Brain Imaging and The Mind: Science or Pseudoscience?

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Initial Comments (1)

• Despite the enormous popular excitement and professional activity, we are not able to read minds or infer thoughts from brain images.
• At best, brain images represent responses that are weakly correlated with mental activity. At worst they are random responses that are actually unrelated to thoughts.
• The current evidence that brain images are associated with deception is inconsistent and unconvincing.
• Much of the current concern is based on hopes and dreams; on a kind of overblown futurism.
Initial Comments (2)

• If you think the ethical problems arising should we have a workable and validated brain imaging lie detector are substantial, consider how even more severe the ethical problems would be if the method did not work and we erroneously assumed that it did.

• We should make every effort now to avoid repeating the current situation with polygraphs—a persistent and continued presence despite little scientific validity.
Brain Imaging is a Wonderful New Science

- Stroke prediction
- Distribution of critical brain chemicals (transmitters)
- Myelination
- Drug effects
- Brain tumors
- Aging effects
- In general, a powerful diagnostic tool
The New Neurosciences

• Neuropolitics
• Neuromarketing
• Neuroethology
• Neuroeconomics
• Neurotheology
• Neuroethics

• And, of course, Neurolaw
Two Main “Hot” Areas of Neurolaw

• Detection of deception
• Impact of brain abnormalities as exculpatory evidence
My Goals

• Review the history of lie detection
• Identify its basic assumptions
• Identify technical arguments against brain images as lie detectors
• Especially, the impact of meta-studies
• Identify some of the reasons for variability
• Identify some practical problems
• Note caution on part of investigators
• Draw conclusions about the state of the process
Lie Detection Throughout History

- Dry mouth (Rice)
- Flushing
- Sweating
- Torture
- Gross behavior (E.g. downcast eyes)
- Pulse and blood pressure (Marston, 1917)
- Respiration
- Galvanic skin response (GSR)
- Polygraph
- Electroencephalograph EEG) and Evoked Brain Potentials (EBP)
- Voice stress analysis (FSA)
- Facial heat distribution
- Facial micro-expressions
- Positron Emission Tomography (PET)
- Functional Magnetic Resonance Imaging (fMRI)
NAS ON POLYGRAPHY

• “The theoretical rationale for the polygraph is quite weak, especially in terms of differential fear, arousal, or other emotional states that are triggered in response to relevant or comparison questions.”

• “Almost a century of research in scientific psychology and physiology provides little basis for the expectation that a polygraph test could have extremely high accuracy.”

• “Research on the polygraph has not progressed over time in the manner of a typical scientific field. It has not accumulated knowledge or strengthened its scientific underpinnings in any significant manner.”

• “The inherent ambiguity of the physiological measures used in the polygraph suggest that further investments in improving polygraph technique and interpretation will bring only modest improvements in accuracy.” (NAS, 2003, pps. 212 - 213)
NAS on Brain Image Lie Detectors

- There is no solid base of repeated scientific findings that associates brain images with deception.
- The new imaging techniques have not been shown to exceed the low accuracy levels of the classic polygraph. (NAS 2003, Paraphrased)
A Popular Hypothesis

Modular cognitive components can be shown to be “localized” in modular regions of the brain by fMRI techniques that examine Blood Oxygenation Level Dependent (BOLD) differences.
Controversial (if not incorrect) Assumptions

• Psychological functions can be compartmentalized into specific modular functions.
• These functions can be located in particular parts of the brain.
• (A task of psychology has been to define these modules. A task of neuroscience has been to locate the brain regions in which the modules are produced.)
Fig. 144.

NAMES, NUMBERS, AND LOCATION OF THE ORGANS.

1. AMATIVENESS.
2. CONJUGAL LOVE.
3. PARENTAL LOVE.
4. FRIENDSHIP.
5. INHABITIVENESS.
6. CONTINUITY.
7. VITALIVENESS.
8. COMBATIVENESS.
9. DESTRUCTIVENESS.
10. AMENIVENESS.
11. ACQUISVITIVENESS.
12. APPROVATIVENESS.
13. SELF-ESTHEM.
14. FIRMNESS.
15. CONSCIENTIOUSNESS.
16. HOPE.
17. SPIRITUALITY.
18. VENERATION.
19. BENEOLOANCE.
20. CONSTRUCTIVENESS.
21. IDEALITY.
22. SUBLIMITY.
23. IMITATION.
24. INDIVIDUALITY.
25. FORM.
26. SIZE.
27. WEIGHT.
28. COLOR.
29. ORDER.
30. CALCULATION.
31. LOCALITY.
32. EVENTUALITY.
33. TIME.
34. TUNE.
35. LANGUAGE.
36. CAUSALITY.
37. COMPARISON.
38. HUMAN NATURE.
39. SPATIVITY.
Figure 3.2
Kleist's 1934 diagram of the human brain depicting the regions in which the various cognitive modules and faculties were supposed to be located.
ARBITRARY THRESHOLD

NO DIFFERENTIAL ACTIVITY
Some Technical Arguments

• Brain images do not measure mental activity any more directly than does the polygraph.
• There is no single place or group of places in the brain that can be uniquely associated with deception or any other mental process.
• Lying or deception is an ill-defined process and probably is composed of many different kinds of mental responses. Therefore, the control of experimental conditions is extremely difficult.
• The empirical results forthcoming in recent years from different laboratories are still inconsistent and variable.
Primary Scientific Argument:

The empirical data as exposed by meta-reviews (aggregation of data from comparable studies) show broad distribution of activated regions.
From Cabeza and Nyberg (2000)
(Sub-sample of 275 PET and fMRI studies)
Figure 2.
Top: 239 activation maxima obtained for fMRI experiments addressing the Stroop interference task. Bottom: 15 activation foci derived from ALE of the above coordinates. Activation maxima and foci are shown in the glass brain view, i.e., projected onto three orthogonal single coronal, sagittal, and axial slices.

(From Neuman, Lohmann, Derfuss, and Von Cramon 2005)
Stroop foci. Activation foci of the studies included in the Stroop meta-analyses are seen here in Talairach space in the BrainMap Search&View environment. Selected contrasts within the 19 studies yielded a total of 205 foci. A diffuse pattern of activation is seen throughout the brain in the three orthogonal views, although some convergence is evident in the cingulate cortex (sagittal view). Each color/symbol combination identifies a study within the BrainMap database, and the number displayed along with each focus refers to the experiment within the corresponding article.

(From Laird, McMillan, Lancaster, Kochunov, Turkeltaub, Pardo, and Fox, 2005)
From Turkeltaub, Eden, Jones, and Zeffiro, 2002
11 PET Studies of Single Word Reading (172 Activations)
Informal summary of 16 studies of lie detection experiments
Interim Conclusions

• Any mental act is likely to activate broad regions of the brain.
• Any region of the brain is likely to be activated by many different mental acts.
• Mental activity is represented by complex, widely distributed, systems in the brain.
• The brain activity that represents mind is highly variable and only weakly correlated with cognitive processes—typically $r=0.33$. 
Reasons Why Responses May Be So Variable

• Random differences in techniques, as well as individual variability.
• The responses are unrelated to mental activity, but are nonlinear wave superimpositions (like rogue waves in the ocean or vibrating plates) dependent on anatomy, not function.
• May be generalized responses to emotion or mental effort, not specifically to lying.

In any case they would be unusable as legal tool
Methods of Testing for Lying in Published Literature

• Lying In Response To Probe Questions
• Guilty Knowledge Test with Playing Cards (2)
• Directed Lying with Playing Cards (3)
• Directed Lying about Real World Events (2)
• Feigned Memory Impairment (2)
• Well Rehearsed Coherent Lies vs. Prompted Lies
• Novel Lies vs. Routine Truths
• Rewarded Guilty Knowledge (2)
• Denying Mock Crime (2)
• Control Question Procedure
• Target of Deceit: To the Subject or to Someone Else
Some Practical Problems

• Countermeasures
• Subject cooperativeness
• Cumbersome procedures
• Persistent technical issues
  - Subtraction or differencing
  - Time lags
  - Double blind experiments rare
  - Ill defined boundaries of activation
• Poor definition of lying
• Inappropriateness of pooled data for individual evaluations
• False positive and missed deceptions
False Positives and Missed Lies
Mental activity is poorly defined resulting in

- Poor control of independent variables in experiments
- Ambiguity and variability of dependent variables
- Lack of control of mental states
- Paradoxical responses ("Don’t think about a cow")
- Questionable validity
- Extreme variability
Cautious Comments BY Investigators

• “our protocol requires refinement”
• “Our experimental evidence provides some initial evidence”
• “our two dimensions for the characterizing of lies are just the beginning”
• This is a “pilot study”
• “Further work is required”
• “Future studies could examine the effects of … countermeasures and physiological states on the accuracy of fMRI based lie detection.
• “the approach could potentially be used” as a lie detector
• “Funding for these studies was provided by Cephos…”
• “The consistency of these findings suggests that the fMRI… may have potential as a reliable lie detection device.”
• “…simulated deception in laboratory experiments cannot be viewed as being the same as deception in real life”
• “These results are preliminary…and it is too early to predict whether functional MR imaging will replace other methods of examining deception.”
Summary of Scientific Problems

• fMRI does not examine the correct level of analysis
• Subtraction method hides some significant activity
• Statistical pooling (Venn summations) may simulate narrow localization
• Peaks may be artifacts: Mathematically any bounded surface has to have at least one maximum
• Averaged results do not predict individual human behavior.
• Thresholds hide widely dispersed activity
• Dissociation method does not establish sufficiency
• Research findings have been wildly inconsistent
• In short we still cannot say with any assurance that any region or group of regions is significantly associated with any particular mental process
CONCLUDING COMMENTS
Of course, no one can predict the future and we may be surprised. However, the following points seem appropriate currently.

There has been enormous progress in both neuroscience and psychology in recent years.

Nevertheless, there remains an enormous gap between the two domains of discourse.

We still have no well substantiated technology that will allow us to read minds, detect deception, or exculpate guilt with brain images.

The experimental literature consists of only 16 studies whose results are inconsistent and unreliable.

Commercial enterprises offering brain imaging as a lie detection process are at best premature and are lucky to fail for purely scientific reasons.

Such enterprises also perpetuate the same kind of pseudoscience that permitted polygraphy to persist on the fringes our our judicial system.
I appreciate that stamping out the attractive and popular idea that we can read minds with brain imaging is as difficult as killing vampires.

However, perhaps a few “wooden stakes” of scientific scrutiny may help us to abort what is all too likely to become another persistent pseudoscientific fad like polygraphy.

My hope is that we will be able to kill this new vampire before it becomes an irreversible part of our legal system.

My expectation, however, is that we are going to live with this kind of pseudoscience for many years.