Associations between psychopathic traits and brain activity during instructed false responding[1]

Andrea L. Glenn[a][2], Hyemin Han[b], Yaling Yang[c], Adrian Raine[d], & Robert A. Schug[e]

[a]Center for the Prevention of Youth Behavior Problems, Department of Psychology, University of Alabama, Tuscaloosa, AL, USA

[b]Educational Psychology Program, University of Alabama, Tuscaloosa, AL, USA

[c]Department of Pediatrics, Children's Hospital of Los Angeles, Los Angeles, USA

[d]Departments of Criminology, Psychiatry, and Psychology, University of Pennsylvania, Philadelphia, PA, USA

[e]Department of Criminology, Criminal Justice, and Forensic Psychology, California State University, Long Beach, CA, USA

[2] alglenn1@ua.edu; Tel: (205)-348-4340

Abstract:

Lying is one of the characteristic features of psychopathy, and has been recognized in clinical and diagnostic descriptions of the disorder, yet individuals with psychopathic traits have been found to have reduced functioning in many of the brain regions that are important for lying. In this study, we examine brain activity in sixteen individuals with varying degrees of psychopathic traits during a task in which they are instructed to falsify information or tell the truth about autobiographical and non-autobiographical facts, some of which was related to criminal behavior. We found that psychopathic traits were primarily associated with increased activity in the anterior cingulate, various regions of the prefrontal cortex, insula, angular gyrus, and the inferior parietal lobe when participants falsified information of any type. Associations tended to be stronger when participants falsified information about criminal behaviors. Although this study was conducted in a small sample of individuals and the task used has limited ecological validity, these findings support a growing body of literature suggesting that in some contexts, individuals with higher levels of psychopathic traits may demonstrate heightened levels of brain activity.

1. Introduction

Individuals with psychopathic traits are described as frequently deceiving others and are thought to be skilled at doing so (Hare, 2003). Deception has been defined as a deliberate act that is intended to foster in another person a belief or understanding which the deceiver considers false (Zuckerman, DePaulo, & Rosenthal, 1981). Lying, or making a statement that is believed by the liar to be false, is one way to deceive. The process of lying involves the inhibition of true responses and the production of deceptive ones (Abe, Suzuki, Mori, Itoh, & Fujii, 2007). It also involves complex socio-cognitive processes such as taking the perspective of another person, reading his or her intentions, moral decision-making, monitoring one's own behavior, and likely emotion regulation (Abe et al., 2007; Lisofsky, Kazzer, Heekeren, & Prehn, 2014). The present study focuses on the basic process of falsifying truthful responses. Brain imaging studies in which participants are instructed to lie under certain conditions show that the process of inhibiting the truth and producing a lie is associated with brain activity in various regions of the prefrontal cortex and the anterior cingulate (e.g., Abe et al., 2007; Kozel et al., 2005; Nunez, Casey, Egner, Hare, & Hirsch, 2005). For example, Abe et al. (2007) found that the DLPFC and the frontopolar cortex were active when falsifying truthful responses, but not when participants were trying to deceive an interrogator. These regions are involved in working memory, maintaining attention, inhibiting prepotent responses, and conflict monitoring (Aron et al., 2007; Kerns et al., 2004; Rossi, Pessoa, Desimone, & Ungerleider, 2009) – processes necessary to intentionally inhibit the truth (i.e., the automatic, prepotent response) in order to lie. The frontopolar cortex has also been associated with switching between alternatives (Boorman, Behrens, Woolrich, & Rushworth, 2009; Sylvester et al., 2003). The anterior cingulate has been implicated in several studies involving falsifying information or malingering (Kozel et al., 2005; Lee et al., 2005; Mohamed et al., 2006) and is involved in directed attention, conflict processing, and inhibitory control (Gasquoine, 2013).

Notably, psychopathic traits have been associated with reduced functioning in many of these regions during various tasks (Yang & Raine, 2009). Because psychopathy is associated with more frequent (i.e., practiced) and possibly skilled lying, yet reduced functioning in brain regions associated

with the process of falsifying information, it is unclear whether psychopathy would be associated with increased or decreased brain functioning when participants falsify information.

ERP studies have examined brain functioning during the process of response inhibition – one important component of falsifying information – in relation to psychopathy, but have found mixed results. Kiehl et al. (2000) found that psychopathic individuals showed abnormalities in the generation of two characteristic ERP components, the N2 and P3, generated by the anterior cingulate and adjacent regions, and suggested that the neural processes involved in response inhibition are abnormal in these individuals. However, Munro et al. (2007) found no relationship between psychopathic traits and the generation of these ERP components during response inhibition.

Two previous studies have examined brain activity during the process of falsifying information in relation to psychopathic traits (Fullam, McKie, & Dolan, 2009; Nunez et al., 2005). Both studies assessed psychopathy using a self-report measure and found that various aspects of psychopathy were associated with reduced brain activity when participants were instructed to lie versus tell the truth. However, in both of these studies, participants were instructed to lie about relatively mundane information (e.g., "Do you own a laptop computer?"). We sought to build on these studies by asking participants to lie about something of greater personal consequence – one's own criminal behavior – which may be more closely related to lying in the real world.

Although Fullam et al. (2009) and Nunez et al. (2005) identified reduced brain functioning during the process of falsifying information, one recent study found that psychopathy was associated with *increased* activity in frontoparietal regions during two processes that are likely important in the process of falsifying information – interference suppression and response inhibition, two components of inhibitory self-control (Rodman et al., 2016). Thus, it is possible that individuals with psychopathic traits may show increased brain functioning when falsifying information. The goal of the present study was to clarify the relationship between psychopathic traits and brain activity during the process of falsifying information, a central cognitive component of lying.

In the present study, we specifically examined brain activity in regions that have consistently been associated with the process of falsifying information in previous studies in order to examine how activity in these regions was associated with psychopathic traits. Regions included the anterior cingulate, dorsolateral prefrontal cortex (DLPFC), insula, inferior parietal lobe (e.g., angular/supramarginal gyrus), frontopolar cortex, orbitofrontal/ventromedial prefrontal cortex, and temporal pole (Abe et al., 2007; Kozel et al., 2005; Kozel et al., 2004; Lee et al., 2005; Nunez et al., 2005).

Although the ERP and fMRI research is mixed, we hypothesized that psychopathy would be associated with reduced activity in these brain regions during the process of falsifying information because of the larger body of evidence suggesting associating psychopathy with reduced functioning in these regions. We also hypothesized that correlations would be strongest for the aspect of psychopathy that involves frequent lying and conning.

2. Methods

2.1. Participants. Participants were 16 adults (2 females) recruited from temporary employment agencies in the greater Los Angeles area (mean age = 30.2; 40% Caucasian, 40% African American, 13.3% Asian). Samples from this community have been found to show relatively higher rates of psychopathy and violence perpetration (Raine, Lencz, Bihrle, LaCasse, & Colletti, 2000). Participants were excluded if they were under 18 years of age; nonfluent in English; claustrophobic; or had a pacemaker, metal implants, or history of epilepsy. The principal investigator obtained a certificate of confidentiality from the Secretary of Health pursuant to Section 303(a) of Public Health Act 42. Participants were informed that any information they might provide about uninvestigated crimes could not be subpoenaed by any court. All participants provided informed consent.

2.2. Stimuli and Design.   The fMRI task was adapted from previous studies (Fullam et al., 2009; Spence et al., 2001). A 2x2 design was used to examine lying (selecting a false response) versus telling the truth in response to a series of yes/no questions that varied in (1) autobiographical versus non-autobiographical content, and (2) criminal versus non-criminal content, resulting in eight conditions (lie/truth ×

autobiographical/non-autobiographical × criminal/non-criminal). Table 1 contains sample questions. Twenty-four questions were presented in each of the four categories. Participants were instructed to respond truthfully or falsely to the questions using a button box. Questions were presented for four seconds each and were grouped into blocks of four questions each. At the beginning of each block, a screen appeared for two seconds instructing the participant either to lie or tell the truth about the following set of questions. Each block was followed by a four second fixation period. The task was divided into two runs. The structure of the task is depicted in Figure 1.

[INSERT TABLE 1 AND FIGURE 1 HERE]

2.3. Psychopathy and IQ Assessment. Psychopathic traits were assessed using the PCL-R: 2nd Edition (Hare, 2003), which is supplemented by seven sources of collateral data (described in Glenn, Raine, Schug, Gao, & Granger, 2011). Psychopathy has been found to be dimensional in nature (Edens, Marcus, Lilienfeld, & Poythress, 2006). The PCL-R has previously been used to assess psychopathic traits in community samples (Coid, Yang, Ullrich, Roberts, & Hare, 2009; Gao, Raine, & Schug, 2011; Neumann & Hare, 2008).The PCL-R consists of 20 items and reflects for facets of psychopathy: Facet 1 represents interpersonal features such as glibness, superficial charm and pathological lying; Facet 2 represents affective features such as lack of empathy, guilt, and remorse; Facet 3 represents lifestyle features such as impulsivity, risk-taking, and sensation seeking, and Facet 4 represents antisocial behavior. Ratings were made by a Ph.D. clinical graduate student who received systematic training on the administration and scoring of the PCL-R. Means, standard deviations, and ranges for psychopathy total and facet scores can be found in Table 2. The two females' scores were 32 and 26.3. Subtests of the Wechsler Adult Intelligence Scale-Revised (Wechsler, 1981) were used to estimate verbal, performance, and total IQ.

2.4. MRI data acquisition. Functional images were acquired on a Siemens 3T Trio scanner using an echo planar imaging (EPI) sequence with the following parameters: repetition time (TR) = 2000 ms, echo time (TE) = 60 ms, matrix = 64 × 64, field of view (FOV) = 192 mm, slice thickness = 3.5 mm, gap = 0 mm, 32 axial slices. The duration of each of the two EPI scans was 11 minutes, 20 seconds. These were

followed by an 8-minute T1-weighted magnetization prepared rapid gradient echo (MPRAGE) structural scan (256×256 matrix, $1 \times 1 \times 1$ mm voxel size).

2.5. fMRI image analysis. Image preprocessing was conducted using SPM8 and involved slice timing correction, image realignment and unwarping, normalization into a standard stereotactic space using the Montreal Neurologic Institute (MNI) template, and spatial smoothing with an 8 mm full width at half maximum Gaussian kernel. Data from one participant was excluded because of failure to complete the task.

A fixed effects model was used to analyze individual participant data. For each participant a General Linear Model was set up by specifying the onsets and durations (16 s) of the task blocks. The spatial realignment parameters were added to the design matrix as conditions of no interest. Resulting box-car functions were convolved with the canonical hemodynamic response function. To remove low-frequency scanner drifts, data were high-pass filtered with a frequency cutoff at 128 seconds.

To improve power when examining differences in task-related activity for lying versus telling the truth in response to the questions, we first defined a (GLM) for each participant with only two conditions – lie and truth. For comparisons between lie and truth conditions, second-level estimation was conducted. Statistical non-parametric mapping (SnPM) was used to correct for multiple comparisons (Nichols, 2014; Nichols & Holmes, 2002). This method enables us to address issues originating from multiple comparisons in fMRI analysis with greater confidence that the false positive rates are controlled appropriately (Eklund, Nichols, & Knutsson, 2016). Because SnPM does not require parametric assumption, this method is more robust against possible error associated with inflated false positives compared to parametric fMRI analysis methods (Nichols & Holmes, 2002). A voxel-wise threshold of $p <$ .05 controlling for family-wise error (FWE) and cluster-wise threshold of $p < .001$ after applying SnPM was used and 5,000 permutations were performed to examine areas in which brain activity differed in the lie and truth conditions in the group as a whole. It should be noted that the focus of the present study was to identify regions in which brain activity was associated with psychopathy scores. Thus, we only briefly report main effects for the whole group.

After examining main effects, correlation analyses were performed to examine brain regions in which activity was correlated with psychopathy scores (total and facet scores). We utilized the 'MultiSub: Simple Regression (correlation); single covariate of interest, one scan per subject' method provided by SnPM. Each participant's PCL:R score was entered to the SnPM analysis model as the single covariate. Correlational analyses were restricted to a priori regions of interest. These included regions previously associated with falsifying information (the anterior cingulate [BA 32], DLPFC [BA 8/9], the inferior parietal lobe (e.g., angular/supramarginal gyrus [BA 40]), the frontopolar cortex [BA 10], and the orbitofrontal/ventromedial prefrontal cortex [BA 11] (Abe et al., 2007; Lee et al., 2005), including those associated with falsifying information about autobiographical events (Fullam et al., 2009; Nunez et al., 2005)). These regions were selected based on previous associations with the process of falsifying information, not because of associations with psychopathy. The regions of interest were created using Talairach Daemon (TD) anatomic label masks from the WFU PickAtlas (http://fmri.wfubmc.edu/downloads/WFU_PickAtlas_User_Manual_v3.0.pdf) (Lancaster, Summerlin, Rainey, Freitas, & Fox, 1997; Lancaster et al., 2000; Maldjian, Laurienti, & Burdette, 2004; Maldjian, Laurienti, Kraft, & Burdette, 2003). Using SnPM, the statistical threshold was $p < .05$ for voxel-wise comparisons with a threshold of $p < .001$ for cluster-level inference. Although cluster-wise inference as implemented in widely-used fMRI analysis software such as SPM and FSL can inflate false-positive rates, clusterwise inference with SnPM is considered to be more stringent (Eklund et al., 2016).

Because of the correlational nature of our study, it was not feasible to interpret interaction effects (for a more detailed explanation, see supplementary materials). Thus, we examined correlations between psychopathy scores and brain activity for the eight specific contrasts (e.g. autobiographical lie > autobiographical truth, autobiographical lie > nonautobiographical lie, etc.).

3. Results

Psychopathy total and facet scores were not correlated with verbal, performance, or full scale IQ and none of these correlations approached significance (all $p > .49$; total psychopathy and full scale IQ: r

= .01, *p* = .97). Therefore, IQ was not used as a covariate. An overview of the significant associations between psychopathy scores (total and facet) and brain activity for all contrasts can be found in Table 3.

Lie > truth contrast

We first examined differences in activity between blocks in which participants were instructed to lie versus tell the truth. Consistent with prior studies utilizing similar tasks (Fullam et al., 2009), we found clusters of activation in the right DLPFC (Brodmann's area (BA) 8), frontopolar cortex (BA 10) and the right inferior parietal lobule, including the supramarginal gyrus and angular gyrus (BA 40) when lying versus telling the truth (full details can be found in Table S1). No voxels were significantly more active when participants were instructed to tell the truth versus lie.

Next we examined correlations between psychopathy scores and brain activity for the lie > truth contrast within the a priori ROIs. Table 4 lists regions in which psychopathy scores (total and facet) were correlated with brain activity within the ROIs. Total psychopathy scores were positively associated with activity in the frontopolar cortex, supramarginal gyrus, and lateral frontal cortex (Figure 2). There were no areas within the ROIs in which psychopathy scores were significantly negatively associated with activity. Activity in the frontopolar cortex and supramarginal gyrus was positively correlated with each of the four facets of psychopathy. Facet 4, which reflects antisocial behavior, was also positively correlated with activity in the orbitofrontal/ventromedial prefrontal cortex and anterior cingulate cortex. Facets 1 and 2, the Interpersonal/Affective facets, were negatively correlated with activity in the left DLPFC, and Facet 2 was negatively correlated with activity in the orbitofrontal cortex (see Table 3 and Table S2).

[INSERT TABLES 3 AND 4 AND FIGURE 2 HERE]

Contrasts involving autobiographical versus non-autobiographical information

Next we examined the contrasts involving lying or telling the truth about autobiographical compared to non-autobiographical information. We first examined areas that were associated with psychopathy when participants were instructed to lie about autobiographical versus non-autobiographical information (autobiographical lie > non-autobiographical lie). Total psychopathy scores were positively associated with activity in the dorsolateral and dorsomedial prefrontal cortex, frontopolar cortex,

supramarginal gyrus, and anterior cingulate cortex (Table 5). There were no ROIs in which activity was negatively associated with total psychopathy scores. All facets were associated with increased activity in the DLPFC and frontopolar cortex, with stronger associations for the Lifestyle and Antisocial facets. Facets 3 and 4 were also associated with activity in the bilateral supramarginal gyrus. Although there were no negative associations with total psychopathy scores, a few negative associations were observed with facet scores, though these relationships were weaker.

[INSERT TABLE 5 HERE]

We next examined areas that were associated with psychopathy when participants were instructed to lie versus tell the truth about autobiographical information. Total psychopathy scores were positively correlated with activity in the lateral part of the frontal lobe bilaterally, the insula, the frontopolar cortex, and supramarginal gyrus (Table 6, Figure 3). Total psychopathy scores were negatively associated with activity in the orbitofrontal cortex, angular gyrus, and DLPFC, though these effects were weaker. Positive associations were observed between Facets 1, 2, and 3 and the bilateral lateral frontal lobe and bilateral insula. Facets 2, 3, and 4 were positively associated with activity in the frontopolar cortex and all facets were correlated with activity in the supramarginal gyrus. All facets were negatively associated with activity in the orbitofrontal cortex.

[INSERT TABLE 6 AND FIGURE 3 HERE]

Results for the remaining two contrasts (autobiographical truth > non-autobiographical truth and non-autobiographical lie > non-autobiographic truth) are presented in Tables S3 and S4. When lying versus telling the truth about non-autobiographical information, psychopathy was positively correlated with activity in the frontopolar cortex and supramarginal gyrus. When telling the truth about autobiographical versus non-autobiographical information, psychopathy positively associated with activity in the frontopolar cortex, but negatively associated with activity in the dorsal anterior cingulate and insula. These negative associations were primarily driven by negative relationships with Facet 2.

Contrasts involving criminal versus non-criminal information

We also examined contrasts involving lying or telling the truth about criminally relevant information versus information that was not criminal in nature. We first examined areas that were associated with psychopathy when participants were instructed to lie about criminal versus non-criminal information. Total psychopathy scores were positively associated with activity in the anterior cingulate and dorsal prefrontal cortex, orbitofrontal cortex, insula, and frontopolar cortex. No negative associations were observed with total psychopathy scores (Table 7). All facets were positively associated with activity in the insula, orbitofrontal and frontopolar cortex, though associations tended to be stronger for Facets 3 and 4. Facet 3 was positively associated with activity in each of the regions associated with the total score. None of the facets were negatively associated with activity in the ROIs.

[INSERT TABLE 7 HERE]

Next we examined areas associated with psychopathy when participants were instructed to lie versus tell the truth about criminal information. Total psychopathy scores were positively associated with activity in the anterior cingulate, lateral and dorsolateral prefrontal cortex, insula, and frontopolar cortex (Table 8; Figure 4). No negative associations were observed with total psychopathy scores. Positive associations were observed between Facets 2 and 3 and the anterior cingulate, insula, and lateral and dorsolateral prefrontal cortex. Facet 4 was associated with increased activity in the frontopolar cortex. None of the facets were negatively associated with activity in the ROIs.

[INSERT TABLE 8 AND FIGURE 4 HERE]

Results for the remaining two contrasts (criminal truth > non-criminal truth and non-criminal lie > non-criminal truth) are presented in Tables S5 and S6. When lying versus telling the truth about non-criminal information, psychopathy was positively associated with activity in the frontopolar cortex and anterior cingulate, and negatively associated with activity in the DLPFC. Activity in the frontopolar cortex was positively associated with all facets of psychopathy. Activity in the angular gyrus demonstrated the strongest relationship with Facet 1. Activity in the DLPFC was negatively associated with Facets 2 and 3. When telling the truth about criminal versus non-criminal information, psychopathy was negatively associated with activity in the DLPFC, and this was primarily driven by Facets 2 and 3.

4. Discussion

Although previous studies have often found psychopathy to be associated with reduced levels of brain functioning during various tasks (Koenigs, 2012; Yang & Raine, 2009), the present study adds to a growing literature suggesting that there are contexts in which psychopathic individuals may demonstrate increased levels of functioning (Glenn, Raine, Schug, Young, & Hauser, 2009; Müller et al., 2003; Rodman et al., 2016), even in regions such as the orbitofrontal cortex, which is commonly described as demonstrating reduced functioning in psychopathic individuals (Koenigs, 2012; Yang & Raine, 2009). In this study, participants were instructed to lie and tell the truth about different categories of information (e.g., personally relevant, criminally relevant). Across different conditions, we primarily observed positive associations between psychopathy scores and brain activity in regions of interest in the prefrontal cortex, anterior cingulate, insula, angular gyrus, and inferior parietal lobe.

The region of the anterior cingulate that we found to be more active in individuals with higher levels of psychopathic traits (MNI: 20, 36, 22) has previously been found to be active during inhibitory processing in the Stroop task (Gruber & Yurgelun-Todd, 2005). It has also been found to be active when participants are asked to think about hypothetical situations (e.g., respond to questions as you would if you had woken up this morning as a member of the opposite sex) (Tamir & Mitchell, 2011), which is similar to the instruction to falsify information. The anterior cingulate has been associated with a number of executive functions that are likely important in the process of falsifying information, including conflict monitoring and cognitive control (Gasquoine, 2013). One possibility is that individuals with higher levels of psychopathic traits may be more practiced at lying, and may be better able to recruit brain regions such as the anterior cingulate to facilitate the process. In contrast to the current findings, Crowley et al. (2010) found *reduced* functioning in this same region of the anterior cingulate (MNI: 22, 36, 28) in adolescent boys with conduct problems during a decision-making task involving inhibitory control. Although speculative, it may be that increases in functioning are specific to the process of lying, in which

individuals with higher levels of psychopathic traits may be more practiced, rather than general tasks that involve inhibitory control.

Positive correlations were also observed in the lateral and dorsolateral regions of the prefrontal cortex and the insula, which have been associated with inhibition, working memory, task preparation, and higher-level cognitive control (Christ, Van Essen, Watson, Brubaker, & McDermott, 2009; MacDonald, Cohen, Stenger, & Carter, 2000). The lateral prefrontal cortex has been associated with goal directed attention (Asplund, Todd, Snyder, & Marois, 2010) and with controlling the flow of information in other brain regions and networks during the performance of cognitive tasks (Cole et al., 2013). In every contrast we examined, activity in the frontopolar cortex was positively associated with psychopathy scores; the frontopolar cortex has been associated with switching between alternatives (Boorman et al., 2009; Sylvester et al., 2003) and attending to mental states (Raposo, Vicens, Clithero, Dobbins, & Huettel, 2010). Although increased activity in individuals with higher psychopathy scores could reflect an increased ability to recruit this brain region that is important for manipulating information, it is also possible that increased activity in the frontopolar cortex could reflect *less* efficient functioning. Karim et al. (2010) used transcranial direct current stimulation (tDCS) to inhibit the frontopolar cortex and found that it resulted in *improvements* in lying abilities on the Guilty Knowledge Test. They suggest that the frontopolar cortex is involved in socioemotional judgments, and so activity in this region may represent moral conflict; inhibiting this region with tDCS and relieving the person from this moral conflict may result in the individual being able to "deceive unhinderedly" (Karim et al., 2010). Thus, one possibility is that psychopathic individuals, who may have committed more of the crimes that were asked about, may have more moral conflict during the task compared to individuals scoring low in psychopathy.

We also found positive associations in areas of the angular gyrus and supramarginal gyrus within the temporoparietal junction, which have been found to be active in tasks involving theory of mind, or mental state reasoning (Schnell, Bluschke, Konradt, & Walter, 2011; Young, Dodell-Feder, & Saxe, 2010) as well as counterfactual reasoning, which involves making inferences about how an event or state could have been different (e.g., changing the true outcome of an event and inferring how this could have

come about) (Van Hoeck et al., 2014). Similar to the process of falsifying information, these processes involve integrating knowledge and information in a mental representation about a specific action or situation away from reality (i.e., mentally simulating an alternative model that is contrary to the fact). Increased activity in this region in individuals with higher levels of psychopathic traits may again reflect more efficient processing in these individuals who may engage in frequent lying behavior. They may be more practiced at lying, or find lying to be less novel, and thus are better able to recruit brain regions that facilitate the process. This would be in line with neuropsychological research suggesting that in psychopathy, many aspects of executive functioning appear to be preserved, and in some cases enhanced (Baskin-Sommers et al., 2015; Sellbom & Verona, 2007).

The finding of increased activity in individuals scoring higher in psychopathic traits during the process of falsifying information is consistent with findings from a recent study by Rodman et al. (2016) in which psychopathy scores in an incarcerated sample predicted increased activity within a distributed frontoparietal network during tasks that assessed components of inhibitory self-control: interference suppression and response inhibition – two skills that are likely important in the process of falsifying information. Regions demonstrating increased activity included the frontopolar cortex, temporoparietal junction, and DLPFC.

In the present study, positive associations between brain activity and psychopathy scores were relatively stronger for the contrasts involving criminal information. Although speculative, it may be that individuals scoring higher in psychopathy may have committed more of the crimes that were asked about, and therefore may have more information to process when thinking about these events (e.g., recalling details of the event) than someone who had not committed the crime and required little effort to recall the truth. Although we do not have response time data available that might help us to further explore this idea, social-cognitive models for understanding lying suggest that one of the first steps of the lying process is that truths are searched for and retrieved from long term memory and transferred to working memory – a process requiring cognitive resources (Walczyk, Harris, Duck, & Mulay, 2014).

Contrary to hypotheses, associations tended to be weaker for the interpersonal facet (Facet 1), which involves pathological lying, and stronger for the lifestyle and antisocial facets, which tend to be more reflective of externalizing behaviors in general. One exception to this is that when lying versus telling the truth about noncriminal information, Facet 1 was positively associated with activity in the angular gyrus and frontopolar cortex. One possible explanation for the stronger associations with the lifestyle and antisocial facets is that individuals who are more impulsive and disinhibited may require more effort to perform the task, which relies on the ability to inhibit responses.

Although the majority of brain regions demonstrated positive correlations with psychopathy, a few negative correlations were observed. Interestingly, the orbitofrontal cortex was *positively* correlated with psychopathy scores for the contrasts involving criminal information, but was *negatively* associated with psychopathy scores (total and all facets) when participants lied versus told the truth about autobiographical information. Further, it was negatively correlated with the Affective facet (Facet 2) when participants lied versus told the truth in general. This is consistent with findings from the study by Fullam et al. (2009) which found negative correlations between scores on the Fearlessness subscale of the PPI (similar to Facet 2) and activity in the orbitofrontal cortex. They speculated that individuals with low levels of fear and harm avoidance may find it easier to lie, and therefore do not show activity in the orbitofrontal cortex. Some negative associations were also observed when participants lied versus told the truth about noncriminal information, primarily in the DLPFC.

The positive correlations between psychopathy and orbitofrontal cortex functioning when participants were instructed to lie about criminal information suggests that the content of the lie may have a significant influence. A previous study of deception by Abe et al. (2007) showed that the orbitofrontal/ventromedial region was more associated with the intent to deceive an interrogator – an aspect of deception that may be more emotional in nature – whereas lateral regions were associated with the process of falsifying truthful responses. Activity in the orbitofrontal/ventromedial prefrontal cortex was associated with more anxiety about deceiving the interrogator (Abe et al., 2007). The fact that we observe positive correlations between psychopathy and functioning in the orbitofrontal cortex when

falsifying information about criminal behavior specifically could reflect increased anxiety in individuals who may have previously committed some of these crimes. Future studies could help to clarify whether this is the case by assessing anxiety via self-report or physiological measures during the process of deception.

Limitations

Like many prior studies of lying using fMRI (Lee et al., 2002; Nunez et al., 2005), our task involved instructing participants to lie, and thus is not necessarily indicative of the process of lying in real-world situations. There were no consequences for telling a lie in this study, which likely reduced the emotional salience that may typically accompany lying. The task also did not require that the participant monitor his own behavior and that of the listener while lying, as would happen in a face-to-face interaction. Furthermore, we did not have a way to ascertain whether participants were actually telling the truth or lying, and it is possible that there are differences between people scoring high and low in psychopathy in how closely they followed instructions in the task. This is a problem that occurs in many brain imaging studies in which participants are required to follow instructions. In studies examining psychopathy – a construct associated with antisocial behavior – failure to comply may be especially problematic. Finally, the sample size in the present study was small. To account for this, we have done a few things: (1) we used ROI analyses to reduce the number of tests conducted, (2) we have utilized a more sensitive method (SnPM) to correct for multiple comparisons in order to avoid Type 2 error, and (3) we have tried to interpret general trends in our data rather than focusing on specific single findings.

Overall, our findings provide information about the neural correlates of the cognitive aspect of lying – falsifying information – in relation to psychopathic traits. Unlike prior neuroimaging studies of psychopathy which have focused on tasks involving the processing of emotion-related stimuli and have demonstrated reduced levels of functioning (Decety, Skelly, & Kiehl, 2013; Harenski, Harenski, Shane, & Kiehl, 2010; Marsh & Cardinale, 2012), our study suggests that, in some contexts, individuals scoring higher in psychopathic traits demonstrate increased levels of brain functioning. Future studies involving more ecologically valid and interactive experimental paradigms will likely help to further our

understanding of how the brains of individuals with psychopathic traits may function differently during

deception in real-world contexts.

Acknowledgments

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Table 1. Sample questions from each category. Participants were instructed to lie or tell the truth about each type of question, resulting in eight conditions for the task.

	Autobiographical	Non-autobiographical
Criminal	Have you ever robbed a person?	Is it a crime to break into someone's house?
Non-criminal	Did you drive a car to get here today?	Is California on the East Coast?

Table 2. Descriptive statistics for the PCL-R.

	Mean	SD	Range
Total PCL-R	22.7	8.8	7.4 - 35
Facet 1 (transformed)	6.2	2.6	1.25 – 8.75
Facet 2 (transformed)	7.1	3.3	0 – 10
Facet 3	6.5	2.3	2 – 10
Facet 4	4.0	2.6	0 – 9

Note. Facets 1 and 2 can range from 0 to 8 whereas Facets 3 and 4 can range from 0 to 10. In order to allow for direct comparisons of means and ranges across facets, we transformed scores on Facets 1 and 2 to a 0 to 10 scale.

Table 3. Overview of the significant associations with psychopathy total and facet scores for each contrast.

	Lie vs. truth	Criminal vs. non-criminal	Autobiographical lie vs. non-autobiographical lie	Autobiographical lie vs. autobiographical truth	Non-autobiographical lie vs. non-autobiographical truth	Criminal lie vs. non-criminal lie	Criminal lie vs. criminal truth	Non-criminal lie vs. non-criminal truth
Total Psychopathy								
Positive associations								
Anterior cingulate		+	+	+			+	
Lateral frontal cortex	+			+		+	+	
Insula	+			+	+	+	+	+
DLPFC			+	+			+	
DLPFC / Anterior cingulate						+		
Orbitofrontal cortex			+			+	+	
Frontopolar cortex	+	+	+	+	+	+	+	+
Supramarginal gyrus	+		+	+	+		+	+
Dorsomedial PFC			+	+				
Inferior frontal gyrus				+		+		
Temporal pole		+	+			+	+	
Angular gyrus			+				+	+
Inferior parietal lobe							+	
Postcentral gyrus			+			+	+	
Ventromedial PFC						+	+	
Negative associations								
Orbitofrontal cortex				-				-
Angular gyrus				-				-
DLPFC		-		-				-
Insula					-			
Dorsomedial PFC								-
Anterior cingulate								-
Frontopolar cortex								-
Postcentral gyrus								-

Interpersonal (Facet 1)									
Positive associations									
Lateral frontal cortex	+			+			+		
DLPFC			+	+	+			+	+
Insula	+			+	+		+	+	
Anterior cingulate		+		+			+	+	
Angular gyrus	+								+
Superior parietal lobule	+								
Supramarginal gyrus	+			+	+			+	+
Frontopolar cortex	+	+	+				+	+	+
Orbitofrontal cortex				+			+	+	
Dorsomedial PFC								+	
Temporal pole		+				+			+
Postcentral gyrus									+
Negative associations									
Temporal pole			-						
Frontopolar cortex				-					
DLPFC	-			-					
Angular gyrus			-						
Supramarginal gyrus			-						
Orbitofrontal cortex			-	-					
Affective (Facet 2)									
Positive associations									
Lateral frontal cortex	+		+	+			+	+	
Insula	+			+			+	+	+
DLPFC			+	+			+		
Frontopolar cortex	+	+	+	+	+		+	+	+
Supramarginal gyrus	+			+	+				+
Angular gyrus			+					+	
Orbitofrontal cortex			+				+	+	
Anterior cingulate		+		+			+	+	
Dorsomedial PFC			+				+	+	
Temporal pole							+		
Ventrolateral PFC							+		

Region	C1	C2	C3	C4	C5	C6	C7	C8
Superior parietal lobule	+							
Postcentral gyrus								+
Negative associations								
Orbitofrontal cortex	-			-				-
DLPFC	-	-			-			-
Ventrolateral PFC			-					-
Frontopolar cortex				-				-
Temporal pole			-					
Insula					-			
Supramarginal gyrus					-			
Anterior cingulate								-
Medial PFC								-
Lateral PFC								-
Angular gyrus		-						
Lifestyle (Facet 3)								
Positive associations								
DLPFC	+		+	+		+	+	
Anterior cingulate		+		+		+	+	
Lateral PFC				+		+	+	
Orbitofrontal cortex			+			+	+	
Insula	+		+	+		+	+	+
Dorsomedial PFC			+	+		+		
Angular gyrus				+			+	+
Supramarginal gyrus			+	+	+	+	+	+
Frontopolar cortex	+	+	+	+	+	+		+
Temporal pole			+			+	+	
Postcentral gyrus			+					+
Supramarginal gyrus	+							
Ventrolateral PFC						+	+	
Negative associations								
Orbitofrontal cortex				-				-
Insula					-			
DLPFC								-
Frontopolar cortex								-
Ventrolateral PFC								-

Region									
Dorsomedial PFC									-
Anterior cingulate									-
Angular gyrus									-
Antisocial (Facet 4)									
Positive associations									
Orbitofrontal cortex	+					+	+	+	
Frontopolar cortex	+	+	+	+	+	+	+	+	
Lateral PFC	+			+			+	+	
Insula	+		+	+	+		+	+	
Temporal pole			+				+		
Angular gyrus			+	+				+	
Supramarginal gyrus	+		+		+		+	+	
DLPFC			+	+			+		
Dorsomedial PFC	+		+	+	+				
Anterior cingulate	+	+	+	+	+				
Ventrolateral PFC						+	+	+	
Ventromedial PFC	+								
Middle frontal gyrus	+								
Negative associations									
Angular gyrus				-					-
Orbitofrontal cortex			-	-					-
Temporal pole	-			-					
Inferior parietal lobule					-				
Insula					-				-
Anterior cingulate									-
DLPFC									-
Frontopolar cortex									-

Note. This table is intended to provide an easier comparison of associations from the different contrasts. Between the different contrasts, associations for each region do not represent the exact same coordinates, but are found within the specified brain region. For specific coordinates, see Tables 4-8, S4 and S6. Black shading indicates significance at $p < 0.05$ after FWE correction. Dark gray shading indicates significance at $p < 0.01$ uncorrected for voxel-wise comparison. Light grey shading indicates significant at $p < 0.05$ uncorrected for voxel-wise comparison.

Table 4. Brain regions associated with psychopathy scores for the contrast lie vs. truth.

	BA	x	y	z	T
Total Psychopathy					
Positive associations					
Frontopolar cortex	**10**	**-28**	**62**	**8**	**3.01**
		-14	**60**	**4**	**2.75**
		-22	62	10	2.57
		8	64	14	2.17
		24	58	2	2.17
Supramarginal gyrus	40	-44	-48	36	2.58
		-54	-42	42	2.05
Insula	13	-36	-6	22	2.57
Lateral frontal cortex	9	-46	-2	24	1.93
Negative associations					
None					
Interpersonal (Facet 1)					
Positive associations					
Angular gyrus	**40**	**-46**	**-50**	**40**	**2.69**
Insula	13	28	-32	18	2.53
		-60	-44	20	2.08
Superior parietal lobule	40	50	-40	60	2.45
Supramarginal gyrus	40	-66	-42	22	2.31
Frontopolar cortex	10	-34	62	8	2.15
		-36	60	14	1.84
Lateral frontal cortex	9	-46	2	24	2.09
		48	0	24	2.08
Negative associations					
DLPFC	10	-32	56	28	-2.18
Affective (Facet 2)					
Positive associations					
Frontopolar cortex	**10**	**-28**	**62**	**6**	**2.97**
		-12	64	6	2.62
		-22	64	10	2.26
		6	64	14	2.06
		24	58	2	1.78
		22	56	-6	2.15
Supramarginal gyrus	**40**	**-44**	**-48**	**36**	**2.67**
		-62	-50	22	2.08
Insula	13	-36	-6	22	2.47
Superior parietal lobule	40	52	-36	60	1.97
Lateral frontal cortex	9	-46	-2	24	1.89
Negative associations					
Orbitofrontal cortex	11	44	46	-14	-1.81
DLPFC	10	-32	58	24	-1.85

Lifestyle (Facet 3)					
Positive associations					
Supramarginal gyrus	**40**	**-44**	**-46**	**36**	**2.82**
		36	-50	44	2.24
Frontopolar cortex	10	-14	60	4	2.62
		-28	62	6	2.59
		-22	66	10	2.35
		8	64	14	2.21
		40	60	12	2.07
		22	56	-6	1.94
Insula	13	-46	-46	18	2.47
DLPFC	9	-50	4	34	2.02
		52	18	26	1.94
Negative associations					
None					
Antisocial (Facet 4)					
Positive associations					
Frontopolar cortex	**10, 11, 32**	**-14**	**60**	**4**	**4.13**
	10, 11, 32	**16**	**56**	**2**	**3.42**
	10	-26	62	-6	1.96
Orbitofrontal cortex	**11**	**24**	**50**	**-14**	**2.81**
Insula	**13**	**-38**	**-2**	**18**	**2.74**
Anterior cingulate	9, 32	20	34	24	2.49
	32	-2	40	-4	1.87
Ventromedial PFC	11,32	-4	40	-18	2.36
Dorsomedial PFC	9, 10, 32	-10	40	28	2.28
		14	48	10	2.22
Middle frontal gyrus	10	34	40	10	2.11
Supramarginal gyrus	40	-60	-64	32	1.92
Lateral PFC	10	-36	38	14	1.88
Negative associations					
Temporal pole	38	**-34**	**20**	**-30**	**-3.21**
		32	**16**	**-28**	**-2.66**

Note. Bold indicates that associations were significant at *p* < 0.01 uncorrected for voxel-wise comparison.

Table 5. Brain regions associated with psychopathy (total and facet) scores for the contrast autobiographical lie vs. non-autobiographical lie.

	BA	x	y	z	T
Total psychopathy					
Positive associations					
DLPFC	**8, 9**	**40**	**36**	**38**	**3.34**
Frontopolar cortex	**10**	**36**	**64**	**6**	**2.96**
Dorsomedial PFC	**8**	**4**	**42**	**46**	**2.94**
		-16	**30**	**58**	**2.84**
		2	**22**	**56**	**2.70**
		-2	**40**	**46**	**2.69**
		-2	20	58	2.42
Supramarginal gyrus	**40**	**62**	**-56**	**24**	**2.82**
		-44	-32	32	2.38
Angular gyrus	40	46	-66	44	2.61
Anterior cingulate	32	-8	8	52	2.24
Postcentral gyrus	40	38	-30	50	2.12
Orbitofrontal cortex	11	24	52	-10	2.05
	10	22	56	-8	1.81
Temporal pole	38	-42	20	-22	2.03
Negative associations					
None					
Interpersonal (Facet 1)					
Positive associations					
Frontopolar cortex	9	28	52	38	2.29
	10	40	54	24	1.80
	10	42	56	18	1.78
DLPFC	8	32	18	58	2.27
	9	58	20	30	2.13
	9	-56	12	38	1.98
Negative associations					
Temporal pole	**38**	**52**	**16**	**-16**	**-2.80**
		-32	8	-22	-2.40
Angular gyrus	40	-54	-62	42	-2.33
Supramarginal gyrus	40	-60	-62	30	-2.11
Orbitofrontal cortex	11	42	36	-14	-1.86
Affective (Facet 2)					
Positive associations					
DLPFC	**8, 9**	**34**	**30**	**50**	**3.41**
	9	-44	32	42	2.34
	10	40	40	28	2.29
	8, 9	-54	12	42	2.24
Lateral PFC	**9**	**54**	**0**	**26**	**2.68**
Frontopolar cortex	10	18	66	22	2.48
		2	54	8	2.02

Dorsomedial PFC	8	4	42	46	2.47
		2	22	56	2.36
		-2	40	46	2.34
Orbitofrontal cortex	11	24	52	-10	2.12
Angular gyrus	40	60	-56	26	1.92
Negative associations					
Temporal pole	38	-32	8	-24	-2.26
Ventrolateral PFC	10	46	54	-6	-1.89
Lifestyle (Facet 3)					
Positive associations					
DLPFC	**8, 9, 10, 32**	**38**	**34**	**36**	**5.21**
	9	36	4	28	1.89
	9	-46	2	36	1.80
Dorsomedial PFC	**8**	**-16**	**30**	**56**	**3.98**
	8, 9, 10, 32	**-2**	**20**	**56**	**3.76**
Supramarginal gyrus	**40**	**-54**	**-30**	**32**	**3.48**
	40	**62**	**-56**	**24**	**3.19**
Temporal pole	**38**	**-44**	**20**	**-24**	**3.45**
Frontopolar cortex	**10**	**36**	**64**	**6**	**3.05**
	10, 32	-14	54	2	2.42
	10	-28	56	-2	2.40
	9	-30	50	36	2.09
	10	10	52	16	1.88
Postcentral gyrus	**40**	**38**	**-30**	**50**	**2.82**
Insula	13	26	20	-10	2.63
		-40	24	8	2.46
Orbitofrontal cortex	11	24	52	-10	2.21
	11	24	26	-14	2.18
Negative associations					
None					
Antisocial (Facet 4)					
Positive associations					
Supramarginal gyrus	**40**	**62**	**-52**	**24**	**3.89**
Frontopolar cortex	**10**	**36**	**64**	**6**	**3.28**
		-4	**66**	**10**	**2.84**
		2	66	12	2.27
DLPFC	**8, 9**	**28**	**42**	**44**	**3.03**
	8, 9	-28	40	44	2.54
	9	-32	46	34	2.36
	9	52	0	26	1.98
Dorsomedial PFC	**8**	**4**	**42**	**48**	**2.72**
	8	-2	40	46	2.56
	8, 32	2	14	54	2.09
	8	-16	30	58	2.08

Region					
Supramarginal gyrus	**40**	**-44**	**-32**	**32**	**2.67**
	40	38	-30	50	2.48
Angular gyrus	40	44	-66	44	2.52
Anterior cingulate	32	-8	8	52	2.43
Insula	13	36	-22	22	2.15
		-36	-18	22	2.09
Temporal pole	38	-44	20	-24	1.89
Negative associations					
Orbitofrontal cortex	11	42	50	-14	-2.13
		-38	34	-14	-1.88

Note. Bold indicates that associations were significant at $p < 0.01$ uncorrected for voxel-wise comparison.

Table 6. Brain regions associated with psychopathy (total and facet) scores for the contrast autobiographical lie vs. autobiographical truth.

	BA	x	y	z	T
Total psychopathy					
Positive associations					
Lateral frontal cortex	**9**	**-36**	**4**	**28**	**3.31**
		-46	**12**	**30**	**3.01**
		48	16	28	2.41
		-30	12	42	1.96
Insula	**13**	**-34**	**-6**	**22**	**3.38**
		42	12	14	2.23
Frontopolar cortex	**10**	**-22**	**62**	**10**	**3.20**
		-30	62	0	2.34
		-14	60	4	2.17
		24	54	6	2.06
Supramarginal gyrus	**40**	**-44**	**-34**	**32**	**3.19**
		-44	**-42**	**36**	**2.74**
Inferior frontal gyrus	**9**	**34**	**4**	**28**	**2.88**
Anterior cingulate	32	12	34	-8	2.46
		18	34	24	2.02
		-16	12	38	1.91
DLPFC	9	30	36	30	2.26
	10	40	40	20	2.07
Dorsomedial PFC	9	-4	40	34	2.22
	8	2	20	54	2.20
	9	2	40	36	2.07
	8	-4	24	56	2.03
Negative associations					
Orbitofrontal cortex	11	42	48	-14	-2.38
Angular gyrus	40	40	-58	42	-1.87
DLPFC	10	-32	58	26	-1.83
Interpersonal (Facet 1)					
Positive associations					
Lateral PFC	**8, 9**	**-62**	**4**	**24**	**3.23**
	9	**46**	**-2**	**24**	**2.88**
DLPFC	8	30	12	42	2.41
	9	-54	20	38	2.35
	8	-28	12	42	1.94
Insula	**13**	**-36**	**-6**	**22**	**2.79**
		28	**-32**	**18**	**2.79**
Frontopolar cortex	10	-34	62	8	2.37
	10	-36	60	14	2.05
Supramarginal gyrus	40	-42	-32	32	2.36
	40	-44	-42	36	2.22
Anterior cingulate	32	-16	10	48	2.18
	10, 32	12	34	-10	2.03
	32	16	8	38	2.02

Orbitofrontal cortex	11	24	42	-10	2.17
Negative associations					
Frontopolar cortex	10	-32	56	28	-2.41
	10	22	62	18	-2.01
	10	-4	60	16	-1.81
Orbitofrontal cortex	11	42	50	-14	-1.88
DLPFC	8	20	32	58	-1.81
Affective (Facet 2)					
Positive associations					
Lateral PFC	**9**	**-36**	**4**	**28**	**3.53**
	8, 9	**-46**	**10**	**30**	**2.77**
	9	36	4	28	2.53
Insula	**13**	**-34**	**-6**	**22**	**3.46**
		42	10	12	2.01
Frontopolar cortex	**10**	**-30**	**64**	**4**	**3.10**
	10	-38	60	2	2.46
Supramarginal gyrus	**40**	**-44**	**-34**	**32**	**2.93**
	40	-44	-42	36	2.41
Anterior cingulate	10, 32	12	34	-10	2.49
DLPFC	9	-54	20	38	2.17
	8	-28	12	42	1.84
Negative associations					
Frontopolar cortex	10	-32	58	26	-2.35
Orbitofrontal cortex	11	42	48	-14	-2.31
Lifestyle (Facet 3)					
Positive associations					
Lateral PFC	**8, 9**	**-48**	**12**	**32**	**4.13**
	9	**-38**	**4**	**28**	**3.58**
	9	**48**	**16**	**28**	**3.43**
	9	**36**	**4**	**30**	**3.39**
	9	**-54**	**26**	**34**	**3.10**
	8	28	12	42	1.99
Angular gyrus	**40**	**-44**	**-34**	**32**	**3.97**
Frontopolar cortex	**10**	**-28**	**62**	**8**	**3.54**
	10	**40**	**40**	**24**	**3.24**
	10	-14	58	4	2.38
	9, 10	-38	40	24	2.32
	10	-36	60	14	2.30
	10	24	54	6	2.10
Dorsomedial PFC/ Anterior cingulate	**8, 9, 10, 32**	**4**	**18**	**52**	**3.08**
	9, 10, 32	**-6**	**48**	**26**	**2.84**
Insula	**13**	**-34**	**-6**	**22**	**3.05**
		28	-32	20	2.59
Anterior cingulate	**8, 32**	**-4**	**22**	**46**	**2.69**
	32	**-16**	**12**	**38**	**2.65**
	10, 32	12	34	-8	2.48

	32	-12	22	26	2.46
	10, 32	8	50	-4	2.04
DLPFC	9	22	44	36	2.27
	8	-22	16	48	1.84
Supramarginal gyrus	40	62	-32	38	2.23
Negative associations					
Orbitofrontal cortex	11	42	48	-14	-1.91
Antisocial (Facet 4)					
Positive associations					
Frontopolar cortex	**10**	**-22**	**62**	**10**	**4.18**
	10	**-28**	**62**	**8**	**3.77**
	10	**24**	**56**	**8**	**3.09**
	10	**-14**	**60**	**4**	**2.75**
	10, 32	14	56	4	2.46
	10	40	40	22	2.32
Insula	**13**	**-36**	**-6**	**22**	**2.71**
		42	12	14	2.06
Lateral PFC	9	50	18	26	2.54
	9	-46	12	30	2.30
	9	-40	26	38	2.30
Angular gyrus	40	-46	-36	36	2.50
Anterior cingulate	9, 32	-18	38	26	2.30
	9	-6	48	26	2.29
	9, 32	20	36	24	2.27
	10, 32	12	34	-8	2.15
Dorsomedial PFC	9	4	48	34	2.20
DLPFC	9	34	34	34	1.91
Negative associations					
Angular gyrus	40	46	-64	42	-2.38
	40	-42	-66	48	-1.88
Orbitofrontal cortex	11	42	48	-14	-2.13
Temporal pole	38	-32	8	-22	-2.10

Note. Bold indicates that associations were significant at $p < 0.01$ uncorrected for voxel-wise comparison.

Table 7. Brain regions associated with psychopathy (total and facet) scores for the contrast criminal lie vs. non-criminal lie.

	BA	x	y	z	T
Total psychopathy					
Positive associations					
Dorsal PFC / Anterior cingulate	**8, 9, 10, 11, 32**	**18**	**36**	**22**	**3.89**
		-10	**48**	**26**	**3.72**
	32	16	12	38	2.07
	32	18	6	50	1.98
	8	4	24	50	1.77
Orbitofrontal cortex	**10, 11**	**28**	**42**	**-6**	**3.73**
	11	**-24**	**28**	**-12**	**2.73**
Insula	**13**	**-44**	**24**	**10**	**3.42**
		42	**12**	**12**	**3.34**
Frontopolar cortex	**10,11**	**-28**	**56**	**8**	**3.26**
Lateral frontal cortex	**9**	**44**	**-4**	**26**	**3.15**
		36	**4**	**28**	**2.74**
		-36	4	28	2.63
Inferior frontal gyrus	10	54	42	0	2.47
		-52	42	0	1.93
DLPFC	9	-30	50	36	2.21
	8	-28	12	42	2.15
	8	-20	28	58	2.13
	9	-54	20	38	2.10
Ventromedial PFC	10	10	56	-6	2.18
Postcentral gyrus	40	64	-22	20	1.91
Temporal pole	**38**	**50**	**0**	**-12**	**2.73**
Negative associations					
None					
Interpersonal (Facet 1)					
Positive associations					
Lateral PFC	9	-48	16	28	2.15
	9	-48	34	36	2.14
Frontopolar cortex	10	-38	58	14	1.97
Anterior cingulate	32	-6	24	-8	1.97
Orbitofrontal cortex	11	38	36	-12	1.79
Insula	13	-36	-6	20	2.21
		28	20	-4	1.94
Negative associations					
None					
Affective (Facet 2)					
Positive associations					
Frontopolar cortex	**10**	**-46**	**46**	**16**	**3.10**
	10, 32	-20	50	2	1.98

Orbitofrontal cortex	**10, 11**	**28**	**42**	**-6**	**2.93**
	11	**-30**	**42**	**-6**	**2.85**
Insula	**13**	**42**	**12**	**12**	**2.91**
		-34	4	18	2.63
Anterior cingulate	**9, 10, 32**	**18**	**36**	**22**	**2.83**
	8, 9, 10, 32	**-18**	**42**	**16**	**2.82**
	32	4	32	-6	2.28
	32	-16	10	40	2.15
	32	10	16	30	1.84
Lateral PFC	9	44	-4	26	2.56
	9	-52	28	36	2.55
	9	-36	4	28	2.13
Temporal pole	38	50	0	-12	2.33
Ventrolateral PFC	10	54	40	0	2.19
DLPFC	9	34	32	34	2.18
	9	-18	48	36	2.15
Dorsomedial PFC	9	12	48	26	2.04
Negative associations					
None					
Lifestyle (Facet 3)					
Positive associations					
Orbitofrontal cortex	**10, 11**	**28**	**42**	**-6**	**4.14**
	11	**-26**	**38**	**-6**	**3.08**
	11	**-24**	**30**	**-12**	**2.94**
Anterior cingulate	**8, 9, 10, 11, 32**	**18**	**36**	**22**	**4.05**
	8, 9, 10, 11, 32	**-4**	**32**	**-6**	**3.96**
Lateral PFC	**9**	**44**	**-4**	**26**	**3.61**
		-36	4	28	2.47
Insula	**13**	**42**	**12**	**12**	**3.39**
		-44	**24**	**10**	**3.33**
Frontopolar cortex	**10**	**-24**	**52**	**8**	**3.11**
DLPFC	**9**	**30**	**32**	**34**	**2.70**
	9	-30	50	36	2.50
	8	-28	12	42	2.26
	8	-16	30	54	2.25
	9	-54	20	38	2.16
Ventrolateral PFC	**10**	**54**	**40**	**0**	**2.70**
		-52	42	0	1.78
Temporal pole	38	50	0	-12	2.34
Supramarginal gyrus	40	64	-22	20	2.05
		54	-30	24	1.96
Anterior cingulate	32	16	4	42	1.96
Dorsomedial PFC	8	8	36	50	1.89
		14	38	54	1.80
Negative associations					

None					
Antisocial (Facet 4)					
Positive associations					
Orbitofrontal cortex	**8, 9, 10, 11, 32**	**-12**	**34**	**-10**	**5.16**
	11	**-24**	**28**	**-12**	**3.79**
	11	**34**	**38**	**-12**	**3.14**
Frontopolar cortex	**8, 9, 10, 11, 32**	**6**	**60**	**16**	**4.58**
Insula	**13**	**42**	**12**	**12**	**3.73**
		-44	**24**	**10**	**3.57**
Temporal pole	**38**	**50**	**0**	**-12**	**3.35**
		-54	0	-8	2.14
Supramarginal gyrus	**40**	**66**	**-24**	**18**	**3.11**
	40	-56	-26	14	2.16
	40	50	-30	32	2.16
	40	-62	-24	30	1.84
DLPFC	**9**	**-30**	**50**	**36**	**2.95**
Lateral PFC	**9**	**-36**	**4**	**28**	**2.88**
	9	**36**	**4**	**28**	**2.86**
Ventrolateral PFC	10	-52	42	0	2.18
Negative associations					
None					

Note. Underline indicates that associations were significant at $p < 0.05$ after FWE correction. Bold indicates that associations were significant at $p < 0.01$ uncorrected for voxel-wise comparison.

Table 8. Brain regions associated with psychopathy (total and facet) scores for the contrast criminal lie vs. criminal truth.

	BA	x	y	z	T
Total psychopathy					
Positive associations					
Anterior cingulate	**8, 9, 10, 11, 32**	**20**	**36**	**22**	**4.54**
Lateral PFC	**9**	**36**	**4**	**28**	**4.26**
		-36	**4**	**28**	**4.01**
		40	**40**	**22**	**3.38**
Insula	**13**	**-34**	**-6**	**22**	**4.28**
		32	**6**	**18**	**3.58**
DLPFC	**8, 9, 10, 32**	**-34**	**20**	**34**	**4.12**
Frontopolar cortex	**10, 11**	**24**	**50**	**4**	**3.21**
Inferior parietal lobule	40	-58	-42	48	2.59
Angular gyrus	40	42	-52	52	2.56
Temporal pole	38	-46	-46	18	2.42
Orbitofrontal cortex	11	-26	38	-6	2.33
		24	34	-12	1.81
Supramarginal gyrus	40	-44	-48	34	2.21
Ventromedial PFC	10	10	56	-6	2.15
Postcentral gyrus	40	62	-30	18	1.88
Negative associations					
None					
Interpersonal (Facet 1)					
Positive associations					
DLPFC	**8, 9, 32**	**30**	**12**	**42**	**3.11**
	9	**36**	**4**	**32**	**2.84**
	8, 9, 10, 32	**-42**	**16**	**54**	**2.67**
	9	-38	4	32	2.40
	9	-20	38	36	2.09
	10	32	42	28	1.77
Insula	**13**	**-34**	**-6**	**22**	**3.07**
		40	-40	20	2.07
Anterior cingulate	32	-14	4	42	3.00
		16	4	46	2.40
		10	22	26	2.13
		-12	24	26	2.07
	9, 32	6	38	20	1.88
Supramarginal gyrus	40	-58	-42	48	2.36
		52	-36	60	2.05
		56	-32	54	2.00
Orbitofrontal cortex	11	24	38	-6	2.21
Dorsomedial PFC	9	-4	44	38	2.09
	8	-20	30	56	1.92

Region	BA	x	y	z	value
Frontopolar cortex	10	-20	48	0	1.81
Negative associations					
None					
Affective (Facet 2)					
Positive associations					
Lateral PFC	**9**	**36**	**4**	**28**	**4.09**
	9	**-36**	**4**	**28**	**3.82**
	8, 9, 10, 32	**40**	**2**	**28**	**3.77**
	8, 9, 10, 32	**-40**	**20**	**34**	**3.72**
	9, 10	**34**	**40**	**22**	**2.79**
Insula	**13**	**-34**	**-6**	**22**	**4.05**
		32	**4**	**18**	**3.36**
Angular gyrus	**40**	**-52**	**-52**	**50**	**2.89**
	40	**42**	**-42**	**40**	**2.69**
	40	-44	-48	34	2.02
	40	38	-38	60	2.02
Orbitofrontal cortex	10, 11	26	54	-2	2.62
	11	-26	38	-6	2.38
	10, 32	20	50	2	2.30
	10, 32	-18	44	-2	2.06
Anterior cingulate	10, 32	2	36	-2	2.11
Frontopolar cortex	10	-14	62	24	2.03
Dorsomedial PFC	8	-18	46	44	1.80
Negative associations					
None					
Lifestyle (Facet 3)					
Positive associations					
Anterior cingulate	**8, 9, 10, 11, 32**	**20**	**36**	**24**	**5.04**
DLPFC	**9**	**36**	**4**	**32**	**4.85**
Lateral PFC	**8, 9, 10, 11, 32**	**-42**	**40**	**24**	**4.74**
	9	**-36**	**4**	**28**	**4.44**
	40	-64	-24	22	1.99
Insula	**13**	**-34**	**0**	**18**	**4.11**
		32	**6**	**18**	**3.74**
Angular gyrus	**40**	**46**	**-46**	**46**	**3.52**
	40	54	-56	32	2.04
Supramarginal gyrus	**40**	**-62**	**-24**	**30**	**3.20**
DLPFC	9	-30	50	36	2.35
Temporal pole	38	50	-2	-8	2.15
Orbitofrontal cortex	11	24	34	-12	2.05
	10	-10	56	-6	1.89
Ventrolateral PFC	10	-52	42	0	1.81
Negative associations					

None					
Antisocial (Facet 4)					
Positive associations					
Frontopolar cortex	**8, 9, 10, 11, 32**	**8**	**62**	**16**	**4.83**
	8, 9, 10, 11, 32	**-22**	**62**	**10**	**4.58**
	10	**-26**	**58**	**8**	**3.89**
Lateral PFC	**9**	**-36**	**4**	**28**	**3.51**
	9	**36**	**4**	**28**	**3.23**
	9	-54	20	38	2.64
Insula	**13**	**-34**	**0**	**18**	**3.24**
		32	**6**	**18**	**3.14**
Angular gyrus	**40**	**52**	**-48**	**46**	**3.06**
Supramarginal gyrus	**40**	**-66**	**-26**	**30**	**2.71**
	40	-44	-48	34	2.33
	40	-64	-24	22	2.18
Orbitofrontal cortex	11	-44	34	-14	2.48
	11	46	44	-10	1.96
Ventrolateral PFC	10	50	42	0	2.26
	10	-52	42	0	2.15
Negative associations					
None					

Note. Underline indicates that associations were significant at $p < 0.05$ after FWE correction. Bold indicates that associations were significant at $p < 0.01$ uncorrected for voxel-wise comparison.
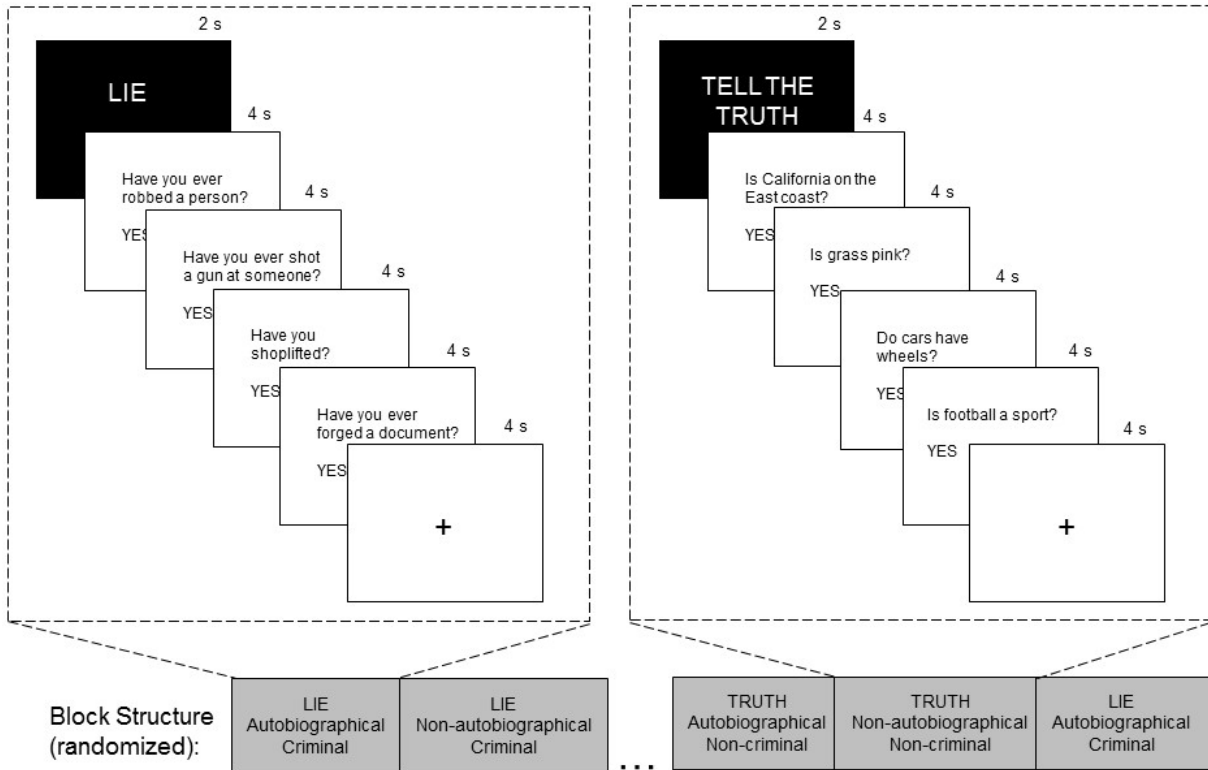
Figure 1. Schematic of task structure. In separate blocks, participants were instructed to lie or tell the truth about each type of question. Participants indicated "yes" by pressing the left button and "no" by pressing the right button on a button box. The 16-second period in which participants answered the four questions was modeled for each block.
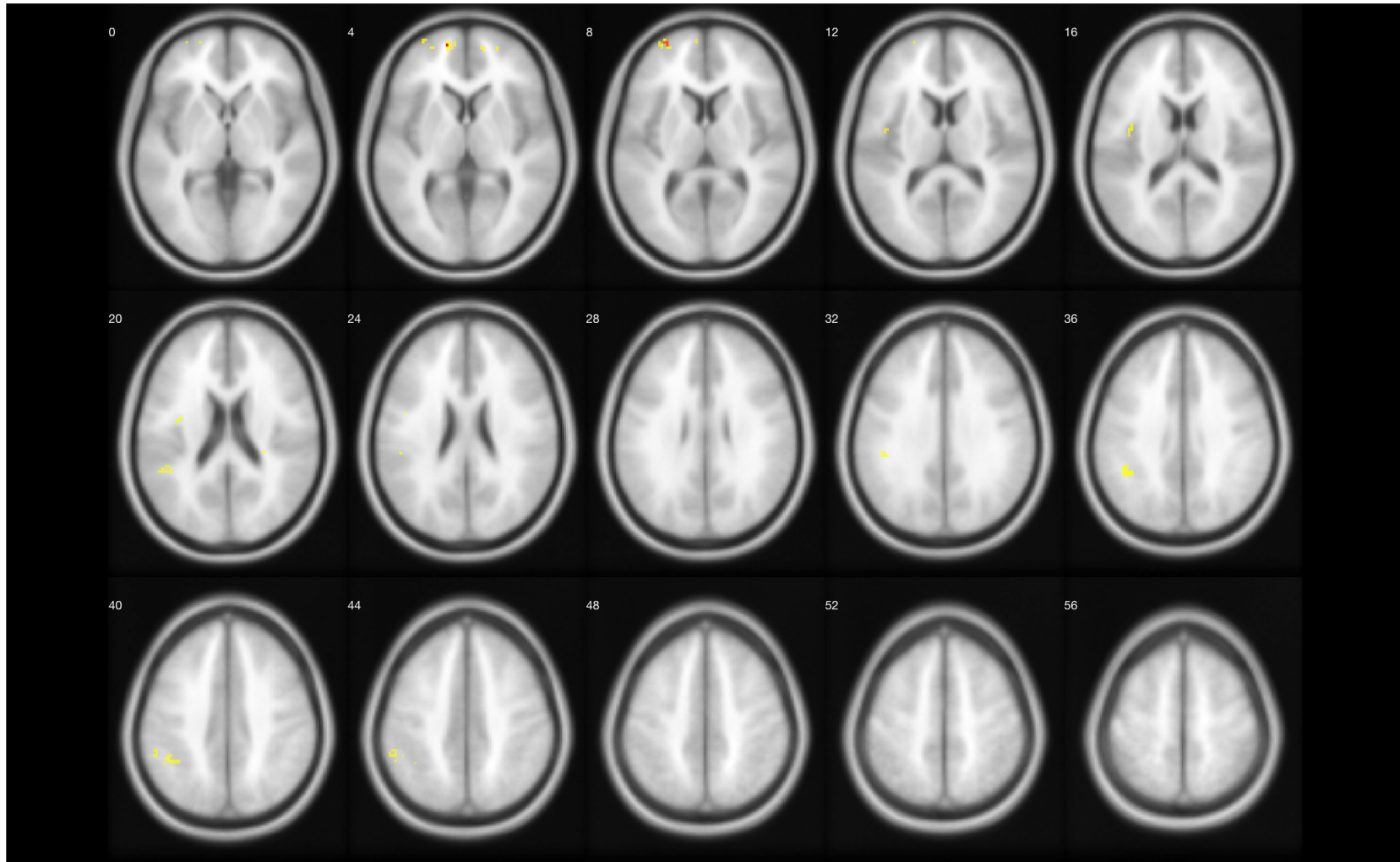
Figure 2. Brain areas in which total psychopathy scores were positively associated with activity during the contrast lie versus truth (Table 4). Yellow: $p < 0.05$ uncorrected voxel-wise

Orange and red: $p < 0.01$ uncorrected voxel-wise
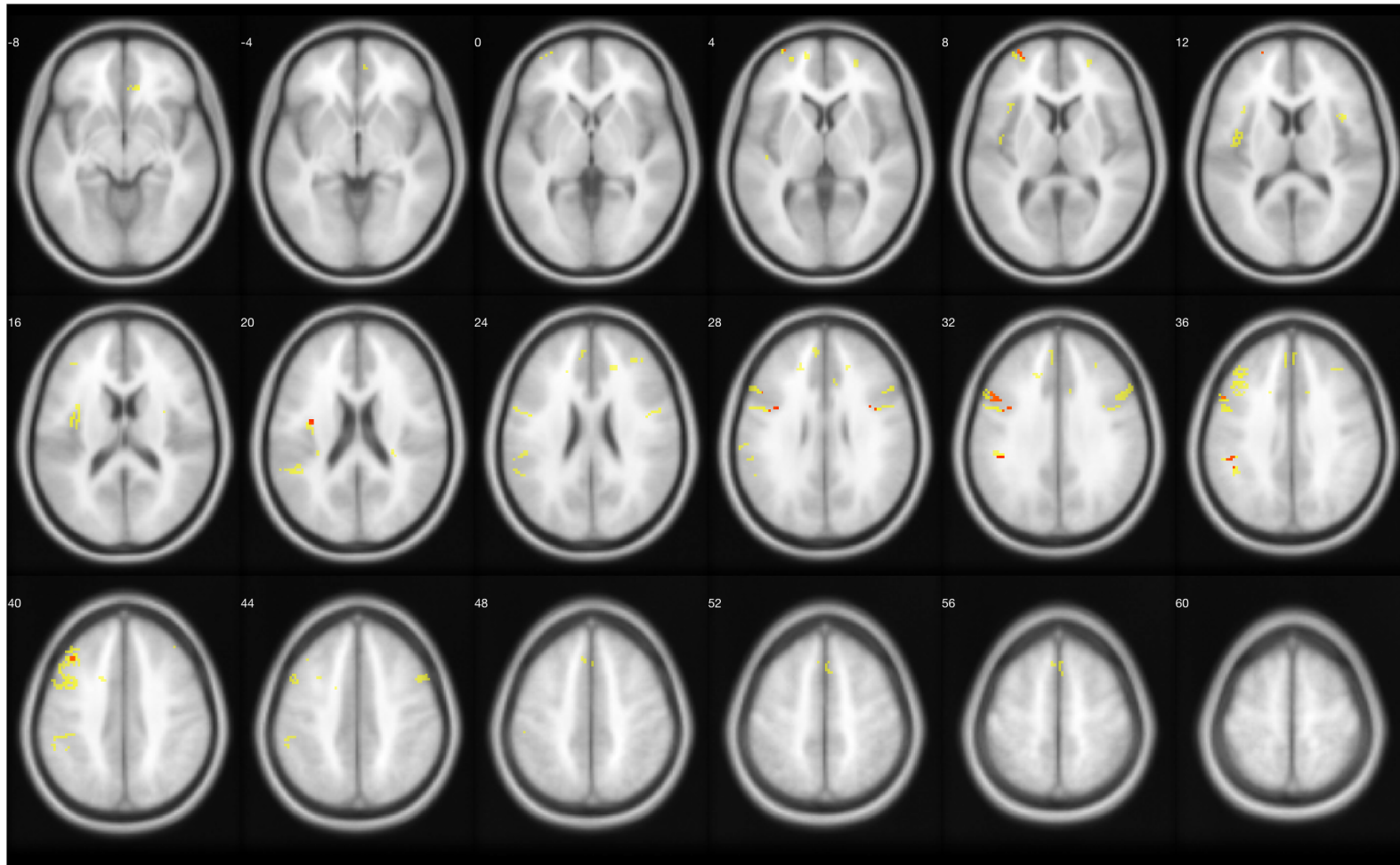
Figure 3. Brain areas in which total psychopathy scores were positively associated with activity during the contrast autobiographical lie versus autobiographical truth (Table 6).
Yellow: $p < 0.05$ uncorrected voxel-wise

Orange and red: $p < 0.01$ uncorrected voxel-wise
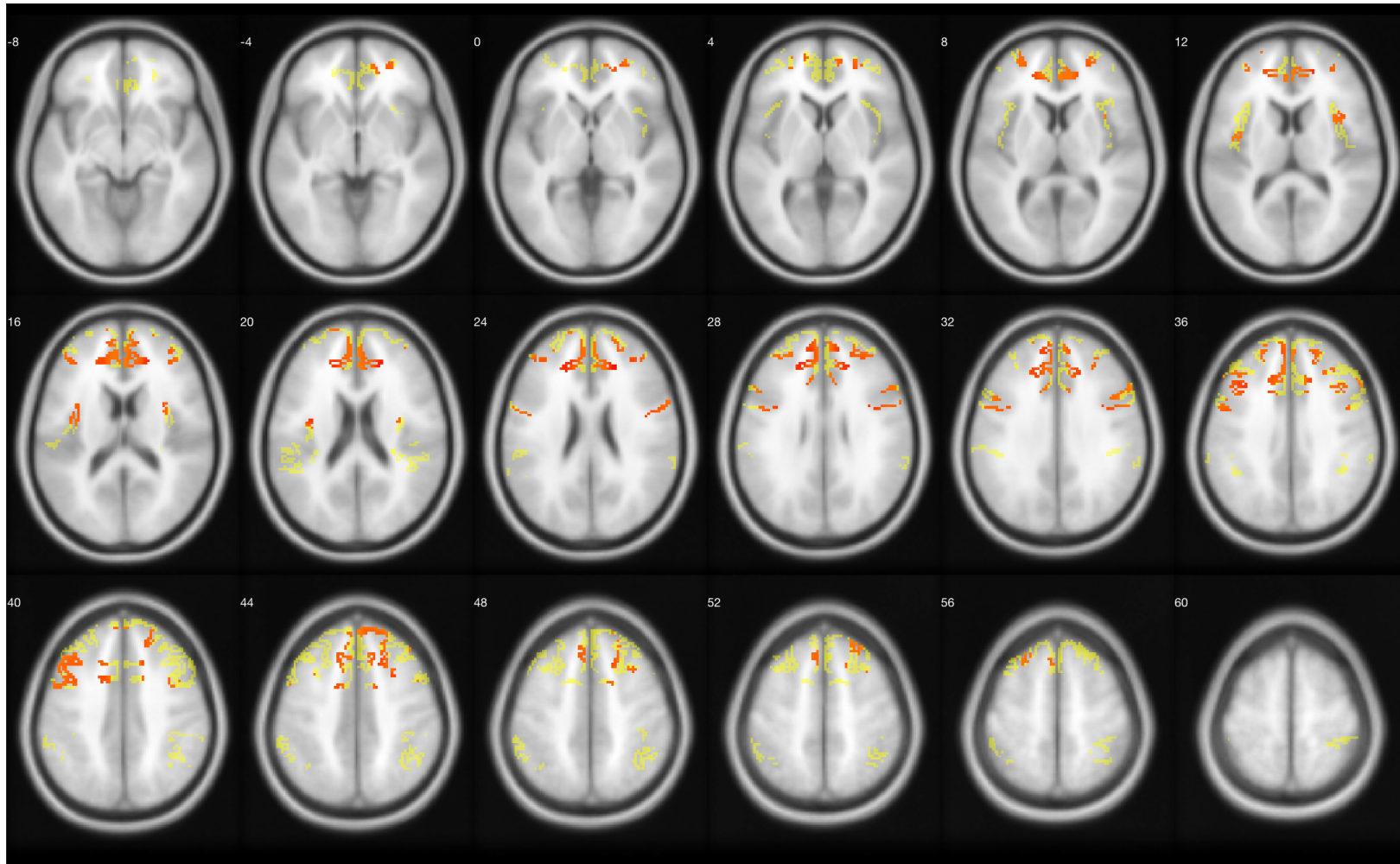
Figure 4. Brain areas in which total psychopathy scores were positively associated with activity for the contrast criminal lie versus criminal truth (Table 8).
Yellow: $p < 0.05$ uncorrected voxel-wise Orange and red: $p < 0.01$ uncorrected voxel-wise

Supplementary Materials for Glenn, A.L., Han, H. Yang, Y. Raine, A. & Schug, R.A. Associations between psychopathic traits and brain activity during instructed false responding.

Supplementary Methods:

Because of the correlation nature of our study, it was not feasible to first conduct higher-level interactions before examining simple contrasts. The interaction analyses (e.g., lie x autobiographical) would have reflected regions in which psychopathy scores were correlated with the interaction term (F-value). Within each significant region, we would need to figure out how that interaction term was arrived upon for each individual (e.g., what the plot of activity for the lie x autobiographical interaction looks like), and it is likely that these interactions would be different for each person. Thus, we did not think that interaction analyses would provide useful information. Follow-up tests examining simple contrasts (of the type presented in the current study) reflect a different correlation test that is not related to the correlation test that would have been conducted in an interaction analysis.

Supplementary Results:

Table S1. Brain areas active for the contrast lie versus truth across the whole sample (main effect). A voxel-wise threshold of $p < 0.05$ FWE and a cluster-wise threshold of $p < 0.001$ after applying SnPM was used and 5,000 permutations were performed.

	BA	x	y	z	T	k
DLPFC	8,9	40	18	50	4.82	313
Frontopolar cortex	10	40	56	14	4.57	134
Inferior parietal lobule	40	50	-44	50	4.42	162

Table S2. Overview of the strongest associations with psychopathy total and facet scores for each contrast.

	Lie vs. truth	Criminal vs. non-criminal	Autobiographi cal lie vs. non-autobiographic al lie	Autobiographical lie vs. autobiographical truth	Non-autobiographical lie vs. non-autobiographical truth	Criminal lie vs. non-criminal lie	Criminal lie vs. criminal truth	Non-criminal lie vs. non-criminal truth
	r	r	r	r	r	r	r	r
Total Psychopathy								
Positive association								
Anterior cingulate		0.51	0.53	0.56			**0.78**	
Lateral frontal cortex	0.47			**0.68**		**0.66**	0.76	
Insula	0.58			**0.68**	0.45	**0.69**	0.76	0.55
DLPFC			**0.68**	0.53		0.52	**0.75**	
DLPFC / Anterior cingulate						**0.73**		
Orbitofrontal cortex			0.49			**0.72**	0.54	
Frontopolar cortex	**0.64**	**0.65**	**0.63**	**0.66**	**0.65**	**0.67**	0.66	**0.73**
Supramarginal gyrus	0.58		**0.62**	**0.66**	**0.61**		0.52	0.49
Dorsomedial PFC			**0.63**	0.52				
Inferior frontal gyrus				**0.62**		0.57		
Temporal pole		0.49	0.49			**0.60**	0.56	
Angular gyrus			0.59				0.58	**0.61**
Inferior parietal lobe							0.58	
Postcentral gyrus			0.51			0.47	0.46	0.58
Ventromedial PFC						0.52	0.51	
Negative association								
Orbitofrontal cortex				-0.55				-0.61
Angular gyrus				-0.46				-0.48
DLPFC		-0.49		-0.45				**-0.63**
Insula					-0.46			
Dorsomedial PFC								**-0.63**
Anterior cingulate								-0.56

Frontopolar cortex								-0.44
Postcentral gyrus								0.50
Interpersonal (Facet 1)								
Positive association								
Lateral frontal cortex	0.50			**0.67**		0.51		
DLPFC			0.53	0.56	0.51		**0.65**	
Insula	0.57			0.61	0.51	0.52	**0.65**	**0.65**
Anterior cingulate		0.53		0.52		0.48	**0.64**	
Angular gyrus	**0.60**							**<u>0.81</u>**
Superior parietal lobule	0.56							
Supramarginal gyrus	0.54			0.55	**0.68**		0.55	**0.64**
Frontopolar cortex	0.51	0.49	0.54			0.48	0.45	**0.76**
Orbitofrontal cortex				0.52		0.44	0.52	
Dorsomedial PFC							0.50	
Temporal pole		**0.56**			0.55			0.58
Postcentral gyrus								0.48
Negative association								
Temporal pole			**-0.61**					
Frontopolar cortex				-0.56				
DLPFC	-0.52			-0.45				
Angular gyrus			-0.54					
Supramarginal gyrus			-0.51					
Orbitofrontal cortex			-0.46	-0.46				
Affective (Facet 2)								
Positive association								
Lateral frontal cortex	0.46		**0.60**	0.70		0.58	**0.75**	
Insula	0.57			**0.69**		0.63	0.75	
DLPFC			**0.69**	.52		.52		
Frontopolar cortex	**0.64**	0.54	0.57	**0.65**	**0.61**	**0.65**	0.49	**0.72**
Supramarginal gyrus	**0.60**			**0.63**	**0.66**			**0.66**
Angular gyrus			0.47				**0.63**	

Orbitofrontal cortex			0.51			**0.63**	0.59	
Anterior cingulate		**0.60**		0.57		**0.62**	0.51	
Dorsomedial PFC			0.57			0.49	0.45	
Temporal pole						0.54		
Ventrolateral PFC						0.52		
Superior parietal lobule	0.48							
Postcentral gyrus								**-0.64**
Negative association								
Orbitofrontal cortex	**-0.64**			-0.54				-0.57
DLPFC	**-0.60**	-0.52			-0.49			**-0.64**
Ventrolateral PFC			-0.46					**-0.62**
Frontopolar cortex				-0.55				**-0.72**
Temporal pole			-0.53					
Insula					-0.51			
Supramarginal gyrus								
Anterior cingulate					-0.45			**-0.61**
Medial PFC								-0.45
Lateral PFC								-0.44
Angular gyrus		-0.52						
Lifestyle (Facet 3)								
Positive association								
DLPFC	0.49		**0.82**	0.53		**0.60**	**0.80**	
Anterior cingulate		0.46		**0.60**		**<u>0.75</u>**	**<u>0.81</u>**	
Lateral PFC				**0.75**		**<u>0.71</u>**	**0.80**	
Orbitofrontal cortex			0.52			**<u>0.75</u>**	0.49	
Insula	0.57		0.59	**0.65**		**0.68**	**0.75**	0.54
Dorsomedial PFC			**0.74**	**0.65**		0.46		
Angular gyrus				**0.74**			**0.70**	0.51
Supramarginal gyrus			**0.69**	0.53		0.49	**0.66**	0.53
Frontopolar cortex	0.59	0.58	**0.66**	**0.70**	**0.61**	**0.65**		**0.74**
Temporal pole			**0.69**			0.54	0.51	
Postcentral gyrus			**0.62**					0.45
Supramarginal gyrus	**0.62**				0.56			

Ventrolateral PFC						**0.60**	0.45	
Negative association								
Orbitofrontal cortex				-0.47				**-0.60**
Insula					-0.48			
DLPFC								**-0.75**
Frontopolar cortex								**-0.65**
Ventrolateral PFC								-0.58
Dorsomedial PFC								-0.57
Anterior cingulate								-0.49
Angular gyrus								-0.47
Antisocial (Facet 4)								
Positive association								
Orbitofrontal cortex	0.61				0.51	**0.82**	0.57	
Frontopolar cortex	**0.75**	**0.67**	**0.67**	**0.76**	**0.79**	**0.79**	**0.80**	**0.65**
Lateral PFC	0.46			0.58		**0.62**	0.70	
Insula	**0.61**		0.51	0.60	0.54	**0.72**	0.67	
Temporal pole			0.46			**0.68**		
Angular gyrus			0.57	0.57			**0.65**	
Supramarginal gyrus	0.47		**0.73**		0.51	**0.65**	**0.60**	
DLPFC			**0.64**	0.47		**0.63**		
Dorsomedial PFC	0.53		**0.60**	0.52	0.60			
Anterior cingulate	0.57	**0.62**	0.56	0.54	0.49			
Ventrolateral PFC					0.47	0.52	0.53	
Ventromedial PFC	0.55							
Middle frontal gyrus	0.51							
Negative association								
Angular gyrus				-0.55				
Orbitofrontal cortex			-0.51	-0.50				**-0.65**
Temporal pole	**-0.66**			-0.50				
Inferior parietal lobule					-0.46			
Insula					-0.45			**-0.70**
Anterior cingulate								**-0.68**

							-0.66
DLPFC							**-0.66**
Frontopolar cortex							**-0.61**

Note. This table provides the association coefficients for the associations in Table 3. As noted by Yarkoni (2009), in studies with small sample sizes, association sizes can be inflated such that a true association that is only moderate in size appears to be large. Thus, it is highly unlikely that these association coefficients are actually this high. Between the different contrasts, associations for each region do not represent the exact same coordinates, but are found within the specified brain region. Underline indicates that associations were significant at $p < 0.05$ after FWE correction. Bold values indicate associations that were significant at $p < 0.01$ uncorrected for voxel-wise comparison.

Table S3. Brain regions associated with psychopathy (total and facet) scores for the contrast autobiographical truth vs. non-autobiographical truth.

	BA	x	y	z	T
Total Psychopathy					
Positive association					
Frontopolar cortex	**10**	**22**	**66**	**12**	**3.06**
	10	-22	60	2	2.33
	10	-6	58	-6	2.12
	10	24	58	4	1.85
Medial PFC	**10, 32**	**-4**	**60**	**8**	**2.93**
	10, 32	12	58	4	2.34
Dorsomedial PFC	9	14	54	42	2.50
	8	16	50	46	2.48
	8, 9	-10	48	46	2.24
	8	-20	46	46	1.94
Supramarginal gyrus	40	-54	-56	48	2.40
	40	48	-64	42	2.37
	40	40	-48	34	1.87
	40	-56	-58	32	1.79
Ventrolateral PFC	10	32	56	-8	1.95
Negative association					
Anterior cingulate	**32**	**10**	**16**	**36**	**-3.14**
	32	**-14**	**12**	**38**	**-2.86**
Insula	**13**	**38**	**-10**	**18**	**-2.67**
	13	-50	12	10	-2.27
DLPFC	8, 9	58	12	38	-2.46
	9	-56	20	34	-2.43
	9	-54	20	38	-2.00
Lateral PFC	9	-60	4	24	-2.13
Supramarginal gyrus	40	-44	-30	46	-2.10
	40	56	-24	16	-1.88
Interpersonal (Facet 1)					
Positive association					
Dorsomedial PFC	8	-16	30	58	2.29
	8	16	48	48	2.20
	8	-4	48	48	1.80
Frontopolar cortex	10	24	66	14	1.98
Ventrolateral PFC	10	-22	56	-6	1.78
Negative association					
Anterior cingulate	**32**	**10**	**16**	**36**	**-3.47**
	2	**-14**	**10**	**40**	**-3.25**
Insula	13, 38	38	-10	18	-2.58
		-44	-4	12	-2.15
		-42	2	-10	-2.08

Lateral PFC	9	-62	4	24	-2.42
Supramarginal gyrus	40	-50	-34	54	-2.35
		-66	-26	28	-2.12
		56	-26	28	-2.00
DLPFC	8, 9	58	16	38	-2.26
	9	-44	10	32	-1.96
Affective (Facet 2)					
Positive association					
Frontopolar cortex	**10**	**20**	**66**	**10**	**3.28**
		-4	62	8	2.12
		-20	62	-2	1.93
		30	64	4	1.80
Supramarginal gyrus	40	42	-66	44	1.77
Negative association					
Anterior cingulate	**32**	**12**	**16**	**34**	**-4.08**
		-14	**12**	**38**	**-3.39**
	9, 32	-14	24	34	-2.43
Insula	**13**	**36**	**-12**	**18**	**-2.93**
		-42	-4	10	-2.33
DLPFC	**9**	**-46**	**12**	**32**	**-2.79**
		-42	14	34	-2.43
	8, 9	42	38	42	-2.40
Lateral PFC	**9**	**-60**	**4**	**24**	**-2.76**
		36	4	28	-1.89
Supramarginal gyrus	40	-44	-30	46	-2.11
		56	-24	16	-1.98
		-52	-36	56	-1.92
		60	-24	28	-1.90
Lifestyle (Facet 3)					
Positive association					
Frontopolar cortex	**10**	**-4**	**62**	**10**	**3.32**
		22	**68**	**12**	**3.01**
		-20	62	0	2.00
		-4	58	-6	1.96
		30	64	4	1.91
		12	68	12	1.87
Dorsomedial PFC	**9, 10**	**14**	**54**	**42**	**2.68**
	8, 9	**-10**	**48**	**46**	**2.68**
	8	16	50	46	2.65
	8	-22	40	50	2.15
	9, 10	-14	60	32	2.11
Supramarginal gyrus	40	-52	-60	48	2.52
		48	-64	42	2.04
		65	-52	22	1.88
Negative association					
DLPFC	**9**	**-56**	**20**	**34**	**-3.07**

		-54	**20**	**38**	**-2.88**
		58	14	38	-2.38
		42	38	42	-2.26
Anterior cingulate	32	10	18	32	-2.60
		-14	12	38	-2.35
Supramarginal gyrus	40	64	-28	34	-1.90
		-50	-30	46	-1.83
Insula	13	-44	8	0	-1.86
Antisocial (Facet 4)					
Positive association					
Frontopolar cortex	**9, 10, 11, 32**	**-4**	**60**	**10**	**4.41**
	10	**-22**	**60**	**2**	**3.26**
	9, 10, 11, 32	**2**	**62**	**10**	**3.14**
	8, 9, 10, 11	**22**	**66**	**14**	**3.05**
	8, 9, 10	**-14**	**60**	**32**	**2.73**
	10	-32	62	4	2.22
	9, 10	-26	56	32	2.00
	10	-22	56	-6	1.95
	10	12	34	-10	1.79
	10	-42	52	4	1.77
Supramarginal gyrus	**40**	**48**	**-64**	**42**	**3.16**
		-54	**-52**	**50**	**3.15**
		-44	-48	34	2.38
		40	-48	34	2.22
		-42	-46	60	2.22
Orbitofrontal cortex	11	24	28	-12	2.29
		24	32	-12	2.07
		-40	34	-14	1.87
Temporal pole	38	-44	18	-28	2.16
Insula	13	44	-20	0	1.90
Dorsolateral PFC	9	-20	52	40	1.85
Anterior cingulate	32	12	34	-10	1.79
Negative association					
Insula	13	40	-10	18	-2.04
Supramarginal gyrus	40	68	-30	22	-1.81
DLPFC	9	58	12	38	-1.82

Note. Bold indicates that associations were significant at $p < 0.01$ uncorrected for voxel-wise comparison.

Table S4. Brain regions correlated with psychopathy (total and facet) scores for the contrast non-autobiographical lie vs. non-autobiographical truth.

	BA	x	y	z	T
Total Psychopathy					
Positive association					
Frontopolar cortex	**10**	**20**	**66**	**10**	**3.12**
		-22	**62**	**2**	**2.78**
		-6	**62**	**8**	**2.77**
		12	64	6	2.46
		-28	62	6	2.27
		22	60	2	1.99
Supramarginal gyrus	**40**	**-52**	**60**	**48**	**2.74**
		-54	-44	54	2.09
Insula	13	-36	-6	22	1.84
Negative association					
Insula	13	34	-24	20	-1.89
Interpersonal (Facet 1)					
Positive association					
Supramarginal gyrus	**40**	**-52**	**-60**	**48**	**3.37**
		-60	-38	48	2.64
		-38	-48	34	1.85
		44	-52	56	1.81
Temporal pole	38	34	10	-22	2.35
DLPFC	8	-40	14	56	2.15
Insula	13	44	-46	20	2.12
Negative association					
None					
Affective (Facet 2)					
Positive association					
Supramarginal gyrus	**40**	**-52**	**-60**	**48**	**3.15**
		-52	-38	58	1.79
Frontopolar cortex	**10**	**-20**	**62**	**0**	**2.74**
		12	64	6	2.49
		20	66	10	2.38
		-14	62	4	2.32
		-30	64	4	2.32
Negative association					
Insula	13	32	-22	22	-2.14
Supramarginal gyrus	40	56	-26	34	-1.80
DLPFC	9	58	6	40	-2.00
Lifestyle (Facet 3)					
Positive association					
Frontopolar cortex	**10**	**-4**	**62**	**8**	**2.79**
		12	64	6	2.48
		20	66	10	2.43

		-20	62	0	2.35
Supramarginal gyrus	40	-56	-60	42	2.43
		-52	-42	56	2.06
Negative association					
Insula	13	36	-18	22	-1.95
Antisocial (Facet 4)					
Positive association					
Frontopolar cortex	**10**	**20**	**64**	**10**	**4.66**
	10, 32	**-6**	**62**	**8**	**3.44**
	10, 11, 32	**14**	**60**	**4**	**3.11**
	10	**-22**	**62**	**2**	**2.87**
	10	-22	62	10	2.30
	10	-30	62	0	2.01
Dorsomedial PFC	**8**	**22**	**36**	**54**	**2.73**
	8, 9	14	54	42	2.43
	9	-12	48	26	1.77
Insula	13	-36	-6	22	2.33
Supramarginal gyrus	40	-56	-60	42	2.16
		52	-60	44	2.07
Orbitofrontal cortex	11	-4	46	-16	2.15
Anterior cingulate	10, 32	2	46	10	2.03
	10, 32	-16	44	-4	2.00
	32	-2	44	10	1.86
Ventrolateral PFC	10, 11, 32	26	50	-4	1.92
Negative association					
Inferior parietal lobule	40	68	-30	22	-1.87
Insula	13	34	-24	20	-1.81

Note. Bold indicates that associations were significant at $p < 0.01$ uncorrected for voxel-wise comparison.

Table S5. Brain regions associated with psychopathy (total and facet) scores for the contrast criminal vs. non-criminal.

	BA	x	y	z	T
Total Psychopathy					
Positive association					
Frontopolar cortex	**10**	**20**	**66**	**10**	**3.10**
		42	60	2	2.16
		28	66	8	1.84
Anterior cingulate	32	4	30	-8	2.16
	32	-8	34	-10	2.00
Temporal pole	38	-44	18	-28	2.02
Negative association					
DLPFC	8	-48	18	46	-2.04
Interpersonal (Facet 1)					
Positive association					
Temporal pole	**38**	**-44**	**18**	**-29**	**2.43**
Anterior cingulate	32	-4	24	-8	2.28
Frontopolar cortex	10	20	68	12	2.02
Negative association					
None					
Affective (Facet 2)					
Positive association					
Anterior cingulate	**32**	**-4**	**22**	**-8**	**2.70**
Frontopolar cortex	10	20	66	10	2.34
		24	68	12	1.92
Negative association					
Angular gyrus	40	-50	-52	54	-2.20
DLPFC	8	-38	20	56	-2.19
Lifestyle (Facet 3)					
Positive association					
Frontopolar cortex	10	20	66	10	2.60
		24	68	12	2.08
Anterior cingulate	32	-4	24	8	1.89
Negative association					
None					
Antisocial (Facet 4)					
Positive association					
Frontopolar cortex	**10**	**42**	**60**	**2**	**3.25**
		20	**68**	**12**	**3.21**
		28	66	8	2.41

Anterior cingulate	**32**	**-4**	**24**	**-8**	**2.85**
	32	4	30	-8	2.52
	10, 32	-10	36	-10	2.43
Negative association					
None					

Note. Bold indicates that associations were significant at *p* < 0.01 uncorrected for voxel-wise comparison with a threshold of *p* < 0.001 for cluster-level inference.

Table S6. Brain regions associated with psychopathy (total and facet) scores for the contrast criminal truth vs. non-criminal truth.

	BA	x	y	z	T
Total Psychopathy					
Positive association					
Frontopolar cortex	10	22	66	10	2.62
		42	60	2	2.51
		24	62	2	1.90
Temporal pole	38	-44	20	-24	2.46
Negative association					
DLPFC	**8**	**-28**	**48**	**40**	**-3.10**
		-32	**22**	**58**	**-2.80**
	9	-54	26	34	-2.49
	10	-46	44	24	-2.37
	9	62	6	26	-2.16
	8	-48	18	46	-2.04
	10	-36	56	22	-1.98
Supramarginal gyrus	40	44	-36	60	-2.01
Insula	13	38	16	14	-2.00
	13	-32	22	14	-1.98
Anterior cingulate	32	-18	32	22	-1.80
Interpersonal (Facet 1)					
Positive association					
Temporal pole	38	-42	20	-24	3.12
		52	12	-18	2.06
Frontopolar cortex	10	20	66	10	2.46
		24	62	2	2.31
		6	64	4	1.89
Negative association					
None					
Affective (Facet 2)					
Positive association					

Frontopolar cortex	10	22	66	10	2.52
		12	64	6	1.84
Temporal pole	38	-44	20	-24	2.00
Negative association					
DLPFC	**8, 9**	**-28**	**48**	**40**	**-3.94**
	9	**-46**	**44**	**24**	**-2.81**
	8, 9, 10, 32	-16	34	32	-2.55
	9	42	38	42	-2.37
	10	-44	42	16	-2.32
	9, 10	38	48	34	-2.31
	9	-20	52	40	-2.29
	9	-36	4	28	-2.19
	9	-54	20	38	-1.95
	8	-30	12	42	-1.87
	8	-20	28	58	-1.87
	9	10	46	32	-1.79
Lateral PFC	**9**	**62**	**6**	**26**	**-2.92**
Insula	**13**	**38**	**16**	**14**	**-2.68**
		-32	22	14	-2.58
Anterior cingulate	32	-10	8	50	-2.48
		-12	22	26	-2.30
		10	22	26	-2.12
		10	16	30	-2.09
	8, 9, 32	12	22	40	-2.01
Postcentral gyrus	40	44	-38	50	-2.47
Frontopolar cortex	10	34	62	20	-2.29
		-28	52	8	-1.94
OFC	11	44	34	-14	-2.00
Angular gyrus	40	-52	-52	52	-2.00
Lifestyle (Facet 3)					
Positive Associations					
Frontopolar cortex	10	22	66	10	2.13
Angular gyrus	40	48	-46	60	2.00
Negative Associations					
DLPFC	**8, 9**	**-28**	**48**	**40**	**-3.82**
	9, 10	**-46**	**44**	**24**	**-3.03**
	10	-40	54	20	-2.33
	9, 10	38	52	28	-2.25
	9	62	6	26	-2.18
	9	-54	2	34	-1.98
	9	-54	20	38	-1.96
	9	-30	50	36	-1.94
	8	22	26	58	-1.90
	9	12	48	30	-1.79
Insula	13	-32	22	14	-2.59

		38	16	12	-2.49
Medial PFC	8, 9, 32	-6	44	30	-2.42
	9, 32	8	38	30	-2.16
	8	-4	20	54	-2.12
		-8	34	44	-2.03
Orbitofrontal cortex	10, 11	-6	44	30	-2.41
	11	42	34	-14	-1.99
		-24	46	-8	-1.98
Supramarginal gyrus	40	44	-36	60	-2.30
Frontopolar cortex	10	20	50	0	-2.19
	10	32	62	20	-2.10
		-32	48	12	-1.96
		-48	50	4	-1.94
		6	48	16	-1.78
Anterior cingulate	32	-12	22	26	-2.10
		-16	16	36	-2.07
		14	16	34	-1.90
Antisocial (Facet 4)					
Positive associations					
Frontopolar cortex	**10**	**40**	**60**	**0**	**2.88**
Negative associations					
DLPFC	9	-28	48	40	-2.64
		-30	44	42	-2.00
		38	48	34	-1.91
	8	-38	20	56	-1.85
	9	62	6	26	-1.80

Note. Bold indicates that associations were significant at $p < 0.01$ uncorrected for voxel-wise comparison.

Table S7. Brain regions associated with psychopathy (total and facet) scores for the contrast non-criminal lie vs. non-criminal truth.

	BA	x	y	z	T
Total Psychopathy					
Positive associations					
Frontopolar cortex	**10**	**20**	**66**	**0**	**3.87**
		30	**32**	**0**	**3.80**
		-20	**62**	**0**	**3.32**
		12	**64**	**6**	**3.23**
		-30	**64**	**4**	**3.23**
		-14	**62**	**4**	**2.89**
Angular gyrus	**40**	**-42**	**-46**	**36**	**2.77**
		64	-48	32	1.94
		60	-48	42	1.98
Supramarginal gyrus		-50	-32	24	2.01
Postcentral gyrus	40	52	-38	58	2.54
Insula	13	-46	-36	20	2.35
Negative associations					
DLPFC	**9, 10**	**-32**	**56**	**22**	**-2.92**
	8, 9	**-50**	**28**	**38**	**-2.76**
	8	**-42**	**16**	**54**	**-2.71**
	10	-44	44	16	-2.36
	8	-52	6	46	-2.11
	9	62	8	24	-2.04
Dorsomedial PFC	**8, 32**	**-6**	**14**	**54**	**-2.91**
Orbitofrontal cortex	11	44	34	-14	-2.50
		-42	34	-12	-2.42
Anterior cingulate	32	-8	8	52	-2.46
Postcentral gyrus	40	38	-30	46	-2.08
Angular gyrus	40	38	-60	44	-1.97
Frontopolar cortex	10	-34	52	12	-1.79
Interpersonal (Facet 1)					
Positive associations					
Angular gyrus	**13, 40**	**-58**	**-56**	**38**	**5.06**
Frontopolar cortex	**10**	**-24**	**62**	**2**	**4.28**
		-30	**64**	**4**	**3.25**
		-12	**64**	**6**	**2.88**
		12	**64**	**6**	**2.79**
		30	**62**	**0**	**2.67**
Insula	**13**	**-34**	**-36**	**20**	**3.06**
		28	-32	18	2.44
Supramarginal gyurs	**13, 40**	**46**	**-42**	**18**	**3.04**
	40	-26	-48	56	2.09
Temporal pole	38	42	10	-18	2.60
		-50	8	-24	2.00
Postcentral gyrus	40	64	-24	22	1.97

	40	-34	-40	56	1.77
Negative associations					
None					
Affective (Facet 2)					
Positive associations					
Frontopolar cortex	**10**	**12**	**64**	**6**	**3.79**
		-24	**62**	**2**	**3.45**
		8	**64**	**6**	**3.33**
		30	**62**	**0**	**3.30**
		-30	**64**	**4**	**3.12**
		-14	**62**	**4**	**2.98**
Supramarginal gyurs	**13, 40**	**-60**	**-44**	**20**	**3.15**
	40	**-60**	**-44**	**20**	**3.15**
		64	-52	30	2.11
		-50	-32	24	2.05
Postcentral gyrus	**40**	**52**	**-38**	**58**	**3.01**
		-34	-42	56	1.92
Insula	13	-40	34	20	1.98
Negative associations					
Frontopolar cortex	**9, 10**	**32**	**56**	**22**	**-3.78**
	10	26	62	18	-2.23
DLPFC	**8, 9**	**-50**	**28**	**38**	**-2.99**
	8	-42	16	54	-2.51
	8, 9	-26	48	40	-2.30
	9	-30	50	36	-2.09
	9	40	14	34	-1.99
	8	-22	26	44	-1.89
Ventrolateral PFC	**10**	**54**	**42**	**0**	**-2.85**
		-44	48	8	-2.01
Anterior cingulate	**8, 9, 32**	**-8**	**8**	**52**	**-2.79**
	9, 32	-20	40	20	-2.07
	32	10	16	30	-1.83
Orbitofrontal cortex	11	44	38	-14	-2.52
		-42	34	-12	-2.50
Medial PFC	9	12	48	26	-1.84
Lateral PFC	9	32	8	24	-1.78
Lifestyle (Facet 3)					
Positive associations					
Frontopolar cortex	**10**	**30**	**62**	**0**	**3.92**
		-20	**62**	**0**	**3.17**
		20	**66**	**10**	**2.94**
		12	64	6	2.55
		-14	62	4	2.28
		-30	64	4	2.28
Insula	13	-46	-36	20	2.29
Supramarginal gyrus	40	-42	-46	36	2.26

		-66	-32	30	2.10
		-54	-52	30	2.08
Angular gyrus	40	52	-38	58	2.14
Postcentral gyrus	40	56	-32	54	1.80
Negative associations					
DLPFC	**8, 9, 10, 32**	**-34**	**20**	**58**	**-4.07**
	8, 9	**-50**	**18**	**42**	**-3.78**
	9	-54	20	38	-2.38
	9	-30	50	36	-1.82
	9	36	8	40	-1.81
	9	62	8	24	-1.95
Frontopolar cortex	**9, 10, 32**	**22**	**62**	**20**	**-3.09**
	9, 10, 32	4	56	18	-2.41
	10	-2	54	12	-1.98
	10	20	50	0	-1.92
	10	24	50	-2	-1.86
	10	16	50	-4	-1.78
	10	-20	48	0	-1.78
Orbitofrontal cortex	**11**	**-42**	**34**	**-12**	**-2.71**
		42	40	-14	-2.49
	10, 11	-24	50	-4	-1.92
Ventrolateral PFC	10	54	40	0	-2.57
		-44	46	4	-2.04
Dorsomedial PFC	8	20	38	48	-2.52
		-20	28	54	-2.13
		2	20	52	-2.11
		14	28	46	-1.84
Anterior cingulate	10, 32	-12	34	-8	-2.00
	32	18	8	50	-1.80
Angular gyrus	40	38	-60	44	-1.94
Antisocial (Facet 4)					
Positive associations					
Frontopolar cortex	**10**	**30**	**62**	**0**	**3.11**
		-14	**62**	**4**	**2.81**
		20	66	10	2.41
		-4	62	2	2.40
Negative associations					
Insula	**13, 40**	**64**	**-26**	**20**	**-3.54**
	13	-42	-14	-8	-2.08
Anterior cingulate	**8, 32**	**-6**	**14**	**54**	**-3.33**
	32	6	4	42	-2.41
	8	2	16	54	-2.03
	32	-6	22	38	-1.96
Orbitofrontal cortex	**11**	**-44**	**34**	**-12**	**-3.07**
		42	**48**	**-14**	**-2.74**
		-24	28	-12	-1.93

Frontopolar cortex	**10**	**-32**	**58**	**24**	**-2.74**
	9, 10	-4	60	30	-2.50
	10	-40	54	20	-1.80
DLPFC	**9**	**62**	**6**	**24**	**-3.21**
	8	**-34**	**20**	**58**	**-2.69**
	8	-52	6	46	-2.57
	8, 9	-28	44	42	-2.41
	8, 9	-50	28	38	-2.37
	8	-26	24	58	-2.09
	10	-46	44	22	-2.02
	9	-62	4	24	-2.01
	9	-20	52	40	-1.98
	8	-54	14	42	-1.86
	8	40	14	56	-1.84
Angular gyrus	40	38	-60	44	-2.51

Note. Underline indicates that associations were significant at $p < 0.05$ after FWE correction. Bold indicates that associations were significant at $p < 0.01$ uncorrected for voxel-wise comparison.