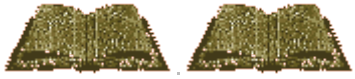
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Book Reviews: Technical Books Section



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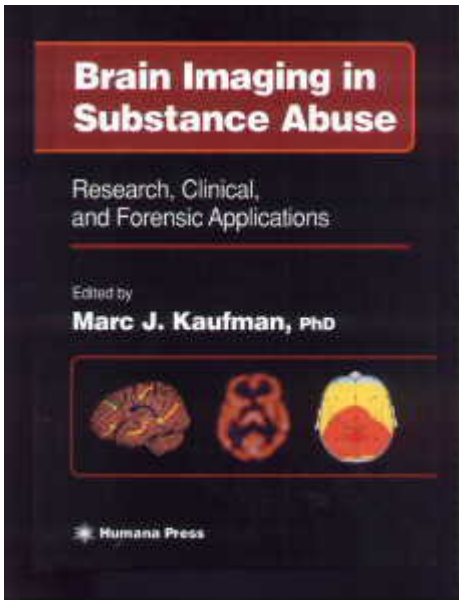
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REVIEWS IN THE PREVIOUS ISSUE | NEXT ISSUE

...BRAIN IMAGING IN SUBSTANCE ABUSE ...To sum up, a great book for clinicians, radiologists, radiographers, pharmacologists, Emergency room physicians, and in general anyone who would care to know how remarkably substance abuse can be detected by modern imaging methods...

Brain Imaging in Substance Abuse - Research, Clinical and Forensic Applications, 1st Edition, *Edited by* Marc J. Kaufman. Hard Bound, 7" x 10".
(A Book from *Forensic Science and Medicine* Series by Humana Press)
Humana Press Inc., 999 Riverview Drive, Suite 208, Totowa, New Jersey 07512; Publication Date 10 October, 2000. xxvi + 425 pages, ISBN 0-89603-770-3 (alk. Paper). Price $125.00

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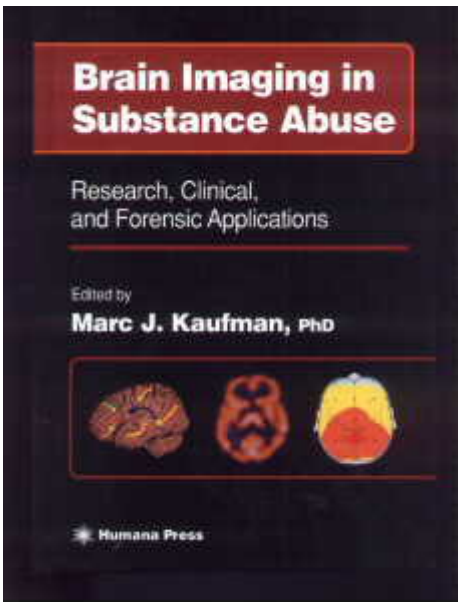


The phenomenal rise of newer imaging modalities has found applications not only in the diagnostic field, but in medicolegal field and courts as well. The book under review attempts to assemble, collate and organize data from these diagnostic tools as applied to substance abuse.

Four major diagnostic tools are discussed in the present book - EEG, MRI, PET and SPECT. The book is written by 13 contributors, including the editor Marc J. Kaufman himself (as many as seven of them happen to be from the Harvard Medical School, where Kaufman works as the Assistant Professor of Psychiatry). The first three chapters describe the basic fundamentals of these techniques, the next three summarize results of these techniques as applied to cases of substance abuse. Chapter seven gives neuropsychological correlates of drug abuse, and the last chapter attempts to describe how all this data can be applied to legal settings.

While expert radiologists can immediately afford to jump to chapter 4, those having only a rudimentary or no background in these techniques would find it useful to browse through the first three chapters. These chapters give the basic fundamentals of these techniques. Those of us who have very little or no knowledge of these techniques, may imagine these first three chapters to be intimidating, but they are not. They are written in a language a person with basic knowledge in medicine can understand. Let me give examples.

Extracts from the Preface



The goal of [this book] is to describe the methods and to review the research findings generated by clinical brain imaging modalities most commonly used in the study of substance abuse and dependence. These include electroencephalography, emission tomography, and magnetic resonance.....

Pursuit of an integrated understanding of the literature from all of these fields is by no means a trivial goal, since each modality has numerous technical complexities. This book has been organized to assist in this effort.

The first three chapters of the book describe the technical foundations for electroencephalography, emission tomography, and magnetic resonance. [These] are written so that readers with nontechnical backgrounds will be able to appreciate how these technologies work.

Chapters 4-6 present comprehensive reviews of the electroencephalographic, emission tomographic, and magnetic resonance research findings in substance abuse, and also discuss the methodological factors that complicate the interpretation of results from studies of chronic substance abusers.....

Chapter 7 focuses on the neuropsychology of substance abuse. While neuropsychological assessment is not strictly a form of brain imaging, it offers standardized and reliable methods for relating neuroimaging findings to higher levels of brain function.....

There is a nexus between substance abuse and crime, and as a result, it is expected that brain imaging findings will see expanded use [and misuse] in legal contexts. Chapter 8 discusses these issues and proposes guidelines for appropriate use of brain imaging findings in the courtroom.. .This chapter is particularly relevant to judges.....

The last part of the book is a comprehensive bibliography of clinical brain imaging and neuropsychological research in substance abuse.

It is my hope that [this book] will help to foster a more complete understanding of the effects of substance abuse on the human brain, by providing better access to the methods and findings in this field.

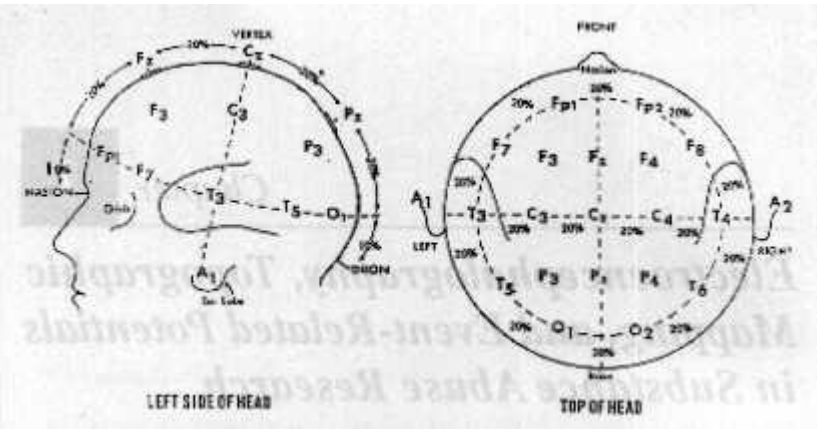
-Marc J. Kaufman, PhD

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The first chapter (written by two authors Elena M. Kouri and Scott E. Lukas, both of the Harvard Medical School) starts with the basics of EEG. In simple non-technical language we are told that usually a set of 21 electrodes is used to cover the scalp, according to the 10-20 International System of electrode placement. Now what in the world is this "10-20 International System of electrode placement"? The authors understand that this is the question a person not trained in EEG is likely to ask. And they go ahead immediately with the answer. It is called so "owing to the placement of electrodes at a distance of either 10% or 20% from specific landmarks on the skull. Two illustrative diagrams (figure 1 and 2) round off the explanation beautifully showing all these landmarks.

Mention is made of EEG amplifiers, EEG filters and EEG montages in subsequent pages. These too are explained well. Voltages coming from the brain are not strong enough to produce deflections in the pens of EEG machines. To produce such deflections, EEG amplifiers are used. They increase the amplitude without introducing distortion. EEG filters serve to filter electric disturbances coming from the heart, muscles and activity from extrinsic sources. These filters are so devised that they selectively allow activity within specific frequencies to be transmitted while removing for diminishing activity outside the specified frequency ranges. EEG montage refers to a specific arrangement by which a number of electrode pairs is displayed simultaneously in an EEG record. The purpose of montages is to make EEG interpretation as easy and accurate as possible. Table 1 on page 6 makes this concept very easy to understand.

Schematic Diagram of the 10-20 International System for Electrode Placement (This figure appears on page 2 of the book)



A type of spectral analysis used in EEG is fast Fourier transform (FFT) analysis. Those of us who have read and remember our high school physics may be able to recollect it vaguely. But the authors do not leave anything to chance, and go right ahead describing it. It is a way of expressing the EEG in terms of its *amplitude vs. frequency* instead of *amplitude vs. time* components. Once again a number of line diagrams accompanying this explanation makes the concept still easier to understand.

A little bit about EEG waves. It was an Austrian psychiatrist named Hans Berger, who in 1924 was the first to record EEG. He noticed that the rhythm in a normal EEG was not a simple one, but made up of several types of contributory waves. Berger gave the most pronounced rhythm the name of *alpha wave* or *rhythm*. These are sometimes also referred to as *Berger rhythm* in his honor. These

waves have a voltage of 50 microvolts on an average (although it can range from 5 to 100 microvolts) and they occur about 8-13 times a second (8-13 Hertz). They are more pronounced over the back parts of our brain, where visual signals are processed (occipital region). For this reason, they are also sometimes known as the *posterior-dominant rhythm*. The alpha waves are most pronounced when our eyes are closed. They vanish the moment we open our eyes. Thus alpha waves are a hallmark of inattentive brain, which is waiting to be stimulated. In fact, they have been called the "waiting rhythm" by some writers. (They could be likened to an impatient waiting person shifting from foot to foot or drumming his fingers on the table as he waits for some command that will rouse him to activity!). The moment the waiting is over (either by opening the eyes or by doing mental calculation etc), the alpha waves disappear.

In the front portions of the brain (frontal region), a faster wave - *the beta wave*- is seen. It occurs 13-35 times a second, but has a voltage below 30 microvolts. Yet another kind of wave - *the theta wave* - has a frequency of 4-8 Hz and is normally seen during drowsiness and during light stages of sleep. There is a fourth type of wave - *the delta wave* - which can rarely be recorded from a normal adult while awake, but appear normally during deep sleep or during the waking hours in early childhood. Delta waves have the highest amplitude of all EEG waves. Generally speaking, their presence in an adult, except in during sleep, indicates some brain disease-tumor, epilepsy, raised pressure around the brain, mental deficiency or depression of consciousness. When present they tend to displace the alpha rhythm. Neither the beta nor the delta waves are affected by opening or closing the eyes.

Now to topographical mapping. It is yet another useful technique in EEG analysis. It provides a complete view of the distribution of brain electrical activity over the scalp at any point in time. But what's the big idea of using topographic mapping in substance abuse? The authors explain this on page 10 quite beautifully. We have seen that alpha activity is mostly seen in the occipital region. However daily marijuana users show an increased alpha activity in the frontal and frontal-central scalp regions. Had it not been for topographic mapping - which records activity over the entire scalp - one was likely to miss this finding, for the simple reason that nobody would have looked for alpha waves in the frontal region.

EEG studies of Substance use and abuse is the subject of chapter 4. This has been written by Lance O. Bauer of the University of Connecticut School of Medicine. The author discusses the EEG findings in a number of psychoactive drugs such as alcohol, benzodiazepines, Marijuana/THC, Opioids and Cocaine. EEG Findings in both acute and chronic use are given.

Forensic Science and Medicine Series of Humana Press

This book is just one of seven books published by Humana Press in their excellent *Forensic Science and Medicine* series. Steven B. Karch, MD, is the series editor of this series. This journal has already reviewed four books of this series in its earlier issues. These were John H. Trestrail, III's *Criminal Poisoning*, Salvatore J. Salamone's *Benzodiazepines and GHB: Detection and Pharmacology*, Amanda J. Jenkins and Bruce A. Goldberger's *On-Site Drug Testing* and Pascal Kintz and Pierre Marquet's *Buprenorphine Therapy of Opiate Addiction*. Here is the full listing of the books in this series:

1. Buprenorphine therapy of Opiate Addiction, edited by **Pascal Kintz** and **Pierre Marquet**, 2002 (Already Reviewed in Vol.3, No.1 [January - July 2002] of this journal) at page 15)

2. On-site drug testing, edited by **Amanda J. Jenkins** and **Bruce A. Goldberger**, 2001 (Already Reviewed in Vol.3, No.1 [January - July 2002] of this journal) at page 10)
3. Benzodiazepines and GHB: Detection and Pharmacology, edited by **Salvatore J. Salamone**, 2001 (Already Reviewed in Vol.2, No.2 [July - December 2001] of this journal at page 21)
4. Toxicology and Clinical Pharmacology of Herbal Products, edited by **Melanie Johns Cupp**, 2000
5. Criminal Poisoning: Investigational Guide for law enforcement, toxicologists, forensic scientists, and attorneys, by **John H. Trestrail, III**, 2000 (Already Reviewed in Vol.1, No.2 [July - December 2000] of this journal)
6. A Physician's guide to clinical Forensic Medicine, edited by **Margaret M. Stark**, 2000
7. Brain Imaging In Substance Abuse: Research, Clinical and Forensic Applications, edited by **Marc J. Kaufman**, 2000

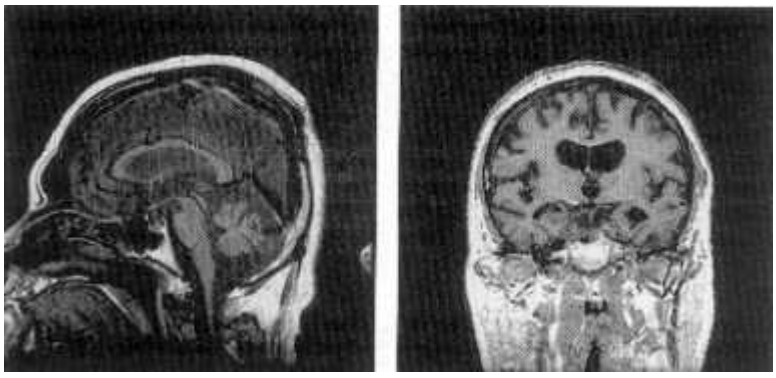
This reviewer found various findings quite revealing. I read with interest that if one administers 25 mg of heroin intravenously, there is a decrease in alpha power, and a compensatory increase in delta and theta power. Heroin does induce a sleep like state and delta and theta waves are seen in sleep states. So these findings appeared quite logical to me. But the author goes on to illustrate yet another revealing experiment. This involved recording EEG following a 30 mg intramuscular injection of morphine sulphate. The subjects showed an increase in all three waves (alpha, delta and theta). *These subjects were performing an active stimulus monitoring task*, while the EEG tracings were made. So these waves can't really be explained off by the production of sleep. Instead - the author informs us - these changes are the result of a direct pharmacological effect of morphine on the EEG. Similar striking examples await the reader under the heading of each psychoactive drug.

What's the principle of the MRI? Chapter 3 entitled "Fundamentals of Magnetic Resonance" allows us to understand that. It was *Paul C. Lauterbur* of the State University of New York at Stony Brook, who in 1973, produced the first NMR images. It is common knowledge that atomic nuclei contain protons and neutrons. Since they are both present within the nucleus, they are often known by the common name "nucleon". Both protons and neutrons possess a spin, i.e. they revolve round their own axis, much as earth does. If the nucleus has just one proton, it would spin on its axis and would impart a net spin to the nucleus as a whole. One would imagine that two protons would double up the spin for the nucleus but it doesn't happen that way; the spins of the two protons tend to cancel out, with the result that the nucleus has no net spin. A nucleus with three protons again has a net spin (as there is one unpaired proton) and a nucleus with four protons again would have no spin. The same is true for neutrons; an odd number of neutrons imparts a net spin to the nucleus, an even number doesn't. So out of protons or neutrons if any one of these (or both) are in odd number, the nucleus would have a net spin. If both are even, the nucleus would not have any net spin.

Since the nucleus is a charged object, a net spin produces a magnetic field around it. It is as if the nucleus is a tiny bar magnet which is revolving round its own axis. Some nuclei which exhibit this property are ^{1}H (Hydrogen nucleus with 1 proton only), ^{2}H (Hydrogen nucleus with 1 proton and 1 neutron), ^{7}Li (Lithium atom with 3 protons and 4 neutrons), ^{13}C (Carbon atom with 6 protons and 7

neutrons), ^{14}N (Nitrogen atom with 7 protons and 7 neutrons), ^{19}F (Fluorine atom with 9 protons and 10 neutrons), ^{23}Na (sodium nucleus with 11 protons and 12 neutrons), ^{31}P (Phosphorus nucleus with 15 protons and 16 neutrons), ^{35}Cl (Chlorine atom with 17 protons and 18 neutrons), ^{43}Ca (Calcium nucleus with 20 protons and 23 neutrons), ^{63}Cu (Copper atom with 29 protons and 34 neutrons) and ^{127}I (Iodine atom with 53 protons and 74 neutrons). Note that in all the above examples, at least one group of particles (either protons or neutrons) are odd in number (in the case of ^{2}H and ^{14}N, both are odd). There are in fact over a hundred stable nuclear species with a spin and a magnetic moment, and all the chemical elements have at least one naturally occurring magnetic isotope. On the other hand, nuclei which are composed of even numbers of both protons and neutrons have no resultant spin and no magnetic moment and can not be used in MRI. Examples of such even-even non-magnetic nuclei are ^{12}C (carbon atom with 6 protons and neutrons), ^{16}O (oxygen atom with 8 protons and neutrons), ^{32}S (sulphur atom with 16 protons and neutrons) and ^{40}Ca (calcium atom with 20 protons and neutrons). These numerous examples would serve to illustrate the point of magnetic nuclei very well. To recapitulate, there should be at least one odd number among the protons and neutrons (both odd numbers would also do); but if both numbers are even, the nucleus would have no net spin and thus no net magnetic moment. Magnetic Resonance Imaging makes use of nuclei which behave as magnets; it can not make use of non-magnetic nuclei.

MR images of a patient with Wernicke's encephalopathy. T1-weighted midline sagittal image (left) and coronal 3D SPGR images through the thalamus and temporal lobes (right) reveal brain volume changes typically noted in alcoholics and in patients with Wernicke-Korsakoff syndrome. The corpus callosum is abnormally thin (left), the cerebellum vermis is atrophic (left), and the ventricles are enlarged (left and right). (These figures appear on page 164 of the book)



How are these nuclei used in MRI? Well, fortunately human body is largely made up of magnetic nuclei- the hydrogen atom. Remember that the human body is almost 70% water, and the water molecule has two atoms of hydrogen (the other - oxygen- is useless for MRI as seen above). Body fats also have a lot of hydrogen nuclei. For MRI, these hydrogen nuclei are utilized. But they are not arranged in any order. If one could look at these "nuclear magnets" in the body, they would be found to be oriented in all sorts of directions.

When an external magnetic field is applied, the nuclei tend to align themselves to it, just as a magnetic compass points along the north-south axis of the earth's magnetic field. It would be expected that the north pole of all "nuclear magnets" would face towards the south pole of the external magnetic field. This is what indeed happens. But there are some nuclei with higher energy

levels which align themselves "antiparallel" to the external field, i.e. their north pole faces the external field's north pole. This might seem paradoxical, but it does happen.

Generally however, the nuclei are in the lower energy level, and they remain parallel to the external field. There are thus more nuclei which are parallel to the external field than those that are antiparallel. The magnetic field generated by those nuclei aligned antiparallel tends to cancel out most of the field generated by those aligned parallel. But since there are more nuclei parallel to the external field, there is a net magnetization, although quite weak, of the tissue parallel to the direction of the external field. A drop of water placed in a magnetic field would thus become temporarily and weakly magnetized because it hydrogen "nuclear magnets" on an average would point in the direction of the field.

In MRI this magnetization is detected with a second much smaller magnetic field (known as the resonant magnetic field), which is applied at right angles to the first field. The second field tends to tip the magnetization direction of the tissue under study away from its initial, or "equilibrium" position. By analogy, one can bring a small bar magnet close to a compass needle so as to tip it away from its orientation with the Earth's field.

...Almost all psychoactive drugs are dealt with in the chapter on Magnetic Resonance Imaging. Among several drugs that find mention here are alcohol (and alcohol related syndromes), marijuana, hallucinogens, benzodiazepines, heroin, opiates, cocaine, amphetamine, solvent abuse, occupational exposure and polydrug abuse...

In practice, radio waves, which have a magnetic component are used to generate the second field. This radio-frequency (RF) energy is delivered by means of a coil of wire wrapped around the tissue. A short pulse of radio waves will cause the bulk nuclear magnetization of the tissue to precess (tip down); in doing so, it will generate a small, detectable voltage in a detector coil. The precessional motion thus detected is the genesis of the nuclear signal with which ultimately the image is constructed. To give an analogy, when the radio pulse is given to the nuclei, it is as if someone had struck a bell with a hammer; the bell starts to ring. Here the hammer is the radio pulse, and the bell are the nuclei. The small detectable voltage in the detector coil is equivalent to the sound that is produced from the bell. Just as the sound of the bell dies down after a little time, the NMR signal also dies down.

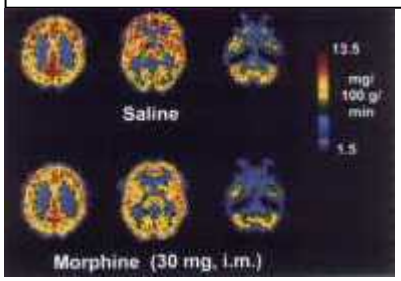
As its name implies, NMR is a resonance phenomenon. This means that it will occur only if the applied RF pulse is "tuned" to the natural resonance frequency of the nucleus in question. The natural resonance frequency of any given nucleus depends on the strength of the applied main magnetic field; more the strength, more the frequency and vice-versa.

This provides us with a very clever way to locate each atom within the sample. In fact this is what Lauterbur had hit upon in 1973. If the main magnetic field be graded so that it is not of uniform strength but rather increases slightly in strength from one side of the sample to the other, the resonance frequencies of different nuclei would differ. To continue our old analogy, they would "ring" with different "notes" depending on their position in the sample. This enables the investigator to construct an exact map of the body's interior.

With the passage of time, we now have more sophisticated techniques to produce better MRI images. Now we have the facility of contrast agents (compounds of Gadolinium), which can alter magnetic fields in the body. We can now perform such tests as *Functional Magnetic Resonance Imaging* (fMRI), which depict the function of an organ (principally the brain), rather than only the

structure, MR Spectroscopy, Dynamic Susceptibility Contrast MRI, Diffusion Weighted Imaging (DWI), Magnetic Resonance Angiography (MRA) and Relaxometry. MR findings in Substance abuse? Well, they are given in detail in chapter 6 (written by the editor himself along with Jonathan M. Levin, both of Harvard Medical School).

Here are a few color slides from this book in this "Interactive Slideviewer". Click on the button to view a particular slide. The captions appear below each picture.



Some color slides from this book
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Almost all psychoactive drugs are dealt with in this chapter but alcohol gets the lion's share. About 15 pages out of a total of around 30 are devoted to alcohol and alcohol related syndromes. In the rest we find mention of such drugs as marijuana, hallucinogens, benzodiazepines, heroin, opiates, cocaine, amphetamine, solvent abuse, occupational exposure and polydrug abuse. Among the several alcohol related disorders investigated are ventricular enlargement, cortical atrophy, Corpus Callosum atrophy, Cerebellar degeneration, white matter lesions, hepatic cirrhosis and encephalopathy, Wernicke's encephalopathy, Korsakoff's syndrome, Central Pontine Myelinolysis (CPM), Marchiafava-Bignami Disease and fetal alcohol syndromes. There is a small section on methanol too.

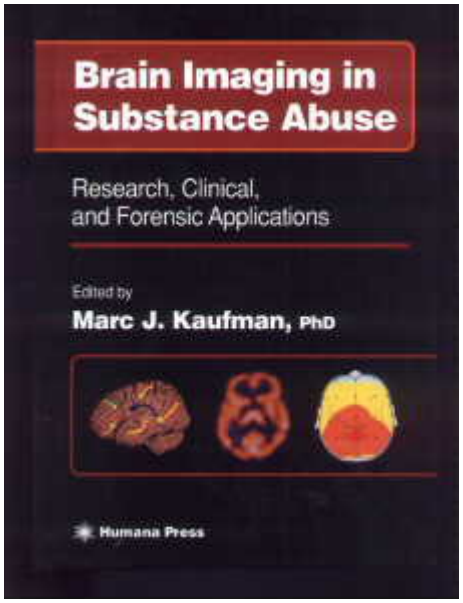
Let me give you some MRI findings in substance abuse to indicate what this book has to offer us. On pages 176-181, the authors describe the MR findings in cocaine abuse. The first fMRI study on cocaine abusers was published as late as in 1997 by Breiter and his colleagues. They reported "early" and "late" fMRI findings which they tried to co-relate with the "rush" (the early behavioral effect of cocaine) and the "craving" (the late behavioral effect of cocaine). Among the early findings, they reported rapid and transient activation of numerous brain regions, including the cingulate and lateral prefrontal cortex, basal forebrain, caudate nucleus, ventral tegmentum and pons. Among the late findings was the sustained activation of the nucleus accumbens. Does this mean that the activation of this region of the brain *confirms* that the subject is suffering from "cocaine

craving"? The readers may want to read the book to find out. Just a note: the authors supplement these findings with their own studies too.

PET and SPECT? Their basic physics and their findings in substance abuse? Well, I am quite tempted to describe them here, but I will refrain from doing so. Readers may find it much more rewarding to buy the book and go on their own voyages of discovery. I am sure, they will feel rewarded. I certainly enjoyed each page of this book thoroughly.

But try hard as I may, I can not resist the temptation to describe some of the facts mentioned in the last chapter entitled "Neuroimages as Legal evidence". This chapter is written by Jennifer J. Kulynych and Douglas W. Jones. As a forensic pathologist often having to attend courts of law in cases of substance abuse, I was quite interested in knowing if we could really use these images as valid evidence in a court of law. A bit about Frye and Daubert before we move on. Expert testimony in courts has traditionally been evaluated by a test called the *Frye test*. This test is nothing but part of a judgment in a court case occurring in 1923 [*Frye v. United States, 923 F. 1013 (D.C. Cir. 1923)*]. In this particular case, a psychologist attempted to use the results of his primitive polygraph machine on a defendant called Alphonse Frye. The court ruled that the psychologist's testimony was inadmissible, *because the polygraph machine had not gained general acceptance among psychologists as an instrument for detecting lies*. The thrust was on the phrase "general acceptance", meaning thereby that any new test must first be "generally acceptable" within the scientific community itself, before it can be used in a court of law.

QUICK NOTES



Some major highlights of *Brain Imaging in Substance Abuse - Research, Clinical and Forensic Applications* at a glance:

& Comprehensive review of research findings from brain imaging studies of drug abuse
& Non-technical introduction to major brain imaging techniques
& Discussion of caveats, confounds, and limitations of each technique
& Applications involving most abused substances
& Guidelines for use of brain imaging findings in the courtroom
& Extensive bibliography and index organized for rapid access to methods and literature

This rule seemed to make sense, and was immediately accepted by courts all around the United States. However there had been tremors in between. In 1975, the newly adopted Federal Rules of Evidence appeared to revise the *Frye standard*. Rule 702 talked about "assistance to the judges or jury" rather than on "general acceptance". But *Frye* met its ultimate death in 1993, when in *Daubert V. Merrel Dow Pharmaceuticals, Inc., 509 U.S. 579, at p. 593, 1993*, the Supreme Court ruled that the *Frye test* was no longer the Federal Law. A new standard was announced, which became known as the *Daubert test*. According to this test, the scientific testimony must be *valid, reliable, and relevant* to the issues in dispute. The Supreme Court also instructed the trial court judges to act as "gatekeepers" who would shield the courts from pseudoscience. Today *Daubert* is applied in most US states, although a few continue using the old *Frye*.

I was quite interested to know the legal position of these neuroimages vis-à-vis *Frye* and *Daubert*. This chapter addresses this question quite well. I will not go in any detail here (the reader would thoroughly enjoy reading this chapter himself, I am sure), but will mention just one striking example, the authors give right at the beginning of this chapter. This illustrates how these results can be *misused*. Obviously one must be careful not to allow one's research being so grossly misused as in this hypothetical case.

The case goes something like this: An investigator conducts a typical fMRI study on 20 subjects of mixed age, gender and handedness. He is studying the fMRI images following the ingestion of a dose of alcohol, while the subjects' fingers were stimulated (somatosensory stimulation). He uses a paramagnetic contrast agent and finds that the amplitude of somatosensory cortical activation is reduced in the alcohol condition. He however leaves out one subject who showed higher absolute values for signal intensity *and fails to mention this in his paper*. The paper entitled "Alcohol Reduces Focal Cortical Activation During fMRI" is sent to a prestigious journal for publication.

The media catches on this story, and the next day, his interviews etc are flashed on the TV and newspapers etc. Some days later an attorney trying a defense of diminished capacity on his client phones the investigator asking him to make an fMRI scan of his client. The university asks the investigator to co-operate. The defendant's activation values turn out to be lower than the average values in the published study. The investigator knows that this finding is meaningless because of the absence of any normative data for focal cortical activation in response to somatosensory stimulation. Yet the damage has already been done. Because of the wide publicity given to that paper in the media, a reasonable doubt has been created in the minds of lay jurors. And the defendant gets the benefit of diminished capacity!

The chapter then goes on to discuss the various intricacies of the *Frye* and the *Daubert*, and how these neuroimages stand up to these tests. We are even told of a very recent test, the so-called *Kumho test (Kumho Tire, Co., Ltd. V. Carmichael 119 S.Ct. 1167, 1174, 1999)* , which came as recently as in March 1999. This decision says that the *Daubert* must be applied, albeit in a flexible manner, to all forms of expert testimony.

...a great book for clinicians, radiologists, radiographers, pharmacologists, Emergency room physicians, and in general anyone who would care to know how remarkably substance abuse can be detected by modern imaging methods...

An interesting aspect of this book is its bibliography section. It runs from page 261 till 397, an astounding 137 pages. This is impressive considering the whole book amounts to just 425 pages (it is 32% of the whole book!). This can be quite understandable as the editor has tried to gather and collate all the latest related research work. Bibliography section even has its own table of contents!

Another interesting section is the glossary section. It gives rapid fire definitions of terms whose meanings may not be quite clear to a novice. The terms are explained in simple language. An example:

T1-weighted Image (this term appears on page 259)
A T1-weighted image is one in which the neuroanatomy is well demonstrated. Gray matter appears gray, white matter appears white, and cerebrospinal fluid is dark. These images have a very short TE and TR roughly half that of brain T1.

Stumped on TE and TR? Well, don't worry. The book goes on to explain these terms too. I discovered that the glossary section can be read and enjoyed on its own too. In fact by the time you are through with the glossary section, you know much of the basics of all the imaging techniques described in this book.

The book has a number of color plates. These are a marvel to look at. Some of these color plates have been scanned at somewhat lower resolution and have been put in a slider viewer here (above and to the right). This is an interactive slide viewer. Readers may want to click on specific buttons to see various color plates. Please the linked page (#slideviewer) to go to the Interactive Sliderviewer.

To sum up, a great book for clinicians, radiologists, radiographers, pharmacologists, Emergency room physicians, and in general anyone who would care to know how remarkably substance abuse can be detected by modern imaging methods.

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