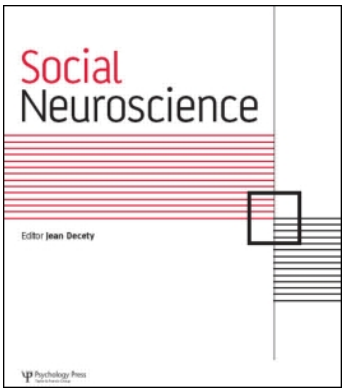

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Towards clinical trials of lie detection with fMRI

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Towards clinical trials of lie detection with fMRI

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Recent reports of successful fMRI-based discrimination between lie and truth in single subjects raised the interest of prospective users and a public concern about the potential scope of this technology. The increased scrutiny highlighted the lack of controlled ''real life'', i.e. prospective clinical trials of this technology that conform to the common standards of medical device development. The ethics of conducting such trials given the paucity of data on fMRI-based lie detection has also been questioned. To probe the potential issues of translating the laboratory research into practice, we conducted a case study in which we adapted the standard Guilty Knowledge Test (GKT), a well-established model of producing deception, to the common scenario of lying on a resumé. The task consisted of questions about pertinent items on the subject's resumé, three of which could be independently verified as truth (KNOWN) and three that could not be verified and were thus termed UNKNOWN. The subject had an incentive to lie on all UNKNOWN items, and on debriefing confirmed that he had done so. Data was preprocessed, masked with *a priori* regions of interest, thresholded, and qualitatively evaluated for consistency with the previously reported prefronto-parietal Lie > Truth pattern. Deceptive responses to two out of the three UNKNOWN items were associated with the predicted prefronto-parietal fMRI pattern. In the third UNKNOWN this pattern was absent, and instead, increased limbic (amygdala and hippocampus) response was observed. Based on published prefronto-parietal Lie response pattern, only the first two items could be categorized as Lie. If confirmed, this demonstration of amygdala and hippocampus activation in a Lie > Truth contrast illustrates the need to integrate the limbic system and its emotional and cognitive correlates into the existing model of deception. Our experiment suggests an approach to a naturalistic scenario and the research questions that need to be answered in order to set the stage for prospective clinical trials of fMRI-based lie detection.

INTRODUCTION

Deceit is ubiquitous in humans, and almost every generation has attempted to apply technology of the age to understanding and detecting it (Eck, 1970). The advent of functional magnetic resonance imaging (fMRI), a reliable and safe measure of regional brain activity, inevitably led to attempts to utilize it for this purpose (reviewed in Spence, 2004). The first generation of fMRI studies of deception was dedicated to the initial demonstration of feasibility (Langleben et al., 2005; Lee et al., 2002; Spence et al., 2001). Subsequent work diverged into two arms: one devoted to further refinement of lie detection techniques and the other principally concerned with functional neuroanatomy and cognition (Davatzikos et al., 2005; Ganis, Kosslyn, Stose, Thompson, & Yurgelun-Todd, 2003; Kozel, 2004, 2005; Nunez, Casey, Egner, Hare, & Hirsch, 2005). Paradigms advanced from group average to single subject studies, demonstrating the potential contributions of memory, learning, emotion, and complex cognition to brain activity

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patterns of deception (Abe, Suzuki, Mori, Itoh, & Fujii, 2007; Ganis et al., 2003; Nunez et al., 2005). Task-related features that covary with deception, such as stimulus familiarity, salience, motor response switching, and oddball interference, were also examined.

There is a converging model of deception as a working memory-intensive task, mediated to a large extent by the prefronto-parietal systems dedicated to behavioral control and attention (Langleben et al., 2002; Leung, Selig, & Gore, 2004; Nunez et al., 2005; Spence et al., 2004). Recent experiments began refining this model by demonstrating the potential contributions of the limbic system to deception, as was anticipated in some earlier theoretical work (Abe et al., 2007; Langleben, Dattilio, & Guthei, 2006). The high degree of reproducibility and accuracy in single subjects raised academic and public curiosity, commercial activity, and political concerns (Henig, 2006; Talbot, 2007). The more fervent critics of the new technology assailed it for being potentially effective enough to warrant its ban to protect ''cognitive freedoms.'' Others had more realistic concerns with its relatively low specificity, which would translate to false positive rates not acceptable in legal applications (Halber, 2007) or for employment screening (Stern, 2004).

Yet another criticism was that it is impossible to conceive of ethically sound prospective clinical trials of fMRI-based lie-detection and equally impossible to proceed to application of this technique to real-life cases without data acquired in such trials (Kanwisher, quoted in Halber (2007)). This debate highlights the lack of critical translational data (Wolpe, Foster, & Langleben, 2005) that is necessary to determine the true potential and limitations of fMRI in lie-detection.

Designing clinical trials of fMRI-based lie detection implies using unproven technology in situations where balancing the risk/benefit ratio represents a legal and ethical challenge (Appelbaum, 2007; Thompson, 2005). To cautiously probe the possibility that this challenge is addressable, we present a case of a volunteer experimental participant (JG) who was writing a story for the *Washington Post* and wanted to test the fMRI method on himself. He intentionally simulated overstatements of personal accomplishments on a resumé, as one would for the purpose of gaining undeserved employment at a fictional job. This experiment closely resembles the recent events involving the Dean of Admissions at the Massachusetts Institute of Technology (Lewin, 2007). The fact that our experiment took place almost a year prior to this scandal may highlight its ecological validity.

Testing resumé statements presented one challenge that had not yet been reported in fMRI studies of deception: the presence of multiple items of unknown veracity, thus limiting our ability to contrast Lie and Truth and demanding that we contrast response to each unknown item with known Truth instead. The experimental paradigm designed to address this case was termed the ''Resumé Query Test'' (RQT). Our working hypotheses were: (1) The pattern of brain response to Lie during RQT will be similar to the prefronto-parietal pattern we observed in prior forced-choice deception paradigms (Langleben, 2005); (2) Lie and Truth could be distinguished by qualitative inspection of the relevant contrasts, thresholded at $p < 0.05$, and masked with a region of interest (ROI) template (see Methods).

METHODS

Participant

JG is a 53-year-old male, healthy, right-handed newspaper reporter. JG gave written consent to publish this manuscript with identifying information included. The study protocol was approved by the University of Pennsylvania IRB.

fMRI paradigm: ''resumé query'' task (RQT)

Scenario

The subject was instructed by one of the authors (DDL) to pretend that he was applying for a job as a science writer, with DDL acting as a recruiter and a co-conspirator and another author (JWL) as a representative of the hiring manager. DDL reviewed JG's resumé and informed him that the key requirements for the job were military service, a college degree, and writing experience that should include two published books. DDL, highlighting the key requirements, then returned the resumé to JG and told him to resubmit it, and accompany these requirements with supporting documents regarding his military service, college degree and writing experience (which were to be used as task stimuli for the fMRI exam). JG was instructed to ''employ

whatever means necessary to be hired," which provided him with a strong incentive to falsify one or more of those items if they were missing from his resumé. The other members of the research team were blinded to all details of this transaction. JG was also told to assume that successful hiring would require that he successfully passed an fMRI exam designed to probe the veracity of some of the items listed on his resumé. Other than the instruction to "employ whatever means necessary" to be hired, the subject was not explicitly instructed to falsify his resumé information. After receiving the subject's (modified) resumé, DDL selected three items that were discrepant with the original resumé (i.e. likely to be a lie) and three statements that could be easily verified as truthful. On the day of the imaging part of the experiment, the subject was escorted to the scanner by a third party and greeted by the MRI examiner (JWL), who informed him that he would test him with fMRI concerning the veracity of his resumé and instructed him to answer each item as accurately and truthfully as possible.

Task design

The subject was instructed to respond "Yes" or "No" to the questions regarding the six specific resumé statements, accompanied by appropriate images of supporting materials he provided with his resumé (Figure 1). The six questions were divided equally between two stimulus classes: (1) "Known truths" (KNOWN)—questions designed to be easily verifiable as truths, and (2) "Unknowns" (UNKNOWN)—questions relevant to job qualification and difficult to verify by a hypothetical job interviewer. The three KNOWN questions probed in this task were: (1) "Did you write this book?"—accompanied by an image of the cover of a book written by the subject; (2) "Do you work for the *Post*?"—accompanied by an image of the cover of the *Washington Post* with an article written by the subject; and (3) "Is this your home?"—accompanied by a picture of the subject's house. The three UNKNOWN questions probed in this task were: (1) "Did you write this book?"—accompanied by an image of the cover of a book not written by the subject, but altered to feature the subject's name as the author; (2) "Did you graduate from Notre Dame?"—accompanied by an image of a Notre Dame University BA diploma with the subject's name as the graduate; and (3) "Did you serve in the military?"—accompanied by an image of a certificate of honorable discharge from the US Marine Corps (USMC), altered to feature the subject's name and a fictional service number.

Each question was repeated 15 times, in a pseudorandom order optimized for event-related fMRI (Dale, 1999). Questions were presented for

Figure 1. RQT stimuli: Known and unknown RQT questions.

2 s followed by a variable ''jittered'' interstimulus interval (ISI; 1–13 s, average 2 s). During the interval, a yellow asterisk was displayed in the center of the black screen (NULL event). A total of 90 questions were presented, for a total task length of 9 min.

Stimuli were rear-projected to the center of the visual field using a video projector (PowerLite 7300; Epson America, Long Beach, CA) viewed through a head-coil-mounted mirror. Stimuli presentation was synchronized with image acquisition using Presentation (version 11.2, www.neurobs.com). Responses were made with a right (dominant) hand press on a two-button fiberoptic-response keypad (fORP; Current Design, Philadelphia, PA) and logged by Presentation software.

The participant was debriefed about the way he responded and queried as to which UNKNOWN items he selected to lie about after the analysis was complete and available.

Image acquisition

Images were acquired with blood-oxygen level dependent (BOLD) imaging (Bandettini, Wong, Hinks, Tikofsky, & Hyde, 1992) on a clinical 3 T Siemens Trio Scanner (Iselin, NJ). A 5-min, magnetization prepared, rapid-acquisition gradient echo image (MPRAGE) was acquired for anatomic overlays of functional data and spatial normalization (T1 MNI Template). BOLD imaging used a 33-slice whole-brain, single-shot gradient echo (GE) echo-planar (EPI) sequence (TR/TE = 3000/21 ms, FOV = 240 mm, matrix = 64×64, slice thickness/gap = 4/0 mm). This sequence delivered a nominal voxel resolution of $3 \times 3 \times 3$ mm.

Data analysis

The fMRI data were preprocessed and analyzed using SPM2 (Wellcome Department of Cognitive Neurology, London, UK). Images were slice time-corrected, motion-corrected to the median image using b-spline interpolation (4 df), high-pass filtered (100 s), and spatially smoothed (8 mm full width at half maximum (FWHM), isotropic). The median functional volume was coregistered to the anatomical volume and then transformed into the standard anatomical space (T1 MNI template, resampled to $2 \times 2 \times 2$ mm resolution) using trilinear interpolation (Ashburner & Friston, 1999). Statistical analysis used a general linear model (GLM) that incorporated an event-related design, which contained a total of four regressors along with their temporal derivatives and an intercept term. Regressors were created by convolving each of the stimuli timecourses with the standard double gamma hemodynamic response function (HRF). The three KNOWN class stimuli were concatenated and entered into the GLM as one regressor. Each of the three UNKNOWN class stimuli was entered as a separate regressor. Statistical contrast activation maps were generated by subtracting the regressor weights (beta-coefficients) associated with the conditions of interest (e.g. UNKNOWN > KNOWN and KNOWN > UNKNOWN) in a random effects model.

Each UKNOWN > KNOWN was masked with an anatomical ROI mask derived from the Wake Forest University PickAtlas (Maldjian, Laurienti, Kraft, & Burdette, 2003) and the regions previously identified as important to deception (Abe et al., 2007; Kozel et al., 2005; Langleben et al., 2005). The mask included both predicted areas associated with Lie > Truth and parts of the limbic system as part of an exploratory analysis. The ROI mask included Broadman's areas (BA) 13, 22, 39, 40, 41, 45, 47; dilated by 2 mm. Broadman's areas 13, 45, 47 (inferior frontal gyrus, IFG), 40 (inferior parietal lobe, IPL and supramarginal gyrus, SMG), 22, 41 (superior temporal gyrus, STG), 39 (middle temporal gyrus, MTG), and 11 (Medial Frontal Gyrus, MFG) were chosen to be part of the *a priori* lie-template mask due to their implication in previous studies as regions associated with Lie > Truth. BA 28 (hippocampus, Hipp); 34 (amygdala, Amyg and uncus); and 36 (parahippocampal gyrus, PHG) were included due to their association with the limbic system and recent report of limbic activation during deception where lying was both endorsed and unendorsed by different team members (Abe et al., 2007). Average of all KNOWN > average of all UNKNOWN contrast was left unmasked as the analysis of this contrast was also exploratory and not hypothesis-driven.

Monte Carlo simulations were performed on the masked and thresholded dataset to determine a dual-threshold (voxel probability and cluster extent probability) family-wise error correction rate using AFNI's Alphasim (Ward, 2000). With this method it was determined that a voxel-height probability of $p < .05$ and a minimum cluster extent of 83 voxels would achieve an $\alpha < .05$ for this masked dataset. All result images were

examined at two thresholds: (1) $p < .05$ family-wise corrected for multiple comparisons; and (2) $p < .05$ (minimum 20 contiguous significant voxels) uncorrected for multiple comparisons for exploratory analysis of clusters below the family-wise threshold. This dual thresholding of result images controls for Type I errors, but also allows for further investigation of subthreshold results in this single-subject example.

RESULTS

Debriefing

JG confirmed that the three KNOWNS were Truth and indicated that all three UNKNOWNS were Lie and that he lied about all three during the task. JG's claim that he lied about all three items throughout the task was corroborated by analysis of the behavioral response data.

RQT task fMRI results

In the contrast of UKNOWN 1 with the average of KNOWN truth, UNKNOWN 1: ''Did you write this book?'' revealed significant bilateral activation in IFG (BA 13, 47) and IPL/SMG (BA 40) (Table 1). In addition, there was activation in bilateral STG (BA 22, 41) and right PHG (BA 36). In terms of height and extent of activation, the most prominent activations in UKNOWN 1 were in the left IFG and the right SMG, though both IFG and SMG activations were bilateral.

When UNKNOWN 2: ''Did you graduate from Notre Dame?'' was contrasted with the average of KNOWN truth, the contrast revealed significant activation in bilateral IFG (BA 45, 47) and IPL/SMG (BA 40). In addition, activation was observed in right subcallosal gyrus, SCG (BA 25), medial frontal gyrus (BA 11), bilateral PHG (BA 35, 36), and left uncus (BA 34). Activations in left and right IPL were equally significant in terms of height and extent; however, left IFG activation was more significant than right IFG activation in both height and extent.

When UKNOWN 3: ''Did you serve in the Military?'' was contrasted with the average of KNOWN truth, the contrast revealed significant activation in right hippocampus (BA 28) and MTG (BA 39). Also, activation was observed in the right amygdala (BA 34) and left IPL/SMG (BA 40).

Lastly, when the average of all KNOWN was contrasted with the average of all UNKNOWN, the contrast revealed significant activation in the right MFG (BA 11), left MTG (BA 21, 39), and right inferior temporal gyrus, ITG (BA 37) (Figure 2).

DISCUSSION

Three members of the study team, blinded as to which, if any, of the UNKNOWN items were lies, evaluated the UNKNOWN > KNOWN contrasts and provided one consensus opinion. Deceptive responses in two of the three UNKNOWN items were associated with increased prefronto-parietal activation (IFG, BA 45, 47 and IPL/SMG, BA 40), as predicted in our first hypothesis, and could be categorized as Lie, as predicted in our second hypothesis. The inferior frontal and inferior parietal are the two regions consistently associated with deception in Lie > Truth comparisons under the GKT model, especially after salience is controlled for (Gamer, Bauermann, Stoeter, & Vossel, 2007; Langleben et al., 2005). The RQT critically departs from the laboratory GKT model by the presence of multiple unknowns instead of one endorsed or possible lie. Similarly to GKT1, the RQT controls for the prepotency of response type, i.e. all responses were uniformly ''Yes'' (RQT) or uniformly ''No'' (GKT1), which changing can in itself activate the prefronto-parietal network (Linden et al., 1999). Also similarly to GKT2, the RQT controls for the familiarity of task items. Thus, the RQT carries enough similarities with the GKT models (Elaad, Ginton, & Jungman, 1992; Langleben et al., 2005) to consider it an adaptation of the GKT1 and GKT2 to a real-life scenario rather than an entirely new task. Therefore, similarities in activation pattern in the RQT and GKT during Lie are expected.

The third UNKNOWN contrast (Figure 2, ''Did you serve in the military?'') stands out. Contrary to our expectations, it was associated with amygdala and hippocampus activation and, while there was activation in the left IPL, there was no prefrontal response. Thus, an expert using a prefronto-parietal model of Lie > Truth brain activation may be unable to categorize this response as a Lie. This may be the first report of limbic activation during Lie in a forced-choice unendorsed deception paradigm, though Abe et al. (2007) found amygdala activation as a

TABLE 1
fMRI results of each UNKNOWN > ALL KNOWN

REGION	*Unknown 1: Book*						*Unknown 2: Notre Dame*						*Unknown 3: Military*					
Frontal	*No. vox*	*BA*	*X*	*Y*	*Z*	Z_{max}	*No. vox*	*BA*	*X*	*Y*	*Z*	Z_{max}	*No. vox*	*BA*	*X*	*Y*	*Z*	Z_{max}
IFG L	**531**	**13,47**	**−38**	**12**	**−8**	**3.16**	**900**	**47**	**−36**	**17**	**−4**	**3.65**						
	209	**45**	**−48**	**20**	**19**	**3.21**	**190**	**45**	**−45**	**36**	**2**	**2.99**						
	61	45	−46	34	6	2.44												
IFG R	37	47	44	17	−10	2.29	**1038**	**47**	**32**	**21**	**−4**	**3.26**						
	29	45	43	19	18	2.29	**241**	**45**	**−45**	**16**	**18**	**3.1**						
SCG R							27	25	11	14	−11	2.68						
MFG L							29	11	−14	30	−14	2.66						
Temporal																		
STG L	71	22	−58	−43	20	2.63												
STG R	33	41	42	−34	14	2.46												
MTG R													31	39	46	−65	26	2.17
PHG L							**100**	**35**	**−23**	**−19**	**−16**	**3.25**						
							71	36	−24	−36	−11	2.92						
PHG R	24	36	24	−30	−15	2.55	**246**	**35**	**21**	**−30**	**−12**	**2.83**						
							40	36	24	−21	−24	2.29						
Hipp R													**142**	**28**	**24**	**−18**	**−19**	**3.13**
Amyg R													40	34	20	−3	−14	2
Uncus L							**188**	**34**	**−24**	**3**	**−19**	**3.38**						
Parietal																		
IPL/SMG L	**149**	**40**	**−43**	**−40**	**38**	**2.67**	**1937**	**40**	**−44**	**−37**	**34**	**3.89**	45	40	−42	−38	36	2.16
	62	40	−32	−60	41	2.89												
IPL/SMG R	**1079**	**40**	**42**	**−51**	**35**	**3.66**	**1900**	**40**	**42**	**−46**	**32**	**3.98**						

Notes: Data in table is thresholded at $p < .05$, uncorrected for multiple comparisons; clusters of activation that survive family-wise correction at $p < .05$ are given in bold type. UNKNOWN 1: ''Did you write this book?'', UNKNOWN 2: ''Did you graduate from Notre Dame?'', UNKNOWN 3: ''Did you serve in the military?'', UNKNOWNs 1 and 2 categorized as lies due to presence of significant activation in IFG and SMG; UNKNOWN 3 categorized as a truth due to lack of IFG activation. No. of voxels expressed as number of contiguous voxels within ROI. Z_{max} refers to the peak Z within a given ROI. Empty rows denote no super-threshold voxels within ROI.

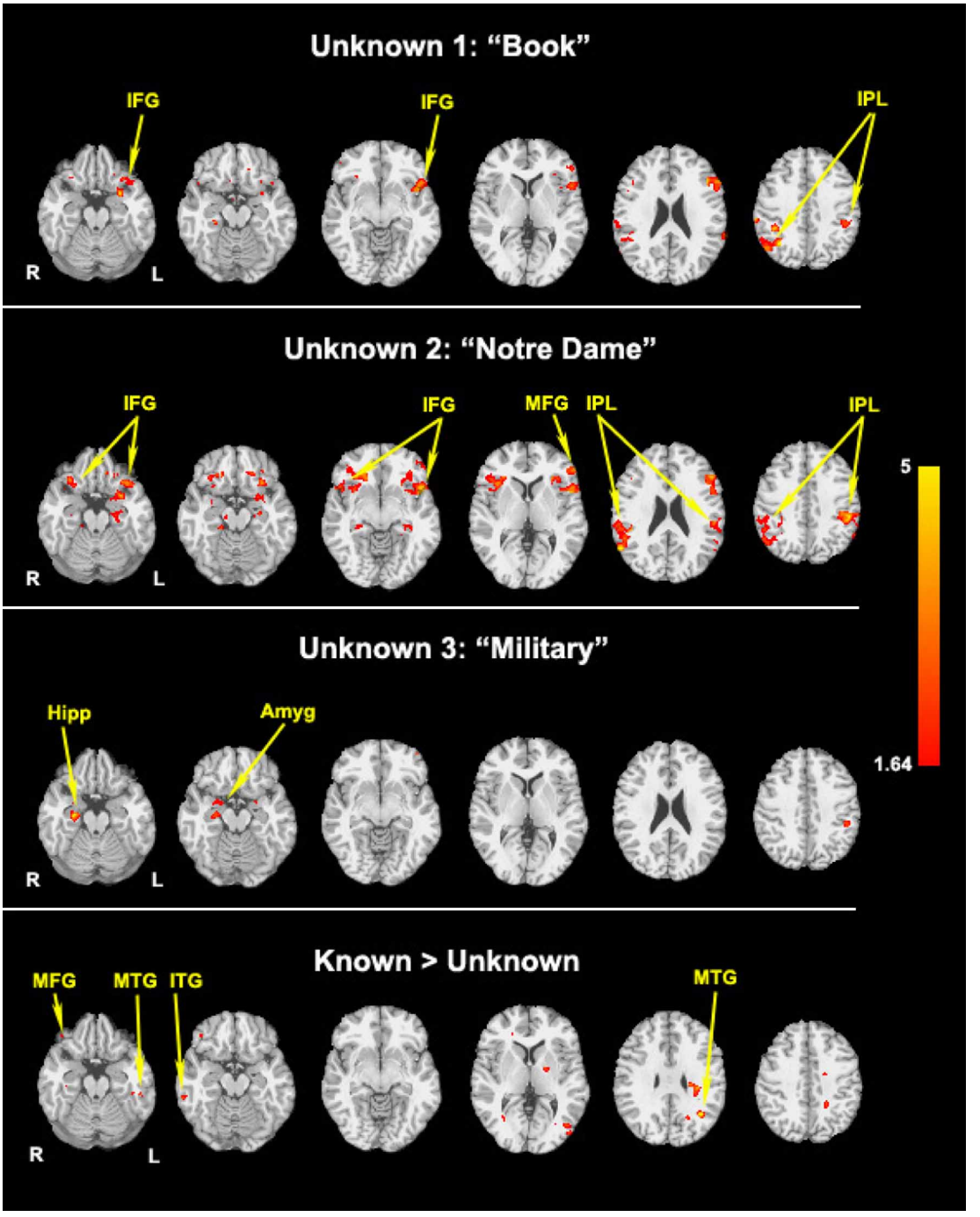

Figure 2. UNKNOWN > KNOWN and KNOWN > UNKNOWN fMRI results. fMRI results of each UNKNOWN > KNOWN, and average of KNOWN > average of UNKNOWN. Top and second row: UNKNOWN 1 and 2 exhibit heightened response in the bilateral IFG and IPL/SMG. UNKNOWN 3 (third row) exhibited heightened activation in the left IPL, right hippocampus and amygdala. Average of KNOWN > average of UNKNOWN (bottom row) exhibited heightened response in the MFG, ITG, and MTG. Single subject results registered to and projected over the MNI template and masked with the *a priori* ROI mask (see Methods). Result images displayed at $p < 0.05$ uncorrected for multiple comparisons.

main effect of non-endorsed responses when a subject engaged in both lying AND truth-telling.

The limbic activation could be due to either arousal related to the topic of the USMC, or specifically to lying about this particular question. The former may relate to JG's feelings about the military that were formed while he was an "embedded" reporter with the USMC (Garreau,

2006). The second may relate to the increased limbic response associated with social inappropriateness (Finger, Marsh, Kamel, Mitchell, & Blair, 2006) and moral dilemmas (Greene, Nystrom, Engell, Darley, & Cohen, 2004), features that are common to the RQT format and may be inherent to lying about socially or personally significant questions.

The concurrent absence of prefronto-parietal response in UNKNOWN 3 with increase in limbic response can be interpreted in several ways. The limbic system could inhibit activation of the prefrontal system mediating deception under conditions of increased emotional and memory involvement (Shafritz, Collins, & Blumberg, 2006). It is also possible that JG did not subjectively perceive an affirmative response to this question as a lie, given his experience of being ''embedded'' with the USMC, a cognitive strategy that JG admitted employing as a countermeasure during debriefing (Garreau, 2006). Finally, the greater difficulty in matching the features of the stimuli in the RQT (in contrast to the GKT, where all items were playing cards) may have confounded the anticipated lie response in IFG and IPL for UNKNOWN 3. Analyzing these data in the style of a controlled question task (CQT) would require proper matching of each UNKNOWN question with a well-matched control question, and might help reduce or eliminate false negative results. This possibility underscores the importance of considering the perceptual features of naturalistic stimuli in future applications of the RQT. Lastly, in order to help interpret counterintuitive results such as those seen in UNKNOWN 3, it would be useful to assess, for each query item, participants' subjective emotions about lying.

Though the findings in this report cannot be simply generalized to populations, they illustrate a number of issues in the neurobiology of deception that should be investigated before conducting clinical trials. First, future studies using scenarios with higher ecological validity may discover fMRI patterns associated with deception, other than those reported so far. Specifically, the absence of limbic system activation in Lie contrasts in all prior fMRI studies is puzzling, considering the role of the limbic system in emotion, memory, and anxiety. This may be due to the technical difficulties in acquiring fMRI signal from the inferior part of the brain or to the low risk/benefit ratio of deception in the laboratory setting. Our RQT paradigm is example of a transitional model, midway between the laboratory and real life, that could provide data to justify prospective clinical trials of fMRI-based lie detection in relevant populations. Elucidating the relationship between the limbic system and the prefronto-parietal network may be one of the missions of such transitional experiments. Second, a major practical limitation of applying the current GKT paradigms to real life is the inability to fully control the visual salience of query items. For example, while the real and forged book covers were well matched, the visual comparability of a forged diploma to an image of one's home is less clear. This issue may be more easily addressed in the laboratory than in the field. One solution is to derive empirical corrections for features such as complexity and lighting, another is to use text-only query items. Such approaches have not been studied and require validation.

The list of the unaddressed issues en route to conclusive clinical trials could be longer. One such issue is identifying a consensus approach for reporting clinical single subject fMRI data. This issue has only recently begun to be elaborated upon in the literature on deception (Kozel, 2008). Specifically means for adequate control of Type I errors is required. Though anatomical masking may be an effective in reducing multiple comparisons, it precludes investigation of unpredicted task-related activation, a potential problem in a situation that may involve a high level of individual variability.

A more theoretical but no less important issue is the concept of theory of mind (TOM) and its place in the neuroscience of deception (Stuss, 2001). Tests that elicit deception for the purpose of detection, including the RQT, do not address TOM, which is invariably engaged by a deceptive social interaction. In order to engage TOM, our RQT could be modified to emulate a human interviewer.

Finally, we would like to propose a distinction between lie-detection and ''mind-reading.'' Lying involves a conscious act of suppression or modification of subjective truth in response to a query. Identifying deception by measuring its physiological markers is the aim of lie-detection. On the other hand, ''mind-reading'' implies making inference about the cognitive or emotional state of an individual through pattern-recognition of fMRI data without explicit query or conscious behavioral response (Haynes & Rees, 2006; Haynes et al., 2007; Norman, Polyn, Detre, & Haxby, 2006). While potentially very powerful,

this approach is currently more vulnerable to interpretation than a forced-choice lie-detection paradigm involving predefined query such as the RQT.

This case report illustrates an approach and the hurdles therein on the way from laboratory experiments to prospective clinical trials of fMRI-based lie detection. Our findings suggest that under conditions closely approximating a real-life situation, fMRI signal patterns associated with deception generated by a GKT-type model may be more variable than previously reported. Our observations indicate that increasing ecological validity of the deception task may not necessarily diminish the accuracy of lie detection, but it may require additional studies to address variations associated with the social and personal consequences of deception scenarios. The study also illustrates the need to further investigate the contribution of emotion and memory to brain activation evoked by deception scenarios with high ecological validity. Finally, our case provides an example of an ethically sound experiment that bridges the gap between the laboratory and clinical trial.

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