Lie Detection by Functional Magnetic Resonance Imaging

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Abstract: The accurate detection of deception or lying is a challenge to experts in many scientific disciplines. To investigate if specific cerebral activation characterized feigned memory impairment, six healthy male volunteers underwent functional magnetic resonance imaging with a block-design paradigm while they performed forced-choice memory tasks involving both simulated malingering and under normal control conditions. Malingering that demonstrated the existence and involvement of a prefrontal-parietal-sub-cortical circuit with feigned memory impairment produced distinct patterns of neural activation. Because astute liars feign memory impairment successfully in testing once they understand the design of the measure being employed, our study represents an extremely significant preliminary step towards the development of valid and sensitive methods for the detection of deception. *Hum. Brain Mapping* 15:157–164, 2002. © 2002 Wiley-Liss, Inc.

Key words: mental processes; lie detection; malingering; neuropsychology; memory; functional magnetic resonance imaging

INTRODUCTION

Intentional falsification or malingering is a commonly observed phenomenon in the real world. It is also a topic of immense fascination to many scientific disciplines. Simply stated, malingering is the intentionally false and fraudulent simulation or exaggeration of physical or mental disease, or other defects [Gorman, 1982]. Abundant research has been con-

ducted until date that has been aimed at designing an instrument sensitive enough to detect malingering. Objective testing with a forced-choice format has been previously documented to be the valid method of choice for the detection of deception [Hall and Pritchard, 1996]. Nevertheless, despite the inherent sophistication of behavioral paradigms for the detection of malingering, astute liars could still fake testing behavior once they understand the design of the measure [Bernard et al., 1993]. Because faking cerebral activity to avoid the detection of deception is not feasible, it was our speculation that the patterns of brain activation in malingerers would provide unique markers for the detection of deception. We, therefore,

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used functional magnetic resonance imaging (fMRI) to specifically investigate the precise nature of cerebral activation during feigned memory impairment, and to determine if in fact it was clearly distinguishable from normal recall.

Before the fMRI experiments, we conducted two behavioral studies. Study 1 was aimed at retesting the validity of forced-choice testing in terms of differentiating malingerers from normal Chinese controls. Study 2, on the other hand, investigated the cognitive strategies that most people adopted when they feigned memory impairment. While Study 1 provided invaluable input toward designing the format of the experimental tasks to be used in the fMRI studies later, Study 2 was extremely beneficial in the formulation of the *a priori* hypothesis for our fMRI experiments.

In Study 1, 38 Chinese university freshmen with an education level of 13 years volunteered to participate (age range = 21.1 ± 1.36 years). None of them had been using any narcotic substances or had any previous history of head trauma or other medical or psychiatric conditions that could possibly have had a bearing upon their cognitive status, which was screened, by their self-reported medical history. By utilizing a forced-choice memory task, intent to deceive was identified based on the premise that performance at less than chance levels violates probability estimates of binomial distributions. This simulation design was adopted because it offered high internal validity [Hiscock et al., 1994]. All participants were tested both while malingering and under normal control conditions. The instrument used was based on the forced-choice memory task format developed by Hiscock and Hiscock [1989]. A five-digit number was initially presented on a card. After a short delay, another card containing the correct choice and a foil were projected. Each participant had to separately identify the correct answer, which was readily distinguishable from the foil by simply recognizing the first or last digit of the number. Because all items had two response possibilities, the overall error rates were expected to be approximately 50% under conditions of random responding. Performance below chance at a low probability was interpreted as a deliberate choice of incorrect answers [Spreen and Strauss, 1998]. The results from this study demonstrated that simulated malingerers and normal controls were clearly distinguishable when tested with a forced-choice memory task ($F(1,37) = 43.19$; $P < 0.01$) [Chiu and Lee, *in press*].

In Study 2, 95 Chinese freshmen (age range = 23.2 ± 2.2 years) with a minimum of 12 years education consented to participate. During an interview, they

were administered a questionnaire that was designed to investigate probable cognitive strategies that would be adopted by them when memory impairment was feigned during forced-choice memory tasks. The same forced-choice memory tasks involving digit memory or autobiographic memory questions were intended to be used in the fMRI experiments conducted later. The responses of all the participating 95 Chinese freshmen were coded. While 76 of the 95 participants (80%) reported that they would manipulate the proportion of correct and incorrect answers, the remaining 19 volunteers (20%) said that they would make random responses to achieve the purpose of deception. It appeared that the most popular cognitive strategy adopted by a majority of individuals faking memory impairment was to calculate the proportion of correct to incorrect responses by answering most of them, but not all, incorrectly. This finding suggested that the activation of neural correlates involved in such calculations could provide an ideal marker for the detection of deception.

Our findings in the above mentioned behavioral studies demonstrated that simulated malingerers and normal controls perform differently during a forced-choice memory task. Further, astute malingerers tended to make calculated responses by adjusting the proportion of correct and incorrect answers in their performance to achieve the purpose of deception. These results prompted the formulation of the *a priori* hypothesis that the activation of neural structures specifically involved in the cognitive control of response manipulation (prefrontal cortex and sub-cortical structures) [MacDonald et al., 2000], selection and adoption of retrieval strategies (prefrontal cortex) [Schacter et al., 1998], and in the calculation of the proportion of correct responses (fronto-parietal cortex) [Cowell et al., 2000; Pesenti et al., 2000] would be observed during the process of feigned memory impairment when subjects were tested with forced-choice memory tasks. We performed two fMRI studies involving a block-design paradigm to test the hypothesis proposed.

MATERIALS AND METHODS

Subjects

All experiments were conducted at the Research Imaging Center (RIC), The University of Texas Health Science Center at San Antonio (UTHSCSA). Six male volunteers participated in the fMRI experiments. Informed consent was obtained from all subjects in accordance with the guidelines devised by the Institutional Review Board at the UTHSCSA. All enrollees

were native Chinese (Mandarin) speakers from Mainland China and ranged in age from 31.6–37.2 years. They were strongly right-handed as judged by the Lateral Dominance Test [Spreen and Strauss, 1998] and were recruited into the study based on the presence of the following criteria: 1) attention span reaching or exceeding a 7-digit level as measured by the Digit Span Test, and 2) full scores on the digit memory and autobiographic memory tasks that were to be administered later during fMRI scanning.

Activation paradigms

Subjects were visually familiarized with the experimental conditions and procedures to minimize anxiety and enhance task performance. They were specifically trained to feign memory impairment and the following instruction was given before the start of the fMRI scanning session:

“You are to feign a memory problem and deliberately do badly on the test. Imagine a scenario, which envisages that a bad result will lead to an attractive sum of money as compensation for your memory problem. You should fake skillfully to avoid detection. So, your goal is to fake well, do it with skill, and avoid detection.”

Each subject was then given 5 min to arrive at a coherent strategy that he would employ during the performance of the forced-choice memory tasks. After this familiarization, each subject lay supine on the scanning table that was supported by a body-length, vinyl-upholstered, dense foam pad. Plastic ear-canal molds were then fitted for each subject. A tightly fitting, thermally molded, plastic facial mask extending from the hairline to the chin was utilized to immobilize each subject's head and to prevent inter-scan motion [Fox et al., 1985].

Two fMRI studies involving a block-design paradigm were employed. Study 1 utilized a digit memory task of a forced-choice format. Each subject was initially presented with a three-digit number that was followed by another after a 2.25-second time lag and asked to decide if the two separately presented stimuli were the same. Three-digit numbers were used instead of five-digit numbers in order to minimize the error variance introduced by task difficulty. Study 2 used an autobiographic memory task of a forced-choice format. Although the procedure was essentially similar to that used in Study 1, the subject was however presented this time with an autobiographic question, e.g., “where were you born?” that was followed by an answer to that question, e.g.,

“London,” which was presented 2.25 sec later. Each participant was instructed to identify if the answer to the presented question was correct. Pressing an air pump connected to a bell in the MRI console room indicated a “yes” response.

Following a simulation design, subjects were requested to answer the questions correctly and then answered it in a way to fake memory impairments. To encourage skillful lying, two other conditions, answering incorrectly and answering randomly, were also added to the experimental paradigm. Therefore, there were four conditions involved: answering correctly, answering incorrectly, answering randomly, and feigning memory impairment. Each experimental condition was repeated three times. Twelve blocks of fMRI scanning were performed with each block 46 sec in duration. The total scan time was 552 sec. The order of presentation of the four experimental conditions was randomized according to a Latin-square table. During each block, a stimulus was presented for 0.75 sec through an LED projector system, which was followed by visual fixation on a cross hair for 2.25 sec. At the end of fixation, a fresh stimulus was presented. Each block represented one experimental condition and consisted of four questions. Each participant responded to the stimulus according to the specific instructions previously outlined for each of the four experimental conditions.

During the post-experimental debriefing that followed the completion of this session, each participant was asked to outline the strategies he had adopted for feigning memory impairment during the experiment.

Imaging protocol

A T_2^* -weighted gradient-echo, echo-planar imaging (EPI) sequence was used for the fMRI scan with the following parameters: slice thickness = 6 mm; in-plane resolution = 2.9 mm $\times$ 2.9 mm; and TR/TE/ θ = 2000 msec/45 msec/90°. Twenty axial slices were acquired to encompass the whole brain. For each slice, 276 images were procured with a total scan time of 552 sec. Anatomical details were obtained from a T_1 -weighted image that was acquired with a spatial resolution of 1 mm³. After scanning was completed, all participants were individually asked about the strategies they had adopted for faking badly during the experiment.

Data processing and analysis

Intentional lying requires accurate recall followed by conscious manipulation of the recalled informa-

(a) Digit Memory Task

(b) Autobiographic Memory Task

Figure 1.

Functional maps. Normalized activation brain maps averaged across five subjects demonstrating the statistically significant activations ($P < 0.01$) in the faking memory impairment condition with the activation for making accurate recall removed when perform-

ing on forced choice testing using (a) Digit Memory and (b) Autobiographic Memory tasks. Planes are axial sections, labeled with the height (mm) relative to the bicommissural line. L, left hemisphere; R, right hemisphere.

tion. We therefore measured brain activation during recall and intentional lying in both the studies. By subtracting cerebral activity measured during recall from that observed while lying intentionally, a clear picture about the pattern of brain activation underlying intentional lying was derived. Activation patterns common to both the studies, which employed stimuli of a very different nature, could then be interpreted as possible neuro-anatomical correlates of deception.

All the post-scan image processing was performed on a SUN workstation using MATLAB (The Math Works, Natick, MA) and in-house software for image data processing [Xiong et al., 1995], including corrections for head motion and global MRI signal shift. Skull stripping of the 3D MRI T_1 -weighted images was performed using Alice (Perceptive Systems, Boulder, CO). Images were then spatially normalized to the Talairach brain atlas [Talairach and Tournoux, 1988] using a Convex Hull algorithm [Downs et al., 1994; Lancaster et al., 1999]. Data from one subject was discarded due to motion induced degradation in image quality.

After the initial processing, functional images were grouped into those derived during correct recall and while malingering. Data from the initial 8 sec of each test condition was excluded from further processing

with the aim of minimizing the transitory effects of the induced hemodynamic response. Using a t -test, activation maps were then calculated by comparing the images acquired during the faking badly with the answering correctly conditions. Images were spatially normalized to the Talairach space using a Convex Hull algorithm. The averaged activation maps across subjects with a t -value threshold corresponding to $P < 0.01$ were then overlaid on the corresponding T_1 -weighted anatomical images. For each condition, the Talairach coordinates of the center-of-mass and volume (mm^3) of the activation clusters were determined based on the averaged activation maps. Anatomical labels (lobes, gyri) and Brodmann area (BA) designations were applied automatically using a 3-D electronic brain atlas [Lancaster et al., 1997].

RESULTS

No errors were committed by any of the subjects in the two experimental conditions. fMRI images illustrating task-induced brain activation averaged across the final five subjects during feigned memory impairment, after removing the activator associated with answering correctly, are presented in Figure 1. Signif-

TABLE I. Regions and corresponding Brodmann's areas of activation common to both block design fMRI studies

Digit			Autobiographic		
Region	BA (Coordinates X, Y, Z)	Vol (mm ³)	Region	BA (Coordinates X, Y, Z)	Vol (mm ³)
R Frontal	6(19, -9, 57); (35, -10, 57) (41, 0, 48); (24, 7, 59) 9(50, 17, 32); (31, 29, 34) (26, 40, 33) 10(38, 57, 9); (7, 56, 19) (31, 47, -2) 46(58, 37, 26)	1512 4664 8688 136	R Frontal	6(13, 17, 59); (34, 10, 57) (52, -4, 43) 9(33, 44, 28) 46(48, 31, 17)	392 120 7704
R Parietal	40(43, -64, 41)	5376	R Parietal	40(45, -62, 46); (57, -51, 32) (61, -44, 29)	1824
R Temporal	21(60, -22, -5)	272	R Temporal	21(61, -54, 0)	128
R Subcortical	Caudate(14, -4, 16)	1056	R Subcortical	Caudate(15, -4, 17)	160
L Frontal	6(-40, 1, 53); (-3, -12, 65) (-29, 15, 48) 9(-41, 26, 34); (-22, 48, 29) (-58, 26, 27) 10(-42, 55, 7) (-6, 60, 23)	2064 4008 5200	L Frontal	6(-43, 6, 50) 9(-45, 26, 33) 10(-23, 59, 5); (-37, 45, 11) (-10, 60, 18); (-25, 62, 18)	184 1368 4816
L Parietal	40(-47, -65, 40)	6264	L Parietal	40(-50, -55, 44); (-58, -44, 38) (-60, -38, 27)	1864
L Temporal	21(-67, -40, 2)	976	L Temporal	21(-62, 5, -12)	392
L Subcortical	Caudate(-13, -1, 19) Posterior cingulate (-2, -39, 20)	440 1368	L Subcortical	Caudate(-15, 2, 14) Posterior cingulate (0, -27, 28)	216 136

* Digit, digit memory task used in Study 1; Autobiographic, autobiographic memory task used in Study 2; BA, Brodmann's Area; Vol, Activation volume (voxels); L, Left cerebral hemisphere; R, Right cerebral hemisphere.

icant areas of activation for these comparisons are summarized in Table I.

Our results indicate that both the left and right cerebral hemispheres were engaged when memory impairment was feigned (Fig. 1). Areas of activation common to both fMRI studies (Table I) included the bilateral prefrontal (BA 9/10/46), frontal (BA 6), parietal (BA 40), temporal (BA 21), and sub-cortical (caudate) regions. We also observed significant activation involving the left posterior cingulate region (BA 23).

DISCUSSION

The detection of feigned memory impairment is even today a challenge to many inter-disciplinary experts. We conducted two fMRI studies utilizing block design activation paradigms, based on the data obtained from our earlier behavioral studies. The goal was to identify whether neural activation observed in malingerers was clearly distinguishable from that seen in normal controls. Our imaging data revealed four

principle regions of brain activation: prefrontal and frontal, parietal, temporal, and sub-cortical.

Prefrontal (BA 10, BA 9/46) and frontal (BA 6) regions

It is well known that prefrontal activation is significant with information manipulation and integration, programming strategies, and during the control of executive functions [Koechlin et al., 1999; Shallice, 1999; Prabhakaran et al., 2000]. Specifically, activation of the fronto-polar prefrontal region (BA 10) is a manifestation of the process of holding in place primary goals while still processing secondary goals simultaneously. Activation of the dorsolateral prefrontal region (BA 9 and 46) on the other hand, represents anticipation of performance [Schacter et al., 1998], intentional retrieval [Schacter et al., 1998], a unique working memory representation [Prabhakaran et al., 2000], cognitive control [MacDonald et al., 2000], and

the selection of retrieval strategies [Rowe et al., 2000; Wagner et al., 1998] in the process of deception.

Both prefrontal regions were activated during the recall tasks used in our fMRI studies, which is consistent with the finding of bilateral prefrontal activation with memory processing that has been reported previously. Though the two prefrontal regions were activated in performing memory tasks, they have a different functional basis. While left-sided prefrontal activation was typically reported during memory encoding, right-sided prefrontal activation was observed only during retrieval. These results are consistent with the hemispheric encoding retrieval asymmetry (HERA) theory propagated earlier by Nyberg et al. [1996].

Some published studies have documented the presence of only left-sided prefrontal activation during retrieval [Kapur et al., 1995; Maguire et al., 1998], whereas others have suggested that the laterality of prefrontal activation in neuroimaging studies depends on "the reflective demands of the task" [Nolde et al., 1998]. Consequently, it is believed that the left prefrontal cortex is active only when retrieval is complex, as for example when information is being maintained while being evaluated.

Scientific literature is also replete with studies that have shown relatively greater activation of the prefrontal cortex due to the increased demands of load, duration or manipulation on working memory [e.g., Baker et al., 1996; Courtney et al., 1997; Jonides et al., 1998; Manoach et al., 1997; Owen et al., 1996; Paulesu et al., 1993; Rypma et al., 1999; Rypma and D'Esposito, 1999]. Larger prefrontal activation has also been observed during the performance of some easier conditions, however, lending credence to the conclusion that prefrontal activation reflects the nature of the working-memory representation allowed for temporary retention of integrated information [Prabhakaran et al., 2000] rather than working-memory load, duration, or manipulation.

The residual activation of BA 6 after the subtraction procedure during the feigned memory impairment condition was most likely due to the effort involved in motor planning/decision processing in terms of the initiation of pump pressing [Banich, 1997].

Parietal region

The activation of the BA 40 region was entirely expected because all participants reported that they had made calculated responses. This finding is consistent with the behavioral data obtained by us in our previous studies. It was also evident that the most

popular strategy adopted in feigned memory impairment was to calculate the proportion of right and wrong answers. Thus, the activation of the frontal and parietal structures is in excellent conformity with previous knowledge of the fronto-parietal network in the comparison and computation of digits [Cowell et al., 2000; Pesenti et al., 2000]. Although it is clearly evident that the medial parietal region is a large cortical area and presumably has many associated functions, relatively little is known about its functional segregation. It is believed that the anterior part of the medial parietal region is activated only when subjects had a mental framework into which they placed incoming information [Maguire et al., 1999].

Temporal region

Activation of BA 21 may be specific to the visual stimulation [Gazzaniga et al., 1998] used in our experiments. Indeed, some subjects reported that they consciously distorted the visual images perceived when feigning memory impairment (e.g., said to themselves that it was a Figure 8 when they actually saw Figure 3).

As expected, we did not observe activation involving the hippocampal formation. Indeed hippocampal activation has only rarely been observed in memory tasks [Schacter et al., 1998]. Furthermore, the failure to see hippocampal activation may have been due to the cancellation effect produced after the subtraction procedure employed by us for data processing. It may be noted that the hippocampus was active during all the experimental conditions because memory was required in all the cases.

Sub-cortical region

Activation of the sub-cortical regions, caudate and posterior cingulate (BA 23), was most likely related to the inhibition of previously learned rules and self-monitoring of random errors [Amos, 2000; Carter et al., 1998]. Maguire et al. [1999] suggest that an important role for the posterior cingulate region is in the linking of incoming information with a repository of activated knowledge and thereby form a coherent representation of discourse. The conjoint activation of the anterior medial parietal/posterior cingulate region, therefore, reflects the online incorporation of information into a preset mental framework. This observation is in excellent agreement with the findings in our study as all participants had already established a mental framework for malingering well before they

entered the experimental conditions and underwent fMRI scanning.

Activation of the caudate region reflects performance monitoring, just as Semrud-Clikeman et al. [2000] observed that the intact structure of the caudate correlates with performance on measures of inhibition. Furthermore, Amos [2000] reported increased errors in performance when activation units representing striatal neurons were reduced, as observed in people with either Parkinson's or Huntington disease. These findings suggest an important role for the caudate in the inhibition of usual response and in the monitoring of error performance when a person is trying to feign memory impairment.

Neural markers for detection of feigned memory impairment

Taking all these findings into consideration, we conclude that the activation of a prefrontal (BA 10/9/46)-parietal (BA 40)-sub-cortical (caudate and posterior cingulate) circuit is generalized to situations of feigned memory impairment when tested with forced-choice memory tasks. This, therefore, confirms the a priori hypothesis of our studies.

CONCLUSIONS

Our experimental findings provide some initial evidence for the existence and involvement of a prefrontal-parietal-sub-cortical circuit in feigned memory impairment when tested with a forced-choice format. It is well known that astute liars feign successfully in testing once they understand the design of the measure [Bernard et al., 1993]. Further, it is also clearly evident that controlling one's cerebral activity to avoid detection is unfeasible. Taken together, this suggests that our work may have identified some extremely significant preliminary markers that have the promise to enhance the development of valid and sensitive methods for the detection of malingering. In addition, examination of lying and its detection in both normal and clinical populations using behavioral [Ettcoff et al., 2000] and functional imaging paradigms will provide further theoretical refinement of our findings. According to "Theory of Mind," which states the ability to make inferences about others mental states [e.g., Baron-Cohen, 1989; Baron-Cohen et al., 1993, 1994; Wellman, 1990], an essence of lying is the recognition of, and attempt to manipulate, the mental states of others. Potentially significant applications of our findings for future investigations include research aiming at dis-

tinguishing different types of liars and different types of lying with or without meta-cognitive calculations.

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