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BRIEF COMMUNICATIONS

A Replication Study of the Neural Correlates of Deception

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The authors attempted to replicate prior group brain correlates of deception (F. Kozel et al., in press) and improve on the consistency of individual results. Healthy, right-handed adults were instructed to tell the truth or to lie while being imaged in a 3T magnetic resonance imaging (MRI) scanner. Blood oxygen level-dependent functional MRI significance maps were generated for subjects giving a deceptive answer minus a truthful answer (lie minus true) and the reverse (true minus lie). The lie minus true group analysis ($n = 10$) revealed significant activation in 5 regions, consistent with a previous study (right orbitofrontal, inferior frontal, middle frontal cortex, cingulate gyrus, and left middle frontal), with no significant activation for true minus lie. Individual results of the lie minus true condition were variable. Results show that functional MRI is a reasonable tool with which to study deception.

Understanding the neurocircuitry involved in deception could have a profoundly beneficial impact on society. Deception, defined as the purposeful misleading of another, is ubiquitous in society and in medicine. Understanding the brain basis of deception could lead to both a method in which deception is accurately detected and to a better understanding of disorders in which deception is a prominent component (e.g., antisocial personality disorder).

The polygraph has been used extensively to detect deception (American Polygraph Association, 1996). The ability of the polygraph to accurately detect deception, however, has been questioned (Brett, Phillips, & Beary, 1986; Lykken, 1998; Steinbrook, 1992). In addition, a recent National Science Foundation report concluded that the polygraph lacked evidence to support its use in detecting deception and highlighted the critical need for new methods to be developed (National Research Council, 2002). A primary problem with the polygraph is that it measures peripheral arousal, not deception itself. Conversely, blood oxygen level-dependent (BOLD) functional magnetic resonance imaging (fMRI) offers a method of measuring brain activity noninvasively (Ogawa, Lee, Kay, & Tank, 1990). Measures of brain activity associated with deception provide an opportunity to investigate the neurocircuitry of deception.

An initial pilot study performed in our lab revealed significant activation in several brain areas during lying compared with truth-telling ($z > 1.645$, with an extent threshold of $p < .05$; the extent threshold attempts to correct for multiple comparisons by determining the likelihood of a cluster of significantly activated voxels occurring by chance). These areas included the right frontal (superior, middle, and inferior including the orbitofrontal) areas, right anterior cingulate gyrus, and right precentral gyrus. In addition, significant activation was found in the left temporal area (superior, middle, and inferior) and left cerebellum (Kozel et al., in press). These findings were significant for the group analyses, but not for the within-subject analyses. Other groups have reported significant group findings in detecting behavior related to deception, but have not reported replication of their original findings or the results of individual subject analyses (Ganis et al., 2003; Langleben et al., 2002; Lee et al., 2002; Spence et al., 2001). Using techniques to improve the statistical power of the fMRI analysis, we sought to test our initial findings for potential replication at the group level,

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Frank Andrew Kozel and Mark S. George have applied for a patent on the use of fMRI for detecting deception. Subsequent to the present study, Frank Andrew Kozel received support for research related to this technology.

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and also to determine whether higher MRI field strength and paradigm modifications might allow for detection of deception at the level of the individual.

Method

Subjects

Subjects were recruited by an advertisement in the Medical University of South Carolina's campus newspaper. After a complete description of the study was provided to the subjects, written informed consent—which was approved by the Medical University of South Carolina Investigational Review Board—was obtained for all subjects. Subjects were required to be 18–40 years old, right-handed, and have a score of at least 9 out of 12 on the Annett handedness rating scale (Annett, 1970). They also had to be able to read and write English and have the capacity to provide informed consent. Potential subjects were excluded if they had a history of any current or past Axis I psychiatric disorder (except simple phobia), including substance abuse/dependence as determined by the Structured Clinical Interview for *DSM–IV* Axis I disorders (SCID-I; First, Spitzer, Williams, & Gibbon, 1995); a history of neurologic disease; a currently unstable medical condition; any medication taken within 5 half-lives of procedure time; caffeinism; nicotine use; any metal implants (not including dental fillings) that would make an MRI unsafe; irremovable medical devices such as pacemakers or fixed hearing aids; presence of shrapnel; previous inability to tolerate MRI procedure; or claustrophobia severe enough to induce substantial anxiety in closed spaces.

Procedure

Screening visit. After written consent was obtained, subjects were evaluated with a SCID-I and an Annett handedness scale. The subjects also underwent a physical exam and review of current and past medical history. Subjects that completed the screening phase received $20. All subjects that met criteria were scheduled for the functional MRI examination within the following 2 weeks.

Scanning visit. Prior to scanning, female subjects were given a pregnancy test and excluded if it was positive. The subjects were then escorted to a room in which six objects were located. Fifty-dollar bills were placed under two of the objects. The subjects were instructed to find both locations of the two fifty-dollar bills and to leave them in place. The subjects then received safety preparation for MRI scanning, including hearing protection. Scanning was performed on a 3.0-T Philips Intera (Philips Medical Systems, Andover, MA). Images were displayed to the subjects, and responses were recorded with the Integrated Functional Imaging System (IFIS; MRI Devices Corporation, Gainesville, FL).

Subjects were instructed that while in the MRI scanner, they would see pictures of the six objects from the room just visited. The picture of each object would be presented to them multiple times. For each picture, the subject would indicate whether money was hidden below the object. The subject would respond "yes" by pushing the right thumb button and "no" by pressing the right index button of the IFIS system. For one of the objects hiding a fifty-dollar bill (subject's choice), the subject was instructed to truthfully respond "yes." The subject would receive $50 for truthfully responding. For the object hiding the other fifty-dollar bill, the subject was instructed to lie by responding "no." In addition, the subject was to choose one of the objects not hiding a fifty-dollar bill and deceptively respond "yes." Therefore, for the two deception conditions, subjects would have to inhibit the truthful answer regarding the money's presence or absence and give a false response as to whether the money was present. The subject was told that a research assistant who did not know the location of the money would attempt to determine when the subject was lying. If the research assistant could not tell when the subject was being deceptive, then the subject would receive an additional $50. All subjects in actuality would receive the additional $50, because there was no way to tell when the subject was lying. The research assistant and the IFIS system recorded the subject's responses. One of the investigators (Frank Andrew Kozel) knew the location of the money. Deception and truthful events were determined by comparing the subject's responses to the actual location of the money.

During the experiment, each picture was presented for 6 s in groups of six (each object once per block), in a randomized order (http://randomization.com). Each group consisted of two deceptive answers and four truthful answers. There were two runs of 10 blocks. Each run was 6 min long, with a 1-min break in between. The BOLD fMRI scans consisted of 26 coplanar transverse slices (4.0 mm thick, 1 mm gap) covering the entire brain and positioned 90° to the anterior commissure–posterior commissure line by means of a sagittal scout image. Each fMRI volume consisted of BOLD weighted transverse scans and used a single-shot gradient echoplanar imaging sequence (flip angle = 90°; TE, 30 ms; TR, 3,000 ms; FOV, 256 × 256; matrix, 64 × 64 mm; in-plane resolution, 4 mm × 4 mm; through-plane resolution, 4 mm). Given these parameters, a set of 120 whole-brain volumes was acquired for each run (total of 240 volumes for the study). After the BOLD fMRI, a structural T1-weighted scan was acquired to ensure that there were no major structural abnormalities. After the scanning, subjects were asked if they had any problems or questions. They were then informed that the research assistant was unable to determine when they had lied. This scanning paradigm is a modification of our earlier study in that there were increased episodes of lying (40 vs. 8) and the images were acquired at higher field strength (3.0 T vs. 1.5 T).

fMRI Analysis

The image data were analyzed with Statistical Parametric Mapping 2 (SPM2; Wellcome Department of Imaging Neuroscience, 2003) on a Sun server using a Sun Sparc workstation. Initially, images were reoriented to the standard orientation for analysis. The volumes were then realigned and spatially normalized with the Montreal Neurologic Institute (MNI) echoplanar imaging template in SPM 2. The resulting images were smoothed, with a 6-mm kernel. An event model was designed for each subject by using deceptive and truthful events convolved with the hemodynamic response function. The data were modeled, and estimations were created. Individual analysis was performed with two contrasts: lie (events of deceptive responses) minus true (events of truthful responses), and true minus lie. Significance was defined as $p < .001$, with a cluster value of $p_{corrected} < .05$. A second-level (random-effects) group analysis was performed with a one-sample *t* test ($p < .001$, cluster-level $p_{corrected} < .05$) of contrast images for both lie minus true and true minus lie. The statistical threshold used for final display and testing was higher for this study (random-effects model, $p < .001$, cluster $p_{corrected} < .05$) than for our prior study (fixed-effects model, $p < .05$, cluster $p < .05$). MRIcro (Rorden, n.d.) was used to determine the anatomic location and Brodmann areas for significant clusters of activation. The SPM functional map was superimposed on the T1 template skull-stripped brain image in MRIcro.

Results

Subjects

We recruited 14 subjects (1 excluded for taking a medication) and scanned 13 (6 women). Of these 13 subjects, only 10 (mean age = 27.8 years, range = 20.0–35.0 years) had usable data; 3 had not adequately followed the protocol. Each of these 3 subjects failed to lie as instructed during one of the two runs. All women enrolled were found to have negative pregnancy tests. The average Annette handedness scale score was 11.2 (range = 10.0–12.0). Because each subject chose both one of the two objects hiding

money to lie about and one of the four objects not hiding money to lie about, the order and timing of lying and truthful events were different across the group.

fMRI

The group analysis for lie minus true revealed significant activation ($p < .001$, cluster $p_{corrected} < .05$) in five areas (right anterior cingulate, right inferior frontal, right orbitofrontal, right middle frontal, and left middle temporal) that are consistent with our prior deception study (see Table 1 and Figure 1). The group analysis of true minus lie revealed no areas of significant activation.

For the within-subject results of lie minus true, there was a variable degree and pattern of increased BOLD signal. Focusing on the areas that were significantly activated on the group analysis during lying in both the current and past study (see Table 2) showed that 5 subjects had significant activation ($p < .001$, cluster $p_{corrected} < .05$) in the right orbitofrontal cortex. Two subjects did not have any significant activation at this threshold. A broader neuroanatomic perspective (i.e., prefrontal cortex vs. just a portion of the prefrontal cortex, e.g., the orbitofrontal cortex) revealed that 7 of the 10 subjects had significant right prefrontal activation during the lie minus true contrast.

Discussion

This study replicates the group analysis findings from a previous study using fMRI to detect deception. The group analysis replicated five of the brain regions significantly activated for periods of lying minus periods of telling the truth. This study, however, had a more conservative threshold for statistical significance (random-effects model with $p < .001$ vs. fixed-effects model with $p < .05$) and used an event-related design versus a block design. The increased level of statistical significance we observed for these regions is perhaps due to the increased number of instances of lying (8 vs. 40) and the increased field strength of the MRI (1.5 T

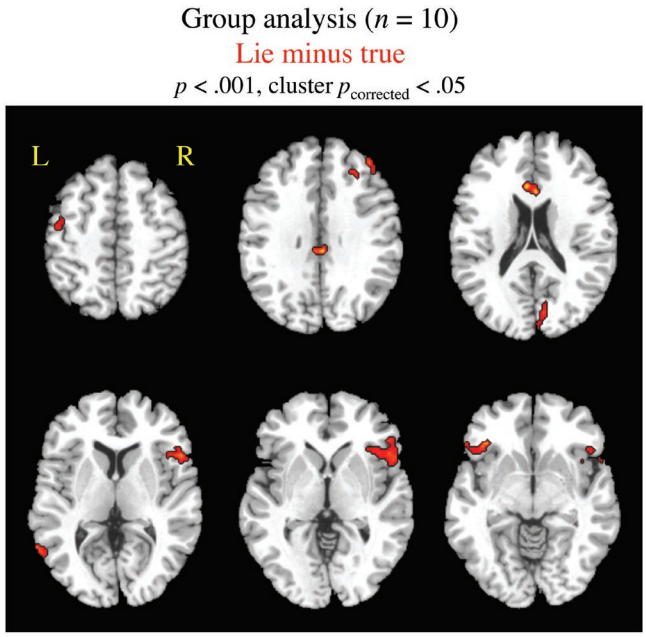

Figure 1. Group analysis of lie minus true, showing areas of significant activation. The group analysis results are displayed on a brain template from MRIcro (Rorden, n.d.). The transverse slices of the brain start dorsal and move ventrally. Events of telling the truth were subtracted from events of lying. Significantly ($p < .001$, cluster $p_{corrected} < .05$) activated regions are indicated by red and yellow. The statistical maps determined with Statistical Parametric Mapping 2 (Wellcome Department of Imaging Neuroscience, 2003) were superimposed onto a structural template of the brain by means of MRIcro. Areas of significant activation are right middle cingulate, left inferior orbitofrontal, right anterior cingulate,* left anterior cingulate, right inferior frontal,* right inferior orbitofrontal,* right insula, left middle temporal,* right middle frontal,* right cuneus, and left postcentral (asterisks indicate areas of replication from prior functional magnetic resonance imaging study of detecting deception). L = left; R = right.

Table 1
Group Analysis of Lie Minus True ($p < .001$, Cluster $p_{corrected} < .05$)

Cluster level		Voxel level		MNI coordinates				
k	$p_{corrected}$	*T*	$p_{uncorrected}$	x	y	z	BA	Anatomic area[a]
65	.006	9.89	.000	4	−28	34	23	R middle cingulate
81	.001	8.53	.000	−40	26	−8	47	L inferior orbitofrontal
56	.013	8.03	.000	4	20	20	24	R anterior cingulate[b]
				−4	24	20	24	L anterior cingulate
396	.000	7.32	.000	52	20	4	45	R inferior frontal[b]
		6.17	.000	52	32	0	45	R inferior orbitofrontal[b]
		5.84	.000	44	22	0	47	R insula
67	.005	7.07	.000	−60	−60	8	37	L middle temporal[b]
52	.020	6.79	.000	42	44	30	46	R middle frontal[b]
131	.000	6.12	.000	10	−78	20	18	R cuneus
79	.001	6.08	.000	−48	−8	54	6	L postcentral

Note. MNI = Montreal Neurological Institute; BA = Brodmann's area; R = right; L = left.
[a] Predominate anatomic area of significant blood oxygen level-dependent signal as determined with MRIcro software (Rorden, n.d.). [b] Areas of replication from prior functional magnetic resonance imaging study of detecting deception.

Table 2
Individual Analysis of Lie Minus True ($p < .001$, Cluster $p_{corrected} < .05$)

	Subjects									
Anatomic location	1	2	6	7[a]	8[a]	9	10	11	12	13
R ant cingulate										x
R inf frontal	x		x							
R orbitofrontal	x		x				x		x	x
L mid temporal							x	x	x	
R mid frontal		x					x		x	
R prefrontal	x	x	x				x	x	x	x

Note. x represents activation in the indicated area; blank cells represent no activation. R = right; L = left; ant = anterior; inf = inferior; mid = middle.
[a] No region of the brain was found to be significantly activated.

vs. 3.0 T). The individual results showed more consistency than the previous study, with 7 of the 10 subjects having significant activation in the right prefrontal region. The results, however, do not support the use of fMRI—as presently performed—to detect deception in an individual. As this study shows, however, continued improvements in equipment and study design could possibly lead to more consistent and robust results.

This study is limited by the small sample size of well-screened, unmedicated adults. Thus, any extrapolation to other populations such as the medically ill or persons with criminal records is unwarranted. In addition, this study was designed to identify brain regions associated with deceptive answers versus truthful answers, not to formally test the method as a means of lie detection. Subsequent work will be needed to determine whether this technology can be used to distinguish deceptive responses from truthful responses within individuals.

One area requiring future study is the manner in which the within-subject analysis is performed. Even with only 10 subjects, there was a large difference between subjects in the number of voxels considered to be significantly activated. Individual variability in the BOLD response may warrant the use of a method in which threshold significance is based on an algorithm to determine the appropriate significance level for an individual versus simply choosing an arbitrary highly significant number. Also, McGonigle and colleagues showed that for an individual subject, there can be considerable variability across separate scanning sessions (McGonigle et al., 2000). Accounting for intersubject and interscan variability will be important for future work in understanding an individual's neural correlates of deception.

Other neuroimaging studies have implicated several of the consistently activated regions as being important in cognitive tasks possibly related to deception. The right inferior and orbitofrontal cortex have been correlated with response inhibition as well as emotion regulation. (Elliott, Dolan, & Frith, 2000; O'Doherty, Kringelbach, Rolls, Hornak, & Andrews, 2001). These regions could inhibit an overlearned response (the truth), especially in order to gain a reward. In addition, the executive regions of the cingulate gyrus have been studied for their involvement in attention, concentration, and multitasking (Bush et al., 1998; Cohen, Dunbar, & McClelland, 1990; George et al., 1997). Further work is needed to understand the specific roles of each region during lying.

In summary, our study shows that BOLD fMRI is a reasonable tool for the detection of brain regions involved in deception at a group level. For lying, compared with telling the truth, there is more activation in the right anterior cingulate, right inferior frontal, right orbitofrontal, right middle frontal, and left middle temporal areas. The technique was not able to detect, within individuals, consistent activation patterns. This does not in any way, however, establish that activation patterns indicating deception are not achievable at the individual level, only that further work is necessary to determine whether this goal can be achieved. Our group results are consistent with an emerging literature implicating activation of these regions when subjects are lying (Ganis et al., 2003; Langleben et al., 2002; Lee et al., 2002; Spence et al., 2001). Further work is needed to understand what each of these regions does during lying (arousal, response inhibition, cognitive parsing, etc.), and which are necessary versus incidental.

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