentiate on anxiety levels, exhibit different physiological reactions towards emotional stimuli, compared to individuals high on both CU and anxiety, which exhibit higher levels of physiological activity. Thus, there is a possibility that other characteristics, for example anxiety, may interact with CU traits and lead to HR hyper-activity. All in all, it is suggested that physiological mechanisms might function differently according to this heterogeneity (e.g., conduct problems or anxiety), indicating that it is important to consider it in future studies. In addition, since this is the very first study investigating interaction of CU and autistic traits with physiological measurements, more studies are clearly needed.

Physiological reactivity in autistic traits

Findings related to autistic traits and physiological arousal, did not fully support our hypothesis of a general hyper-arousal during aversive emotional stimuli. Regarding SC reactivity, results revealed an association with over-reactivity during fear video stimuli, only in boys. To the author's knowledge, there are no prior studies investigating sex differences in physiological arousal for individuals with high levels of autistic traits. These findings are in accordance with some prior work demonstrating that autistic traits are associated with physiological over reactivity (e.g., Bal et al., 2010; Prince et al., 2017). A possible explanation is derived from the self-regulation deficits that children with autistic traits seem to exhibit (Hirstein, Iversen, & Ramachandran, 2001). Hirstein et al. (2001) propose that these children experience deficits in their autonomic system, and they are seeking to regulate this dysfunction through repetitive activities. Regarding gender, there is no prior evidence about sex differences in autistic traits, except that girls might exhibit higher levels of cognitive empathy compared to boys (Baron-Cohen, 2009; Goldenfeld, Baron-Cohen, & Wheelwright, 2005). Thus, SC reactivity in response to fear stimuli may act as a biomarker differentiating boys with autistic and CU traits.

However this relation was not true for HR during threatening situation, where surprisingly autistic traits were related to low HR reactivity. To the authors knowledge this is the first study suggesting HR hypo-activity during threatening emotional cues in autistic traits. A possible explanation is derived from the stimuli that were used in the task. Specifically in the rest emotional stimuli, participants were watching others' being in an aversive emotional situation, or general pictures related with specific emotions. However, during threatening pictures, some stimuli, were directed towards the participant - for example a picture of someone pointing a gun at the participant. As a result these stimuli may lead to an increase of HR reactivity at individuals with low levels of autistic traits compared to other stimuli, while there was no HR reactivity in individuals high on autistic traits. Moreover, emotion recognition task revealed that individuals did not exhibit deficits in understanding the videos' characters emotion. There is a possibility that since boys with high levels of autistic traits successfully understood the emotional state of the character, this lead to their physiological arousal. Regarding static pictures, maybe children did not manage to accurately understand the emotion and it's valence. However, we did not investigate emotion recognition accuracy during picture task, thus these findings, should be interpreted with caution. Overall, our results propose that boys with high levels of autistic traits exhibit increased SC reactivity, and this can be used as a biomarker differentiating boys with high levels of autistic and CU traits.

Startle reactivity

Our hypothesis that children with high levels of CU traits will be associated with diminished startle modulation primarily during fear and threatening stimuli but also during sad and distress emotional cues was not supported. Prior studies investigating startle modulation in CU traits propose a fearlessness temperament related to low levels of startle modulation during negative cues (e.g., Fanti et al., 2016; Kyranides et al., 2016). According to Patrick (1994), the lack of startle modulation in CU individuals is related with deficits at the defensive system, which affects reactions towards threatening cues. However, in a study investigating distinct neurophysiological profiles in primary (non anxious) and secondary (anxious) group of high CU children and adults, results proposed that anxiety and not CU traits may account for the differences in startle reactivity between CU individuals (Fanti et al., 2018). These findings are also in accord with studies supporting the heterogeneity among CU individuals (Frick et al., 2004; Fanti et al., 2016). Investigating differences during positive pictures, we found that high levels of CU traits were related with startle attenuation. Among typical children, it is expected that the exposure to positive stimuli will lead to a startle attenuation and startle potentiation during negative (Bradley & Lang, 2000). Current findings suggest that high CU traits seems to have a typical startle reflex reaction during positive stimuli, but no specific reaction during aversive stimulus, suggesting that CU traits exhibit similar startle reactivity as typical children regarding positive stimuli but no at the case of negative stimuli. To the author knowledge, this is the first study reporting high levels of startle potentiation during positive stimuli, thus the opposite relation of what we expect.. This is a very surprising result, highlighting the importance of investigating startle reaction of individuals high on CU traits in positive emotional cues. Yet, since there are no previous theories supporting these findings, results should be interpreted with caution. In addition, no interactions between CU and autistic traits were revealed, suggesting that there is no interaction related with differences in startle modulation.

Last, our hypothesis regarding autistic traits and startle modulation was partially supported. In contrast with limited previous studies proposing that autistic traits exhibit normal startle modulation during emotional cues (Bernier et al., 2005; Salmond et al., 2003), current findings suggest that children with high levels of autistic traits exhibit low startle modulation during exposure to both positive and distress pictures. These findings are interesting since this is the first study suggesting diminished startle modulation during specific emotional cues in children with high levels of autistic traits. Investigating startle reflex during emotional tasks is an indirect method to test amygdala activity, where diminished startle modulation is related with amygdala hypoactivity. According to Baron-Cohen et al. (2000), autism is related with abnormalities in amygdala, which in turn affects their ability to interpret others' behaviors, empathize and predict how they feel. Specifically, they proposed that adults with high-functioning autism exhibit less activation of amygdala during tasks where participants had to interpret the mental state of a person.

A possible explanation of the current results derived from findings of few previous studies suggesting reduced amygdala responses in individuals with autism, during exposure to emotional facial expression (Ashwin et al., 2007; Critchley et al., 2000). In the current study, during exposure to emotional picture tasks, participants also viewed a number of emotional facial expressions (people being sad, happy, in pain or crying), and this may linked to a low startle modulation. Thus, low startle reactivity during distress and positive pictures may function as an indicator of reduced amygdala responses in individuals with high levels of autistic traits. In addition, our findings can also advance prior work focusing on faces, expanding findings in general emotions and not only in facial expressions. All in all, these results suggest that startle reactivity might function differently in autistic traits – low reactivity - indicating that it is important for future studies to investigate it in more depth, using facial emotional expressions. In addition, more studies investigating physiological reaction and startle reactivity in children with autistic traits are clearly needed, specifying in greater detail if these traits are related with low startle modulation or not.

Emotion recognition in CU and autistic traits

It has been proposed that in CU traits, impairments in amygdala lead to stimuli-reinforcement deficits, diminishing the ability of learning through distress cues, and thus their emotion recognition accuracy in distress cues (Blair, 2009). On the other hand in the case of autistic traits, individuals exhibit difficulties to receive and interpret information for the emotional state of the other, from the eye region, leading to deficits in recognizing other people emotions (Baron-Cohen, 2001). Contrary to our expectations, no unique and interaction association was revealed between CU and autistic traits, and recognizing emotions during emotional scenes. Literature on autism and autistic traits revealed an inconsistency of findings regarding emotion recognition, with evidence suggesting the absence of any emotion recognition impairment (e.g., Castelli, 2005; Rosset et al., 2007). For CU traits, although deficits in recognizing fear and sad emotions have been proposed from several studies, suggesting that the inability to attend to other people distress cues lead to deficits in emotional empathy (Blair, 2009; Blair & Coles, 2000; Blair, Colledge, Murray, & Mitchell, 2001; Dadds et al., 2006; 2008), this relation in our sample was no revealed.

There are several possible explanations for our results. First, previous studies have focused mainly on facial emotion recognition in both autistic and CU traits, investigating individuals' ability in recognizing displays of facial expression, and not general emotional scenes (Dadds et al., 2006; Fairchild et al., 2009; Humphreys et al., 2007; for a metanalysis see: Marsh & Blair, 2008). In the current study we investigated children's ability in recognizing emotions from videos, including both auditory and optical stimuli. Based on the current findings we can assume that participants, in contrast with tasks demanding of focusing in facial expression, manage to combine all the information (music, spoken language, images etc) during the one-minute exposure to each emotional scene and accurately recognize the emotional state of the main character. Thus, CU and autistic traits may be related with deficits in facial recognition, but their ability of combining verbal and environmental contents and information remains intact, leading to decoding emotions correctly. Second, previous studies used humans expressing emotion as emotional stimuli, while in the current study we used cartoon characters. This is not to suggest of course that individuals high on CU and autistic traits show deficits in recognizing emotions expressed by humans and not in the case of cartoons, but rather to highlight that the animated character used on the current study might affect the final results. Third the subclinical nature of the sample and the heterogeneity in both traits may explain our findings. The clinical presentation of autistic symptoms is heterogeneous suggesting a spectrum with different levels of abilities, intelligence and severity, while several studies propose heterogeneity among CU traits (Fanti et al., 2016, 2017) that may explain the absence of relation between autistic and CU traits and emotion recognition. Last, results revealed that older participants were scoring better in emotion recognition accuracy in fear, angry and sad emotional videos. A possible explanation for these results can be derived from Dadds et al. (2009) study. Specifically, Dadds suggested that as individuals are getting older and entering puberty, they learn and become more capable of understanding other peoples' emotions. However, there is a need of longitudinal studies in order to confirm this explanation.

Strengths and limitations

The current study has several strengths that should be noted. First, a multi-method physiological assessment, using HR, SC and startle modulation activity was used to identify unique differences and interactions in CU and autistic traits. Second, a large community sample was used during the screening phase for identification of the individuals that participate in the current study. Third we used a multi-assessment method using both emotional videos and pictures. Forth, this is the first study investigating interaction effect between CU and autistic traits in both physiological measurements and emotion recognition. However, current findings should be interpreted within the context of some limitations. First, both CU and autistic traits were assessed using parent reports. Future studies will be benefit from incorporating clinical interviews, teacher reports, and self-reports, as additional assessment for identifying each profile more accurately. Second we examined differences on physiological measurements and emotion recognition in subclinical, community sample of young children. Future studies should also investigate different emotional profiles in clinical samples of ASD and Limited Prosocial Emotion. Third, for emotion recognition tasks we used general emotional videos and static pictures and not specific facial expressions. It seems that in both traits, children do not exhibit deficits in recognizing general emotion but deficits in recognizing facial expressions. Thus it will be useful to replicate the same study using human static or dynamic facial expressions pictures. Fourth, assessment conducted only for early development children. Implementing a longitudinal design study, expanding our findings in adolescents and adults will be important in order to understand the physiological and emotional processing of individuals with CU and autistic traits, across development. Last, regarding physiological tasks, children participate first at the video task and then at the picture task, an event that may affect their reactions.

Conclusion

In conclusion, our findings highlight the importance of different physiological markers in understanding the emotional processing of children with CU and autistic traits, despite their surface similarities in empathy deficits. First, findings propose that SC reactivity during fear emotional stimuli can be used as a physiological marker for both CU and autistic traits in boys. Findings suggest that this mechanism functions differently in these two traits, where boys with high levels of CU exhibit low SC reactivity, and boys with autistic traits high SC reactivity. In addition, this is the first study suggesting different physiological mechanism in boys and girls for both CU and autistic traits. Second, regarding startle reactivity, current study proposed that in children with high levels of autistic traits, findings of low startle modulation during positive and distress emotional stimuli may suggest impairments in amygdala. In addition, we extend physiological findings for both traits in children, since the majority of previous studies focused on adolescents and adults. Last, current findings in combination with results from previous studies suggest that in both psychological conditions, individuals despite their deficits in facial emotion recognition, they are capable of combining environmental and verbal information for accurately decoding and recognizing general emotions. All in all, our findings suggest that despite surface similarities on empathy deficits, CU and autistic traits have different underlying emotional processing mechanisms. An advance to prior work is that we investigate these differences by comparing both traits in the same study and experimental tasks, and not separately for each trait. Moreover, we shed more light to sex differences, suggesting that it is important to take them into account, since we have evidence that boys and girls with these traits may also exhibit different physiological profile. Last we highlight that heterogeneity and co-occurrence seems to be also an important factor that future studies should take into account. Taking into consideration these results, focusing in biological, physiological markers, and heterogeneity can help in shaping etiological hypothesis and understanding underlying mechanisms related to emotional processing in autistic and CU traits. An event, which will eventually lead to the development and improvement of prevention and intervention programs. For example, high levels of SC reactivity in boys with high levels of autistic traits might br related with a general oversensitivity to distressing stimuli and high emotionality. Thus interventions aiming to help individuals cope with oversensitivity and emotion regulation are clearly needed. On the other hand, in boys with high levels of CU traits, more rewarding tasks that focus on emotion recognition and role taking task might be needed, since their profile is related with low emotionality. Moreover, teachers and parents should understand the different “modus operandi” for those children behavior, and react based on what is beneficial and effective.

General overview and conclusion

The two studies of the project explored three different dimension of CU and autistic traits – empathy, physiological measurements and emotion recognition, the distinct profile in case of interaction and gender differences. The main findings of both studies are briefly mentioned bellow, followed by a general conclusion.

Study 1, has demonstrated that CU and autistic traits have distinct empathy deficits profile. It seem that autistic traits are related only with difficulties in the cognitive empathy, while high levels of CU traits with impairments in both affective and cognitive empathy. This lead to a new perspective in understanding CU traits, where the ability of understanding others' emotions is also impaired in those individuals. Moreover it shed more light in the concept of gender differences in CU traits. Specifically boys with high levels of CU seems to exhibit deficits in both empathy subcomponents, while in girls, only the co-occurrence of CU traits with high levels of autistic traits is related with deficits in affective empathy.

Study 2, revealed different physiological profile in both traits. It seems that children with high levels of autistic traits exhibit higher levels of HR but not SC activity during baseline. An event, which may be associated with high levels of anxiety. Moreover it was revealed that SC reactivity during fear emotional stimuli can be used as a physiological marker for both CU and autistic traits in boys, where CU traits is related with low reactivity and autistic traits with high, suggesting also different physiological mechanism in boys and girls with these traits. In line with these results, boys with high levels of CU traits were also related with low SC reactivity during sad stimuli. In addition low startle reactivity was revealed during positive and distress emotional stimuli, in children with high levels of autistic traits, suggesting potential impairments in amygdala. Surprisingly, no such deficits were revealed for CU traits. On the contrary, high levels of CU traits were related with startle potentiation during positive stimuli. Last in both traits, individuals are capable of combining environmental and verbal information for accurately decoding and recognizing general emotions.

The two studies, taken together have confirmed our initial assumptions. That each physiological condition, despite their superficial similarities, is related with distinct empathy and physiological profile. It is revealed that distinct underlying mechanism lead to distinct empathy abilities, suggesting a different "modus operandi" in each case. Furthermore, findings from both studies suggest that the co-occurrence and interaction of both traits can lead to different deficits, but also highlight the importance of gender differences. Regarding interaction effects, we highlight the importance of heterogeneity by pointing to a different psychological profile – at least in girls. In combination with previous studies we have some strong indications that the notion of "double-hit" is at work. However, does this profile represent the interaction of CU and autistic traits or the co-occurrence of specific characteristics of those traits e.g., behavioral problems and anxiety? Theories propose that anxiety is a main characteristic of autistic traits profile. Similar, studies regarding CU traits propose a heterogenous structure, where anxiety interacts with CU traits, leading to two different profile: primary and secondary. Taking these results into account, there is a possibility that the interaction of CU and autistic traits is actualy an interaction of CU traits and anxiety All in all, there is a clear need of replication of the current findings, and in depth investigation of this relation, addressing the limitations of the current study.

Another interesting finding was gender differences in both traits. Specifically, it was revealed that SC reactivity can be used as a biomarker for both traits only in boys, suggesting that girls exhibit typical SC reactivity. Moreover it is proposed that girls with high levels of CU traits do not exhibit deficits in sharing the emotional state of others, but only in case of co-occurrence with autistic traits. In the research field, which focused on CU and autistic traits, is often discussed that males and females may exhibit different underlying impairments. Specifically, there is a huge discussion, especially about CU traits, regarding the differences between males and females, and a general belief that these traits are related with higher levels of severity and stability in boys compared to girls. In case of autistic traits, it has been suggested that women exhibit less severe empathy deficits than men. However studies are mainly focused on male samples and females are under-represented in prior work, which makes clear the need for more studies investigating gender differences using mix-gender sample or even focused more in girls. One question that remains unanswered, is whether there are actual gender differences - different underlying mechanisms and emotional profile -, or actually these traits are predominant in boys. Current findings are in line with theories suggesting that girls with CU traits do not exhibit deficits in affective empathy. This was evident in both questionnaire and physiological measurements, since girls scored typically in affective empathy and they did not exhibit low levels of SC reactivity. However, as it is mentioned above, there is a need of more studies focusing on different behaviors and emotional processing models between genders. Regarding age, in the majority of our analyses, we did not reveal any significant results, indicating that age differences between children in early development does not affect the relation between CU and autistic traits with empathy, physiological arousal and emotion recognition.

An important strength of the current project was the young age of the sample (children in early development). The fact that we were able to identify different emotional profiles during a very young age is beneficial for both clinical assessment and intervention. Of course, future studies will benefit from the use of an exclusively preschool sample, but still our findings can inform clinical practice and child interventions. First, regarding assessment, specific biomarkers can clarify the distinct underlying mechanism that lead to superficial un-empathic behaviors and reactions, early in development. This suggest that combining physiological measurements with psychological assessment, can lead to a more accurate understanding of psychological conditions and a more complete case conceptualization. This suggestion is related with the Research Domain Criteria (RDoC) framework proposed by the National Institute of Mental Health for investigating mental disorder. The aim of this framework is to integrate many levels of information from genetics and physiological measurements to self-reports, in order to understand the nature of mental health in terms of varying degrees of dysfunctions in both psychological and biological systems. Our findings are line with this framework, since: 1) we investigate CU and autistic traits as continuous and no categorical/ cut-off score dimensions, and 2) proposed possible biomarkesr for autistic and CU traits. Thus, the use of physiological methods during clinical assessment can lead to a more accurate understanding of psychological conditions and personality traits, even in the case of young children. Such findings can lead to more effective interventions based on the specific deficits in emotional processing, empathy and underlying physiological mechanisms and not the behavior per se.

Needless to say, despite that the current project have demonstrated the importance of co-investigating CU and autistic traits, for both unique and interactive effect, more studies are clearly needed for understanding the different emotional processing profiles in both traits, and more findings regarding co-occurrence of both traits. Replication studies should take into account the limitations of the current project and also zoom into other specific components related to these traits, like disruptive behavior and anxiety. It is only through continuous exploration and replication of studies, that we will be able to have significant and clinical useable conclusions – which will lead to the ultimate purpose of research in clinical psychology: to guide treatment and promote best practices in applied psychology.

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Study 1 Tables

Table1*: Estimates from correlational analyses indicating the bivariate associations among study variables*

	Cognitive Empathy	Affective Empathy	CU Traits	Autistic Traits	Age
Cognitive Empathy	———				
Affective Empathy	.07	———			
CU Traits	-.47***	-.23**	———		
Autistic Traits	-.49***	-.09	.60***	———	
Age	-.04	.04	.22**	.28**	———
Descriptives					
Mean	7.28	10.21	21.81	41.77	4.95
SD	8.41	10.76	9.89	21.31	.97

Note: Two-tailed significance: * entries are significant at $p<.05$, ** $p<.01$ and ***$p<.001$ level.

Table 2: *Results of Hierarchical Regression Analysis for variables predicting empathy subcomponents*

	Cognitive Empathy				Affective Empathy			
Variable	*B*	*SE B*	*b*	*R*	*B*	*SE B*	*b*	*R*
Step 1				.29***				.24
Sex	.26	1.30	.02		-1.24	1.89	-.06	
Age	.67	.47	.11		.65	.70	.09	
CU	-.23	.08	-.28**		-.29	.12	-.27***	
Autistic Traits	-.13	.04	-.33***		.03	.06	.07	
Step 2				.30				.30
Sex	.30	1.32	.02		-1.47	1.89	-.07	
Age	.68	.48	.12		.64	.70	.09	
CU	-.31	.25	-.38*		-.38	.37	-.35	
Autistic Traits	-.11	.12	-.28**		.03	.17	.07	
CU*Sex	.06	.16	.10		.05	.23	.07	
Autism*Sex	-.02	.08	-.06		.04	.11	.10	
CU*Autistic Traits	.001	.003	.04		-.01	.004	-.20	
Step 3				.30				.36*
Sex	.79	1.55	.05		1.17	2.18	.05	
Age	.69	.48	.12		.67	.69	.09	
CU	-.29	.25	-.36*		-.26	.37	-.24	
Autistic Traits	-.14	.13	-.35**		-.13	.18	-.26	
CU*Sex	.04	.16	.08		-.05	.23	-.06	
Autism*Sex	.01	.09	.02		.16	.12	.46	
CU*Autistic Traits	.01	.01	.19		-.02	.01	-.68	
CU*Autistic Traits*Sex	-.004	.01	-.16		-.02	.01	-.63*	

Note: Two-tailed significance: * entries are significant at $p<.05$, ** $p<.01$ and *** $p<.001$ level.

Study 2 Tables

Table 1: *Correlations between CU and autistic traits with physiological measurements and, emotion recognition accuracy during exposure to emotional videos*

	CU traits	Autistic traits
	r	r
CU traits	----	.60***
Baseline HR	.02	.18
Baseline SC	.08	.00
Emotional videos		
Heart Rate		
Fear	.06	.02
Sad	.01	.02
Angry	.02	-.02
Happy	-.11	-.01
Skin Conductance		
Fear	-.06	-.02
Sad	-.11	-.04
Angry	.07	.06
Happy	-.00	.01
Startle modulation		
Fear	-11	-.05
Sad	-.02	.11
Angry	.15	-.09
Happy	-.06	.05
Emotion Recognition		
Angry Accuracy	.05	.01
Fear Accuracy	.03	-.09
Happy Accuracy	-.08	-.09
Neutral Accuracy	-.28**	-.24**
Sad Accuracy	-.05	-.12

Note: CU = callous-unemotional; r = correlations controlling for neutral condition. Two-tailed significance: * entries are significant at $p<.05$, ** $p<.01$ and *** $p<.001$ level.

Table 2: *Unique and interactive effects of CU and autistic traits with baseline HR and SC measures*

	Baseline HR				Baseline SC			
Variable	*B*	*SE B*	*b*	*R*	*B*	*SE B*	*b*	*R*
Step 1				.21				.12
Sex	.93	2.53	.04		-1.81	2.42	-.08	
Age	-1.32	.92	-.15		-.91	.88	-.11	
CU	-.18	.16	-.14		.15	.15	.12	
Autistic Traits	.15	.07	.26*		-.04	.07	-.07	
Step 2				.31				.20
Sex	1.20	2.51	.05		-1.56	2.43	-.07	
Age	-1.36	.93	-.15		-.82	.90	-.10	
CU	.65	.49	.51		.57	.48	.47	
Autistic Traits	.07	.23	.11		-.25	.22	-.45	
CU*Sex	-.54	.31	-.65		-.27	.30	-.34	
Autism*Sex	.03	.15	.07		.12	.14	.31	
CU*Autistic Traits	.01	.01	.12		-.01	.01	-.14	
Step 3				.32				.23
Sex	2.54	2.94	.10		-3.11	2.85	-.13	
Age	-1.35	.93	-.15		-.85	.89	-.10	
CU	.72	.50	.56		.49	.48	.40	
Autistic Traits	-.02	.25	-.03		-.16	.24	-.28	
CU*Sex	-.59	.31	-.71		-.21	.30	-.27	
Autism*Sex	.09	.16	.22		.05	.16	.12	
CU*Autistic Traits	.02	.02	.39		-.01	.02	-.19	
CU*Autistic Traits*Sex	-.01	.01	-.29		.01	.01	.35	

Note: CU = callous-unemotional traits; HR = heart rate; SC = skin conductance. Two-tailed significance: * entries are significant at p<.05, ** p<.01 and ***p<.001 level.

Table 3: *Relations between CU and autistic traits and heart rate reactivity during exposure to emotional videos*

	Happy				Sad				Angry				Fear			
Variable	*B*	*SE B*	*b*	*R*	*B*	*SE B*	*b*	*R*	*B*	*SE B*	*b*	*R*	*B*	*SE B*	*b*	*R*
Step 1				.19				.11				.01				.09
Sex	.71	.58	.13		-.81	.80	-.11		-.28	.66	-.05		-.35	.64	-.06	
Age	.40	.21	.21		.62	.29	.24*		.52	.23	.24*		.09	.24	.04	
CU	-.05	.04	-.19		.00	.05	.00		.02	.04	.05		.02	.04	.08	
Autistic Traits	.02	.02	.12		.00	.02	.02		-.01	.02	-.05		-.01	.02	-.03	
Step 2				.24				.24				.26				.29
Sex	.66	.58	.12		-.86	.80	-.12		-.36	.65	-.06		-.44	.63	-.07	
Age	.40	.21	.21		.68	.29	.26*		.56	.23	.26*		.09	.23	.04	
CU	-.08	.05	-.24		-.00	.07	-.01		.00	.06	-.01		.03	.06	.10	
Autistic Traits	.02	.02	.19		-.01	.03	-.04		-.01	.03	-.05		-.01	.03	.03	
CU*Sex	.02	.07	.05		.01	.10	.01		.02	.08	.05		-.03	.08	-.07	
Autism*Sex	.00	.04	.01		.06	.05	.20		.04	.04	.17		.03	.04	.12	
CU*Autistic Traits	-.00	.00	-.14		-.00	.00	-.15		-.00	.00	-.23		-.00	.00	-.30**	
Step 3				.26				.25				.32				.36
Sex	.27	.68	.05		-1.18	.95	-.16		-1.02	.75	-.17		-1.20	.73	-.19	
Age	.40	.21	.21		.68	.28	.26*		.55	.23	.26*		.08	.23	.04	
CU	-.07	.05	-.25		-.01	.07	-.02		-.01	.06	-.02		.03	.05	.08	
Autistic Traits	.03	.02	.23		-.05	.03	-.02		.00	.03	.02		.02	.03	.11	
CU*Sex	.03	.07	.07		.01	.10	.02		.04	.08	.09		-.01	.08	-.02	
Autism*Sex	-.02	.04	-.07		.05	.05	.15		.01	.04	.05		-.01	.04	-.02	
CU*Autistic Traits	-.00	.00	-.23		-.00	.00	.20		-.01	.00	-.35*		-.01	.00	-.45**	
CU*Autistic *Sex	.00	.00	.16		.00	.00	.10		.01	.00	.25		.01	.00	.28	

Note: Two-tailed significance: * entries are significant at *p*<.05, ** *p*<.01 and ****p*<.001 level.

Table 4: *Relations between CU and autistic traits, and skin conductance reactivity during exposure to emotional videos.*

	Happy				Sad				Angry				Fear			
Variable	*B*	*SE B*	*b*	*R*	*B*	*SE B*	*b*	*R*	*B*	*SE B*	*b*	*R*	*B*	*SE B*	*b*	*R*
Step 1				.04				.21				.13				.11
Sex	-.18	.56	-.04		.59	.53	.12		-.66	.68	-.11		-.69	.79	-.09	
Age	.31	.20	.17		.31	.19	.17		.31	.25	.14		.28	.29	.11	
CU	-.00	.04	-.01		-.06	.03	-.22		.02	.04	.07		-.03	.05	-.07	
Autistic Traits	.00	.02	.02		.02	.02	.17		.00	.02	.01		.00	.02	.02	
Step 2				.07				.30				.26				.33*
Sex	-.18	.57	-.03		.55	.53	.11		-.71	.67	-.11		-.80	.77	-.11	
Age	.31	.21	.17		.29	.19	.16		.28	.25	.13		.19	.28	.08	
CU	-.02	.05	-.07		-.12	.05	-.48**		-.06	.06	-.19		-.15	.07	-.40*	
Autistic Traits	.01	.02	.04		.04	.02	.35		.03	.03	.19		.07	.03	.38*	
CU*Sex	.04	.07	.09		.14	.07	.35*		.17	.08	.36*		.25	.09	.43*	
Autism*Sex	-.01	.04	-.06		-.04	.03	-.21		-.05	.04	-.22		-.11	.05	-.40*	
CU*Autistic Traits	.00	.00	.04		.00	.00	-.04		.00	.00	-.02		-.00	.00	-.13	
Step 3				.08				.36				.30				.37
Sex	-.24	.68	-.05		1.18	.61	.23		-.16	.79	-.03		-.14	.89	-.01	
Age	.31	.21	.17		.30	.18	.17		.29	.25	.13		.20	.28	.08	
CU	-.02	.05	-.07		-.12	.05	-.47*		-.06	.06	-.19		-.38	.15	-.39*	
Autistic Traits	.01	.02	.05		.03	.02	.28		.02	.03	.14		.14	.08	.32	
CU*Sex	.04	.07	.10		.12	.07	.31		.16	.09	.33		.23	.10	.40*	
Autism*Sex	-.02	.04	-.07		-.01	.04	-.08		-.03	.05	-.12		-.08	.05	-.28	
CU*Autistic Traits	-.00	.00	.03		.01	.00	.11		.00	.00	.09		.01	.01	-.01	
CU*Autistic *Sex	.00	.00	.03		-.01	.00	-.29		-.01	.00	-.20		-.01	.00	-.23	

Note: Two-tailed significance: * entries are significant at $p<.05$, ** $p<.01$ and ***$p<.001$ level.

Table 5: *Relations between CU and autistic traits and startle modulation during exposure to emotional videos.*

	Happy				Sad				Angry				Fear			
Variable	*B*	*SE B*	*b*	*R*	*B*	*SE B*	*b*	*R*	*B*	*SE B*	*b*	*R*	*B*	*SE B*	*b*	*R*
Step 1				.22				.18				.20				.12
Sex	-.50	1.38	-.04		.98	1.21	.08		2.28	1.75	.13		-.08	1.29	-.01	
Age	.01	.01	.11		.01	.01	.08		.01	.01	.11		.01	.01	.06	
CU	-.09	.09	-.13		-.09	.08	-.14		-.15	.11	-16		-.08	.08	-.13	
Autistic Traits	.04	.04	.12		.06	.04	.20		.01	.05	.01		.01	.04	.02	
Step 2				.25				.27				.28				.25
Sex	-.45	1.40	-.03		1.09	1.19	.09		2.46	1.74	.14		.07	1.28	.01	
Age	.01	.01	.11		.01	.01	.09		.01	.01	.12		.01	.01	.06	
CU	-.05	.12	-.07		.05	.23	.09		.05	.15	.06		.08	.11	.12	
Autistic Traits	.02	.06	.07		-.01	.11	-.02		-.07	.07	-.17		-.04	.05	-.13	
CU*Sex	-.07	.18	-.07		-.28	.15	-.30		-.40	.22	-.29		-.33	.16	-.33*	
Autism*Sex	.03	.09	.05		.13	.07	.26		.12	.11	.17		.07	.08	.13	
CU*Autistic Traits	.00	.00	.04		.00	.00	.06		.00	.00	.10		.00	.00	.10	
Step 3				.25				.27				.28				.25
Sex	-.63	1.66	-.05		1.00	1.41	.08		3.11	2.06	.17		.22	1.52	.02	
Age	.01	.01	.11		.01	.01	.09		.01	.01	.13		.01	.01	.06	
CU	-.05	.12	-.08		.05	.11	.09		.06	.15	.06		.08	.11	.12	
Autistic Traits	.02	.06	.07		-.01	.05	-.02		-.08	.07	-.19		-.04	.05	-.14	
CU*Sex	-.07	.18	-.06		-.28	.15	-.29		-.42	.22	-.30		-.33	.16	-.33*	
Autism*Sex	.02	.10	.03		.12	.08	.25		.15	.12	.21		.07	.09	.14	
CU*Autistic Traits	.00	.00	.03		.00	.00	.05		.01	.01	.14		.00	.00	.11	
CU*Autistic *Sex	.00	.01	.03		-.00	.01	.02		-.01	.01	-.08		-.00	.01	-.03	

Note: Two-tailed significance: * entries are significant at $p<.05$, ** $p<.01$ and ***$p<.001$ level.

Table 6: *Results of Hierarchical Regression Analysis for variables predicting emotion recognition during emotional videos*

	Happy				Sad				Neutral				Fear				Angry			
Variable	*B*	*SE B*	*b*	*R*	*B*	*SE B*	*b*	*R*	*B*	*SE B*	*b*	*R*	*B*	*SE B*	*b*	*R*	*B*	*SE B*	*b*	*R*
Step 1				.11				.16				.32				.20				.15
Sex	-.02	.05	-.05		-.06	.06	-.10		-.09	.07	-.12		.11	.07	.16		-.09	.06	-.14	
Age	.04	.02	.26*		.01	.02	.06		.04	.02	.15		.05	.02	.22*		.06	.02	.28*	
CU	-.00	.00	-.03		.00	.00	.04		-.01	.00	-.19		.00	.00	.11		.00	.00	.08	
Autistic Traits	-.00	.00	-.07		-.00	.00	-.15		-.00	.00	-.13		-.00	.00	-.15		-.00	.00	-.04	
Step 2				.13				.18				.34				.23				.25
Sex	-.02	.05	-.05		-.06	.06	-.10		-.09	.07	-.12		.11	.07	.16		-.10	.06	-.15	
Age	.04	.02	.26*		.01	.02	.06		.04	.03	.15		.05	.02	.21*		.06	.02	.27*	
CU	.00	.01	.05		.01	.01	.15		.00	.01	.03		.02	.01	.42		-.01	.01	-.27	
Autistic Traits	.00	.00	.06		.00	.01	-.03		-.00	.01	-.14		-.00	.00	-.15		.01	.01	.40	
CU*Sex	-.00	-.01	-.09		-.00	.01	-.12		-.01	.01	-.25		-.01	.01	-.33		.01	.01	.34	
Autism*Sex	-.00	.00	-.14		-.00	.00	-.13		.00	.00	.07		.00	.00	.06		-.00	.00	-.36	
CU*Autistic Traits	.00	.00	-.03		.00	.00	-.01		.00	.00	-.12		.00	.00	-.06		.00	.00	-.18	
Step 3				.13				.19				.35				.24				.26
Sex	-.03	.05	-.06		-.09	.07	-.14		-.05	.08	-.07		.13	.08	.19		-.13	.07	-.20	
Age	.04	.02	.26*		.01	.02	.05		.04	.03	.15		.05	.03	.22*		.06	.02	.27*	
CU	.00	.01	.04		.00	.01	.11		.00	.01	.08		.02	.01	.45		-.01	.01	-.32	
Autistic Traits	.00	.01	.09		.00	.01	.08		-.01	.01	-.28		-.01	.01	-.27		.01	.01	.54	
CU*Sex	-.00	.01	-.08		-.00	.01	-.07		-.01	.01	-.31		-.01	.01	-.36		.01	.01	.39	
Autism*Sex	-.00	.00	-.16		-.00	.00	-.25		.00	.00	.22		.00	.00	.15		-.02	.00	-.51	
CU*Autistic Traits	.00	.00	-.07		.00	.00	-.22		.00	.00	.15		.00	.00	.09		-.00	.00	-.46	
CU*Autistic *Sex	.00	.00	.05		.00	.00	.22		.00	.00	-.29		.00	.00	-.16		.00	.00	.30	

Note: Two-tailed significance: * entries are significant at $p<.05$, ** $p<.01$ and *** $p<.001$ level.

Table 7: *Correlations between CU and autistic traits with physiological measurements during exposure to emotional pictures*

	CU traits	Autistic traits
	r	r
Emotional pictures		
Heart Rate		
Positive	-.02	.12
Distress	-.00	.14
Threatening	-.06	.07
Skin Conductance		
Positive	.11	-.06
Distress	.14	-.06
Threatening	.13	-.06
Startle modulation		
Positive	.12	-.14
Distress	-.04	-.20
Threatening	.14	-.03

Note: CU = callous-unemotional; r = correlations controlling for neutral condition. Two-tailed significance: * entries are significant at $p<.05$, ** $p<.01$ and ***$p<.001$ level.

Table 8: *Relations between CU and autistic traits and heart rate reactivity during exposure to emotional pictures.*

	Positive				Distress				Threatening			
Variable	*B*	*SE B*	*b*	*R*	*B*	*SE B*	*b*	*R*	*B*	*SE B*	*b*	*R*
Step 1				.30				.16				.29
Sex	-1.47	.74	-.22*		-.12	.82	-.02		.24	.89	.03	
Age	-.51	.26	-.22		.04	.30	.01		-.15	.33	-.05	
CU	.02	.05	.07		.04	.05	.12		.00	.06	.01	
Autistic Traits	-.04	.02	-.25		-.03	.02	-.20		-.06	.03	-.29*	
Step 2				.31				.28				.30
Sex	-1.50	.75	-.22*		-.25	.81	-.04		.23	.90	.03	
Age	-.54	.27	-.23		-.01	.30	-.00		-.13	.33	-.05	
CU	.01	.07	.04		-.03	.07	-.07		.02	.08	.05	
Autistic Traits	-.03	.03	-.17		.01	.03	.03		-.07	.04	-.35	
CU*Sex	.01	.09	.02		.13	.10	.23		-.04	.11	-.06	
Autism*Sex	-.01	.05	-.05		-.05	.05	-.17		.03	.06	.61	
CU*Autistic Traits	-.00	.00	-.09		-.00	.00	-.22		-.00	.00	-.30	
Step 3				.31				.31				.32
Sex	-1.48	.89	-.22		-.77	.96	-.11		-.37	1.07	-.05	
Age	-.54	.27	-.23		-.02	.30	-.01		-.14	.33	-.05	
CU	.01	.07	.04		-.03	.07	-.08		.02	.08	.04	
Autistic Traits	-.03	.03	-.17		.01	.03	.07		-.06	.04	-.30	
CU*Sex	.01	.10	-.02		.14	.10	.25		-.02	.12	-.03	
Autism*Sex	-.01	.05	-.04		-.07	.06	-.25		.01	.06	.02	
CU*Autistic Traits	-.00	.00	-.09		-.01	.00	-.30*		-.00	.00	-.12	
CU*Autistic *Sex	.00	.00	-.01		.00	.00	.17		.01	.01	.17	

Note: Two-tailed significance: * entries are significant at p<.05, ** p<.01 and ***p<.001 level.

Table 9: *Relations between CU and autistic traits and skin conductance measures during exposure to emotional pictures.*

	Positive				Distress				Threatening			
Variable	*B*	*SE B*	*b*	*R*	*B*	*SE B*	*b*	*R*	*B*	*SE B*	*b*	*R*
Step 1				.17				.09				.12
Sex	-.39	.37	-.12		-.29	.60	-.05		-.41	.40	-.11	
Age	.07	.13	.06		.11	.22	.06		.00	.15	.00	
CU	-.02	.02	-.13		.03	.04	.10		.01	.03	.06	
Autistic Traits	.00	.01	.05		-.01	.02	-.08		-.00	.01	-.05	
Step 2				.25				.31				.20
Sex	-.36	.37	-.11		-.25	.59	-.05		-.37	.41	-.10	
Age	.07	.14	.07		.13	.22	.07		.02	.15	.01	
CU	-.03	.03	-.16		.12	.05	.43*		.04	.04	.23	
Autistic Traits	.00	.02	.00		-.03	.02	-.25		-.02	.02	-.20	
CU*Sex	.02	.05	.07		-.19	.07	-.46*		-.06	.05	-.22	
Autism*Sex	-.01	.02	-.08		.05	.04	.23		.02	.03	.13	
CU*Autistic Traits	.00	.00	.21		.00	.00	-.03		.00	.00	.11	
Step 3				.26				.32				.21
Sex	-.29	.44	-.09		.01	.70	.00		-.40	.48	-.11	
Age	.07	.14	.07		.13	.22	.07		.02	.15	.01	
CU	-.03	.03	-.16		.12	.05	.44*		.04	.04	.23	
Autistic Traits	-.00	.02	-.01		-.03	.03	-.27		-.02	.02	-.19	
CU*Sex	.02	.05	.07		-.20	.08	-.49*		-.06	.05	-.21	
Autism*Sex	-.01	.03	-.04		.06	.04	.28		.02	.03	.12	
CU*Autistic Traits	.00	.00	.23		.00	.00	.03		.00	.00	.10	
CU*Autistic *Sex	-.00	.00	-.05		-.00	.00	-.10		.00	.00	.02	

Note: Two-tailed significance: * entries are significant at $p<.05$, ** $p<.01$ and ***$p<.001$ level.

Table 10: *Relations between CU and autistic traits and startle modulation measures during exposure to emotional pictures.*

	Positive				Distress				Threatening			
Variable	*B*	*SE B*	*b*	*R*	*B*	*SE B*	*b*	*R*	*B*	*SE B*	*b*	*R*
Step 1				.29				.23				.25
Sex	-.64	1.73	-.04		-1.06	2.54	-.05		-1.19	.82	-.16	
CU	.25	.11	.32*		.15	.16	.13		.09	.05	.24	
Autistic Traits	-.12	.05	-.33*		-.15	.07	-.28*		-.03	.02	-.17	
Step 2				.30				.24				.31
Sex	-.63	1.77	-.04		-.93	2.58	-.04		-1.25	.82	-.17	
CU	.28	.15	.35		.17	.23	.15		-.04	.07	.11	
Autistic Traits	-.12	.07	-.32		-.18	.11	-.35		.01	.03	.07	
CU*Sex	-.06	.22	-.05		-.02	.33	-.01		.09	.10	.16	
Autism*Sex	.01	.11	-.02		.03	.16	.03		-.08	.05	-.28	
CU*Autistic Traits	.00	.00	.00		.01	.01	.10		-.00	.00	-.10	
Step 3				.30				.25				.32
Sex	-.19	2.11	-.01		.08	3.06	.00		-1.49	.98	-.20	
CU	.28	.15	.35		.17	.23	.15		.04	.07	-.10	
Autistic Traits	-.13	.08	-.34		-.20	.11	-.37		.02	.04	.09	
CU*Sex	-.13	.23	-.06		-.04	.33	-.03		.10	.11	.18	
Autism*Sex	.03	.12	.01		.08	.18	.09		-.09	.06	-.32	
CU*Autistic Traits	.00	.01	.03		.01	.01	.15		-.00	.00	-.14	
CU*Autistic *Sex	-.00	.01	-.07		-.01	.01	-.10		.00	.00	.07	

Note: Two-tailed significance: * entries are significant at $p<.05$, ** $p<.01$ and *** $p<.001$ level.

Study 1 Figures

Figure 1: *Differences between CU and Autistic traits in boys predicting affective empathy.*

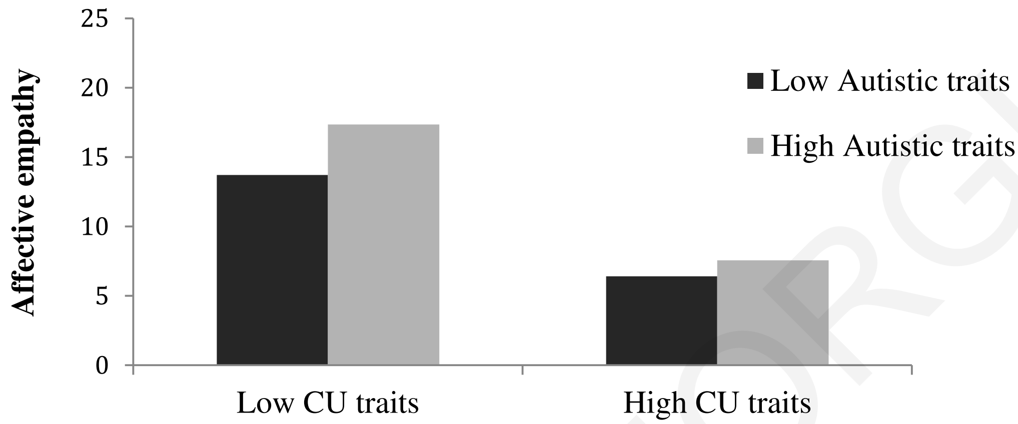
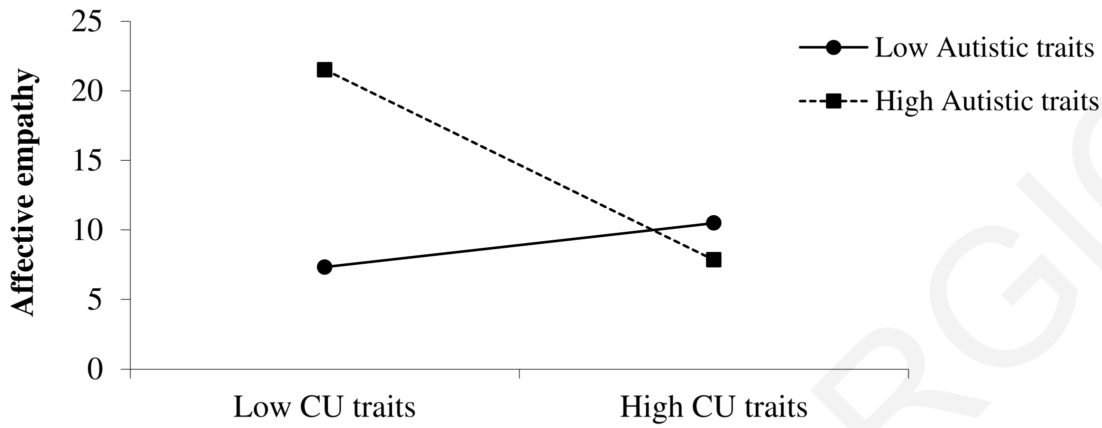


Figure 2: *Interaction between CU and Autistic traits in girls predicting affective empathy.*



Study 2 Figures

Figure 1: *Interaction between CU and Autistic traits on HR during fear emotional video.*

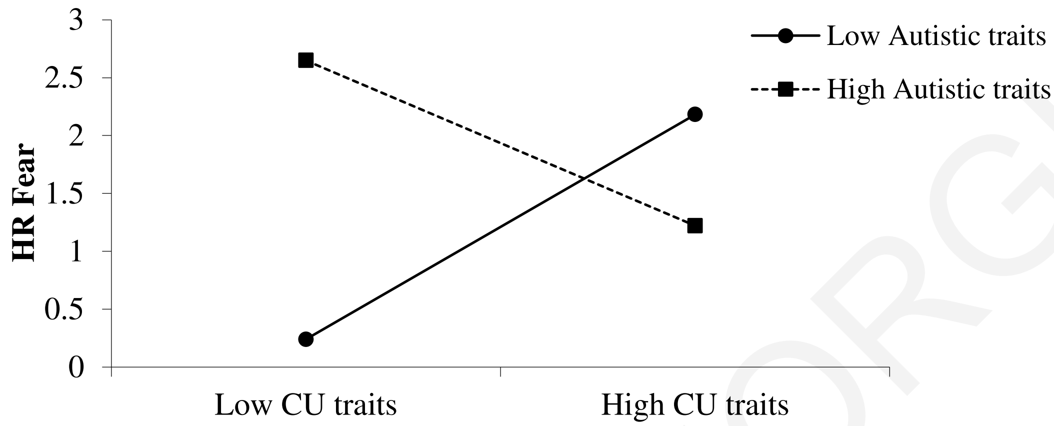


Figure 2: *Sex differences in CU traits, for SC during sad emotional videos*

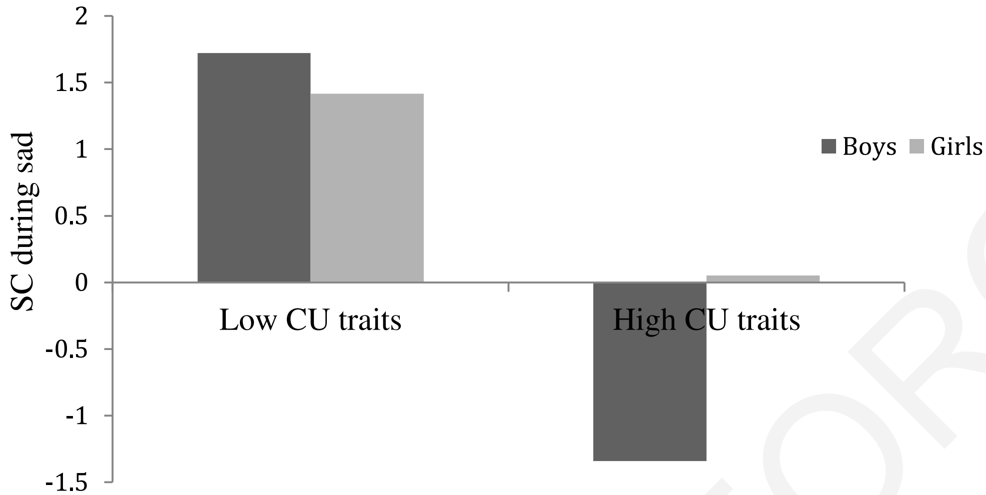


Figure 3: *Sex differences for CU traits, in SC during fear emotional videos*

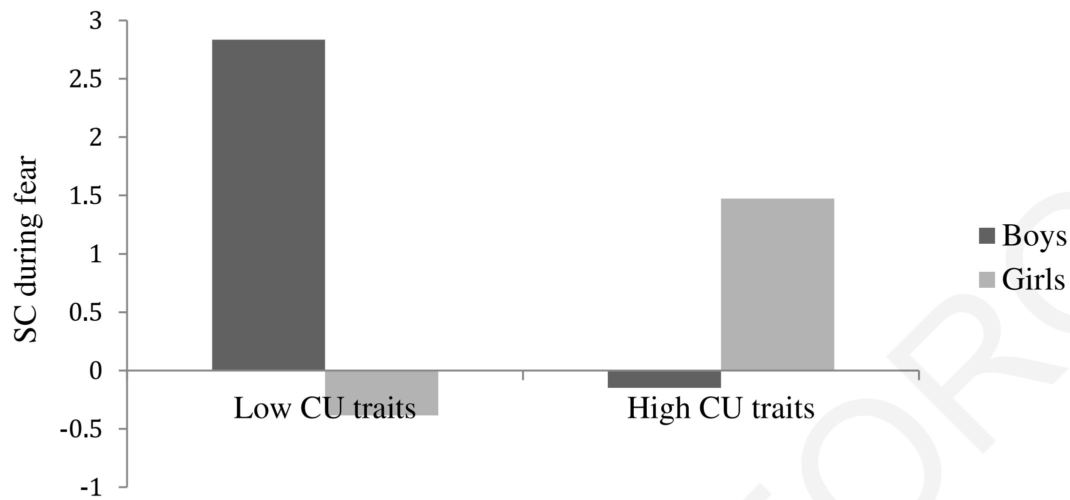
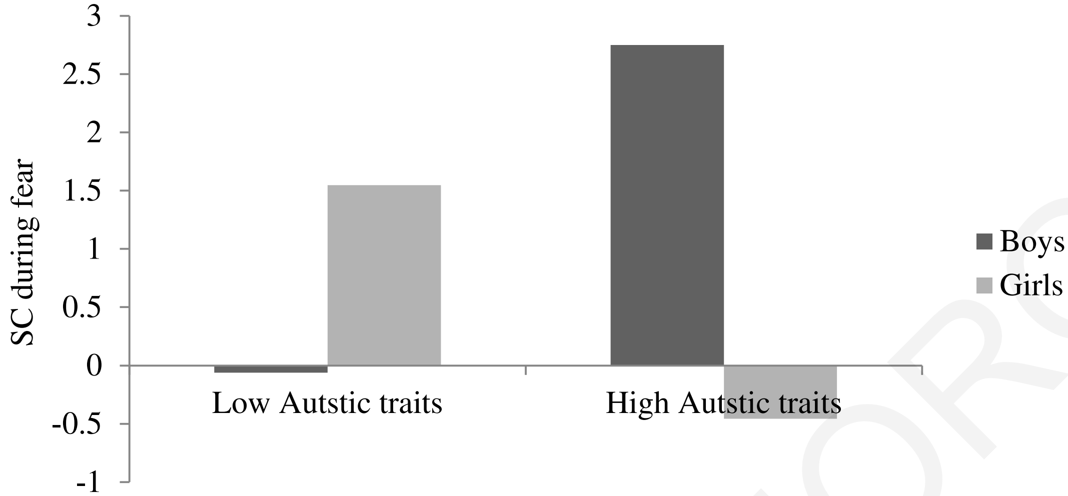


Figure 4: *Sex differences for autistic traits, in SC during fear emotional videos*



Appendix

The International Affective Picture System (IAPS) identification numbers are as follows. Positive: 1710, 1750, 1920, 2000, 2010, 7330, 7350, 7410, 8496, 8540. Distress: 2095, 2276, 2703, 2800, 2900, 3220, 3301, 9041, 9220, 9421. Neutral: 2190, 2200, 2210, 7000, 7002, 7006, 7009, 7010, 7025, 7035. Terrifying: 1050, 1205, 1300, 1321, 1931, 2100, 2110, 2120, 2682, 6250.