MULTIPLE SCALES OF BRAIN-MIND INTERACTIONS

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ABSTRACT: Posner and Raichle's Images of Mind is an excellent educational book and very well written. Some flaws as a scientific publication are: (a) the accuracy of the linear subtraction method used in PET is subject to scrutiny by further research at finer spatial-temporal resolutions; (b) lack of accuracy of the experimental paradigm used for EEG complementary studies.

KEYWORDS: PET; EEG; nonlinear;

VALUE OF THE TEXT

Images (Posner & Raichle, 1994) is an excellent introduction to interdisciplinary research in cognitive and imaging science. Well written and illustrated, it presents concepts in a manner well suited both to the layman/undergraduate and to the technical nonexpert/graduate student and postdoctoral researcher. Many, not all, people involved in interdisciplinary neuroscience research agree with the P & R's statements on page 33, on the importance of recognizing emergent properties of brain function from assemblies of neurons.

It is clear from the sparse references that this book was not intended as a standalone review of a broad field. There are some flaws in the scientific development, but this must be expected in such a pioneering venture. P & R have proposed many cognitive mechanisms deserving further study with imaging tools yet to be developed which can yield better spatial-temporal resolutions.

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OVERSTATEMENT

On page 25, I see the first of several aspects of the book that tend to overstate conclusions not yet fully supported by scientific studies. P & R make a one-to-one correspondence, with no hedging, between the plots of brain-mind and space-time. For example, this does not account for both spatial and temporal multiple scales of interaction that might be required to explain phenomena ascribed to brain or mind.

On page 54, P & R present their recurrent theme of connecting blood flow with brain activity, explicitly or implicitly connecting this activity with the processing of information by brain or mind. On page 66, they stretch scientific credibility by stating that PET scans can address issues of intelligence, degrees of shyness, and so forth. On page 218, their implicit but obvious claim, that they have succeeded in "unambiguously uncovering the neurobiological basis of depression," is most certainly overstated.

SUBTRACTION TECHNIQUE

Images sets forth strong conjectures about spatial interactions across various cognitive tasks. However, P & R also note that PET itself lacks temporal resolutions beyond tens of seconds and lacks a detailed model/explanation of how synaptic and neuronal interactions yield observed cognitive states. It appears that data complementary to those obtained from PET, for example EEG data, will be necessary to improve not only temporal resolution, as emphasized by P & R, but also spatial resolution. Since PET analysis depends on establishing temporal correlations between photon pairs with opposite momenta (possibly only 50% of events actually processed), without a knowledge of the scanner angle of entry, the spatial resolution detected is highly dependent on the scanner aperture, which can lead to resolutions as low as cms for some pairs. Poorer spatial resolution can also occur for shorter temporal resolutions for some chemical tracers (Raichle *et al*, 1993).

It is clear that the supposition of linearity in brain interactions, the basis of the subtraction methodology, must be considered approximate, especially when applied across subjects. This is discussed further below. Only further experimentation with finer spatial-temporal resolutions can resolve the degree of this approximation. This does not diminish the contribution made by PET to setting up plausible "strawmen" for further investigations.

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EEG COMPLEMENTARY TO PET

On page 133, P & R start discussing the problems associated with using scalp EEG to locate underlying neocortical activity to support observations at coarser resolutions made by PET scans. Their solution on page 134, whereby "each electrode's activity is compared to the average activity of all other electrodes, weighted by distance," is simply incorrect when applied across all brain regions. This experimental paradigm neglects the physics of electromagnetism inherent in EEG (Nunez, 1981). For example, Laplacian measurement techniques greatly reduce the ambiguity of nonlocal contributions to derived local signals (Nunez & Pilgreen, 1991). This technique develops second-derivative Laplacians from close sets of electrodes and gives the underlying local sources via Maxwell's equations. I have noted that using derivatives of stochastic data can lead to large-frequency contributions to the noise, diminishing the signal (Ingber, 1996). However, this problem may be handled using spline fits prior to forming the Laplacians (Nunez & Pilgreen, 1991).

Another problem is with their use of averaged evoked potentials (AEP), quite a common technique. This technique quite literally assumes a linearization of first-moment effects of data, data representing a multivariate nonlinear stochastic system, thereby misrepresenting the first moments. This assumption similarly can be as faulty as the assumption of linearity made by the PET subtraction method discussed above. Furthermore, if the "background noise" is considered simply an additive "residual," implicit in these experimental paradigms, then any estimate of the structure in the noise, of course a part of the signal, is lost. There are sound reasons for believing that in fact neocortical interactions are nonlinear multivariate processes of firing interactions (Ingber, 1982; Ingber, 1983). Nonlinear structures continue to be developed across multiple scales, for example representing neocortical interactions underlying each electrode, as well as among long-ranged circuits between electrodes (Ingber, 1991; Ingber & Nunez, 1990; Ingber, 1995).

The discussion on page 137, indicating that N100, measured within 0.1 sec of a stimulus is indicative of processing of the kind of information that P & R observe within their minimal 40-sec PET resolutions, is indeed quite speculative. The EEG data is suggestive, but it is just that.

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Local circuits of spatial extent 0.1–1 mm process patterns of information as nonlinear dynamical interactions among inhibitory and excitatory short-ranged unmyelinated fibers within time scales of 10–100 msecs. A relative increase of inhibitory firings, for example initiated by long-range myelinated excitatory fibers across cms, could lead to a *decrease*, rather than an *increase* of activity, representing an *increase* of information processing. There do exist arguments that the maintenance of such minimal firing surfaces take energy (Ingber, 1984; Ingber, 1994).

Thus, given its spatial-temporal resolution and the experimental paradigm presented, it would seem that PET is more a signature of long-ranged activity/connectivity, not necessarily reflecting the mechanisms and processing taking place via columnar interactions. This does not even address the information processing taking place at the finer spatial scales of synaptic and neuron-neuron interactions. Indeed, on page 233, P & R note that the great similarity of columnar tissue across subjects may account for our similar cognitive processes—the scale they are attempting to address with PET, while finer structures may account for our differences, and they look towards MRI for gathering data at the mm scales (apparently to determine head shape to sharpen the PET analysis—a technique also being used with EEG).

It is therefore possible that conclusions such as those drawn on page 243, that less effort and attention is required to repeat a computation, are misleading or false. Yes, less conscious attention and long-ranged activity seems to be required, but "effort" might also be measured in information processed by local circuits.

CONCLUSION

I believe that the above critique logically leads to the necessity of codifying/modeling neuronal interactions beyond suggestive artificial neural nets that do not faithfully model neuronal processes, fitting parameters constrained by experimental bounds, as is performed across the physical sciences. Just complementing careful anatomical studies with general statistical procedures on raw data does not account for the specific details of nonlinear neocortical interactions which are inherently "stochastic" at the scales being discussed here.

P & R have set forth a clear path for future research, and this path should be followed with gusto and detail.

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