

Neural correlates of moral judgment in pedophilia

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Abstract

Pedophilia is a sexual preference that is often associated with child sex offending (CSO). Sexual urges towards prepubescent children and specifically acting upon those urges are universally regarded as immoral. However, up until now, it is completely unknown whether moral processing of sexual offenses is altered in pedophiles. A total of 31 pedophilic men and 19 healthy controls were assessed by using functional magnetic resonance imaging (fMRI) in combination with a moral judgment paradigm consisting of 36 scenarios describing different types of offenses.

Scenarios depicting sexual offenses against children compared to those depicting adults were associated with higher pattern of activation in the left temporo-parietal-junction (TPJ) and left posterior insular cortex, the posterior cingulate gyrus as well as the precuneus in controls relative to pedophiles, and vice versa. Moreover, brain activation in these areas were positively associated with ratings of moral reprehensibility and negatively associated with decision durations, but only in controls. Brain activation, found in key areas related to the broad network of moral judgment, theory of mind and (socio-)moral disgust - point to different moral processing of sexual offenses in pedophilia in general. The lack of associations between brain activation and behavioral responses in pedophiles further suggest a biased response pattern or dissected implicit valuation processes.

Key words: child sexual abuse; decision-making; morality; pedophilia; sexual preference

Introduction

More than 60 000 cases of child maltreatment and neglect have been reported by the U.S. Department of Health & Human Services in 2012. About 10% suffered from sexual abuse, though

estimates of unreported cases are considered to be at least 10 times higher (Hanson *et al.*, 1999). Pedophilia is defined as a preference disorder: an adult or older adolescent experiences a primary or exclusive sexual attraction to (pre-)pubescent children, age 13 years or younger (World Health Organization, 1993).

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Pedophilia, i.e. the sexual preference disorder, is one of the most important risk factor for actual child sexual offending (CSO) (Seto, 2008). However, only about half of all sexual offenses against children are being committed by pedophiles and it is estimated that only about 50% of pedophiles engage in CSO throughout their lifetime (Maletzky and Steinhäuser, 2002). Thus, pedophilia and CSO are interrelated but distinct phenomena. There is little doubt that pedophilic preferences, once in place, are fixed and do not change across the lifespan (Seto, 2008). This is the case although pedophilic preference and even more CSO are strictly sanctioned and judged as immoral in nearly all-contemporary societies. Therefore it is highly reasonable to assume that there are alterations in e.g. the moral valuation of sexual interest in children and CSO in men suffering from pedophilia.

There is an increasing body of studies investigating the neural basis of pedophilia, which was recently reviewed in depth (Mohnke et al., 2014; Tenbergen et al., 2015). Until now, no consistent structural or functional alterations across studies could be identified for pedophilia. However, there is some converging evidence for a smaller amygdala volume in pedophiles (Mohnke et al., 2014). Moreover, in a series of neuropsychological and neuroimaging studies, findings of increased impulsivity in pedophilic offenders have been reported (Suchy et al., 2009; Schiffer and Vonlaufen, 2011; Joyal et al., 2014) as well as findings of structural abnormalities in fronto-temporal/frontolimbic areas. These are consistent with a model of temporo-frontal dysfunction in pedophilia that had been proposed prior to these imaging findings (Cohen et al., 2002).

The lack of consistency can be explained by several factors, including methodological issues in the paradigms, sample size, selection bias and comorbidity (most samples consisted of forensic inpatients). Another important confound is that almost all studies did not differentiate between pedophilia as a preference (a mental phenomenon) and child sexual offenses as a (criminal) realized action. Highlighting this distinction, a recent study by our group has shown that connectivity differences in resting state were associated with CSO rather than pedophilia (Kargel et al., 2015).

Since the seminal study of Greene et al. (2001), the neural correlates of 'normal' and abnormal moral judgment have been investigated in healthy as well as diverse clinical populations (compare also (Greene and Haidt, 2002; Fumagalli and Priori, 2012; Pascual et al., 2013). By using philosophical moral dilemmas or other tasks it has been shown, that a widespread brain network is involved in moral judgment, including the medial prefrontal cortex, the precuneus, the superior temporal sulcus, the temporo-parietal regions, the temporal poles and the amygdala.

Despite the fact that criminal acts or violence are major consequences of moral abnormality, there is a striking lack of knowledge on the (dys-)function of the brain areas widely implicated in moral judgment processes in the whole area of sexual violence. Here, we therefore and for the first time compared the neural and behavioral correlates of moral judgment between pedophiles (with and without a history of CSO) and healthy controls.

Based on own previous research comparing moral and legal decision making (Schleim et al., 2011), we developed a new paradigm that allowed investigating moral judgment among three types of offenses [general offenses (GO), sexual offenses against adults (SOA) and sexual offenses against children (SOC)] in combination with functional magnetic resonance imaging technique. We hypothesized that pedophiles (regardless of a history of CSO) as compared to healthy controls show differences in moral judgment both on the behavioral level (i.e. slower reaction times and lower ratings of reprehensibility) as well as on the neural level (decreased activation in part(s) of the network

of brain regions widely implicated in moral judgment) in particular regarding SOC scenarios. Moreover, we were interested in analysing the impact of a history of CSO on behavioral and neural response patterns in pedophiles.

Materials and methods

Participants

A total of 31 male participants who met DSM-IV-TR (Saß et al., 2003) criteria for pedophilia and 19 healthy male controls (HC) of similar socioeconomic strata without a history of criminal behavior were included in the present study (for detailed sample characteristics see Table 1). This study built a single-site project of a multisite research collaboration on the neural mechanisms underlying pedophilia and sexual offending against children (www.nemup.de). Pedophilic subjects were divided in those who have/have not committed sexual offenses against children (P + CSO/P-CSO), with CSO defined as at least one hands-on offense against a prepubescent child outside the family. Pedophiles without a history of hands-on delinquency were recruited through postings on relevant internet platforms. To ensure truthful reporting in the P-/+-CSO groups, the interviews were conducted by clinical psychologists trained in the work with pedophiles and sexual offenders. Before assessment, participants were guaranteed 100% anonymity when participating.

Ten pedophiles that actually committed sexual offenses against children were also recruited from the community. Those can be divided into 'darkfield' ($n = 4$) offenders which refers to the fact that their former offense was not accused or sentenced by the German law system, those who already served a prison sentence for a child sexual offense ($n = 5$) and one participant who had a pending proceeding up to the time of data acquisition. The other six pedophilic offenders were recruited from correctional services in the state of North Rhine-Westphalia, Germany. All participants in the P + CSO group had a history of at least 1 case (M_N of victims = 3.31 (2.82); range 1–10) of hands-on sexual offense against children. Individual mean victims age was calculated for each subject and then averaged across the whole P + CSO group (for details see Table 1). The HC group was recruited from by advertisements in municipal institutions in city of Essen, Germany.

Key inclusion criteria for all participants were age between 20–55 years, no current diagnosis of an axis I psychiatric disorder (Saß et al., 2003) (remission was defined as not meeting the criteria for any diagnosis during the last six months) besides paraphilia, no neurological disorders, no mental retardation, explicit sexual orientation (either hetero- or homosexual), no contraindications to magnetic resonance imaging as well as no psychopharmacological treatment or other medication that affect sexual functioning. Moreover, none of the participants underwent psychological treatment before or during assessment or completed a treatment program before (with regard to their sexual preferences as well as other mental illnesses). Informed written consent was obtained from all participants and ethical approval was granted by the Ethics Committee of the Medical Faculty of the University of Duisburg-Essen, Germany.

Measurements

The *Structured Clinical Interview* (SCID) for DSM-IV-TR (Wittchen et al., 1997) was administered by experienced psychologists to assess for axis I and II disorders.

In order to provide an estimation of global intelligence, all participants performed four subtests derived from the German

Table 1. Sociodemographic and clinical sample characteristics (M ± SD)

Measures	P+CSO n = 16	P-CSO n = 15	HC n = 19	Statistics (p-value)
Age	36.44 ± 8.01	31.73 ± 6.49	33.47 ± 10.24	$F_{2,47} = 1.21, p = 0.308$
hetero-/homosexual	4/12	6/9	9/10	$\chi^2_2 = 1.89, p = 0.390$
handedness (right/left)	15/1	14/1	16/3	$\chi^2_2 = 1.14, p = 0.565$
WAIS score	37.75 ± 11.04	43.13 ± 7.08	42.58 ± 10.23	$F_{2,47} = 1.50, p = 0.233$
CP consum lifetime	13 (81.25%)	13 (86.67%)	/	
exclusive/non-exclusive type	7/9	6/9	/	
prison sentence in months	81.80 ± 54.55, range: 18-141			
victims age	9.69 ± 2.63, range: 1-17	/	/	/
ASPD	1	1	0	$\chi^2_2 = 1.28, p = 0.527$
AvPD	3	2	0	$\chi^2_2 = 3.66, p = 0.161$
BPD	1	1	0	$\chi^2_2 = 1.28, p = 0.527$
OCPD	1	0	0	$\chi^2_2 = 2.17, p = 0.338$
combined PD	2	1	0	$\chi^2_2 = 2.42, p = 0.298$

M: mean, SD: standard deviation, ASPD: antisocial personality disorder, AvPD: avoidant personality disorder, BPD: borderline personality disorder, OCPD: obsessive-compulsive personality disorder, CP: child pornography, P+CSO: pedophiles including a history of child sexual offending, P-CSO: pedophiles exclusive a history of child sexual offending, HC: healthy control group.

version of the Wechsler Adult Intelligence Scale, 4th Edition (von Aster et al., 2006) (WAIS), comprising the subtests (1) 'Similarities' and 'Vocabulary' from the verbal comprehension scale and (2) 'Block Design' and 'Matrix Reasoning' from the perceptual reasoning scale. Individual raw scores were converted to scaled scores and afterwards summarized and divided per group (size) to receive means per group (see Table 1). Pedophilic sexual interests, child pornography consumption as well as general offense history were assessed by using a semi-structured clinical interview. Sexual orientation and preference was then confirmed by means of the Kinsey scale for developmental stages (Kirk et al., 2000).

Stimuli and task

The paradigm was an adapted version of a moral and legal dilemma paradigm published by our group (Schleim et al., 2011). During fMRI assessment, participants made moral judgments on hypothetical criminal offence stories related to three moral conditions (3 × 12 stories). Control scenarios comprised four stories out of each target category, which were therefore shown twice during the experiment, enabling us to compare responses to 12 trials per condition. Target stories were developed in collaboration with judges from the district and higher regional court to clearly describe each criminal offense and control for normative severity. Severity in each category ranged from sentences less than six months of imprisonment to those longer than two years equally distributed within and between each category (mean sentence in months GO: 20.54 ± 27.84; mean sentence in months SOA: 21.04 ± 26.39; mean sentence in months SOC: 20.25 ± 23.89; $F_{2,33} = .004, n.s.$). In the first screen participants were instructed to read an offence related story. Subsequently and with regard to the previously shown story, participants were presented with a second screen containing the instruction either to estimate the amount of syllables (control scenarios) or to evaluate how morally reprehensible the offender behaved (experimental scenarios) on a four point Likert scale ranging from 1 = 'a bit' to 4 = 'maximally'. Experimental scenarios comprised three categories: (1) general offenses (GO), (2) sexual offenses against adults (SOA) as well as (3) child sexual abuse (SOC). While subsequent trials were presented in random order, the first stimulus was fixed to the most severe—in

terms of its legal sentence—child sexual offense scenario (estimated prison sentence 102 months) due to provide the participants with a reference allowing for an adequate appraisal of the following stories. In other words, since all scenarios representing serious offences, by using the most severe trial first we assume to prevent that a range of trials were rated as maximal severe. For details please see Figure 1.

Neuroimaging acquisition

Neuroimaging data were acquired using a whole body 3 Tesla magnetic resonance scanner (Skyra, Siemens Healthcare, Erlangen, Germany) equipped with a 32-channel head coil. For the functional MRI paradigm T_2^* weighted echo-planar volumes (EPI) were recorded with the following parameters: 42 anterior commisure-posterior commisure aligned transversal slices in interleaved order, slice thickness = 3.0 mm with 15% gap; field of view = 260 × 260 mm; matrix = 94 × 94; repetition time = 2600 ms; echo time = 26 ms; flip angle = 90°. The initial four scans were discarded as "dummy" scans to account for T_1 equilibration effects.

For intersubject registration a T_1 -weighted 3D MP-RAGE sequence was acquired with the following parameters: 192 sagittal slices; slice thickness = 1.0 mm; field of view = 256 × 256 mm; matrix = 256 × 256; repetition time = 2500 ms, echo time = 4.37 ms; orientation = sagittal; flip angle = 7°.

Data preprocessing

Raw data were visually inspected and scanned for excessive head motions. None of our subjects showed rotations of > 2 mm or 2° and therefore all of them could be included in the following analysis. Functional images acquired during our moral evaluation task were corrected for slice-timing differences (centered at the middle T_2^* scan), realigned to account for within-scan head movement to the mean volume and unwarped to minimize susceptibility-by-movement interactions. Afterwards, images were coregistered to the individual T_1 -weighted scan, spatially normalized to standard space using the Montreal Neurological Institute (MNI) EPI template with a voxel size of 2 × 2 × 2 mm and spatially smoothed using an 8 mm full-width at half-maximum Gaussian kernel. Finally data were temporally

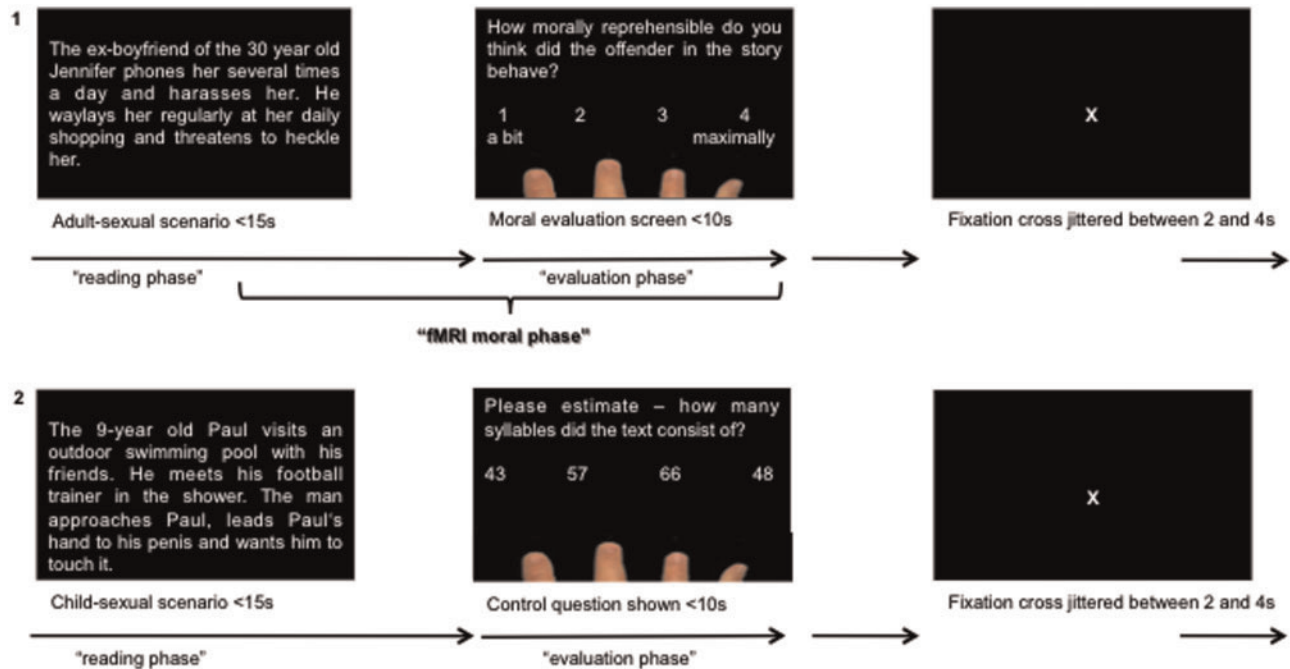


Fig. 1. Experimental design. Each trial started with a scenario shown for a maximum of 15s (screen could be skipped after reading by pressing a button with the index finger), followed by the presentation of either (1) the moral evaluation screen or (2) the control question both shown up to 10s (pressing a button with the index finger advanced). In the target conditions, subjects were requested to judge the moral abjection of the scenario presented on a four-point Likert scale via button press with their right hand (ranging from 1 = a bit reprehensible to 4 = maximally reprehensible for each question). In the control condition subjects were required to estimate the amount of syllables the scenario consists of and to choose between four predetermined numbers via button press, using the corresponding finger of their right hand. Subsequently, a centered crosshair was presented, jittered between 2 and 4 s in order to allow for blood-oxygene level dependent relaxation (BOLD relaxation).

filtered (high-pass filter: 128s) to remove low-frequency drifts in signal.

Data analysis

In line with previous analysis addressing moral judgment (Shenhav and Greene, 2014) we omitted all trials in which subjects were likely to be inattentive, defining reading phase of the scenario shorter than 4 s and evaluations made shorter than 0.75 s and longer than 4.5 s.

Behavioral data

Behavioral data were analysed using IBM Statistical Package for Social Sciences (SPSS), 22nd edition (IBM Corp., Released 2013). Reaction times (RT) and responses were analysed by means of two group (3) x condition (3) repeated measures analysis of variance (ANOVAs) in order to explore whether groups differ in reaction times during (A) their decision and (B) given responses regarding the moral reprehensibility of the scenarios (*group* × *moral evaluation interaction*). Decision duration (DD) was defined as the time between the second screen and the button-press (decision-phase).

Functional imaging analysis

fMRI data analysis was computed within the framework of the general linear model using the Standard Parametric Mapping Software Package (SPM8; <http://www.fil.ion.ucl.ac.uk/spm/>) implemented in Matlab 2013b (The MathWorks, Inc.).

In the present study, we attempted to model the time-window while participants are concluding about their moral judgment. Based on previous research (Greene et al., 2001; Schleim et al., 2011; Chiong et al., 2013) inter-individual timing

differences regarding moral judgment were accounted for by modelling a flexible time-window: the predictor *decision phase* of each target category was defined including the second half of story presentation (*reading phase*) plus the *evaluation phase*. Since we expected differences in timing parameters of judgment processes between target and control stimuli, modelling the latter comprised solely the evaluation phase. Those event-related responses were convolved by using of the canonical hemodynamic response function (HRF) and for each subject four separate linear contrast images were calculated for all scenario types (GO, SOA, SOC and control). These four first level contrast effects were then aggregated into second level analyses of covariance (ANCOVA) models each controlling for confounding effects of age, IQ and sexual orientation.

In order to analyse whether the paradigm was capable of measuring activation in brain areas related to moral judgment, in a first one-factorial ANCOVA model, we compared activation pattern during the moral conditions (pooled) and the control condition within the entire sample.

Then we applied a two (group: P+CSO vs P-CSO vs HC) by three (condition: GO vs SOA vs SOC) ANCOVA model to examine whether (A) firstly activation pattern differ among the three types of offense scenarios (main effect of condition) and (B) secondly whether groups differ with respect to certain conditions (group-by-condition interaction effects). Since we were especially interested in analysing interaction effects reflecting differences due to pedophilia or a history of CSO separately, we had to realize two different interaction analyses within this model, each including two groups only: HC and P-CSO for analysing pedophilia-related activation differences as well as P-CSO and P+CSO for analysing CSO-related activation differences. This latter key interaction analyses were followed up with post-hoc t-constrasts to determine which effects were significant.

Statistical threshold was set to $P < 0.05$, family-wise error (FWE) corrected for multiple spatial comparisons at voxel-level (height threshold) for within-group analysis [moral vs control and main effect of condition-analysis (GO vs SOA vs SOC)]. For group-by-condition interaction analyses, clusters were considered significant at the combined voxel-extent threshold of an uncorrected voxel level of $P < 0.005$ and cluster extent > 218 voxels, which corresponded to a corrected cluster-level significance of $P < 0.05$. The AlphaSim correction (cluster connection radius: $mm = 3$; number of Monte Carlo simulations = 1000) was conducted using the AlphaSim program in the REST toolbox (<http://www.restfmri.net>), which applied Monte Carlo simulation (Ledberg et al., 1998) to calculate the probability of false positive detection by considering both the individual voxel probability thresholding and cluster size (Chao-Gan and Yu-Feng, 2010).

Finally, we performed correlational analyses between behavioral measures and brain activation pattern that distinguished between groups. Whole cluster activation of brain areas that varied as a function of pedophilia (therefore calculating the two difference scores SOC-SOA for HC and SOA-SOC for P-CSO to reflect the detected interaction effect) were extracted by volume of interest analysis (1st eigenvariate) and associations with decision durations and severity ratings were separately estimated in pedophilic and healthy men using Spearman's rho rank correlation coefficient.

Results

Behavioral results

Repeated measures ANOVA showed a significant main effect of DD (decision duration) ($F(2,94) = 6.38^{**}$, $P = 0.003$) across groups with significant differences in reaction times between DD GO and DD SOA ($P = 0.004$) as revealed by post hoc tests with Bonferroni correction.

An examination of response patterns regarding each of the three experimental conditions between ratings of all groups revealed a significant main effect of responses ($F(1.7,78.2) = 45.73^{***}$, $P < 0.001$) and group ($F(2,47) = 3.72^*$, $P = 0.032$). Post-hoc tests with Bonferroni corrections showed that ratings differ significantly between each of the target conditions ($P = 0.002$ between responses GO and SOA with higher reprehensibility ratings for SOA conditions, $P < 0.001$ between responses GO and SOC showing higher reprehensibility ratings for SOC scenarios and with $P < 0.001$ between lower reprehensibility ratings for SOA and compared to higher reprehensibility ratings for SOC). Furthermore the post-hoc Bonferroni corrected multiple comparisons showed ($P = 0.029$) that P-CSO ratings significantly differed from those made by HC with higher ratings regarding all three experimental conditions in the HC group.

Behavioral results (means and standard deviations) regarding DD and ratings are depicted in Table 2 in more detail.

Neuroimaging results

Offense scenarios vs control condition. As provided in detail in Figure 2 and Table 3, moral as compared to non-moral judgment making was associated with activation in brain areas critically involved in moral judgment and that are also known as key areas of the "theory of mind"-network (Vollm et al., 2006; Fumagalli and Priori, 2012). The activation patterns comprised the following areas: the orbitofrontal cortex, ventromedial PFC (vmPFC), leftdorsolateral prefrontal cortex (dlPFC), posterior

cingulate cortex (PCC) as well as the precuneus, left precentral gyrus as well as a widespread activation in the bilateral temporal cortex comprising the area around the superior temporal sulcus (STS) and one the left hemisphere also the temporoparietal junction (lTPJ).

Main effect of the offense type (GO vs SOA vs SOC). The comparison of our three target conditions yielded a main effect of condition in the left TPJ ($F_{2,138} = 19.88$, cluster size: 260 voxel, MNI coordinates peak voxel: $-60, -44, 36$). Post hoc t-tests revealed that this effect was driven by the comparison of $GO < SOC$ events. The direct comparison of $GO < SOC$ revealed three significant clusters: in the left TPJ, the left fusiform gyrus as well as in the left hippocampus ($T = 6.23$, MNI coordinates: $-60, -42, 34$; $T = 5.65$, MNI coordinates: $-28, -34, -6$ and $T = 5.14$, MNI coordinates: $-42, -42, 16$).

Group-by-condition interaction analyses. A group-by-condition interaction analysis that tested for any pedophilia-related effects regarding the three types of offense scenarios revealed a significant cluster, comprising the left pSTS/TPJ ($F_{2,138} = 11.20$, cluster size: 1240 voxel, MNI coordinates peak voxel: $-20, -74, 14$). The follow-up performed t-contrasts revealed three significant clusters, one comprising the left pSTS/TPJ and insular cortex ($T_{2,138} = 4.34$, cluster size: 3414 voxel, MNI coordinates peak voxel: $-38, -42, 14$), one the posterior cingulate cortex ($T_{2,138} = 3.87$, cluster size: 460 voxel, MNI coordinates peak voxel: $-14, -16, 32$) and the third one the middle cingulum as well as the precuneus and postcentral gyrus ($T_{2,138} = 3.47$, cluster size: 619 voxel, MNI coordinates peak voxel: $12, -30, 46$). All three were driven by the same interaction effect: an increased activation within HC relative to P-CSO (and also P + CSO) during SOC as compared to SOA whereas P-CSO show the opposite activation pattern with higher brain activation during the evaluation of SOA compared to SOC. Please refer also to the bar charts as depicted in the upper row of Figure 3A–C.

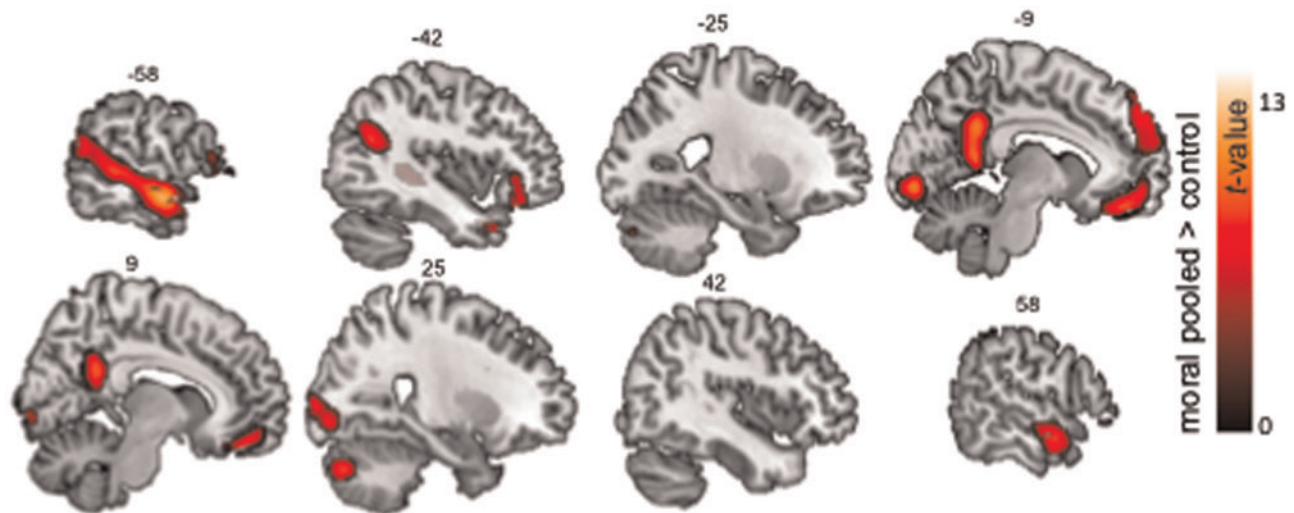
The second interaction analysis that was applied for testing any CSO-related effects revealed no significant differences between offending and non-offending pedophiles.

Correlational analysis. Whole cluster parameter estimates of the three brain activation clusters that distinguished between groups (due to pedophilia) were extracted and entered into a correlation analysis with behavioral performance measures. As depicted in Table 4 as well as in Supplementary Figure S4A–C in the Supplementary Material, all correlation between reprehensibility ratings as well as decision durations and brain activation regarding the three clusters activated in the group-by-condition interaction effect were significant in the HC group. Regarding the cluster comprising the left TPJ and insula three out of four correlations remained significant after Bonferroni correction for multiple comparisons: positively with the ratings of moral reprehensibility regarding SOA ($r = 0.610^{**}$, $P = 0.006$) as well as positively with the ratings of moral reprehensibility regarding SOC ($r = 0.617^{**}$, $P = 0.005$) and negatively with the decision durations regarding SOA ($r = -0.709^{**}$, $P = 0.001$). The activation in the posterior cingulate cortex correlated negatively, Bonferroni corrected for multiple comparisons, with the decision durations regarding SOA ($r = -0.712^{**}$, $P = 0.001$). Finally, the activation in the cluster comprising the postcentral gyrus as well as the precuneus correlated negatively, Bonferroni corrected for multiple comparisons, with the ratings of moral reprehensibility regarding SOA ($r = 0.688^{**}$, $P = 0.001$) as well as with the ratings of moral reprehensibility regarding SOC ($r = 0.653^{**}$, $P = 0.002$) and

Table 2. Behavioral results regarding mean ratings and reaction times of the target scenarios

Decision duration (mean ± standard deviation) over the three experimental conditions			
Group	GO	SOA	SOC
P+CSO	1.92 ± 0.63	1.76 ± 0.60	1.85 ± 0.63
P-CSO	1.94 ± 1.00	1.59 ± 0.49	1.99 ± 0.97
HC	2.06 ± 0.93	1.80 ± 0.68	1.77 ± 0.60
Total	1.98 ± 0.86	1.73 ± 0.60	1.85 ± 0.73
Evaluation ratings (range: 1–4) and standard deviations per experimental condition			
Group	GO	SOA	SOC
P+CSO	2.94 ± 0.54	3.07 ± 0.46	3.43 ± 0.51
P-CSO	2.82 ± 0.56	2.91 ± 0.61	3.19 ± 0.54
HC	3.06 ± 0.50	3.34 ± 0.45	3.75 ± 0.28
Total	2.94 ± 0.53	3.13 ± 0.53	3.48 ± 0.49

P+CSO: pedophiles including a history of child sexual offending, P-CSO: pedophiles exclusive a history of child sexual offending, HC: healthy control group, GO: general offences, SOA: sexual offences against adults, SOC: sexual offences against children.

**Fig. 2.** Whole brain statistical parametric map for random effects t-contrast (moral > control conditions), pFWE < 0.05 at voxel-level.**Table 3.** Brain regions significantly activated during moral conditions (pooled) vs. control condition

Regions ^a	Coordinates of peak activation ^b						T _{1, 185}	cluster
	BA	left/right	x	y	z			
Occipital lobe, lingual gyrus	17	r	16	-90	-4	12.71	575	
Posterior cingulate gyrus	31	l/r	-4	-50	28	11.37	1073	
Middle temporal gyrus	21/22	l	-58	-6	-12	11.22	2675	
Medial frontal gyrus	11	l/r	-4	42	-20	10.35	890	
Occipital lobe, lingual gyrus	17	l	-12	-88	-6	9.70	527	
Cerebellum, posterior lobe	/	r	22	-78	-34	8.28	251	
Middle to inferior temporal gyrus	21	r	58	0	-16	8.05	337	
Superior frontal gyrus	9	l/r	-8	54	34	7.36	535	
Inferior frontal gyrus	11/47	l	-40	32	-14	6.71	335	
Precentral gyrus	6	l	-48	-2	54	5.77	18	
Cerebellum, posterior lobe	/	l	-24	-80	-34	4.93	6	
Middle to superior temporal gyrus	21/22	r	48	-32	2	4.84	4	
Superior temporal gyrus	38	r	48	18	-26	4.83	3	
Angular gyrus, precuneus	39	l	-44	-74	40	4.81	1	
Caudate	/	r	22	-40	16	4.80	2	

P < 0.05 family-wise error (FWE) corrected for multiple comparisons on voxel level.

^aAccording to the Talairach Daemon Atlas (<http://www.nitrc.org/projects/tal-daemon/>).

^bBased on the standard brain template of the Montreal Neurological Institute (MNI).

BA: Brodmann Areas, inf: inferior, mid: middle, sup: superior, post: posterior, l: left, r: right.

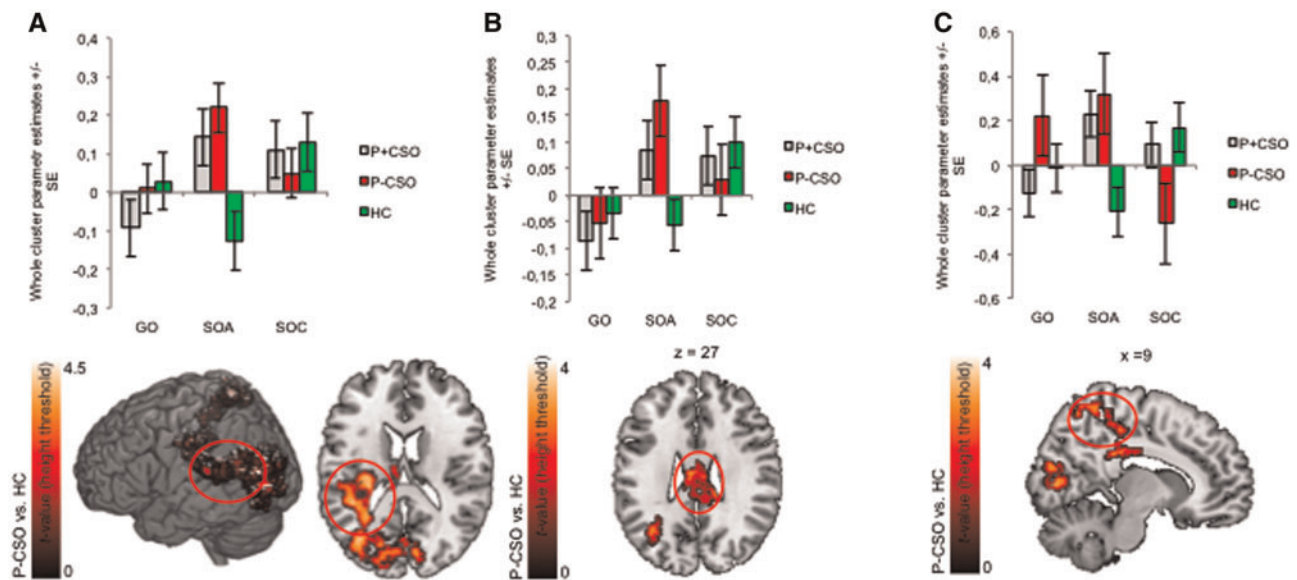


Fig. 3. (A–C) Parameter estimates and whole brain statistical parametric maps showing significant group \times scenario type interaction effects related to pedophilia in: (A) left temporo-parietal junction/left posterior insular cortex, (B) posterior cingulate cortex and (C) right cingulate gyrus/precuneus/postcentral gyrus. $P < 0.005$, uncorrected, extended cluster-size threshold (applying Monte Carlo-Correction) ≥ 218 voxel. Parameter estimates for each whole cluster with the following peak voxels, for (A) $[-38, -42, 14]$, (B) $[-16, -16, 32]$ and (C) $[12, -30, 46]$. GO: General offences, SOA: sexual offences against adults, SOC: sexual offences against children, P+CSO: pedophiles including a history of child sexual offences, P-CSO: pedophiles exclusive a history of child sexual offences, HC: healthy control group.

Table 4. Spearman's rho rank correlation coefficients between behavioral performance (decision durations and ratings) and hemodynamic activity (SOC-SOA for HC, SOA-SOC for P-CSO)

	Behavioral measures			
	rating SOA	rating SOC	DecDur SOA	DecDur SOC
Cluster A (ITPJ, left insula)	$r_{HC} = 0.610^{**B}$ $r_{P-CSO} = -0.537$	$r_{HC} = 0.617^{**B}$ $r_{P-CSO} = -0.456$	$r_{HC} = -0.709^{**B}$ $r_{P-CSO} = 0.421$	$r_{HC} = -0.512^*$ $r_{P-CSO} = 0.139$
Cluster B (PCC)	$r_{HC} = 0.544^*$ $r_{P-CSO} = -0.079$	$r_{HC} = 0.557^*$ $r_{P-CSO} = -0.066$	$r_{HC} = -0.712^{**B}$ $r_{P-CSO} = -0.061$	$r_{HC} = -0.546^*$ $r_{P-CSO} = -0.168$
Cluster C (postcentral gyrus, precuneus)	$r_{HC} = 0.688^{**B}$ $r_{P-CSO} = -0.186$	$r_{HC} = 0.653^{**B}$ $r_{P-CSO} = -0.128$	$r_{HC} = -0.761^{**B}$ $r_{P-CSO} = -0.057$	$r_{HC} = -0.533^*$ $r_{P-CSO} = -0.325$

* = $p < .05$, ** = $p < .01$, ^B = significant after Bonferroni correction for multiple comparisons ($p < .006$).

P-CSO: pedophiles exclusive a history of child sexual offending, HC: healthy control group, GO: general offences, SOA: sexual offences against adults, SOC: sexual offences against children, DecDur: decision duration, ITPJ: left temporo-parietal junction, PCC: posterior cingulate cortex.

negatively with the decision durations regarding SOA ($r = -0.761^{**}$, $P = 0.000$). No significant correlation was found for the P-CSO group. We then tested for significant differences between the correlational coefficients of both groups. All Bonferroni corrected correlations in the HC group differed significantly from those correlation coefficients reported for the P-CSO group.

Discussion

The aim of this imaging study was to assess differences in the neural mechanisms of moral judgment associated with pedophilia and/or sexual offending against children. We therefore used functional imaging technique in combination with a new offense scenario evaluation task that obviously provoked differential and reasonable moral judgment patterns both behaviorally and with respect to activation of brain areas known to be heavily involved in moral judgment processing (Greene et al., 2001; Greene et al., 2004; Fumagalli and Priori, 2012).

As hypothesized, healthy controls showed significantly higher ratings of moral reprehensibility regarding all three types of offenses compared to pedophilic non-offenders.

While evaluating scenarios depicting sexual offenses against adults vs. children, healthy controls and pedophilic non-offending men showed an opposed activation pattern of the left pSTS/TPJ, the left posterior insular cortex as well as the left posterior cingulate gyrus and the precuneus. Moreover, activation in the first of these areas was also found to be positively associated with ratings of reprehensibility but only in controls, not in pedophiles. Finally, we did not find that a history of CSO had an additional impact on the activity of areas discussed in the light of neural moral processing.

Behavioral responses and correlational analysis. The significant differences between (lower) ratings regarding moral abjection of all three scenario types made by pedophilic men compared to higher ratings made by healthy controls seems to strengthen our hypothesis of aberrant moral judgment processes in general

related to pedophilic preference. Supporting this notion, we found significant correlations between brain activation pattern and behavioral measures with respect to scenarios depicting sexual offenses, but in controls only. On the one hand significant positive association between behavioral reprehensibility ratings and hemodynamic responses, which reflect that scenarios evaluated as highly moral reprehensible also elicit stronger activation in brain areas associated with moral processing. On the other, highly negative correlations between the decision durations and the neural activation, which may point to the fact, that if the subject evaluates a scenario as strongly moral reprehensible, the duration to form his decision is short, but it takes more time to assess the abjection of a scenario which is not that strongly morally abjected. That pedophiles did not show such associations may indicate that behavioral responses are not congruent with moral-cognitive and emotional valuation processes during the processing of sexual aggressive scenarios reflected by the 'abnormal' activation pattern in key areas related to moral judgment processes, in our paradigm namely left pSTS/TPJ and left insular cortex, the posterior cingulate cortex as well as the precuneus.

Neural activation pattern of moral judgment related to pedophilia and child sexual offending. Group-by-condition interaction analysis revealed that pedophiles as compared to controls revealed decreased activation pattern in a cluster comprising the pSTS/TPJ and the posterior insular cortex, in the posterior cingulate gyrus as well as in the precuneus/postcentral gyrus while evaluating child molesting scenarios as compared to scenarios depicting sexual offenses against adults. These three areas are critically involved in a number of social cognitive abilities: mentalizing or theory of mind (ToM) especially belief processing in moral judgment (Young et al., 2007; Young and Saxe, 2008), assessing socially salient stimuli (Decety and Lamm, 2007), moral intuition (Harenski, 2010), as well as sharing other's affective state and making decisions about complex vs. easy moral situations (Greene et al., 2004; Harenski et al., 2012).

In our context, distorted cognitions regarding sexual actions involving children as most pedophilic persons show, can be considered as a mentalizing disability regarding the (potential) victims (Hall and Hirschman, 1992) of pedophilic men. Mentalizing abilities are key features of the—in this interaction effect—(opposed to their own sexual preference) activated brain structures (Harenski et al., 2012; Fourie et al., 2014) in pedophilic subjects compared to healthy controls regarding sexual aggressive scenarios.

Therefore our data may suggest a relation between brain activation in situations that have to be morally evaluated and exhibiting preference related cognitive distortions towards children. This goes in line with previous suggestions made by Harenski and colleagues who proposed that sex offenders exhibit cognitive distortions to justify their moral transgressions (Harenski and Kiehl, 2011). However, our data moreover imply that cognitive distortions and impaired moral judgment are linked to pedophilia rather than CSO. As mentioned elsewhere the association between cognitive distortions and offending or re-offending in pedophilic men seems to be rather small (Endrass et al., 2012), which may explain, why no additional CSO-related effect in areas activated during moral judgment tasks could be observed. Still this correlation should be further explored by assessing the extent of cognitive distortions behaviorally in pedophilic subjects additionally in future research.

Moreover, the activation of the posterior insular cortex during the group-by-condition interaction effect, may support a previous hypothesis that pedophilic men suffer from a lack

of disgust processing regarding sexual activity involving children (Harenski and Kiehl, 2011). Disgust can be defined as the highly aversive feeling (Schaich Borg et al., 2008), which has been associated with the activation of usually the anterior part of the insular cortex (Capestany and Harris, 2014). However, recent studies support the idea, that the posterior part of the insular cortex is also involved in disgust processing (Benuzzi et al., 2008). Moreover, a recent meta-analysis found evidence for the least involvement of the posterior part of the left insular cortex regarding positive emotions compared to other emotions and other parts of this brain area (Duerden et al., 2013).

Moreover, Schaich Borg and colleagues were able to show that also a rejection of social interactions, is associated with disgust-related neural activation pattern ('sociomoral disgust') similar but not completely identical, to areas activated by the aversive state that motivates withdrawal from a substance like the aforementioned insular cortex. They found evidence that healthy individuals especially elicited greater TPJ activation during the evaluation of sociomoral acts compared to generally pathogen disgusting acts. Greater TPJ involvement was detected during the processing of sexual (incest) scenarios compared to non-sexual immoral acts.

Some of the previously discussed brain areas, including the TPJ and posterior cingulate, are known to be also involved during implicit moral tasks (Harenski et al., 2010), where the stimuli were morally salient, but the task itself was unrelated to moral judgment. This leads in some way to a limitation of this study: in our control condition we presented morally salient stimuli in a combination with a non-moral control question. This may have lead to an implicit activation of key areas of the neural moral circuit which may have even contributed to an underestimation of our effect found in the comparisons of moral and control conditions.

Another point to mention is the problem that some common neuroimaging analyzing tools (including SPM) produce invalid cluster-wise inference, resulting in inflated alpha error statistics as published by Eklund et al. (2016). With regard to our study, this is necessary to mention, because in our group-by-condition interaction analysis we also utilized cluster-level correction. However, the statistical problems raised by Eklund et al. were detected only for one- and two sample t-tests and thus do not apply to our full-factorial design. Moreover, we used a stringent height-threshold of $P < 0.005$ (uncorrected) and only clusters consisting of 218 or more adjacent voxels were considered significant. Eklund et al. defined the ad hoc cluster size of 10 adjacent voxel, which leads to the largest FWE inflation. However, there is no evidence that alpha error inflation arise also in much larger clusters as those considered significant in the current study only.

Moreover, due to limited sample size and subsequently limited power of our analyses, we were not able to analyse the impact of sexual gender orientation. This is another limitation, because a homosexual orientation is associated with an increased risk for sexual (re-)offending in pedophiles (Blanchard et al., 2000). However, it is important to note that groups did not differ with respect to sexual gender orientation ($\chi^2 = 1.89$, $P = 0.390$), so far, it seems unlikely that this would have significantly affected the results. Also, the pedophilic offender group recruited for this study is heterogeneous with respect to their life situations and ranges from persons who are incarcerated for sexual offending against children, those who already served their prison sentence or received suspended sentence to those from living in the community and whose offenses were never recorded by the police ('darkfield'). However, one could also argue

that the heterogeneity of the offender sample might also be a strength, because it enhances the generalizability of the findings. Finally, without including a general offender group, it remains unclear, whether the P + CSO group differs from the other groups on variables that are elevated in offender populations (e.g., substance use, antisocial personality disorder or psychopathy) and which may be associated with aberrant moral processing.

In conclusion, this study showed a reversed activation pattern in brain areas related to moral judgment and (socio-)moral disgust (ITP), left insular cortex, posterior cingulate gyrus and precuneus) during the evaluation of sexual aggression concerning adults versus those against children in pedophilic subjects compared to healthy controls. Moreover, brain activation patterns were correlated to behavioral measures but only in the control group. Therefore, our data may indicate that pedophiles—regardless whether they have committed a sexual offense against a child or not—judge and process sexual aggression differently compared to non-pedophilic, healthy male controls.

This seems of special interest, because one of the most important goals of forensic psychiatry is the risk-reduction in (potentially) mentally ill offenders. Men diagnosed with pedophilia have been reported to have a high risk of (re-)offending (Hanson and Bussiere, 1998; Hanson and Morton-Bourgon, 2005). Therefore developing and improving adequate and effective therapeutic approaches are of great importance. Determining deficiencies in moral judgment related to pedophilia in general could not only be helpful by complementing existing intervention strategies on this issue in the future but moreover enhance prevention measures as well.

Thus, it will be important to continue this line of work with other types of stimuli (e.g. indicative pictures instead of short stories because the influence of different kind of stimulus material in morality research is well studied (Fumagalli and Priori, 2012) and a clear request with whom of the characters described in the scenarios the participant shall mentalize. As mentioned before, further analysis should also take into account the investigation of an additional group of sexual offenders against children: those without pedophilic disorder. Including this group into future research designs will allow drawing conclusions about the possible impact of deficient moral judgment on sexual offending behavior more precisely.

Supplementary material

Supplementary data are available at SCAN online.

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