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Neural processing associated with cognitive empathy in pedophilia and child sexual offending

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This study presented under the name neural mechanisms underlying pedophilia and child sexual abuse was carried out in accordance with the recommendations of the ethics committee at Medical School, Otto-von-Guericke-University Magdeburg (on behalf of the ethics committee of Charité, Universitätsmedizin Berlin; 57/10), the ethics committee of Medical Faculty at Duisburg-Essen University (12-5002-BO), the ethics committee of Hannover Medical School at University of Hannover (6048) and the ethics committee of the Medical School at Kiel University (A 129/12).

Abstract

Behavioral studies found evidence for superior cognitive empathy (CE) in pedophilic men without a history of child sexual offending (P − CSO) compared to pedophilic men with a history of child sexual offending (P + CSO). Functional magnetic resonance imaging (fMRI) studies also point to differences between P − CSO and P + CSO. Neural processing associated with CE has not yet been investigated. Therefore, the present study aimed to explore the neural correlates of CE in subjects with pedophilia with (P + CSO) and without (P − CSO) child sexual offending. 15 P + CSO, 15 P − CSO and 24 teleiophilic male controls (TC) performed a CE task during fMRI. We observed reduced activation in the left precuneus (Pcu) and increased activation in the left anterior cingulate cortex (ACC) in P − CSO compared to P + CSO. P − CSO also showed stronger connectivity between these regions, which might reflect a top-down modulation of the Pcu by the ACC toward an increased self-focused emotional reaction in social situations. There was also evidence for increased right superior temporal gyrus activation in P − CSO that might constitute a potentially compensatory recruitment due to the dampened Pcu activation. These findings provide first evidence for altered neural processing of CE in P − CSO and underline the importance of addressing CE in pedophilia and CSO in order to uncover processes relevant to effective prevention of child sexual abuse.

Key words: pedophilia; sexual offending against children; cognitive empathy; neuroimaging

Pedophilia is defined as persistent sexual preference toward prepubescent and early pubescent children (American Psychiatric Association, 2013). Pedophilia is no prerequisite for engaging in child sexual offending (CSO) (Beier *et al.*, 2015; Seto, 2018). However, pedophilia can be regarded as a major risk factor for committing CSO (Seto *et al.*, 2006) as individuals with pedophilia account for ∼50% of the officially registered child sexual offenses (Seto, 2018).

To date, only few neuroimaging investigations have been conducted to elucidate neural correlates of pedophilia and CSO, respectively. These have yielded divergent results (see Mohnke *et al.*, 2014b; Tenbergen *et al.*, 2015), which might be explained by small sample sizes, methodological issues and, importantly, the lack of a differentiation between pedophilia and CSO in many studies. Pedophilia (and not CSO) was associated with aberrant function and connectivity within frontocortical and limbic areas during visual sexual stimulation (Walter *et al.*, 2007; Cantor *et al.*, 2008; Schiffer *et al.*, 2008; Poeppl *et al.*, 2011, 2015). CSO in pedophilia (rather than pedophilia per se) was associated with volume reductions in the amygdala (Schiffer *et al.*, 2007; Schiltz

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et al., 2007; Poeppl et al., 2013) and right temporal pole (Schiffer et al., 2017a) as evidenced by structural magnetic resonance imaging (MRI). Also, differences in functional MRI during a behavioral go/nogo paradigm (Kärgel et al., 2017) and aberrant connectivity during resting state were associated with CSO in pedophilia (Kärgel et al., 2015).

It has been suggested that empathy (see below) is important to further the understanding of mechanisms underlying and potentially contributing to pedophilia and CSO (Finkelhor and Lewis, 1988; Hanson and Scott, 1995). It has also been proposed that victim empathy, a complex construct including cognitive and affective aspects, is relevant in preventing CSO (Carich et al., 2003). Therapy programs that aim to reduce the risk of reoffending therefore entail interventions to increase victim empathy (McGrath et al., 2010). In line with this, Blake and Gannon (2008) hypothesized that a limited understanding of a victim's emotional state (i.e. victim empathy) may facilitate offending behavior, while comprehension of a (potential) victim's negative emotional reaction elicited by an offense might deter someone from committing an abuse.

Within social cognitive neuroscience, two main concepts of empathy can be distinguished: cognitive empathy (CE) and affective empathy (AE; Walter, 2012). CE refers to the ability to understand affective states of others. A synonym for CE is affective Theory of Mind, because both do not include adopting the emotions of others (Schurz et al., 2020). In contrast, AE includes the sharing of emotions of others, i.e. is an affective state itself. Here, we have investigated neural correlates of CE specifically. This is of considerable interest as we have found evidence for superior CE performance in P − CSO compared to P + CSO (Schuler et al., 2019, 2021). It has therefore been speculated that CE may act as a potentially therapeutic target to reduce the risk of reoffending in pedophilia.

Targeted investigations of neural underpinnings of CE in samples distinguishing between pedophilia and CSO are lacking. Neuroimaging studies of healthy subjects have shown that CE engages a network of functionally related regions, including the medial prefrontal cortex (MPFC), the temporoparietal junction (TPJ) and the posterior cingulate cortex/precuneus (PCC/Pcu; Carrington and Bailey, 2009; Van Overwalle, 2009; Abu-Akel and Shamay-Tsoory, 2011; Schurz et al., 2014; van Veluw and Chance, 2014). Aberrant neural functioning of CE has been studied in autism (Chung et al., 2014; Cheng et al., 2015; Ilzarbe et al., 2020), schizophrenia (Savla et al., 2013; Chung et al., 2014; Mohnke et al., 2016) or antisocial behavior (Brook and Kosson, 2013; Schiffer et al., 2017b).

One study on moral judgment in pedophilia with and without a history of CSO and non-offending teleiophilic (i.e. sexual preference toward adults) men performed within our research collaboration but using an independent sample demonstrated a reversed activation pattern in key areas associated with CE (bilateral TPJ and PCC/Pcu) in teleiophilic men compared to pedophilic men (irrespective of their offense status) while evaluating scenarios depicting sexual offenses against children compared to those depicting sexual offenses with adults (and vice versa) (Massau et al., 2017). Insofar as moral processing is closely related to empathy, the results show that it is pedophilia rather than CSO that explains neural activation differences. However, the study did not specifically assess neural correlates of CE but moral judgments.

The link between the neural underpinnings of CE, pedophilia and CSO thus remains unclear. The aim of the present study was to shed light on neural processing of CE in pedophilia with and without a history of CSO through bold signal change assessed during a CE task. We examined three groups: (i) pedophilic men with a history of hands-on child sexual abuse, (ii) pedophilic men without a history of hands-on child sexual abuse and (iii) non-offending teleiophilic men. Based on our prior behavioral studies, we expected functional differences within brain areas central to CE (MPFC, TPJ and PCC/Pcu) in P − CSO compared to P + CSO. We additionally aimed at exploring associations between neural CE functioning and behavioral self-rated empathy scores.

Method

Participants

A total of 54 male participants were recruited within the Berlin site of the research network 'NeMUP' (Neural Mechanisms Underlying Pedophilia and sexual offending against children; www.nemup.de) comprising five German collaborative research sites. Thirty participants met the diagnostic criteria of the 10th Revision of the International Statistical Classification of Diseases and Related Health Problems (ICD-10) for pedophilia (World Health Organisation, 1992). Within this subgroup, 15 pedophilic men had a history of hands-on child sexual offenses (P + CSO). Fifteen pedophilic men were included without any committed hands-on child sexual offense (P − CSO). Hands-on CSO was defined as any contact sexual offense against a child under the age of 14 years, including sexually touching or penetrating a child or encouraging a child to touch or manipulate the offender's genitals or penetrate him. Twenty-four non-offending teleiophilic men were included as control participants (TC). Study groups were matched for age, $F(2,51) = 0.64$, $P = 0.53$ ($\eta_p^2 = 0.02$) and intelligence, $F(2,51) = 2.50$, $P = 0.09$ ($\eta_p^2 = 0.09$). Recruitment was carried out by online advertisements, forum posts and mailing lists. Pedophilic men were additionally (not exclusively) recruited from practitioners and the Prevention Project 'Dunkelfeld' (Beier et al., 2009), offering anonymous and confidential treatment to self-identified and undetected pedophilic individuals. Present psychotic, substance use or severe mood disorder (Hamilton Depression Scale score of 15 or above); intake of psychotropic medication (including androgen deprivation therapy); neurological disorders; age above 50 years or an intelligence score below or above 2 s.d.s from the normalized average score led to exclusion from the study. Participants gave written informed consent prior to participation. The study was approved by the institutional review board of the Charité - Universitätsmedizin Berlin.

Measures

Sexual preference assessment

Pedophilic sexual interest was based on criteria of the ICD-10 (World Health Organisation, 1992) and was diagnosed if the participant reported recurrent sexual fantasies involving pre- and/or (early) pubertal children (Tanner stages I to III). Sexual gender preference and sexual age preference, further paraphilic sexual interest, consumption of child sexual exploitation material and hands-on offense history were assessed using a semi-structured clinical interview. An adaptation of the 'Kinsey scale' (Kinsey et al., 1975) extended for developmental stages of desired sexual partners and a 'viewing time paradigm' (Imhoff et al., 2010) verified the self-reported sexual gender and sexual age interest. During the viewing time paradigm, participants had to rate the sexual attractiveness of target images (pictures of males and females throughout all five Tanner stages), while response times were unobtrusively measured. Longer response times for either the group of mature developmental age categories (Tanner stages IV and V, males and females) or for immature developmental age categories (Tanner stages I through III, males and females) were regarded as sexual interest in that group.

Psychopathological assessment

Axis I and II disorders were assessed using German versions of the Structured Clinical Interview (SCID-I: Wittchen *et al.*, 1997; SCID-II: Fydrich *et al.*, 1997) for the Diagnostic and Statistical Manual of Mental Disorders (DSM-IV). Depressive symptoms were additionally assessed dimensionally by the Hamilton Rating Scale for Depression (HAM-D; Baumann, 1976).

Neuropsychological testing

Global intelligence was estimated from four subtests (Similarities, Vocabulary, Block Design and Matrix Reasoning) of the German version of the Wechsler Adult Intelligence Scale, 4th Edition (WAIS; Petermann, 2012). Handedness was assessed with the Edinburgh Handedness Inventory (Oldfield, 1971).

Empathy testing

Three subscales [Perspective Taking, Personal Distress (PD) and Emotional Concern] of the Interpersonal Reactivity Index (IRI) (Davis, 1983; German version: Paulus, 2006) were employed to assess self-reported empathic functioning. The Fantasy scale was left out of the current study as it is rather associated with the general level of emotionality (Paulus, 2006). All assessments were carried out by experienced clinicians.

Cognitive empathy task

The CE task was part of a larger imaging battery. It has been shown previously to robustly activate key areas central to CE in a variety of mental disorders and to show excellent test–retest reliability (intraclass correlation coefficients range from 0.76 to 0.82 for key areas of CE; Schnell *et al.*, 2011; Walter *et al.*, 2011; Mohnke *et al.*, 2014a). The task (~8 min) consisted of 16 cartoon stories with 8 CE trials and 8 control trials. Trials of the CE condition and the control condition were presented in alternation. Each trial started with an instruction (6.51 s) followed by three consecutive pictures (7.51 s per picture). During the CE condition, participants were instructed to take the perspective of the story's protagonist and judge via button press changes in his/her affective state (better, worse, equal compared to the preceding picture). All figures were free of facial expressions, and therefore, affective states had to be inferred by taking the person's perspective. The protagonist was distinguished from the other figures by a bold font. In the control condition, participants had to judge changes in visuospatial representations from first person perspective (more, less and equal than in the preceding picture). Participants jugged changes per keypress with the right index finger. With regard to the terminology, which is not consistently used across the literature, we would like to make the following relations explicit (Walter, 2012). Inferring affective states of others is referred to as CE (our task). AE means to feel the same emotional state of others (e.g. Schuler *et al.*, 2019, 2021). CE is also frequently referred to as affective ToM, namely when it is contrasted with cognitive ToM, which refers to the ability to understand cognitive states of others (e.g. thoughts and intentions; Walter, 2012; Schurz *et al.*, 2020).

Imaging parameters for acquisition

fMRI measurements of BOLD signal were performed on a Siemens Trio 3T MR scanner at the Charité - Universitätsmedizin Berlin using a 32-channel head coil. T2-weighted images were acquired with echoplanar imaging (EPI) sequence of 305 whole-brain scans, 38 slices of 3.00 mm thickness including 10% gap, repetition time (TR) 2.4s, echo time (TE) 30 ms, flip angle 80% and field of view (FoV) 240 × 240 mm. Scans were acquired in interleaved ascending slice order.

Functional imaging preprocessing and statistical analyses

Image processing and statistical analyses were conducted using statistical parametric mapping methods with SPM 12 (Wellcome Department of Cognitive Neurology, London, UK; https://www.fil.ion.ucl.ac.uk/spm/software/spm12/) implemented in Matlab R2020a (Mathworks, Natick, Massachusetts, USA). Data were excluded if movement parameters exceeded >3 mm translation and/or >3° rotation between volumes. Images were corrected for acquisition delay, realigned to the mean slice and spatially normalized to a standard EPI template (created by the Montreal Neurological Institute) to volume units (voxels) with the dimension of 3.0 × 3.0 × 3.0 mm. Then, the normalized images were spatially smoothed with a Gaussian kernel of 8 mm^3 (full width at half maximum) to increase the signal-to-noise ratio in cortical target regions. Five epoch regressors ((i) CE trials and (ii) control trials, introductions for (iii) CE trials and (iv) control trials, and (v) button presses) and six regressors modeling head motion were included in the first-level analyses for each participant.

The individual first-level (CE > control) contrasts and the individual functional connectivity [(CE × seed) > (control × seed)] contrasts were entered into second-level analyses of variance (ANOVAs) with group (P + CSO, P – CSO and TC) as between-subject factor. We use two levels of significance. On a conservative level, we applied a significant threshold of $P < 0.05$ family-wise error (FWE) corrected across the whole brain. On a more liberal level, we report effects that were significant with $P < 0.001$ uncorrected and a minimum cluster size of $k > 10$. There was no cluster size extent imposed at a FWE-corrected threshold level, but the exact cluster size (k) is reported.

Task-dependent functional connectivity was assessed using the generalized form of context-dependent psychophysiological interaction analysis (gPPI). Seeds were defined based on group differences in brain activity during mentalizing in an ANOVA comparing P + CSO, P – CSO and TC (see the 'Results' section). Individual time series were extracted using first eigenvariates from voxels within 6 mm spheres centered on the left anterior cingulate cortex (ACC: x = −18, y = 38, z = 16), the left Pcu (x = −27, y = −64, z = 34) and the right superior temporal gyrus (STG: x = 42, y = −49, z = 7). Subsequently, time series from the respective seed regions were entered into additional first-level models, together with the aforementioned task regressors (psychological variables) and movement regressors. We used the same significance levels as for the categorical effects.

Demographic data and behavioral task performance were analyzed using the Statistical Program for Social Sciences version 25 (SPSS; IBM, Armonk, NY, USA). Pearson's χ^2 tests were employed to assess group differences in categorical variables. Group differences on continuous variables were assessed with ANOVAs.

Association between brain activity and behavioral task performance in the scanner, self-rated empathy scores, HAM-D and WAIS scores were assessed by extracting individual beta weights from peak voxels of group differences during CE (see below) and correlated with the behavioral scores using SPSS. Correlation coefficients were computed with 1000 bootstrap samples and accompanied by 95% bias-corrected and accelerated bootstrapped confidence intervals (CI). Analyses were two-tailed, and

Table 1. Sample characteristics

	P + CSO (n = 15)	P – CSO (n = 15)	TC (n = 24)	Test statistics	Post hoc comparison
Demographics					
Age, years, mean ± s.d.	41.0 ± 9.0	38.8 ± 10.5	36.8 ± 12.9	$F(2,51) = 0.6$	n.s.
Handedness (left/right/both), n	2/11/2	1/13/1	4/19/1	$\chi^2 = 1.95$	n.s.
WAIS score, mean ± s.d.	99.5 ± 17.2	113.9 ± 18.2	105.9 ± 17.4	$F(2,51) = 2.5$	n.s.
Clinical and diagnostic characteristics					
Lifetime DSM-IV-TR diagnoses; Axis I (yes/no), n	11/4	6/9	3/21	$\chi^2 = 14.73^{**}$	P + CS0/P – CSO > TC
Lifetime DSM-IV-TR diagnoses; Axis II (yes/no), n	9/5	6/9	3/21	$\chi^2 = 10.91^{**}$	P + CS0/P – CSO > TC
HAM-D, mean ± s.d.	4.9 ± 5.1	3.2 ± 3.2	0.7 ± 1.43	$F(2,51) = 8.0^{**}$	P + CS0/P – CSO > TC
Neuropsychology, IRI					
Perspective taking, mean ± s.d.	14.43[a] ± 2.06	14.46[b] ± 2.88	15.58 ± 2.21	$F(2, 48) = 1.49$	n.s.
Personal distress, mean ± s.d.	9.92[b] ± 3.04	12.92[b] ± 3.30	8.88[a] ± 2.76	$F(2,47) = 7.87^{**}$	P – CSO > TC
Empathic concern, mean ± s.d.	14.36[a] ± 3.07	15.08[b] ± 2.78	13.52[a] ± 2.52	$F(2,47) = 1.42$	n.s.

Notes: Post-hoc comparisons: ≥significant group difference; two-sided significance values: $^{**}P < 0.01$, n.s. = non-significant.
Abbreviations: P + CSO = pedophilic men with child sexual offenses; P – CSO = non-offending pedophilic men; TC = non-offending teleiophilic controls; n = subsample size; SD = standard deviation; WAIS = Wechsler Adult Intelligence Scale; HAM-D = Hamilton Rating Scale for Depression; IRI = Interpersonal Reactivity Index.
[a]Data missing from one participant.
[b]Data missing from two participants.

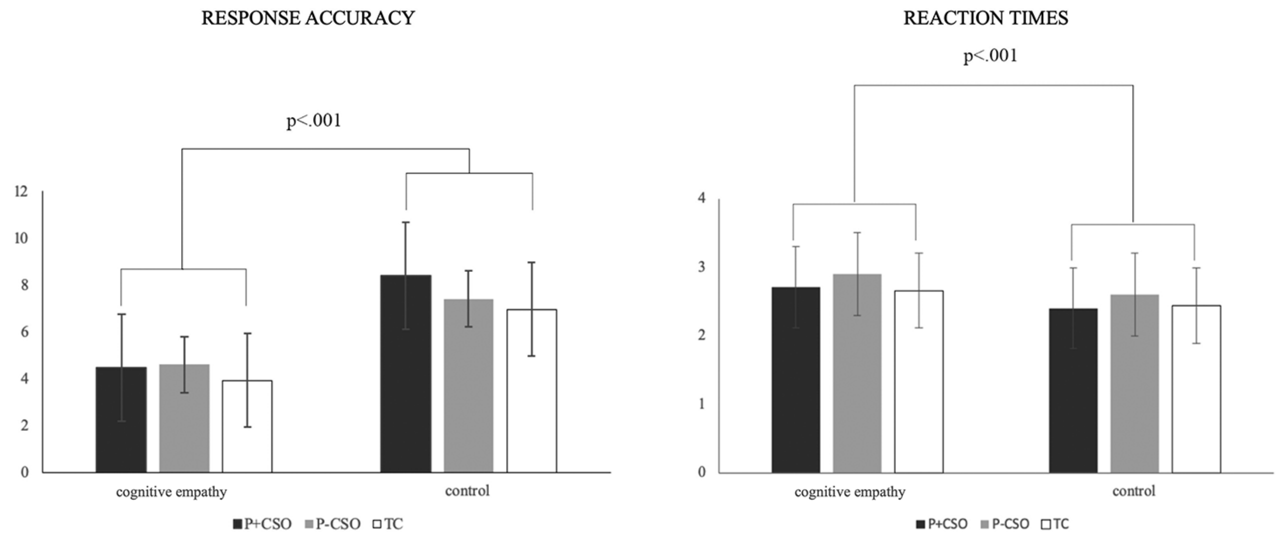

Fig. 1. Number of correct responses and response latencies.
Abbreviations: P + CSO = pedophilic men with child sexual offenses; P – CSO = non-offending pedophilic men; TC = non-offending teleiophilic controls; CE = cognitive empathy; n.s. = non-significant.

the significance threshold was set to $P < 0.05$. Post hoc group analyses of behavioral data were corrected for multiple comparisons using Bonferroni correction.

Results

Characteristics of study groups

There were no significant group differences in age and intellifence. The two pedophilic groups had significantly higher HAM-D scores and fulfilled significantly more often diagnostic criteria for axis I disorders (other than pedophilia) and axis II disorders (Table 1). Moreover, pedophilic men without a history of CSO (P – CSO) reported significantly more PD in social situations compared to teleiophilic controls (TC), $F(2,47) = 7.9$, $P < 0.001$ ($\eta_p^2 = 0.25$).

Task performance

Repeated ANOVAs revealed significantly longer reaction times, $F(1,51) = 19.09$, $P < 0.001$ ($\eta_p^2 = 0.27$), and fewer correct responses, $F(1,51) = 60.76$, $P < 0.001$ ($\eta_p^2 = 0.54$), in the CE condition compared to the control condition (Table 2, Figure 1). Neither the group effect for response accuracy, $F(2,51) = 1.62$,

Table 2. Cognitive empathy (CE) task performance

	P + CSO ($n=15$)	P – CSO ($n=15$)	TC ($n=24$)	Test statistics
Task performance				
CE condition, mean ± s.d.	4.5 ± 2.3	4.6 ± 1.2	3.9 ± 2.3	Group: $F(2,51)=1.6$
Control condition, mean ± s.d.	8.4 ± 3.1	7.4 ± 2.1	7.0 ± 2.3	Condition: $F(1,51)=60.8^{***}$ Group × condition: $F(2,51)=0.6$
Response times (s)				
CE condition, mean ± s.d.	2.7 ± 0.6	2.9 ± 0.7	2.7 ± 0.7	Group: $F(2,51)=0.6$ Condition: $F(1,51)=19.1^{***}$ Group × condition: $F(2,51)=0.2$
Control condition, mean ± s.d.	2.4 ± 0.6	2.6 ± 0.6	2.4 ± 0.5	

Notes: two-sided significance values: $^{***}P<0.001$.
Abbreviations: P + CSO = pedophilic men with child sexual offenses; P – CSO = non-offending pedophilic men; TC = non-offending teleiophilic controls; n = subsample size; s.d. = standard deviation; CE = cognitive empathy.

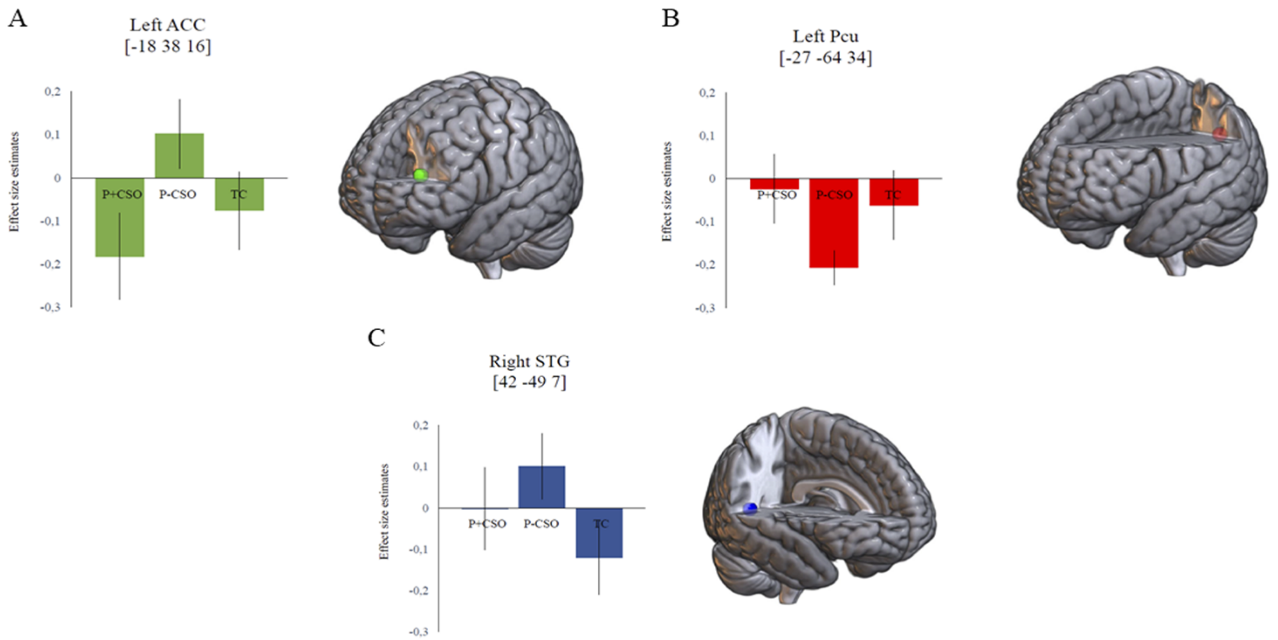

Fig. 2. Group differences in brain activity during cognitive empathy. (A) Pedophilic men without history of child sexual offending (P – CSO) showed significantly stronger left anterior cingulate cortex (ACC) recruitment than pedophilic men with history of child sexual offending (P + CSO) during cognitive empathy (CE). (B) P – CSO significantly stronger deactivated the Precuneus (Pcu) compared to P + CSO during CE. (C) P – CSO showed significantly stronger right superior temporal gyrus (STG) activation compared to teleiophilic controls (TC) during CE. Results are significant at an uncorrected threshold level (p<.001); Bars indicate mean values per subsample; error bars indicate 95% confidence intervals

$P=0.21$ ($\eta_p^2=0.06$), or for reaction times, $F(2,51)=0.57$, $P=0.57$ ($\eta_p^2=0.02$), nor the group × condition interaction effect for response accuracy, $F(2,51)=0.61$, $P=0.55$ ($\eta_p^2=0.02$), or for reaction times, $F(2,51)=0.18$, $P=0.83$ ($\eta_p^2=0.01$), reached significance.

Moreover, there were no significant correlations between the condition effect of performance and IQ (Supplementary Table S1).

Functional neuroimaging data

In the CE condition, the study groups activated areas associated with CE including frontal, temporal and parietal structures (Table 3).

We observed no significant group differences at a FWE-corrected significance level. Using a more liberal uncorrected threshold of $P<0.001$ and a cluster size of $k>10$, group comparisons revealed that P – CSO exhibited significantly stronger activation of the left ACC ($x=-18$, $y=38$, $z=16$; $t=3.41$) than pedophilic men with a history of CSO (P + CSO; Figure 2). In addition, P – CSO showed significantly less activation of the left Pcu ($x=-27$, $y=-64$, $z=34$; $t=3.29$) compared to P + CSO in the CE condition. In comparison to TC, P – CSO exhibited significantly enhanced activity of the right STG ($x=42$, $y=-49$, $z=7$; $t=3.36$). There is no region in which P + CSO showed stronger brain activity than P – CSO or TC in the CE condition.

Functional connectivity

The gPPI analysis for condition effects revealed a significantly increased functional coupling between the left ACC (seed) and the right Pcu ($x=18$, $y=-70$, $z=16$; $Z=5.03$, $P_{\text{FWE-whole brain corrected}}<0.001$, $k=22$) in the CE compared to the control condition. Between-group analysis showed that this effect was stronger in P – CSO than TC ($t=4.56$, $P<0.001$ uncorrected, $k>10$). Functional coupling between these regions in P + CSO was intermediate between TC and P – CSO without significant between-group

Table 3. Brain activity associated with cognitive empathy

		P + CSO ($n = 15$)					P − CSO ($n = 15$)					TC ($n = 24$)				
		x	y	z	T		x	y	z	T		x	y	z	T	k
Frontal																
Inferior frontal gyrus							51	2	−23	3.24	L	−48	26	−8	5.18[a]	2
											L	−54	35	7	4.63	
											L	−54	26	10	4.38	
											L	−60	20	19	3.32	
Superior frontal gyrus	L	−6	95	53	4.45	L	−3	56	28	4.87						
	L	−18	56	34	3.62											
	R	9	20	64	4.17											
Medial frontal gyrus	L	−6	65	10	4.00	L	−6	53	46	4.23	L	−3	59	31	6.55[a]	65
						L	−9	50	22	3.32	L	−3	59	31	5.34	
						L	−18	44	19	3.88	L	−6	53	46	5.92[a]	11
Temporal																
Superior temporal gyrus						R	51	−40	7	3.73	L	−51	−49	25	4.38	
						R	51	17	−23	3.44						
						R	45	20	−26	3.33						
Parietal																
Inferior parietal lobule											L	−57	−37	28	4.22	
Postcentral gyrus											L	−54	−22	40	3.51	
											L	−48	−19	46	3.27	
											L	−45	−52	−11	3.46	
											L	−48	−19	22	3.34	

Notes: Peak voxels of regions showing a significant effect of metalizing (i.e. CE > control condition) assessed with SPM whole-brain analysis at an uncorrected threshold level ($P < 0.001$);
[a]significant at a FWE corrected threshold level of $P < 0.05$ across the whole brain.
Abbreviations: P + CSO = pedophilic men with child sexual offenses; P − CSO = non-offending pedophilic men; TC = non-offending teleiophilic controls; n = subsample size; L = left; R = right; x, y, z = location in mm with the three axes, coordinates in Montreal Neurological Institute space; k = cluster size.

Table 4. Correlations between psychopathology, neuropsychology and regional brain activity

	PT			EC			PD			HAM-D			WAIS		
	r	Lower BCa	Upper BCa	*r*	Lower BCa	Upper BCa	*r*	Lower BCa	Upper BCa	*r*	Lower BCa	Upper BCa	*r*	Lower BCa	Upper BCa
P + CSO (*n* = 14)															
ACC	0.30 (0.35)	−0.43	0.94	−0.25 (0.43)	−0.83	0.57	−0.33[a] (0.30)	−0.57	0.05	−0.00 (1.0)	−0.67	0.62	0.06 (0.86)	−0.47	0.39
Pcu	0.43 (0.17)	−0.03	0.75	−0.18 (0.59)	−0.79	0.43	0.12 (0.71)	−0.51	0.62	−0.27 (0.40)	−0.58	0.01	0.05 (0.88)	−0.34	0.28
STG	0.10 (0.75)	−0.55	0.66	0.36 (0.25)	−0.19	0.77	0.26 (0.41)	−0.37	0.71	−0.37 (0.24)	−0.68	0.06	−0.25 (0.44)	−0.66	0.25
P − CSO (*n* = 13)															
ACC	0.31 (0.31)	−0.30	0.81	−0.20 (0.51)	−0.81	0.52	0.05 (0.89)	−0.48	0.52	0.13 (0.68)	−0.54	0.61	−0.19 (0.54)	−0.77	0.75
Pcu	−0.03 (0.93)	−0.51	0.57	0.11 (0.72)	−0.60	0.89	**−0.56 (0.04)**	−0.83	0.09	−0.29 (0.33)	−0.77	0.23	−0.22 (0.48)	−0.74	0.40
STG	−0.44 (0.13)	−0.89	0.42	−0.32 (0.29)	−0.74	0.39	−0.33 (0.28)	−0.71	0.15	0.03 (0.93)	−0.46	0.45	**−0.69 (0.01)**	−0.85	−0.47
TC (*n* = 24)															
ACC	0.31 (0.31)	−0.30	0.81	−0.24 (0.28)	−0.52	0.12	0.05 (0.81)	−0.46	0.31	−0.17 (0.44)	−0.71	0.30	−0.11 (0.63)	−0.54	0.42
Pcu	−0.03 (0.93)	−0.50	0.57	0.28 (0.20)	−0.14	0.65	−0.06 (80)	−0.44	0.48	0.32 (0.13)	−0.29	0.64	0.04 (0.86)	−0.41	0.45
STG	−0.44 (0.13)	−0.89	0.42	−0.05 (0.83)	−0.48	0.39	0.16 (0.47)	−0.24	0.53	−0.10 (0.66)	−0.49	0.32	0.10 (0.64)	−0.44	0.58

Notes: Pearson correlations (significance values in brackets) and bootstrapped confidence intervals between beta weights extracted from the peak voxels of significant group differences between P − CSO and P + CSO (ACC; x = −18, y = 38, z = 16; Pcu; x = −27, y = −64, z = 34) and between P − CSO and TC (STG: x = 42, y = −49, z = 7), psychopathology and neuropsychology measures. The significant values are shown in bold.
Abbreviations: P + CSO = pedophilic men with child sexual offenses; P − CSO = non-offending pedophilic men; TC = non-offending teleiophilic controls; PT = perspective taking, EC = empathic concern, PD = personal distress of the Interpersonal Reactivity Index; HAM-D = Hamilton Rating Scale for Depression; WAIS = Wechsler Adult Intelligence Scale; r = Pearson correlation, BCa = bias-corrected and accelerated confidence interval; ACC = anterior cingulate cortex; Pcu = precuneus; STG = superior temporal gyrus;
[a]data missing from one participant.

differences. There were no other differences in functional connectivity for the analyzed seed regions.

Correlations between brain activity, psychopathology and neuropsychological variables

In P – CSO, higher levels of self-reported PD of the IRI were associated with greater left Pcu deactivation (Table 4). Additionally, decreasing intelligence was associated with increasing STG activity in P – CSO. There were no other significant associations between brain activity, psychopathological, neuropsychological variables and differences in performance between task conditions (Supplementary Table S1).

Discussion

Summary

This is the first study investigating neural CE processing in pedophilic men with a history of CSO (P + CSO), pedophilic men without a history of CSO (P – CSO) and teleiophilic male controls (TC). In accordance with our hypothesis, we observed altered neural CE processing in P – CSO compared to P + CSO. We found less activation in the left Pcu and increased activation in the left ACC in P – CSO compared to P + CSO. We additionally observed increased right STG activity in P – CSO compared to TC. Moreover, P – CSO showed increased task-dependent functional coupling between the left ACC and the right Pcu compared to TC.

The Pcu is considered one of the core regions underlying CE and has been implicated in mental imagery, self-other distinction, and the attribution and processing of third-person emotions and intentions (Cavanna and Trimble, 2006; Atique *et al.*, 2011; Corradi-Dell'Acqua *et al.*, 2014; Schurz *et al.*, 2014). Contrary to what might be expected, given prior behavioral results on CE (i.e. superior CE performance in P – CSO compared to P + CSO; Schuler *et al.*, 2019, 2021), it is the group of P – CSO that exhibited reduced recruitment of the Pcu during cognitively inferring affective states. However, since we also observed increased ACC activity and enhanced task-dependent functional coupling between the Pcu and the ACC in P – CSO, we want to carefully speculate that the Pcu may be top-down modulated by the ACC in P – CSO.

The ACC has not only been associated with the processing of self and other mental-state representations (Van Overwalle, 2009; Abu-Akel and Shamay-Tsoory, 2011; Denny *et al.*, 2012; Schurz *et al.*, 2014) or with the evaluation of negative social experiences (Dedovic *et al.*, 2016). The ACC has also been observed during detection of conflict between competing response alternatives and conflict monitoring (Botvinick *et al.*, 2004; Kerns *et al.*, 2004) and has been ascribed a presumably key role in the top-down processing in favor of behaviorally relevant information over competing information (Casey *et al.*, 2000). Following this line of interpretation, we hypothesize that the ACC may have attenuated Pcu activation in the CE condition in P – CSO. The Pcu has repeatedly been associated with the process of self-other differentiation (e.g. Decety and Sommerville, 2003; Fuentes-Claramonte *et al.*, 2020). In light of a proposed top-down modulation, we would expect the group of P – CSO to show a bias toward a limited distinction between the self and others. Indeed, in P – CSO, we observed (I) the highest level of self-rated PD of the IRI and (II) a cautiously inferred negative correlation (see the 'Limitations' section) between the level of PD and the deactivation of the Pcu, i.e. the lower Pcu activation the stronger self-reported PD. The PD scale assesses the tendency of experienced discomfort in response to seeing others in distress. Since PD implies that mental states displayed by others are attributed to oneself, it has been associated with a reduced self-other differentiation (Decety and Lamm, 2006). In accordance to that, it might be suggested that the proposed top-down modulation in P – CSO may represent a greater merge between the self and others in face of socially salient stimuli. Or differently expressed, by virtue of the presumably top-down modulated Pcu activity, the group of P – CSO may tend to show a self-oriented emotional reaction to another's emotional state rather than a mere apprehension of emotions that usually comes along without affective response. It remains questionable why the ACC presumably top-down modulated the Pcu in P – CSO. The pedophilic sexual preference has been associated with stigmatization and discrimination (Jahnke *et al.*, 2015a,b). It might therefore be hypothesized that pedophilic individuals are overall more receptive to affective states displayed by others. However, in this study, the top-down modulation was only observed in the group of P – CSO (and not in P + CSO). It might be speculated whether characteristics associated with CSO attenuate self-focused processes in social situations. For example, a reduced self-focused distress response might facilitate pursuing sexual offending behavior despite the child victim's negative affective response (Ward *et al.*, 1997; Ward, 2000). It would be warranted to examine the proposed mechanism with lager samples.

Together with the superior temporal sulcus, the STG has also been associated with cognitively inferring affective states of others (Schurz *et al.*, 2014; Tholen *et al.*, 2020). In our sample, P – CSO recruited the STG significantly stronger than TC. On a descriptive level, P – CSO showed more STG activity than P + CSO, as well. This non-significant difference between P – CSO and P + CSO might be attributable to small sample sizes and lack of statistical power. Future studies with larger samples would be needed to examine STG activity in P + CSO more carefully. Studies suggest that the STG is involved in the perception of socially salient information and affect related stimuli (Beyer *et al.*, 2014; Jung *et al.*, 2020). As dampened Pcu activity might lead to additional recruitment of resources for processing of socially salient information, increased STG activity in P – CSO might therefore represent a compensational mechanism. This compensatory mechanism might have led to the absence of performance differences between the groups. Additionally, we observed a negative association between the STG activation and intelligence in P – CSO. It could therefore be speculated that within this group, individuals with lower intelligence more strongly relied on the proposed compensational mechanism in the CE condition. The relationship between IQ and CE has extensively been examined. Results suggest that intelligence explains (if any) only minimal variance in CE performance (e.g. Montag *et al.*, 2012; Ibanez *et al.*, 2013; Mohnke *et al.*, 2016; Navarro *et al.*, 2021). This might explain why we did not find any association between intelligence and behavioral CE performance measures. Hence, further research with larger subsamples is required to examine the potentially compensatory recruitment of the STG and its link to intelligence.

Limitations

First, although we found group differences for CE on the neural level, there were no corresponding effects on the behavioral level or correlations between behavior and brain activation. This might be due to the fact that the CE scanner task was primarily developed to induce CE-related network activation and not for behavioral sensitivity. In addition, this study examined the cognitive interference of emotional states of a cartoon's protagonist based on the understanding of presented social scenes. Prior studies on behavioral CE performance required participants to infer affective states of presented facial expressions (Schuler *et al.*, 2019, 2021). It can therefore be assumed that both tasks assess important but different facets of CE and require independent replications. Second, as pedophilic participants were recruited from the community, we were not able to verify whether in the group of P – CSO, participants falsely denied CSO. However, if any, the proportion of non-disclosed CSO is expected to be small, as all participants have been informed about medical/therapeutic confidentiality and the possibility of an anonymous participation of the study. Third, both pedophilic groups showed higher rates of axis I and axis II disorders than teleiophilic controls. However, as our main findings are between the pedophilic groups, this does not affect our conclusions. Fourth, the bootstrapped Measures, functional imaging preprocessing and statistical analyses CI for the association between the deactivation of the Pcu and the level of PD does not provide clear evidence to infer a clinically meaningful association. Therefore, the significant correlation indicated by $P < 0.05$ needs to be interpreted with caution and warrants repetition. Fifth, a meta-analysis on 708 meta-analytically derived correlations revealed that only 2.7% of the correlations were 0.50 or greater (Gignac and Szodorai, 2016). Therefore, the magnitude of the correlation between the right STG and the WAIS scores can be regarded as particularly large. According to Button *et al.* (2013), effect estimates of small and rather low-powered samples will likely be exaggerated with an increased probability of type II errors. Consequently, to avoid overestimation of the correlation coefficient, replications with larger samples are needed. Sixth, our study had relatively small sample size, and our neuroimaging results therefore were not corrected for whole-brain comparison. Hence, they should be regarded as preliminary, interpreted only with caution and are in need of replication. Seventh and finally, our results were only cross-sectional and do not allow inference with respect to future behavior.

Conclusion

The present study investigated for the first time neural processing during performance of a CE task. We found empirical evidence that individuals with a diagnosis of pedophilia differ in their neural processing depending on their offense history. If these are true effects, there are potential implications of our findings for effective prevention and treatment approaches in two respects. Firstly, current therapy programs that aim to reduce the risk of reoffending do not yet entail interventions specifically focusing at CE (Marques *et al.*, 1989; Beier, 2021), which might be worthwhile. Secondly, therapy programs might fine-tune these interventions with respect to the history of sexual offense. More precisely, training of CE may be potentially useful to reduce the risk of reoffending in pedophilia, whereas distress may specifically be addressed in pedophilic individuals that are at risk of sexual offending.

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Conflict of interest

The authors declare no conflicts of interest.

Supplementary data

Supplementary data is available at SCAN online.

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