Common Structural Correlates of Trait Impulsiveness and Perceptual Reasoning in Adolescence

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Abstract: *Background:* Trait impulsiveness is a potential factor that predicts both substance use and certain psychiatric disorders. This study investigates whether there are common structural cerebral correlates of trait impulsiveness and cognitive functioning in a large sample of healthy adolescents from the IMAGEN project. *Methods:* Clusters of gray matter (GM) volume associated with trait impulsiveness, Cloningers' revised temperament, and character inventory impulsiveness (TCI-R-I) were identified in a whole brain analysis using optimized voxel-based morphometry in 115 healthy 14-year-olds. The clusters were tested for correlations with performance on the nonverbal tests (Block Design, BD; Matrix Reasoning, MT) of the Wechsler Scale of Intelligence for Children IV reflecting perceptual reasoning. *Results:* Cloningers' impulsiveness (TCI-R-I) score was significantly inversely associated with GM volume in left orbitofrontal cortex (OFC). Frontal clusters found were positively correlated with performance in perceptual reasoning tasks (Bonferroni corrected). No significant correlations between TCI-R-I and perceptual reasoning were observed. *Conclusions:* The neural correlate of trait impulsiveness in the OFC matches an area where brain function has previously been related to inhibitory control. Additionally, orbitofrontal GM volume was associated with scores for perceptual reasoning. The data show for the first time structural correlates of both cognitive functioning and impulsiveness in healthy adolescent subjects. *Hum Brain Mapp 34:374–383, 2013.* © 2011 Wiley Periodicals, Inc.

Key words: trait; impulsiveness; structural correlates; frontal cortex; perceptual reasoning; adolsecence

INTRODUCTION

Impulsiveness is a fundamental behavioral trait with substantial heritability [Hur and Bouchard, 1997; Pedersen et al., 1988; Seroczynski et al., 1999] and has a considerable impact on individual as well as on social life. For instance, impulsiveness is a predictor of behaviors such as aggression, delinquency, substance use, and the number of sexual partners [Flory et al., 2006; Miller et al., 2004]. In addition, impulsiveness has been associated with borderline personality disorder [Bagge et al., 2004; Conrod et al., 2000; Fossati et al., 2004; Links et al., 1999], substance abuse [Sher et al., 2000], attention-deficit/hyperactivity disorder [ADHD; Avila et al., 2004; Lijffijt et al., 2005], and suicidal behavior [Dougherty et al., 2004; Esposito et al., 2003; Swann et al., 2005; Yen et al., 2004]. Some evidence indicates that impulsiveness is a stronger predictor for antisocial behavior than other major personality dimensions such as extraversion/sociability and neuroticism/emotionality [Cale and Lilienfeld, 2006].

An extensive literature has focused on the association of impulsiveness with cognitive processing and intelligence [Baron, 1982; Brebner, 1995], because Barratt [1967] described perceptual-motor performance as being related to impulsiveness. The link between high impulsiveness and impaired cognitive functioning has been related to deficits in attention, efficiency of information processing, and reasoning. Empirical evidence indicates that high impulsive individuals compared to low impulsive ones show worse performance in reaction time tasks in terms of reaction time and errors [Dickman, 1993, 2000; Marsh et al., 2002], working memory [Whitney et al., 2004], figural and numeric/alphabetical reasoning tasks [Schweizer, 2002], planning strategy [de Wit, 2007], and fluid or crystalline intelligence [Corr, 1998; de Wit, 2007; Harmon-Jones et al., 1997; Russo et al., 2008], although negative findings have also been published [Ashton et al., 2000; Austin et al., 2002]. For instance, despite high intelligence quotients (IQ) children with an impulsiveness-related disorder (ADHD) showed a poorer performance on the Block Design (BD), a subtest of the Wechsler Scale of Intelligence for Children (WISC) III [Antshel et al., 2007]. The effect of impulsiveness is also observed in animal models with several studies indicating that animals with pharmacologically increased impulsiveness perform worse in cognitive tasks, which require them to wait or to process a large amount of information [Bizot and Thiebot, 1996]. Thus, impulsiveness appears to be an important modulatory factor in cognitive function.

The multifaceted construct of impulsiveness has been investigated as a personality measure using self-report questionnaire data as well as in the behavioral domain investigating disinhibition. Several subfactors have been described at the level of personality measures, but most evidence indicates three dimensions termed motor, attention, and nonplanning impulsiveness [Patton et al., 1995], which may form an underlying common trait in healthy individuals [Barratt, 1994; Cloninger, 1986]. This article focuses on impulsiveness as a trait, because personality-related dimensions of impulsiveness predict individual behavior [Perales et al., 2009; Romer et al., 2009], psychopathological syndromes, and mental disorders [Berlin et al., 2005; Solanto et al., 2009] and further provide the best empirical evidence for a high heritability [Hur and Bouchard, 1997; Pedersen et al., 1988; Seroczynski et al., 1999] as well as associations with genetic variants of particular neurotransmitter systems [Kazantseva et al., 2009; Munafo et al., 2008].

Functional neuroimaging studies on impulsiveness have tended to focus on behavioral inhibition, while many other dimensions of impulsiveness have remained unexplored. For instance, one popular but rather narrow conceptualization of impulsiveness, motor response inhibition as tested by Go/NoGo and stop signal tasks, has frequently shown activity in the right inferior frontal cortex and the subthalamic nucleus [STN; Congdon and Canli, 2008]. The inferior frontal cortex has been hypothesized as being essential for controlling behavioral inhibition and the STN for playing a central role in braking ongoing motor commands [Aron and Poldrack, 2005; Gerfen, 2000; Mink, 1996; Nambu et al., 2002]. Hence, when impulsiveness as a trait is targeted in fMRI, the results are restricted to correlational analyses with brain activation patterns related to specific disinhibition tasks. In this context, brain morphometry may be advantageous, because it is not restricted neither to certain paradigms tailored to specific regions of interest nor to specific operationalizations of impulsiveness.

Brain morphometry studies in psychiatric patients have reported associations between impulsiveness and gray matter (GM) volume of the orbitofrontal, cingulate, bilateral parietal, and temporal cortex as well as of the ventral striatum [Antonucci et al., 2006; Carmona et al., 2005; Lotfipour et al., 2009; Monkul et al., 2007; Schwartz et al., 2010]. Studies in healthy subjects are rare. Gardini and colleagues [Gardini et al., 2009] have shown a positive association with GM volume in frontal and posterior cingulate regions. Conversely, negative associations between nonplanning as well as motor impulsiveness and right ventromedial prefrontal cortex volume have been reported [Boes et al., 2009]. Similarly, identical aspects of impulsiveness were negatively correlated with bilateral orbitofrontal cortex (OFC) GM volume [Matsuo et al., 2009]. In particular, middle frontal cortex volume has been shown to be related not only to inhibition [Boehler et al., 2010; Kuhn et al., 2009; Sharp et al., 2010], but also to attention [Andersson et al., 2009]. Thus, cerebral regions related to the inhibitory aspects of the impulsiveness trait are also critical for attention and executive components of cognitive processing. This structural link may provide an explanatory framework for the association between trait impulsiveness and cognitive performance.

This study focuses on the common structural underpinnings of both trait impulsiveness and related cognitive functions using optimized voxel-based morphometry (VBM) in a large sample of adolescents. This may be clinically relevant, because personality traits and intelligence in children explain to some degree the drinking and smoking behavior of the adults they become [Kubicka et al., 2001]. We investigated healthy 14-year-old subjects ($N = 115$), for whom mechanisms of impulsiveness may not be confounded with disease-specific variables or life style factors such as alcohol, nicotine, and illegal drug use, which, in turn, affect brain morphology [Gallinat et al., 2006; Lotfipour et al., 2009]. Impulsiveness was operationalized using a specific personality facet instead of broad personality concepts like novelty-seeking [Gardini et al., 2009] or a questionnaire targeting behavioral aspects such as the Pediatric Behavior Scale [Boes et al., 2009]. Cloninger's TCI-R-I was used, because it is based on a psychobiological model derived from empirical findings on personality, neurobiology and genetics [Cloninger et al., 1993]. The TCI-R-I appeared to be particularly suitable for our study, because it is a precisely defined personality facet based on a comprehensive model of personality. To assess cognitive functioning, while controlling for nuisance effects caused by verbal or numerical testing material [Goel, 2007], the nonverbal core tasks of the abbreviated WISC IV were chosen. More importantly, these tests are conceptualized to assess in particular abstract reasoning and executive dysfunctions [Szeremi et al., 2005], which were hypothesized to be affected by impulsiveness. Both nonverbal tasks (BD; Matrix Reasoning, MT) require attention, spatial reasoning, and response selection [Petermann and Ulrike, 2007; Wechsler, 2003].

Although there is some consensus for a prominent role of frontal and parietal structures in impulsiveness and cognitive function [Greening et al., 2011; Schneider et al., 2010; Westlye et al., 2011], we aimed to identify relevant structures by means of a whole brain analysis for trait impulsiveness and a subsequent analysis of the identified clusters with perceptual reasoning.

METHODS AND MATERIALS

Participants

One hundred and fifteen 14-year-olds (*SD* 0.32 years; 70 females) volunteered for this study within the scope of the

IMAGEN project, an European multicenter genetic-neuroimaging study in adolescence [Schumann et al., 2010]. Written informed consent was obtained from all participants as well as from their legal guardians. The adolescents were recruited from secondary schools in Berlin. The assessment was approved by both the ethics committee and by each head teacher of the school. All interested students were screened for MR contraindications. Furthermore, any participant with a medical condition such as a tumor, neurological disorders like epilepsy or mental-health problems like affective disorders was excluded. All participating students were assessed by means of both a self rating and two external ratings (parents; psychiatrists specialized in pediatrics) as part of a scale tailored to adolescents and based on ICD-10 as well as DSM-IV (The Development and Well-Being Assessment Interview, DAWBA; [Goodman et al., 2000]. Additionally, data on life time substance use were collected (*number of occasions in your whole lifetime you have had any alcoholic drinks M* 1.41, *SD* 1.48; [...] *used marijuana M* 0.04, *SD* 0.25; [...] *smoked cigarettes M* 0.78, *SD* 1.43, Scale: European School Survey Project on Alcohol and Drugs, ESPAD, www.espad.org).

Materials

Personality measure

Participants filled in the TCI-R [Cloninger, 1999] a computerized, self-rating personality questionnaire with the scale impulsiveness versus reflection as one of the novelty seeking facets (administered in German, [Richter et al., 1999]). Answers were given by means of a five-point Likert scale. By adding up the scores of the nine items of interest, a total was computed with higher values signifying higher impulsiveness.

Performance measures

Perceptual reasoning was assessed by means of two subscale scores according to the nonverbal core tests included in the abbreviated WISC IV [Wechsler, 2003] in a German version [Petermann and Ulrike, 2007]: BD and MT. Both tasks require attention, spatial reasoning, and response selection. BD involves putting together red-and-white blocks in a pattern so as to match to a displayed model. Speed is stressed, and some of the more difficult puzzles award bonuses for speed. MT asks participants to pick out of five images one fitting a shown array of pictures with one missing square. Sum scores, both in BD and MT, were converted to the more precise age equivalent scores, higher ones indicate higher performance.

MR Imaging

Structural MRI was performed on a General Electric SIGNA EXCITE 3T scanner (Milwaukee, WI) with a standard eight-channel head coil. High-resolution anatomical magnetic resonance images were obtained using a three-dimensional T1-weighted magnetization prepared gradient-echo sequence (MPRAGE) based on the ADNI protocol (sequence version = adni14m4; www.adni-info.org; repetition time = 7.16 ms; echo time = 3.02 ms; flip angle = 8°; 256 × 256 × 166 matrix, 1.1 × 1.1 × 1.1 mm resolution).

Image Analysis

First, anatomical images were visually controlled for motion artifacts and gross structural abnormalities. The image processing followed the optimized VBM protocol [Good et al., 2001] implemented in Statistical Parametric Mapping (SPM) 8 (Wellcome Department of Neuroimaging, London, United Kingdom; http://www.fil.ion.ucl.ac.uk/spm) running on Matlab R2007a (MathWorks, Natick, MA). Images were preprocessed using the SPM8 modules segmentation and smoothing involving bias correction, spatial normalization, and smoothing with an 8-mm full-width-at-half-maximum Gaussian kernel by means of SPM8. In line with Good and colleagues [2001], a recursive process of segmentation, extraction, and normalization integrated in SPM8 was applied in our study. So, initially, structural MR images were segmented into gray and white matter images. Following, unconnected nonbrain voxels were removed from the segmented images, before images were normalized to gray/white matter templates. Resulting images were then subject to segmentation into gray and white matter, CSF, and non-CSF-partition, a second extraction step. Individual brains were normalized to Montreal Neurological Institute (MNI) space. Moreover, images were modulated in order to focus on volumetric differences instead of tissue concentration [Ashburner and Friston, 2000].

Statistical Analysis

At first, whole brain analysis on the association of GM volumes with impulsiveness (TCI-R-I) was modeled by means of voxelwise multiple regression. To control for nuisance effects arising from interindividual differences in local GM content due to modulation [Mechelli et al., 2005] total GM volume was included as a covariate of no interest besides age in days and gender [Good et al., 2001]. The total GM volume was estimated from the modulated and normalized GM images using Matlab (MathWorks) code (http://www.cs.ucl.ac.uk/staff/G.Ridgway/vbm/get_totals.m). Cluster criteria were a voxel threshold of $P < 0.001$ without correction for multiple comparisons but a cluster volume of >25 voxels. Standardized regression coefficients and t values are reported for the maximum voxel within the resulting brain region. Although such a liberal approach has been shown to be sensitive for detecting subtle structural differences, we additionally applied the more conservative cluster level threshold of $P < 0.05$ provided by SPM.

To explore their relationship to perceptual reasoning, for all clusters identified in the above analysis data were extracted by means of MarsBaR (http://marsbar.sourceforge.net). Respectively, for all clusters, the GM values of all

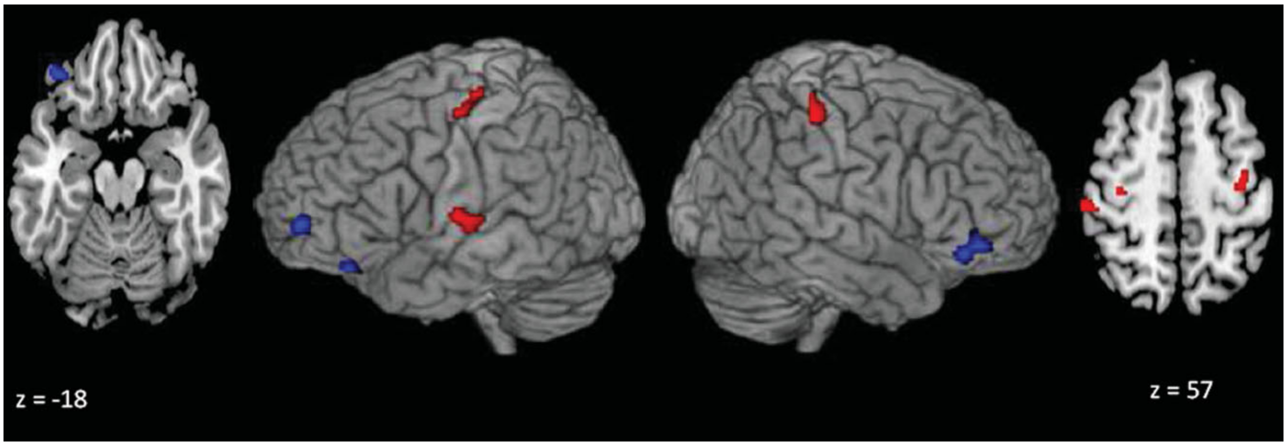

Figure 1.
The regions inversely (blue) and positively (red) correlated with trait impulsiveness; $z = -18$; $z = 57$; co-varied for total gray matter, age, and gender; ($p < 0.001$ uncorrected; $N = 115$). [Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com.]

voxels were averaged within each area. Subsequently, the resulting values were correlated separately with BD and MT scores (WISC IV) with a statistical threshold of $P < 0.05$, applying a Bonferroni correction for all seven clusters that were included in these analyses at $P < 0.003$ (0.05/14), in PASW Statistics 18 (SPSS, Chicago, IL).

RESULTS

Descriptive Data on Personality and Performance Measures

The participants' trait impulsiveness scores (TCI-R-I; *M* 26.14, *SD* 4.35) were normally distributed (Kolmogorov–Smirnov test $P = 0.38$) and comparable to the average in the general population [Elovainio et al., 2004]. Total scores achieved in the nonverbal tasks of the WISC IV indicated an average level of performance (BD *M* 10.73, *SD* 2.75; MT *M* 10.97, *SD* 2.29). Neither BD ($r = 0.04$, $P = 0.69$) nor MT ($r = 0.06$, $P = 0.55$) were correlated with TCI-R-I.

Whole Brain Analysis—Correlation Between GM Volume and Impulsiveness

The whole brain regression analysis showed a significant inverse relationship between GM volume in frontal cortex areas and impulsiveness (TCI-R-I). In particular, the impulsiveness score was negatively correlated with both left and right OFC, right IFG as well as left middle frontal cortex at a threshold of $P < 0.001$ uncorrected (Fig. 1 and Table I). The more conservative, cluster level threshold of $P < 0.05$ confirmed the negative correlation for a cluster in the left orbitofrontal area (−32, 36, −24, MNI coordinates; Fig. 2).

Additionally, the whole brain analysis revealed that impulsiveness (TCI-R-I) was positively correlated with GM volume in the parietal, precentral, and temporal cortex (see Table II for details; Fig. 1). The positive associations were significant at $P < 0.001$ uncorrected, but did not survive the correction for multiple comparisons.

Association Between Neuronal Correlates of Impulsiveness and WISC

Although none of the pre-, postcentral, and temporal clusters resulting from the whole brain analysis of impulsiveness (TCI-R-I) were significantly correlated with the WISC subtests, all orbital frontal and the middle frontal regions showed a significant positive correlation. Although MT was statistically significantly ($P < 0.05$) associated with two out of three regions (−32, 60, 2 $r = 0.19$; −32, 36, −24 $r = 0.21$, MNI coordinates), BD was linked to all three

TABLE I. The Regions Inversely Correlated With Impulsiveness ($N = 115$)

	MNI coordinate[a]	Brodmann area	Cluster size	*t*	*P* uncorrected
Left middle frontal cortex	(−32, 60, 2)	10	34	4.21	<0.001
Left OFC	(−32, 36, −24)	11	82	4.06	<0.001
Right OFC/IFG orbitalis	(46, 42, −2)	47/45	60	3.63	<0.001

Note: Analyses are covaried for total gray matter, age, and gender. OFC, orbitofrontal cortex; IFG, inferior frontal gyrus.
[a]MNI coordinates of the voxel of maximal statistical significance.

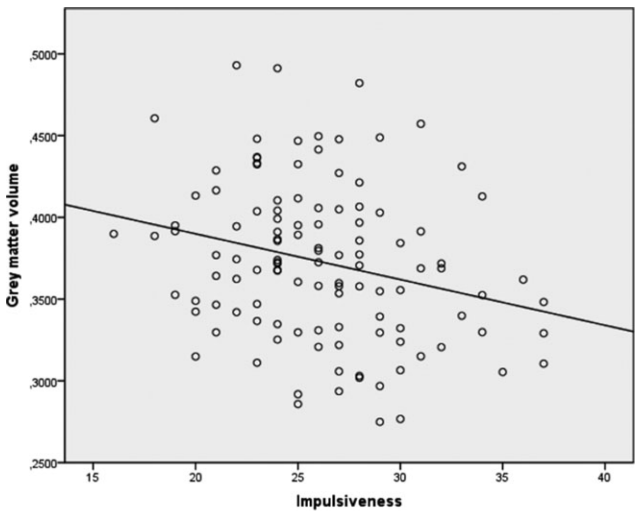

Figure 2.
Correlation between average gray matter volume of the cluster in the left orbitofrontal area (−32, 36, −24, MNI coordinates) and trait impulsiveness. Co-varied for total gray matter, age, and gender; ($p < 0.05$ cluster level threshold; $N = 115$).

clusters (−32, 60, 2 $r = 0.31$; −32, 36, −24 $r = 0.32$; 46, 42, −2 $r = 0.27$, MNI coordinates). Two, out of the three, correlations of BD with GM survived a Bonferroni correction at $P < 0.003$, indicating two left frontal clusters including the left orbitofrontal area (−32, 60, 2; −32, 36, −24, MNI coordinates; Fig. 3). The explained variance ranged from 4 to 10%.

DISCUSSION

The present study is the first investigation on morphometric correlates of trait impulsiveness in a large sample of healthy 14-year-olds without psychiatric disorders, nicotine, alcohol (max. one drink during their whole life), or any illegal drug use (IMAGEN, [Schumann et al., 2010]. The results provide evidence for a link between trait impulsiveness and structures in the left OFC. Exploratory analyses further suggest associations with inferior as well as middle frontal, pre-, and postcentral cortical areas, which have previously been attributed to inhibitory control of action or for motor and somatosensory processing respectively. In particular for OFC, an association with perceptual reasoning was found indicating a structural correlate of impaired cognitive function in high impulsive subjects.

The inverse correlation between trait impulsiveness and GM volume of the left OFC is compatible with reports in nonclinical adult samples [Kumari et al., 2009; Matsuo et al., 2009]. GM volumes of the bilateral OFC have been found to be inversely correlated with the BIS total score as well as the subfactors nonplanning and motor impulsiveness [Matsuo et al., 2009]. However, because impulsiveness and substance use are associated in adult samples, those investigations cannot rule out a confounding effect on GM volume as described previously [Gallinat et al., 2006; Kühn et al., 2010]. Consistently, MRI studies in clinical, adult populations stress a link between reduced OFC GM volume and disorders comprising impulsive symptoms [Hesslinger et al., 2002; Ogura et al., 2011]. Thus, conversely, our findings may indicate that reduced GM volume in adults might not necessarily be a consequence of their illness/substance use [Schwartz et al., 2010]. In the fMRI literature, the OFC has been reported to be active during response inhibition [Horn et al., 2003]. Beyond its involvement in motor impulsiveness, OFC has been found to be associated with higher cognitive functions such as decision making [Schoenbaum et al., 2006; Wallis, 2007].

Supplementary considering the results of the exploratory analyses may help to understand the role of frontal structures related to the phenomenon impulsiveness. In addition to the OFC, the IFG has also been associated with the inhibitory control of action. Aron and Poldrack [2005] have shown that particularly the activity of the right IFG was correlated with response inhibition, a causal role for which had been suggested by previous lesion studies [Aron et al., 2004]. Similarly, the left middle frontal cortex, which we also found to be correlated negatively with impulsiveness in an exploratory analysis, is known to be important for both inhibitory control [Sharp et al., 2010] and cognitive functions such as the regulation of executive attention [Andersson et al., 2009]. However, in the current analysis, only correlations with left frontal clusters survived the cluster level threshold. The observed correlations and possible consequences for brain function should be interpreted with caution. Moreover, studies of neural plasticity in humans (e.g., hippocampal volumes on taxi drivers [Maguire et al., 2000]) suggest that such plastic changes may sometimes be a consequence of experience rather than a causal factor in biologically predetermined behavior.

TABLE II. The Regions Positively Correlated With Impulsiveness ($N = 115$)

	MNI coordinate[a]	Brodmann area	Cluster size	t	P uncorrected
Right postcentral gyrus	(48, −28, 58)	1	45	3.97	<0.001
Right precentral gyrus	(32, −22, 52)	4	32	3.90	<0.001
Left precentral gyrus	(−36, −18, 58)	4	60	3.89	<0.001
Left superior temporal cortex	(−60, −10, 10)	42	34	3.78	<0.001

Note: Analyses are covaried for total grey matter, age, and gender.
[a]MNI coordinates of the voxel of maximal statistical significance.

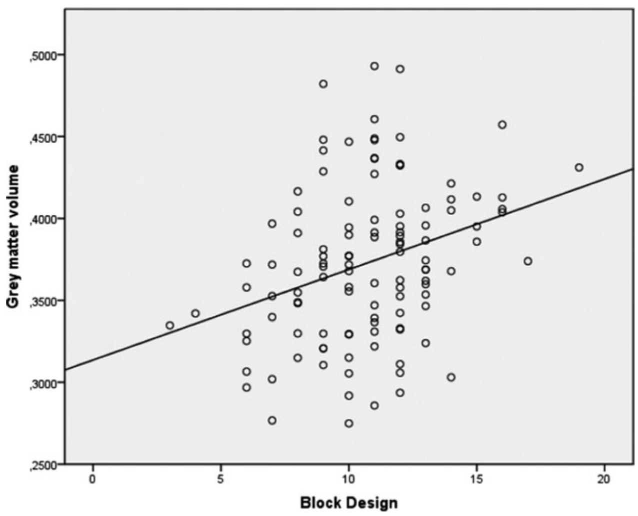

Figure 3.

Correlation between average grey matter volume of the cluster in the left orbitofrontal area (−32, 36, −24, MNI coordinates) and Block Design. Covaried for total gray matter, age, and gender; ($p < 0.003$ Bonferroni corrected; $N = 115$).

In line with the general role that prefrontal structures play in directing attention [Mesulam, 1981], Frangou and colleagues [2004] have reported a positive association between IQ and GM density of the OFC in healthy adolescents and young adults. Consistently, Russo and colleagues [2008] showed that highly impulsive individuals had difficulties to inhibit irrelevant information in intelligence tests. However, despite some evidence for the involvement of the OFC and of the middle frontal cortex in both impulsiveness and cognitive functions as discussed earlier, relatively little is known about overlapping brain structures of personality dimensions of impulsiveness and mental abilities. The positive correlations between the subtests of the WISC IV and the frontal clusters of GM reduction identified in this study support the hypothesis of brain areas being involved in both impulsiveness and cognitive functioning. Both subscale scores, BD and MT, have been conceptualized as performance measures of perceptual reasoning. In particular, MT is thought to assess attention and executive functioning, which have been considered to engage aspects of fluid intelligence by some researchers. Even though Tranel and colleagues [2008] did not find a connection between fluid intelligence and prefrontal lobe damage, our results are in line with studies relating perceptual reasoning to OFC function [Sabbagh, 2004] and the medial frontal cortex [Prado and Noveck, 2007]. Similarly to MT, BD has been conceptualized as assessing abstract reasoning, namely spatial cognitive ability. Interestingly, impulsiveness was found to be especially associated with spatial cognitive function. For instance, similar to the negative correlation between BD and right IFG orbitalis shown in our study, spatial working memory performance has been found to be associated with right IFG damage in adults with an impulsiveness-related disorder (ADHD; [Clark et al., 2007]. With regard to spatial attention, the activity of the OFC, as part of a circuitry critical for selective allocation of attentional resources, has especially been found to be associated with the speed of attentional shifts [Mohanty et al., 2008]. However, in additionally performed whole brain analyses, no correlative associations between the perceptual reasoning subtests and those prefrontal areas were found in our study. In sum, the correlations between the frontal clusters and the WISC subscales discussed might suggest frontal structures associated both with trait impulsiveness and aspects of the participants' behavior related to impulsiveness [Szeremi et al., 2005].

Furthermore, in uncorrected whole brain analyses, we found higher impulsiveness to be associated with larger GM volumes of primarily the bilateral precentral gyrus as well as the parietal and the temporal cortex. In particular, the correlations with primary motor cortex (BA 4) GM volume suggest an association with motor functions [Ellermann et al., 1998; Gelnar et al., 1999]. Cloninger [1986] has defined impulsiveness as one of the facets of the personality trait novelty seeking, described as a so-called temperament actively searching for particularly stimulating, novel environments, as shown for adolescents' impulsiveness predicting risky behavior [Zimmerman, 2010]. Furthermore, it has been shown that motor activity, such as learning to juggle, can result in GM volume increase in the motor cortex [Driemeyer et al., 2008]. The greater exploratory activity of the high impulsives is further presumably associated with more stimulating experiences from other different modalities besides kinaesthetic and proprioceptive feedback. Structural neuroimaging studies have provided evidence for the fact that exposure to acoustic stimuli can alter brain structure [Golestani et al., 2002]. Hence, it appears plausible, even though speculative, that the clusters of the somatosensory cortex and secondary auditory cortex found in our study might suggest a similar association driven by heightened impulsiveness and hence increased exploratory behavior.

Some methodological limitations of this study shall be noted. Although, there is a more recent junior TCI scale for children and adolescents [Luby et al., 1999], the TCI-R was used. This revised scale has been specifically modified for the purposes of neuroimaging and repeatedly applied previously [Cloninger, 2008]. Furthermore, participants have not been assessed with the standard instrument, the Structural Criteria Interview for Diagnosis nonpatient version. Yet, based on both a self-rating and external ratings (parents; psychiatrists specialized in pediatrics) as part of a scale developed for children and adolescents (DAWBA, [Goodman et al., 2000], volunteers with psychiatric disorders according to ICD-10 and DSM-IV were excluded. Moreover, instead of more objective measures such as urine drug screenings the well established self-rating scale

ESPAD (www.espad.org) was chosen, because it provides information on, for example, life time alcohol use. To minimize social desirability biases, participants got an individual, but anonymous online login to fill in the computerized questionnaire on their own in an undisturbed environment.

In summary, our findings support an association between higher trait impulsiveness and smaller GM volume of the left OFC. For the first time, morphological correlates of the impulsiveness personality facet have been identified in an adolescent, healthy, and substance naive sample. This study further suggests possible neural substrates of an important risk factor for various psychiatric disorders like substance abuse and potentially relevant for defining a neural endophenotype for such disorders For instance, novelty seeking, a personality dimension comprising impulsiveness, measured during childhood predicted alcohol abuse in young adults [Cloninger et al., 1988]. We have also shown that predictive studies might benefit from focusing on possible interactions of impulsiveness with aspects of cognitive functioning.

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