SMI 2022 Founder's Talk

Daniel B. Rowe

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May 27, 2022

Outline

Part I. Founding of Section on Statistics in Imaging

1. Genesis
2. Planning
3. Coalescence

Part II. Foundations of Functional MRI

1. Background
2. Measured Data
3. Opportunities in FMRI

Discussion

Outline

Part I. Founding of Section on Statistics in Imaging

1. Genesis
2. Planning
3. Coalescence

I.1. Genesis

Before there was a section, I used to get the Imaging Statisticians together.

Leading up to each JSM I would email the imaging statisticians I knew.
Tom Nichols, Brian Caffo, Martin Lindquist, Hernando Ombao, Hongtu Zhu…

I liked getting together at an Irish Pub so we could have refreshments.

There were many times where it was me and a couple others.

I.1. Genesis

Before there was a section, I gathered the imaging Statisticians together.

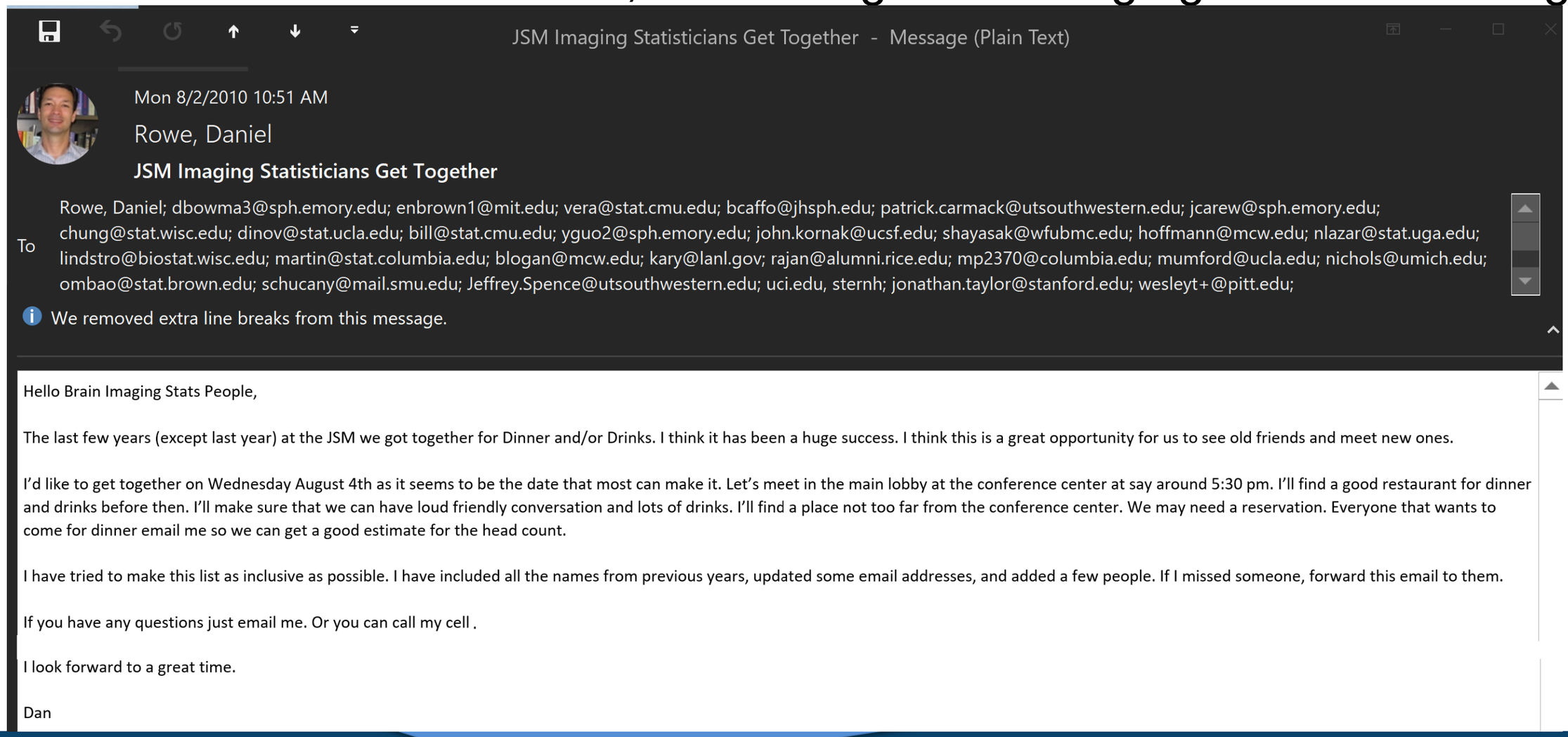
I started the “Society of Imaging Statisticians” AKA SINS.

Everyone emailed the imaging statisticians they knew to email me.

The webpage is still up.
http://www.mssc.mu.edu/~daniel/sins.html

I.1. Genesis

Before there was a section, I used to get the Imaging Statisticians together.



JSM Imaging Statisticians Get Together - Message (Plain Text)

Mon 8/2/2010 10:51 AM

Rowe, Daniel

JSM Imaging Statisticians Get Together

To Rowe, Daniel; dbowma3@sph.emory.edu; enbrown1@mit.edu; vera@stat.cmu.edu; bcaffo@jhsph.edu; patrick.carmack@utsouthwestern.edu; jcarew@sph.emory.edu; chung@stat.wisc.edu; dinov@stat.ucla.edu; bill@stat.cmu.edu; yguo2@sph.emory.edu; john.kornak@ucsf.edu; shayasak@wfubmc.edu; hoffmann@mcw.edu; nlazar@stat.uga.edu; lindstro@biostat.wisc.edu; martin@stat.columbia.edu; blogan@mcw.edu; kary@lanl.gov; rajan@alumni.rice.edu; mp2370@columbia.edu; mumford@ucla.edu; nichols@umich.edu; ombao@stat.brown.edu; schucany@mail.smu.edu; Jeffrey.Spence@utsouthwestern.edu; uci.edu, sternh; jonathan.taylor@stanford.edu; wesleyt+@pitt.edu;

We removed extra line breaks from this message.

Hello Brain Imaging Stats People,

The last few years (except last year) at the JSM we got together for Dinner and/or Drinks. I think it has been a huge success. I think this is a great opportunity for us to see old friends and meet new ones.

I'd like to get together on Wednesday August 4th as it seems to be the date that most can make it. Let's meet in the main lobby at the conference center at say around 5:30 pm. I'll find a good restaurant for dinner and drinks before then. I'll make sure that we can have loud friendly conversation and lots of drinks. I'll find a place not too far from the conference center. We may need a reservation. Everyone that wants to come for dinner email me so we can get a good estimate for the head count.

I have tried to make this list as inclusive as possible. I have included all the names from previous years, updated some email addresses, and added a few people. If I missed someone, forward this email to them.

If you have any questions just email me. Or you can call my cell .

I look forward to a great time.

Dan

I.1. Genesis

The first I heard about forming a section was an email chain from Henando.

% -----Original Message-----
%From: Hernando Ombao [mailto:ombao@stat.brown.edu] % Sent: Thursday, September 30, 2010 10:31 AM % To: nusser@iastate.edu % Subject:
%
% Dear Sarah -
%
% My name is Hernando Ombao. We have a group of %statisticians who % would like to form a section "Statistics in the Imaging %Sciences"
% within the ASA. I believe that Ranjan has already spoken %with you % about this effort.
%
% Is there a document that spells out the policies for %forming a section?
%
% Do you have some time this week or next to talk about %this?
%
% Many thanks for your help!
%
% Hernando
% _____

On Fri, 8 Oct 2010 11:22:16 -0500
"Nusser, Sarah M [STAT]" <nusser@iastate.edu> wrote:
% Hi Hernando,
%
% Sorry for the delay in getting back to you. Ranjan did %talk to me about your group.
%
% Rick Peterson is the ASA liaison to the Council of %Sections. He will be the person working with you to %establish your interest group.
%
% In the meantime, I've attached a document that %summarizes my understanding at this point. This year the %Council of Sections Governing Board has been trying to %develop a better method of working with Interest Groups.
% We are nearly done with that process, so I don't expect %the information in the document to change much, but it %might. Rick will keep you informed of any meaningful %changes.
%
% Sarah

I.1. Genesis

The first I heard about forming a section was an email chain from Henando.

-----Original Message-----
From: Hernando Ombao [mailto:ombao@stat.brown.edu]
Sent: Friday, October 08, 2010 7:22 PM
To: Bowman, DuBois; Rowe, Daniel; Lindquist, Martin; Zhu, Hongtu; Caffo, Brian; Maitra, Ranjan; Nichols, Thomas; Ombao, Hernando

Subject: SIS Section Formation

Dear All -

I received confirmation from Sarah Nusser and Rick Peterson.
Pls read email below. Here's the bottomline:

(1.) It is NOT necessary for SIS to be a special interest group before it becomes a section. We can become a section directly.

(2.) To become a section, here are the requirements:

(a.) Petition with 100 full members.
- To date, we have 45 signatures. Please solicit more signatures.

(b.) List of officers - I guess that is us. What positions would we like to create? Here's a sample from Stat Learning Data Mining:
Chair
Vice-Chair
Program Chair
Secretary
Treasurer
Publications Liaison Officer

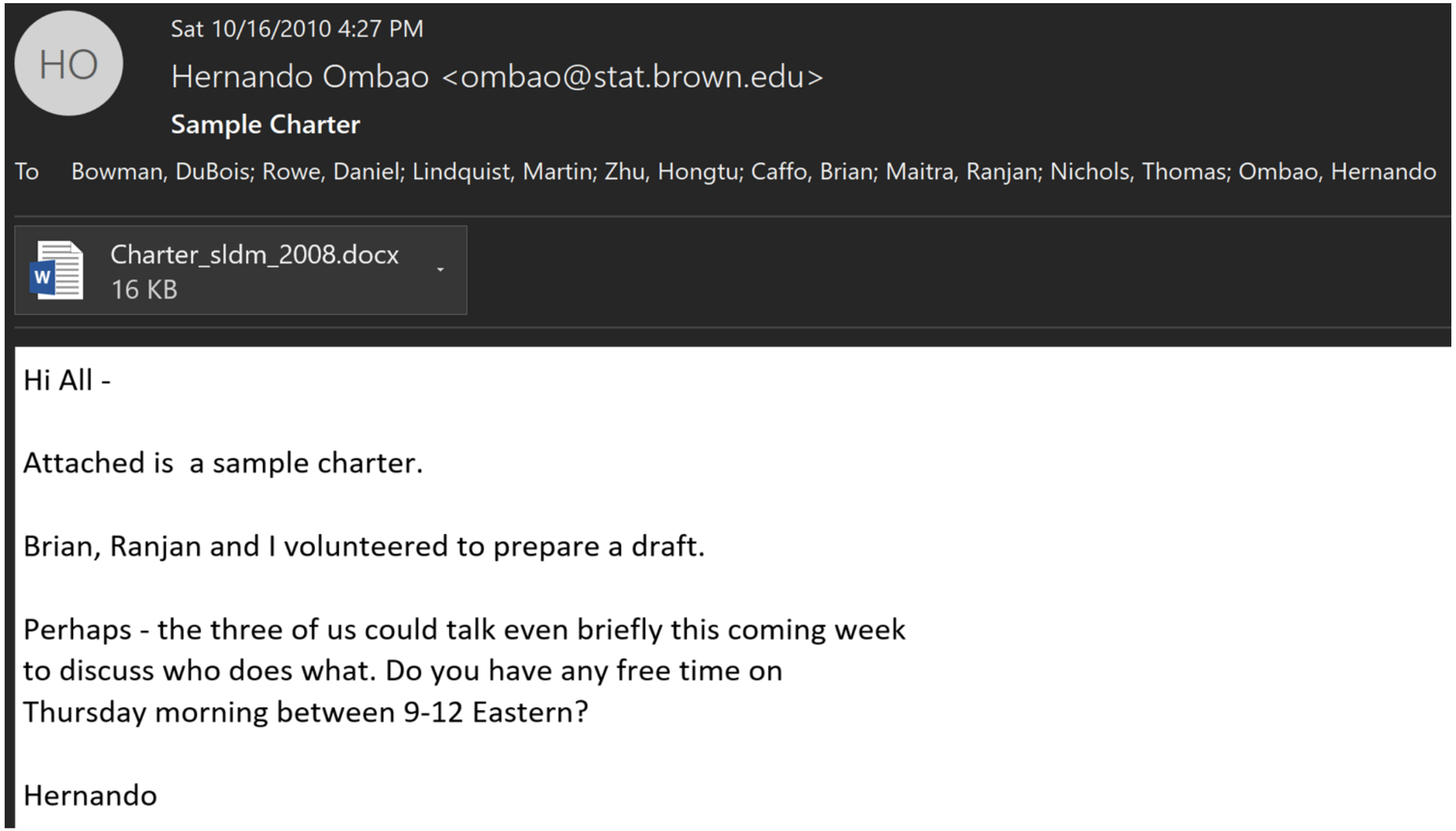
I suggest that we add the ff:
Liaison to the Human Brain Mapping
Liaison to the Biomedical Computing

(c.) A proposed Section Charter
- It will be good to have 2 people work on this. I can help but I need one more person
to work with me. I can get a sample draft from the Section on Stat Learning. Any volunteer?

Hernando

I.2. Planning

Hernando Ombao obtained a sample charter to work with.



HO

Sat 10/16/2010 4:27 PM

Hernando Ombao <ombao@stat.brown.edu>

Sample Charter

To Bowman, DuBois; Rowe, Daniel; Lindquist, Martin; Zhu, Hongtu; Caffo, Brian; Maitra, Ranjan; Nichols, Thomas; Ombao, Hernando

Charter_sldm_2008.docx
16 KB

Hi All -

Attached is a sample charter.

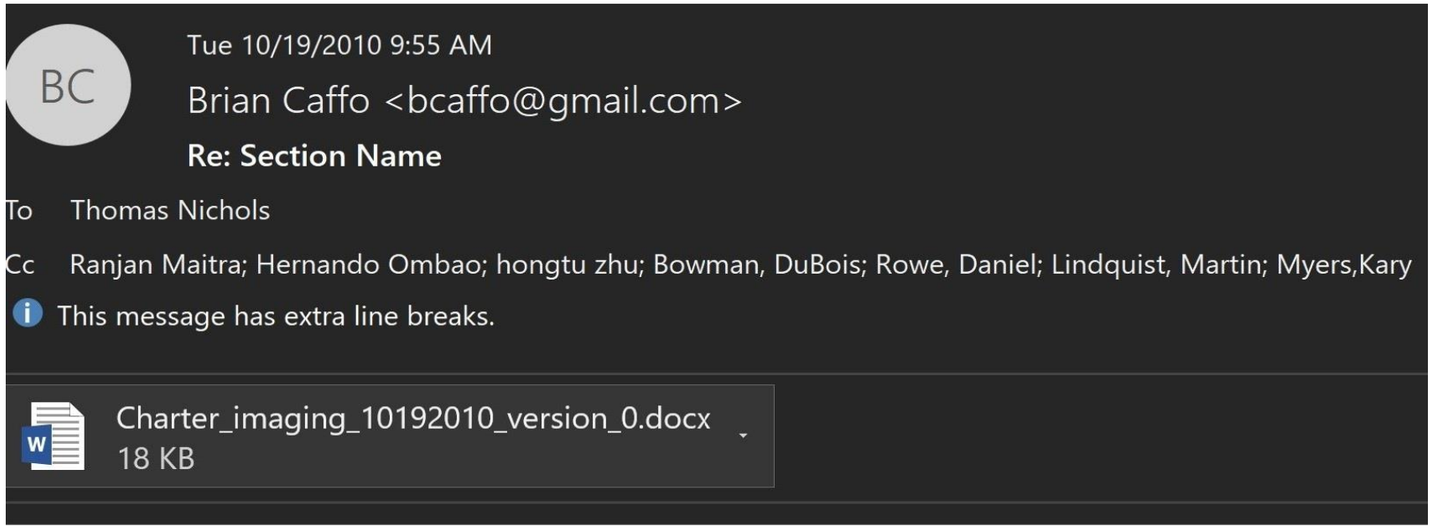
Brian, Ranjan and I volunteered to prepare a draft.

Perhaps - the three of us could talk even briefly this coming week to discuss who does what. Do you have any free time on Thursday morning between 9-12 Eastern?

Hernando

I.2. Planning

Brian Caffo took an initial stab at the charter.



Here's my first stab at editing the charter and I have since ran out of time. I didn't track the changes as I think we want to change a lot of it. The amendments are all pretty much exactly the same, which need to be discussed.

Also, we have to decide on the name.

(I also deleted a line that said business may be conducted by mail as I'm sure we want to do everything electronically.)

Brian

I.2. Planning

Of course, coming up with a name is one of the hardest parts.

On Thu, Oct 21, 2010 at 3:47 AM, Ranjan Maitra <maitra@iastate.edu> wrote:

> Dear friends,
>
> I have spent some time thinking about this over the past couple of days and I have come to the conclusion that Statistics in the Imaging Sciences is probably not the name we want to have. This despite the
>
> Just some convoluted rationale for why I am not completely happy with the Statistics in the Imaging Sciences name. Of course, I would happily go with whatever gets ultimately decided.
>
> Best wishes,
> Ranjan

HZ

Wed 10/20/2010 3:34 PM

hongtu zhu <hzhu@bios.unc.edu>

Re:

To Hernando Ombao

Cc Bowman, DuBois; Rowe, Daniel; Lindquist, Martin; Caffo, Brian; Maitra, Ranjan; Nichols, Thomas; Myers,Kary

We removed extra line breaks from this message.

We are defining image in a more narrow sense.

best
hongtu

TN

Thu 10/21/2010 3:54 AM

ten.photos@gmail.com on behalf of Thomas Nichols <t.e.nichols@warwick.ac.uk>

Re: Section name

To Ranjan Maitra

Cc Hernando Ombao; Bowman, DuBois; Rowe, Daniel; Lindquist, Martin; Zhu, Hongtu; Caffo, Brian; Myers,Kary

I'm happy with either SI (Statistics in Imaging) or Statistics in Imaging Science (SImS).

HO

Thu 10/21/2010 8:23 AM

Hernando Ombao <ombao@stat.brown.edu>

Doodle: Link for poll "Vote on Section Name"

To Bowman, DuBois; Rowe, Daniel; Lindquist, Martin; Zhu, Hongtu; Caffo, Brian; Maitra, Ranjan; Nichols, Thomas; Ombao, Hernando; Myers,Kary

We removed extra line breaks from this message.

Thanks Ranjan for clarifying your concerns.

Let's put this to a formal vote via a doodle poll below:

You have initiated a poll "Vote on Section Name" at Doodle. The link to your poll is:

http://doodle.com/participation.html?pollId=vdxmmumzh5fptaqq

I.2. Planning

We needed to elect a Founding Section Chair.

On Oct 29, 2010, at 9:56 AM, Thomas Nichols wrote:

Hi all,

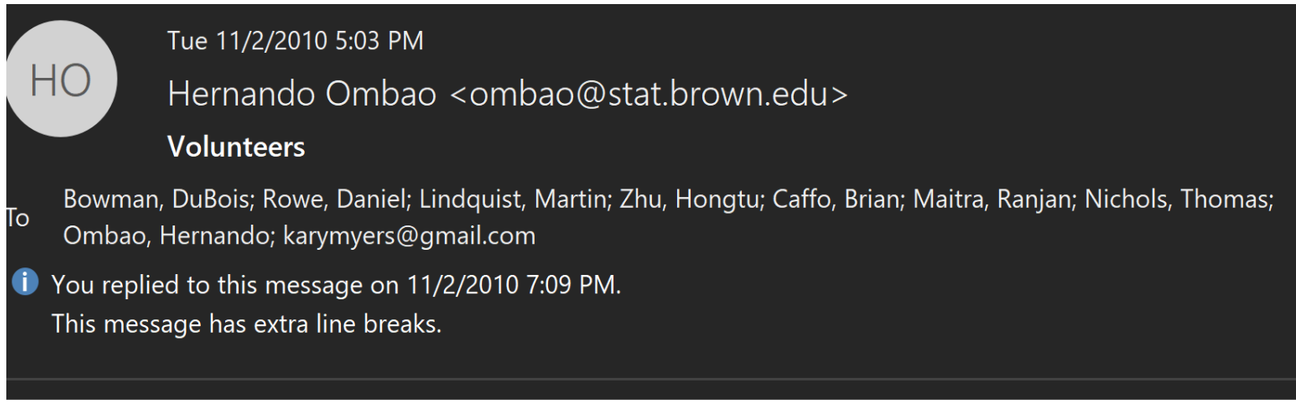
To get things rolling, I would like to nominate Martin for Chair.

-Tom

From: hongtu zhu <hzhu@bios.unc.edu>
Date: October 29, 2010 11:26:36 AM EDT
To: "Hernando Ombao" <ombao@stat.brown.edu>
Subject: Re: SI Moving forward

I would nominate Daniel Rowe for this.

best
hongtu



Hi All -

We have some who have graciously volunteered to carry this section to the finish line.

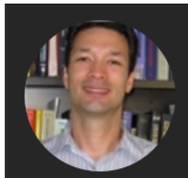
Perhaps others need some time to think this through? Shall we try to complete this part by the weekend?

If you are flexible about serving in any post, please feel free to let me know.

Hernando

I.2. Planning

We voted and I was electedthe Founding Section Chair.



Wed 11/3/2010 10:56 AM

Rowe, Daniel

RE: Volunteer update

To hongtu zhu; Hernando Ombao

Cc Bowman, DuBois; Lindquist, Martin; Caffo, Brian; Maitra, Ranjan; Nichols, Thomas; karymyers@gmail.com

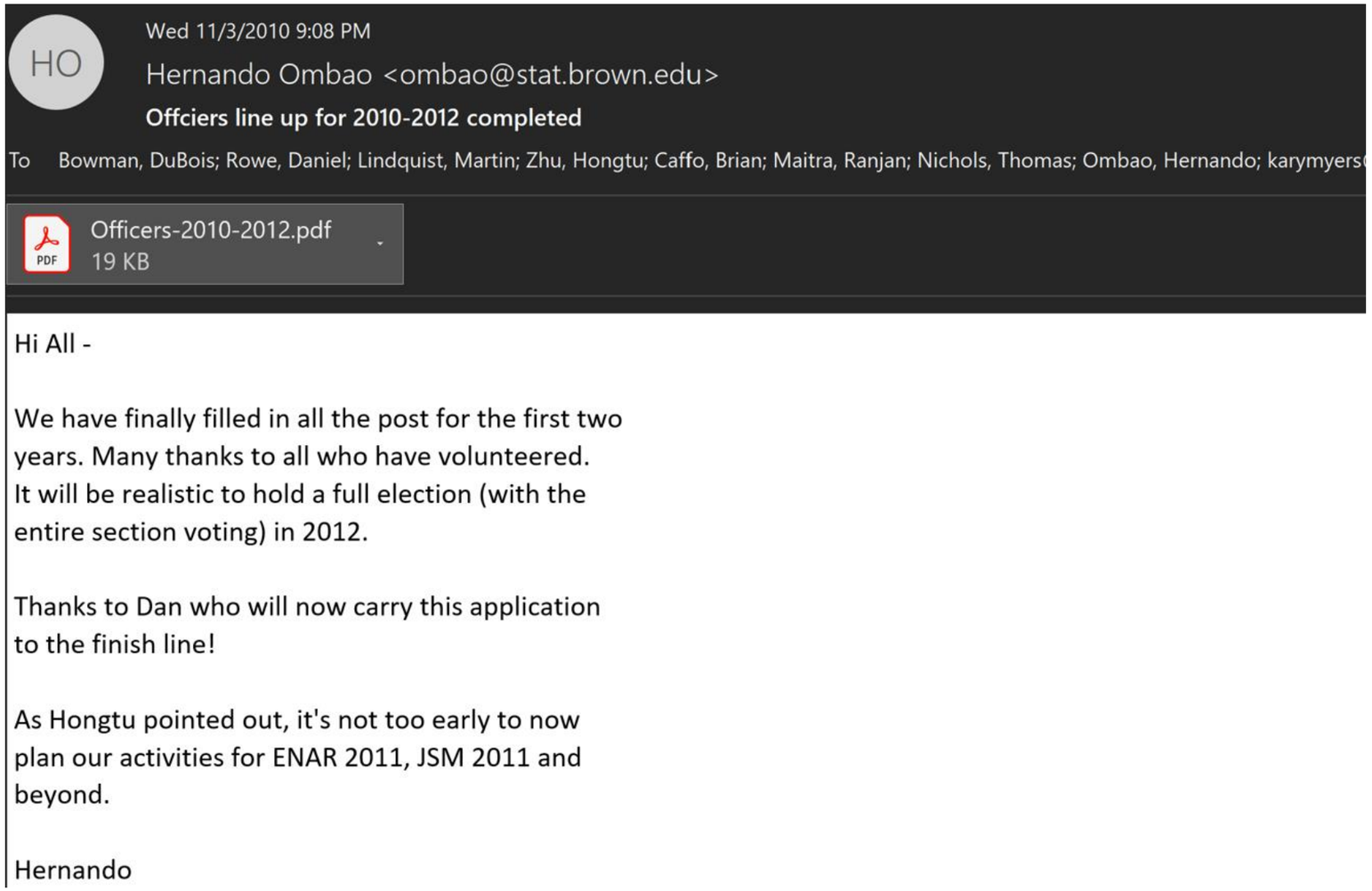
We removed extra line breaks from this message.

ok, I would be willing to serve as first chair (unless there are any objections). I need a week to clear a few things off my desk before getting to it.

Dan

I.2. Planning

After Founding Chair, we filled the other founding members.



Wed 11/3/2010 9:08 PM

Hernando Ombao <ombao@stat.brown.edu>

Offciers line up for 2010-2012 completed

To Bowman, DuBois; Rowe, Daniel; Lindquist, Martin; Zhu, Hongtu; Caffo, Brian; Maitra, Ranjan; Nichols, Thomas; Ombao, Hernando; karymyers

Officers-2010-2012.pdf
19 KB

Hi All -

We have finally filled in all the post for the first two years. Many thanks to all who have volunteered. It will be realistic to hold a full election (with the entire section voting) in 2012.

Thanks to Dan who will now carry this application to the finish line!

As Hongtu pointed out, it's not too early to now plan our activities for ENAR 2011, JSM 2011 and beyond.

Hernando

Officers

2010-11

Chair	Dan Rowe
Secretary	Brian Caffo
Treasurer	DuBois Bowman
Rep to COS	Kary Myers
Program Chair	Ranjan Maitra

2011-12

Chair	Hongtu Zhu
Secretary	Brian Caffo
Treasurer	DuBois Bowman
Rep to COS	Kary Myers
Program Chair	Martin Lindquist

As you can see, 2010 was already gone.
So we pushed all officers back two years.

I.3. Coalescence

I started working with the ASA to get them the needed documents.

PR

Thu 12/30/2010 1:23 PM

Peterson, Rick <rick@amstat.org>

RE: Petition for ASA Section on Imaging

To Rowe, Daniel

Hi Rick,

I'm working on gathering all the materials for submission for a new section on Imaging. I have an email that was forwarded to me that includes the text from you "The required petition, proposed charter, and list of Section officers will be submitted to the Council of Sections Governing Board 60 days before either the winter meeting in February or the annual meeting in August."

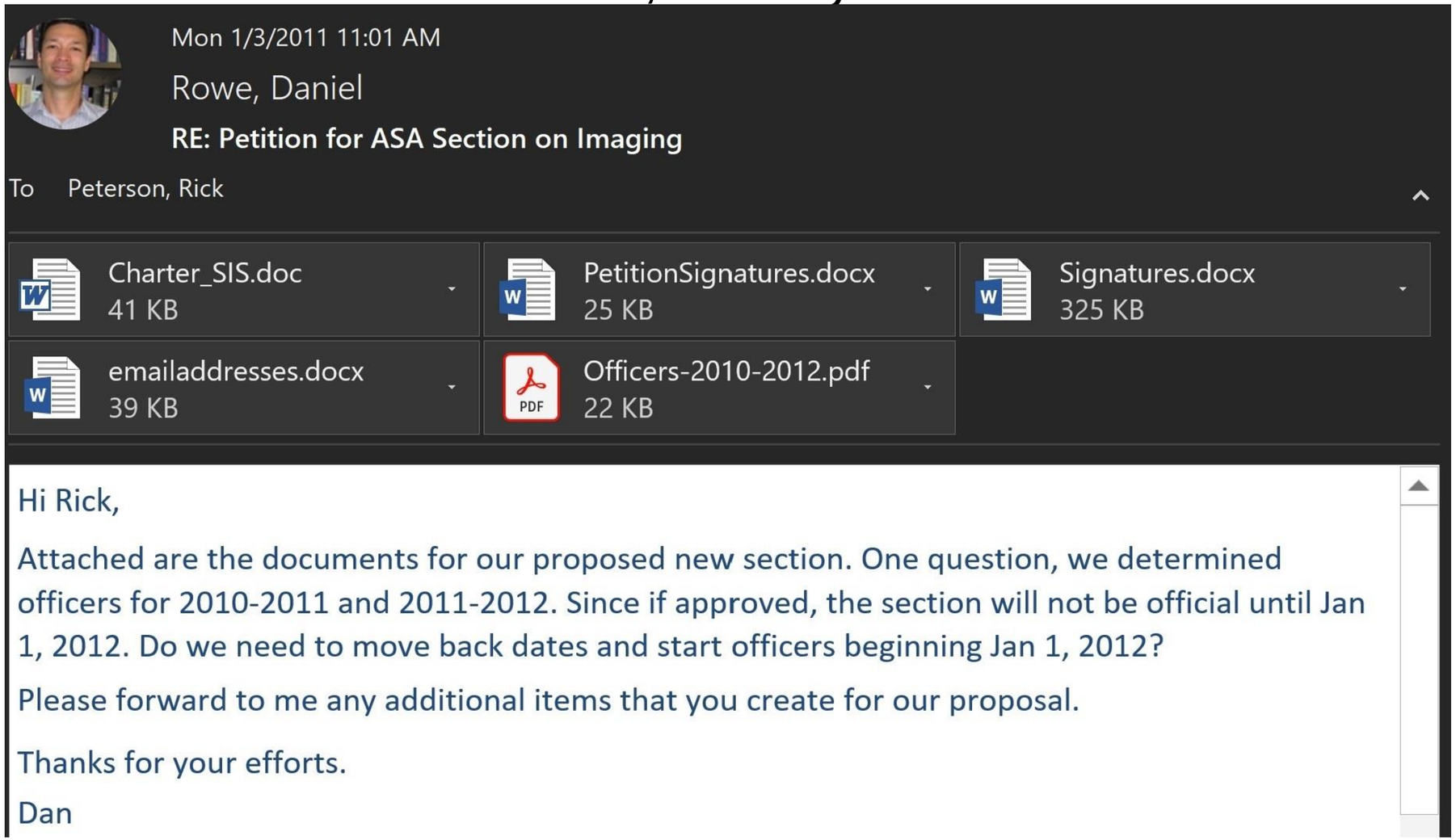
Do I just send you an email with the petition from over 100 ASA members, our proposed charter, and officers? Do I need to draft a cover letter?

Thanks

Dan

I.3. Coalescence

After some modifications, I finally submitted the Section documents.



I made some changes, gathered the signatures and email addresses.

I.3. Coalescence

I had to make more changes to the charter.

PR

Tue 2/1/2011 3:12 PM

Peterson, Rick <rick@amstat.org>

RE: Petition for ASA Section on Imaging

To Rowe, Daniel

Hi Dan,

The chair of the Council of Sections Governing Board is going to contact you regarding the discussion that took place during our meeting on Saturday. Basically the council thought this was worthy to move towards a vote at the Council of Sections Meeting at JSM 2011. The chair is going to recommend some minor changes to the charter. With regard to the officers, if approved, the terms would begin on January 1, 2012 and last to December 31, 2012.

Best,
Rick

I.3. Coalescence

Been waiting through the summer and early fall.
We were all getting impatient. Hernando asked for a status update.

Hernando Ombao

RE: Status of the Section 8/25/2011

Hi Hernando, There were some additional minor changes needed to the charter and some confusion that they heard that we wanted to change the name to medical imaging. The COS will vote on it on Oct 1. Dan

I.3. Coalescence

Still waiting for a vote on the section.

PR

Wed 8/31/2011 2:56 PM

Peterson, Rick <rick@amstat.org>

COS Vote to Approve Section on Statistics in Imaging

To Rowe, Daniel

Cc Czajka, John L.

Hi Dan,

I just wanted to keep you in the loop on this process. Today I sent the final version of the charter for the proposed Section on Statistics in Imaging to the Council of Sections and asked that they respond to me with their vote to approve or not approve the formation of this new section. The deadline to vote is September 30. I wanted to give them some time to confer with their section's officers or poll the section members themselves. We'll let you know the results in early October.

If approved by a majority of the Council of Sections, the section will become officially chartered on January 1, 2012.

Please let me know if you have any questions.

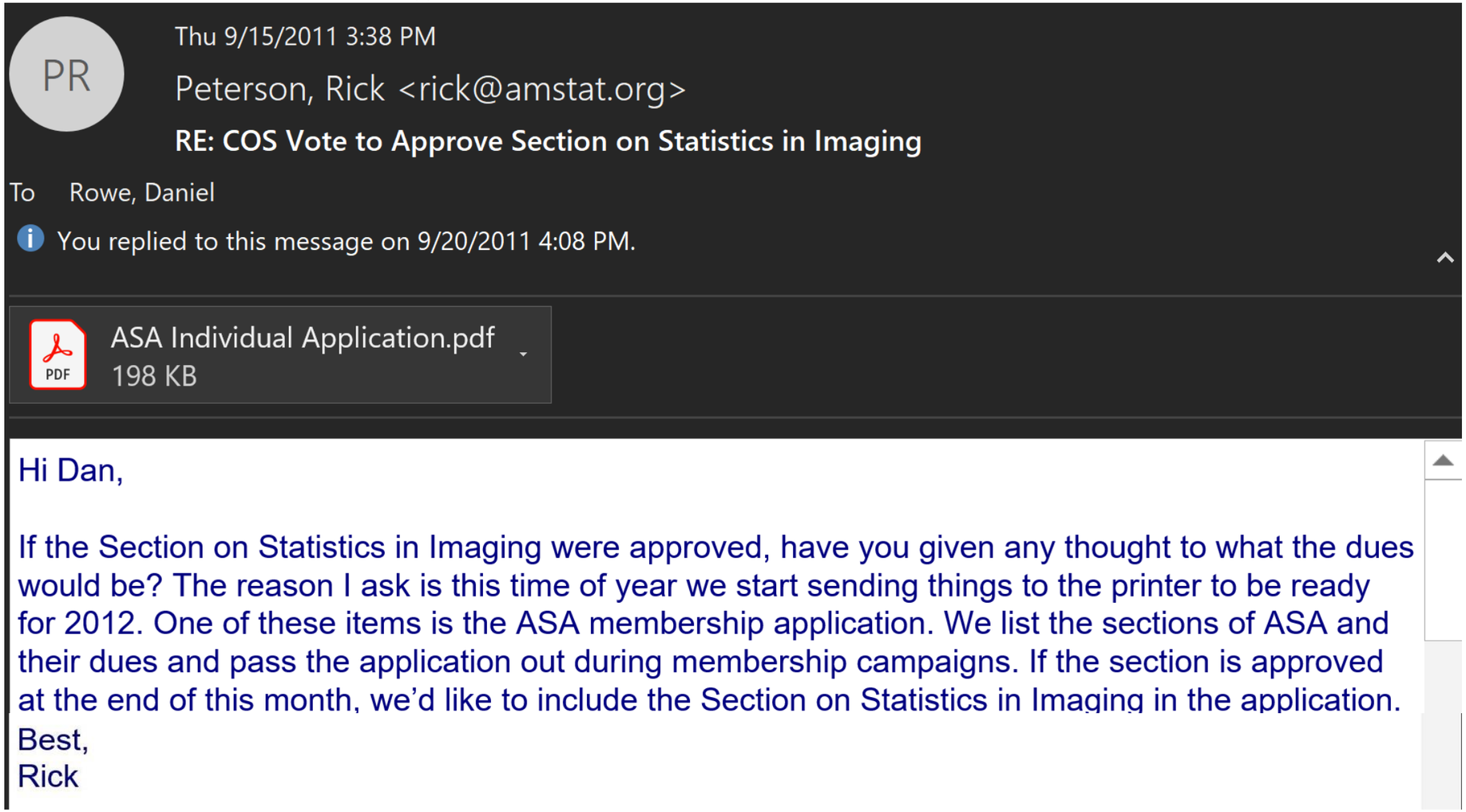
Best regards,
Rick

Rick Peterson

Continuing Education & Chapter and Sections Associate

I.3. Coalescence

We needed to figure out dues. Not too much and not too little. Just right.



PR

Thu 9/15/2011 3:38 PM

Peterson, Rick <rick@amstat.org>

RE: COS Vote to Approve Section on Statistics in Imaging

To Rowe, Daniel

You replied to this message on 9/20/2011 4:08 PM.

ASA Individual Application.pdf
198 KB

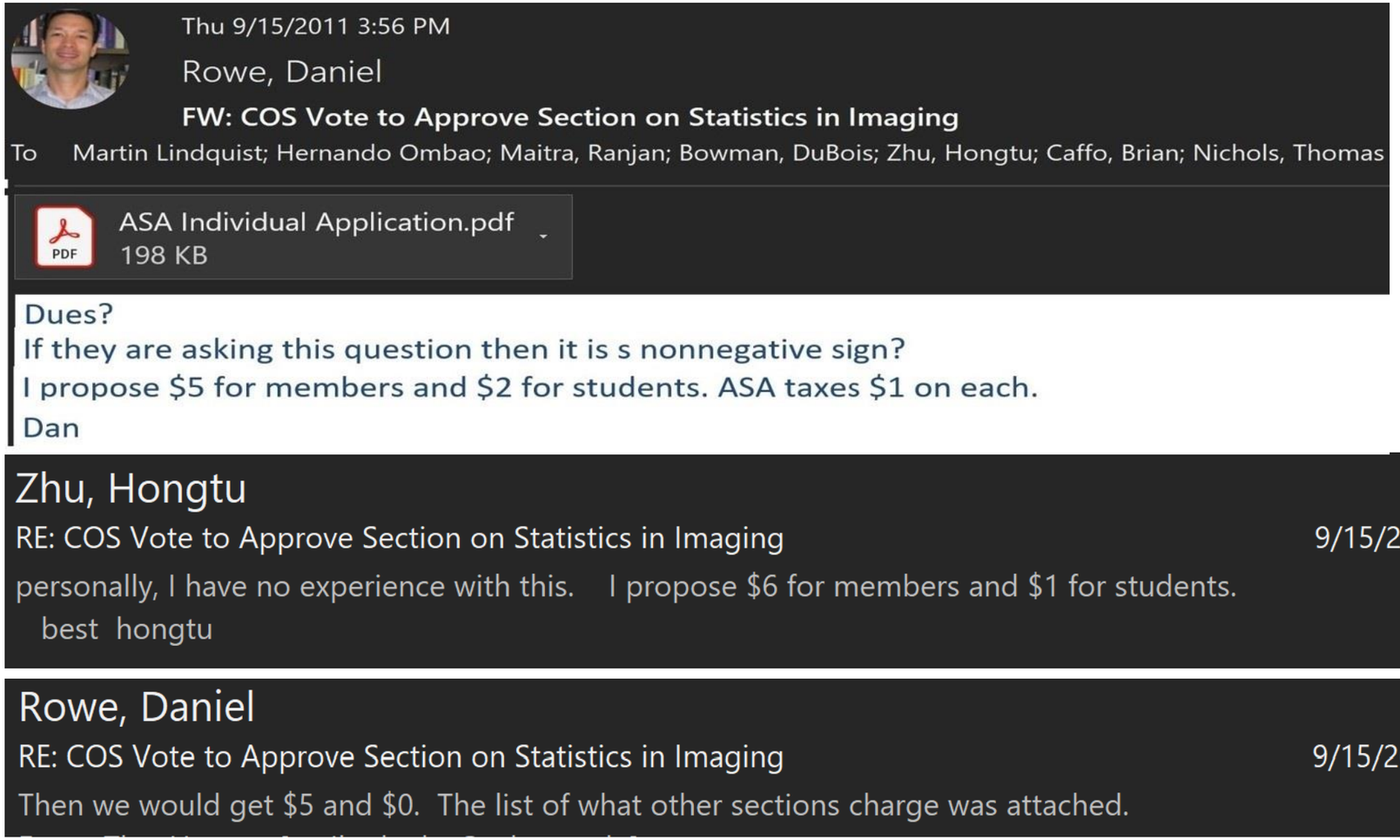
Hi Dan,

If the Section on Statistics in Imaging were approved, have you given any thought to what the dues would be? The reason I ask is this time of year we start sending things to the printer to be ready for 2012. One of these items is the ASA membership application. We list the sections of ASA and their dues and pass the application out during membership campaigns. If the section is approved at the end of this month, we'd like to include the Section on Statistics in Imaging in the application.

Best,
Rick

I.3. Coalescence

We discusses via email.



Thu 9/15/2011 3:56 PM

Rowe, Daniel

FW: COS Vote to Approve Section on Statistics in Imaging

To Martin Lindquist; Hernando Ombao; Maitra, Ranjan; Bowman, DuBois; Zhu, Hongtu; Caffo, Brian; Nichols, Thomas

ASA Individual Application.pdf
198 KB

Dues?
If they are asking this question then it is s nonnegative sign?
I propose $5 for members and $2 for students. ASA taxes $1 on each.
Dan

Zhu, Hongtu

RE: COS Vote to Approve Section on Statistics in Imaging 9/15/2011

personally, I have no experience with this. I propose $6 for members and $1 for students.
best hongtu

Rowe, Daniel

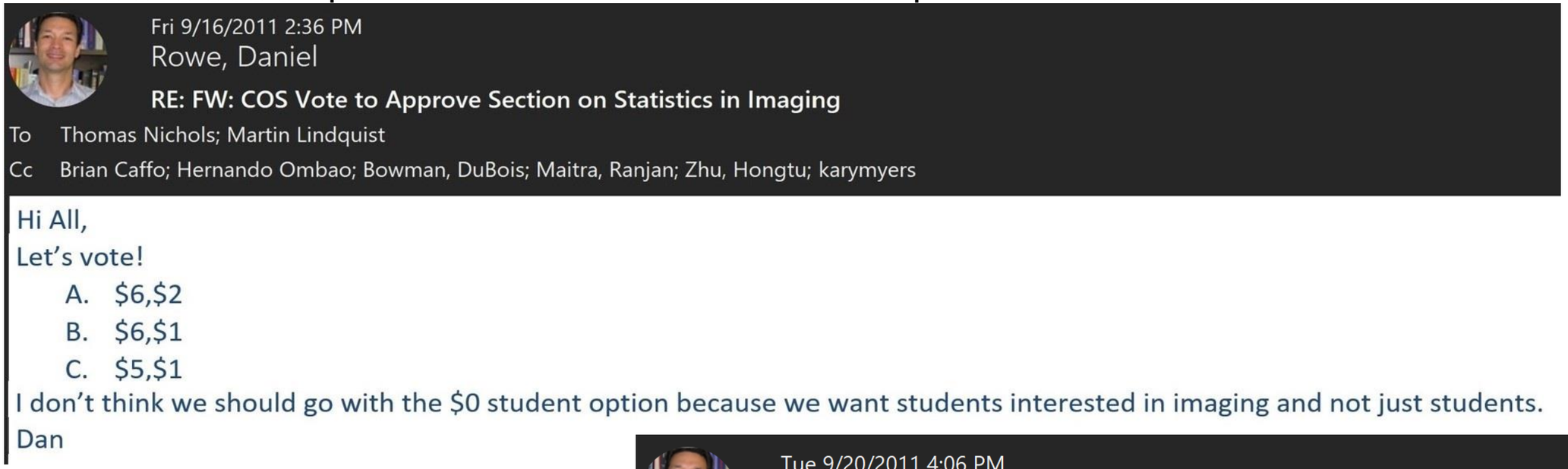
RE: COS Vote to Approve Section on Statistics in Imaging 9/15/2011

Then we would get $5 and $0. The list of what other sections charge was attached.

Others had opinions too.

I.3. Coalescence

We selected $6 for full members and $1 for students. ASA taxed each $1.

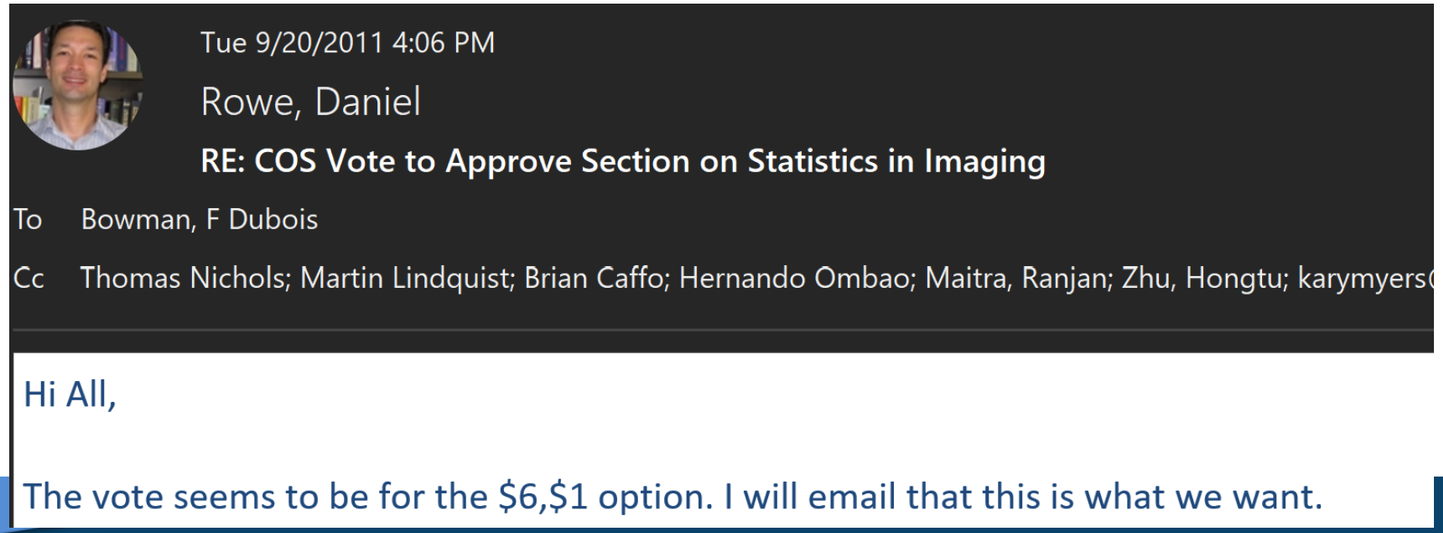


Fri 9/16/2011 2:36 PM
Rowe, Daniel
RE: FW: COS Vote to Approve Section on Statistics in Imaging
To Thomas Nichols; Martin Lindquist
Cc Brian Caffo; Hernando Ombao; Bowman, DuBois; Maitra, Ranjan; Zhu, Hongtu; karymyers

Hi All,
Let's vote!

A. $6,$2
B. $6,$1
C. $5,$1

I don't think we should go with the $0 student option because we want students interested in imaging and not just students.
Dan



Tue 9/20/2011 4:06 PM
Rowe, Daniel
RE: COS Vote to Approve Section on Statistics in Imaging
To Bowman, F Dubois
Cc Thomas Nichols; Martin Lindquist; Brian Caffo; Hernando Ombao; Maitra, Ranjan; Zhu, Hongtu; karymyers

Hi All,

The vote seems to be for the $6,$1 option. I will email that this is what we want.

I.3. Coalescence

Finally notified the section was approved!

PR

Thu 10/6/2011 11:25 AM

Peterson, Rick <rick@amstat.org>

Proposed New Section on Statistics in Imaging

To Rowe, Daniel

Cc Lepkowski, James M.; King, Eileen C.; Nusser, Sarah M.

Dear Dan,

The deadline for the Council of Sections to vote on the proposed new Section on Statistics in Imaging was last Friday, September 29. I am very pleased to report to you that the Council of Sections approved the formation of this section. Congratulations!

The section will be officially chartered beginning January 1, 2012. I have already begun working with other ASA staff so we will be ready to service the new section by that date. This includes listing the section and its officers on the ASA web site and the ability for persons to pay dues to become a member of the section. We discussed the dues rates for the section in an earlier email.

One thing you may consider is creating a web site for the section. When you begin looking into this let me know and we can discuss how ASA can help.

Once again, congratulations. As the ASA sections staff liaison, please do not hesitate if ever there is anything I can do for you and the Section on Statistics in Imaging.

Best regards,

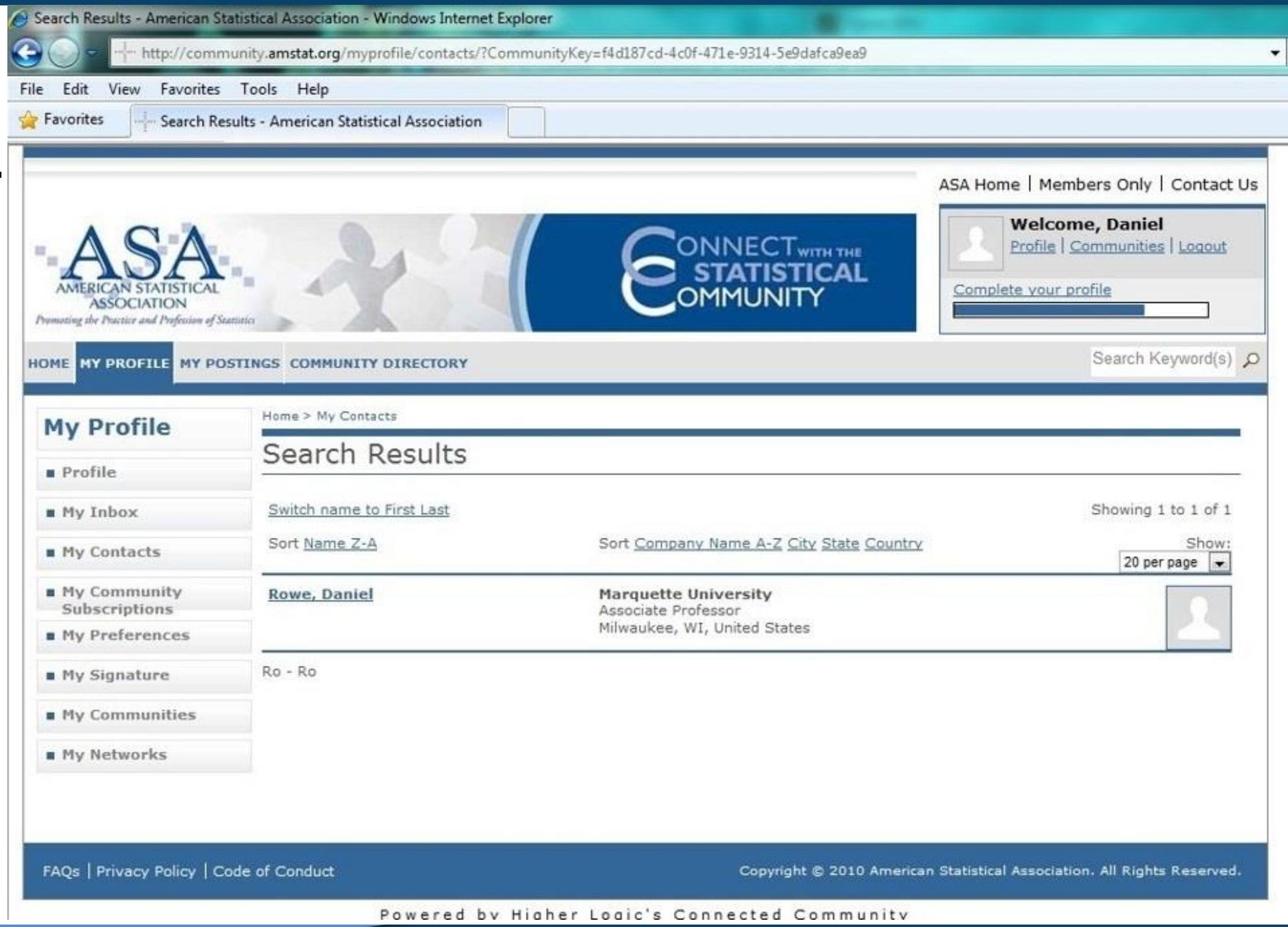
Rick

I.3. Coalescence

First section member. 10-19-2011

By 01-24-12 there were 60 members,

Now 364 members.



I.3. Coalescence

I remember our first officer's meeting at the 2012 JSM in San Diego.

I believe there were only three people and we met at a high table on the patio of a restaurant in San Diego's gas light district.

I think somebody took notes on a napkin.

Now we have a vibrant successful Section on Imaging.

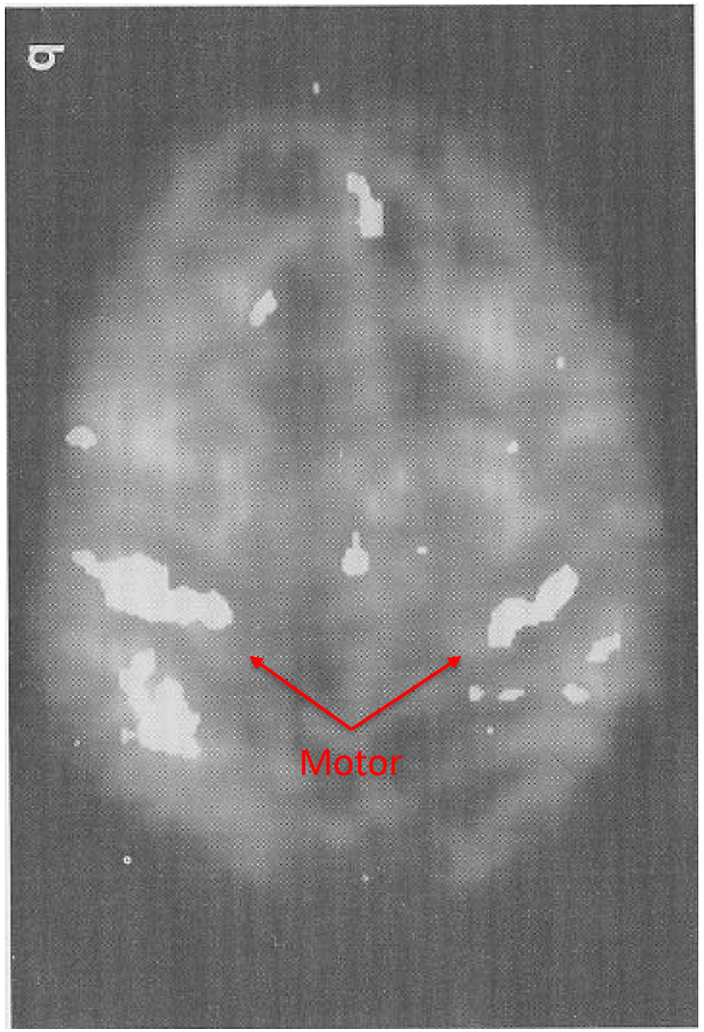
Outline

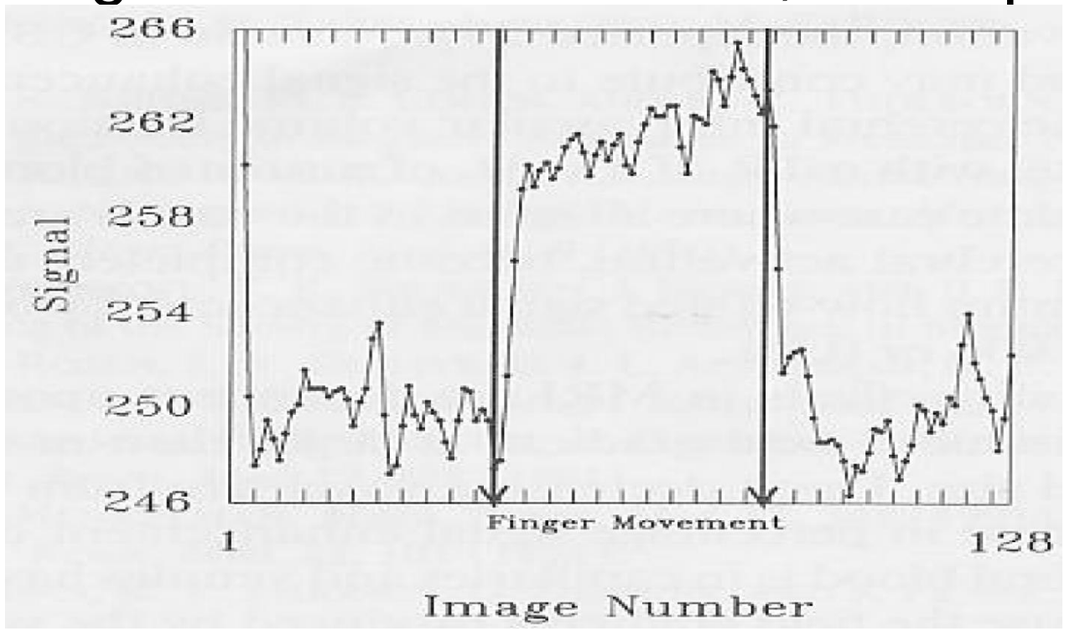
Part II. Foundations of Functional MRI

1. Background
2. Measured Data
3. Opportunities in FMRI

II.1. Background

When I first started reading about FMRI in 1998, I saw pictures of FMRI





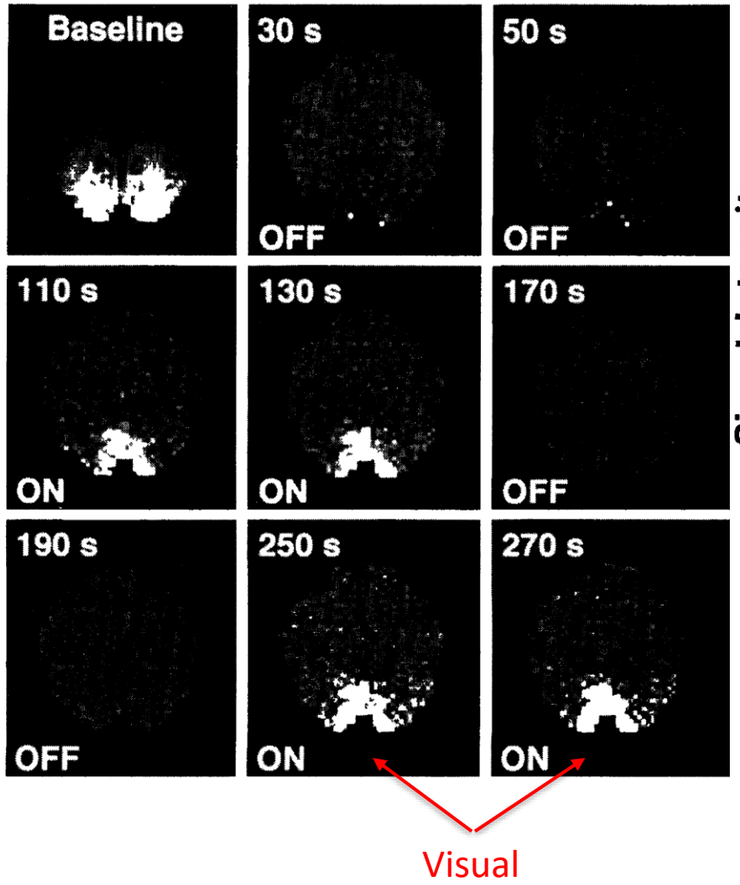
Magnitude-Only Time Series

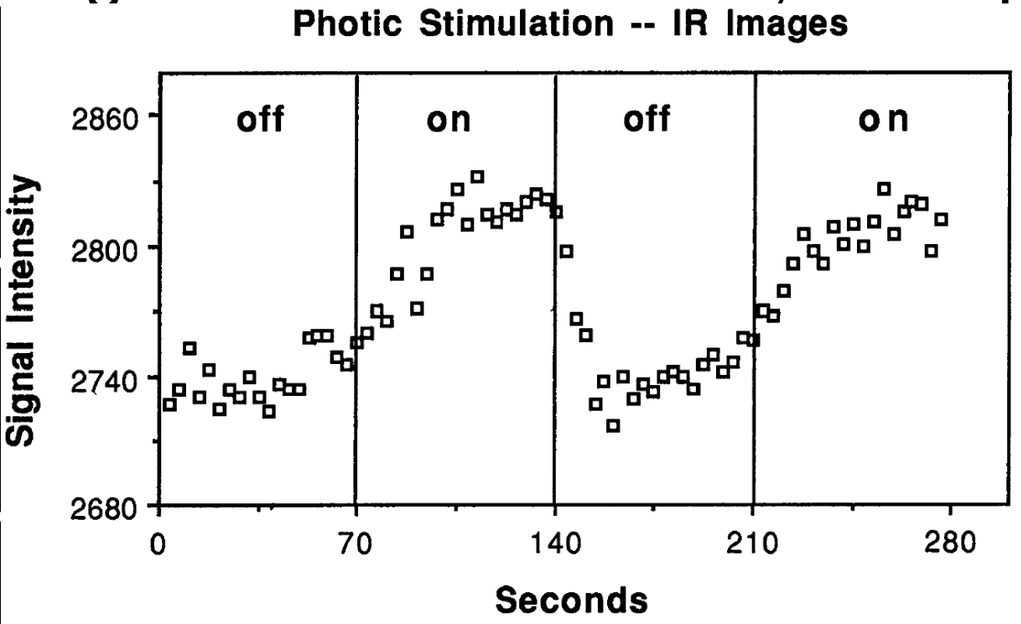
Bandettini P.A., Wong E.C., Hinks R.S., Tikofsky R.S, and Hyde J.S. Time course EPI of human brain function during task activation. Magn Reson Med, 25(2):390-397, Submitted **February 1992**, Published **March 1992**.

No Exogenous Contrast Agent. Endogenous BOLD Contrast.

II.1. Background

When I first started reading about FMRI in 1998, I saw pictures of FMRI





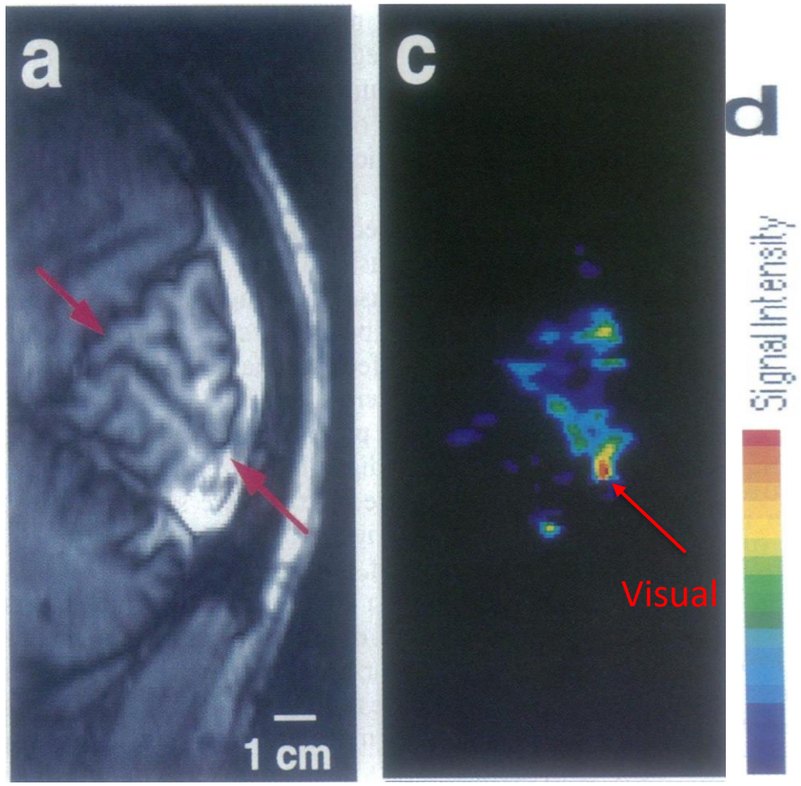
Magnitude-Only Time Series

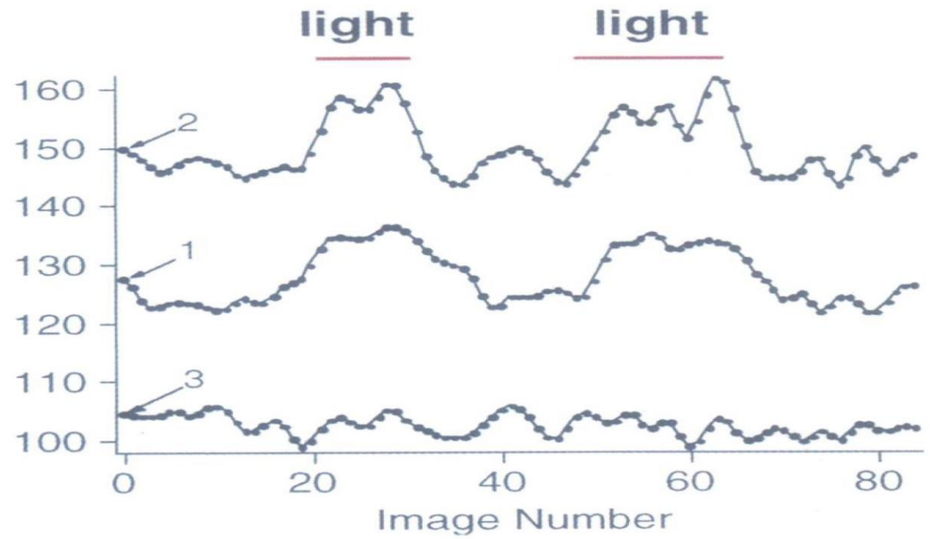
Kwong K.K., Belliveau J.W., Chesler D.A., Goldberg I.E., Weissko
R.M. Poncelet
B.P. Kennedy D.N., Hoppel B.E., Cohen M.S., and Turner R. Oxygenation-sensitive contrast in magnetic resonance image of rodent brain at high magnetic elds. Proc Natl Acad Sci USA, 89(12):5675-5679, **March 1992**.

No Exogenous Contrast Agent. Endogenous BOLD Contrast.

II.1. Background

When I first started reading about FMRI in 1998, I saw pictures of FMRI





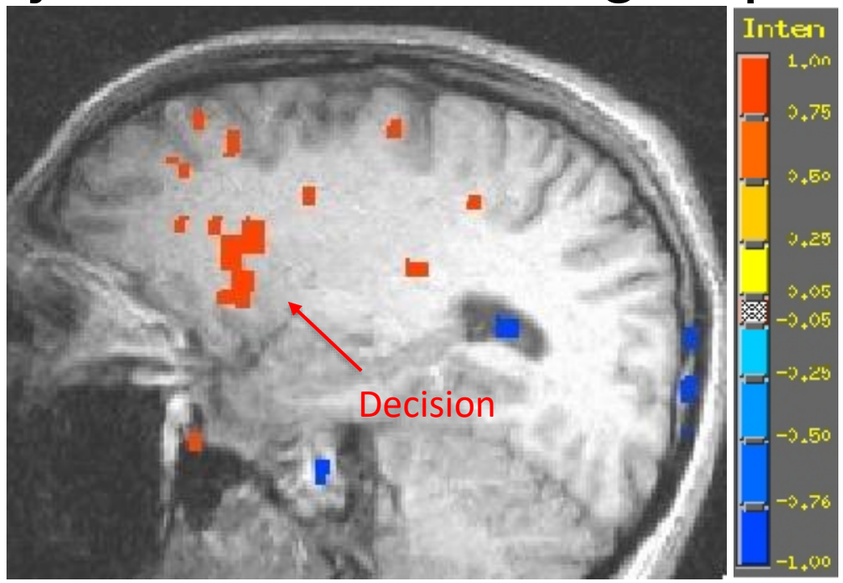
Magnitude-Only Time Series

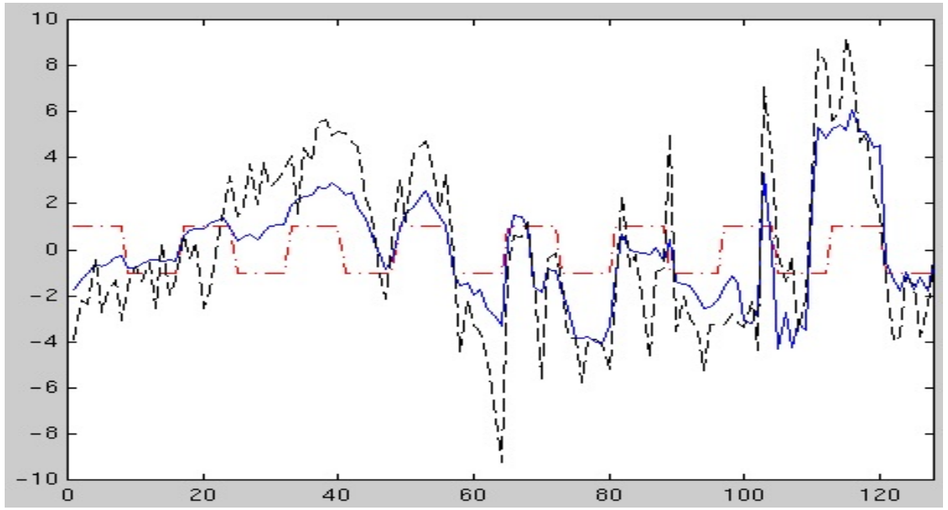
Ogawa S., Tank D.W., Menon R.S., Ellermann J.M. ad Kim S.G., Merkle H., and Ugurbil K. Intrinsic signal changes accompanying sensory stimulation: Functional brain mapping with magnetic resonance imaging. Proc Natl Acad Sci USA, 89(13):5951-5955, **March 1992**.

No Exogenous Contrast Agent. Endogenous BOLD Contrast.

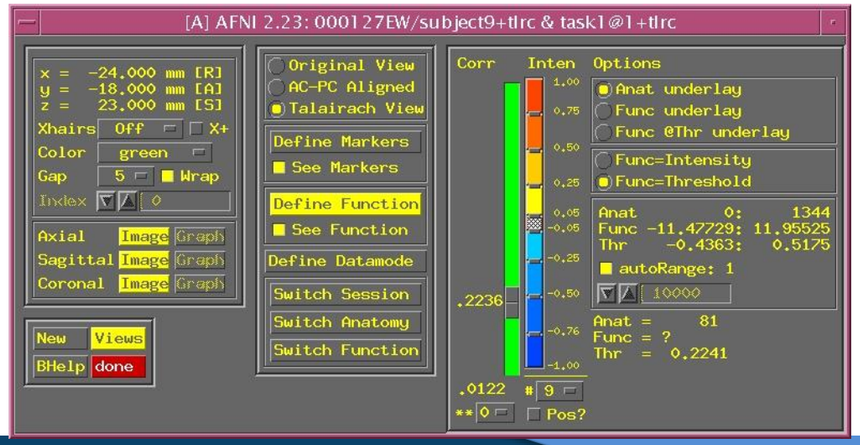
II.1. Background

I joined a research group at Caltech in 1999 and published in 2001.





Rowe DB. Bayesian source separation for reference function determination in fMRI. Magn. Reson. Med. 46(2):374-378 (2001).



Magnitude-Only Time Series

II.2. Measured Data

At MCW in 2001 I learned time series not just *k*-space are complex-valued.

from *Proc. 5th Mtg. ISMRM*, Vancouver, Canada, p. 1671, 1997.

Detection of BOLD fMRI Signals Using Complex Data

SONG LAI, G.H. GLOVER
Lucas MR Center, Department of Radiology
Stanford University, Stanford, CA 94305-5488

$$cc = \frac{\left\{[\Sigma(x-\bar{x})\,(r-\bar{r})]^2 + [\Sigma(y-\bar{y})\,(r-\bar{r})]^2\right\}^{1/2}}{(N-1)\,\sigma_r\sqrt{\sigma_x^2+\sigma_y^2}}$$

$x = \mathrm{Re}(\mathbf{I})$ and $y = \mathrm{Im}(\mathbf{I})$

r is time-dependent periodic reference signal

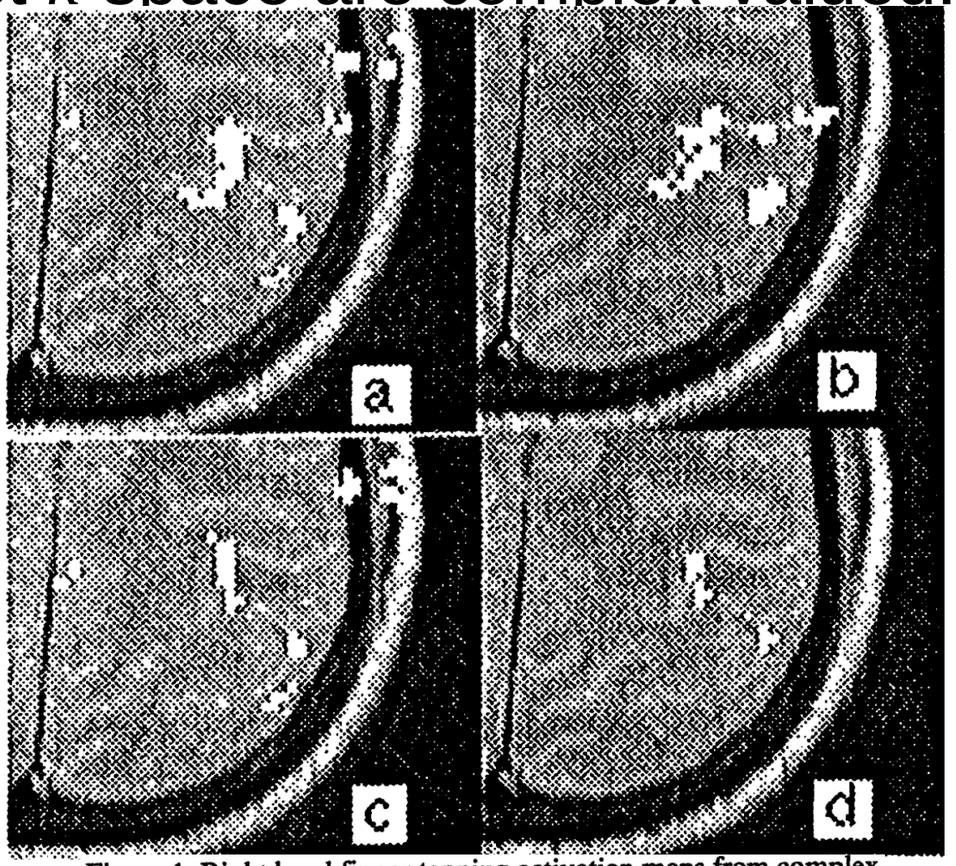


Figure 1. Right hand finger tapping activation maps from complex data (a), magnitude detection (b), and NMR phase detection (c), respectively. The bright pixels in Fig. d are seen in both the magnitude detection (b) and the phase detection (c), most likely delineating large veins [2].

Very simple model.

II.2. Measured Data

At MCW in 2001 I learned time series not just *k*-space are complex-valued.

IEEE TRANSACTIONS ON MEDICAL IMAGING, VOL. 18, NO. 4, APRIL 1999

Generalized Likelihood Ratio Detection for fMRI Using Complex Data

Fangyuan Y. Nan and Robert D. Nowak

$$\mathbf{x} = (a\mathbf{1} + b\mathbf{r})(\cos\vartheta + i\sin\vartheta) + \sigma.\mathbf{n}_c.$$

$$\mathbf{y} = \mathbf{S}\phi + \mu\mathbf{H}\phi + \sigma\mathbf{n}$$

$\mu = b/a$ and

$$\mathbf{y} = \begin{bmatrix} \mathbf{x}_R \\ \mathbf{x}_I \end{bmatrix}, \quad \mathbf{S} = \begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix}, \quad \mathbf{H} = \begin{bmatrix} \mathbf{r} & 0 \\ 0 & \mathbf{r} \end{bmatrix},$$

$$\phi = \begin{bmatrix} a\cos\vartheta \\ a\sin\vartheta \end{bmatrix}, \quad \mathbf{n} = \begin{bmatrix} \mathbf{n}_{cR} \\ \mathbf{n}_{cI} \end{bmatrix}.$$

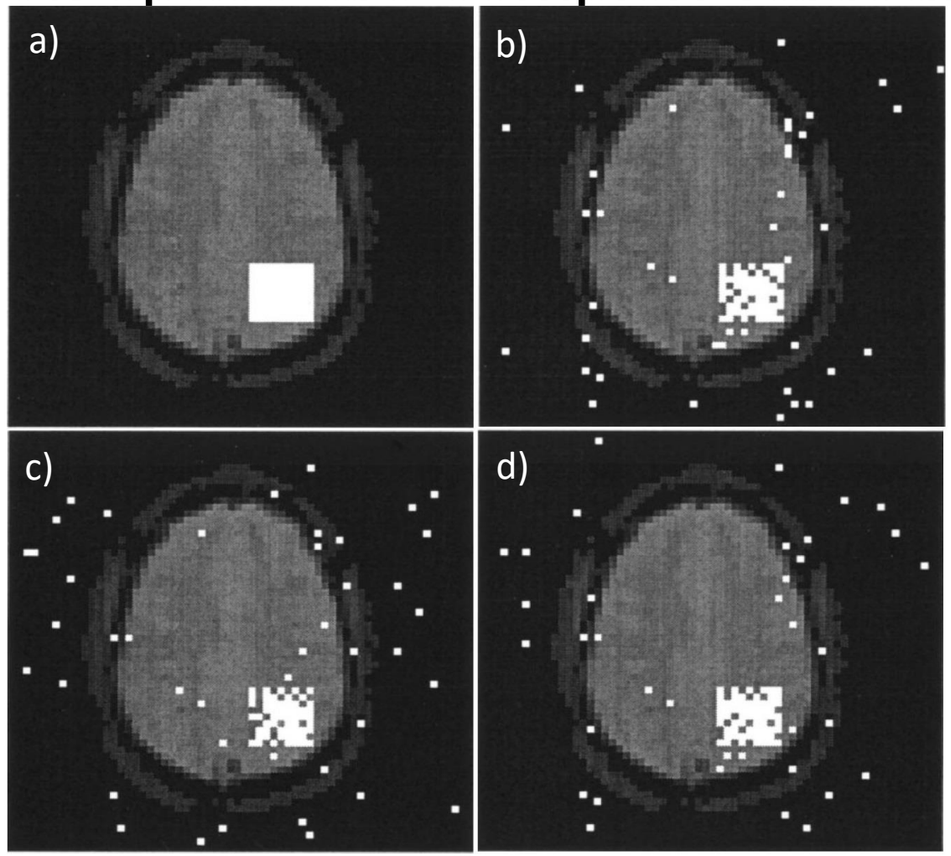


Fig. 3. Simulated fMRI experiment. (a) Brain image with simulated activation region highlighted. The MC test, CC test, and GLRT test are compared in (b)–(d). A threshold was selected for each test to produce a $P_f = 0.01$. (b) MC test results. Detection rate $P_d = 0.77$. (c) CC test results. $P_d = 0.70$. (d) GLRT results. $P_d = 0.79$.

Simple model and only simulated data.

II.2. Measured Data

In 2004 published paper on a more general model to experimental data.

D.B. Rowe, B.R. Logan / NeuroImage 23 (2004) 1078–1092

A complex way to compute fMRI activation

Daniel B. Rowe[a,*] and Brent R. Logan[b]

[a]*Department of Biophysics, Medical College of Wisconsin, Milwaukee, WI 53226, USA*
[b]*Division of Biostatistics, Medical College of Wisconsin, Milwaukee, WI, USA*

$$\begin{pmatrix} y_{Rt} \\ y_{It} \end{pmatrix} = \begin{pmatrix} \rho_t \cos\theta \\ \rho_t \sin\theta \end{pmatrix} + \begin{pmatrix} \eta_{Rt} \\ \eta_{It} \end{pmatrix}$$

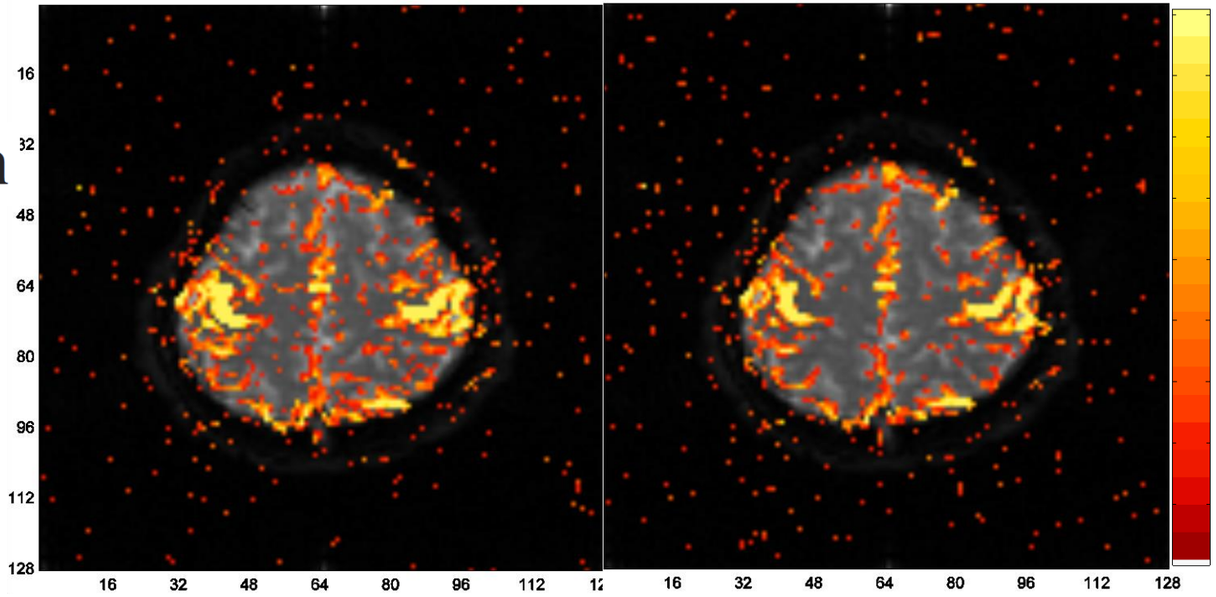
Bivariate Observations

$$y_{Rt} = \rho_t \cos\theta + \eta_{Rt}$$
$$y_{It} = \rho_t \sin\theta + \eta_{It}$$

Real and Imaginary

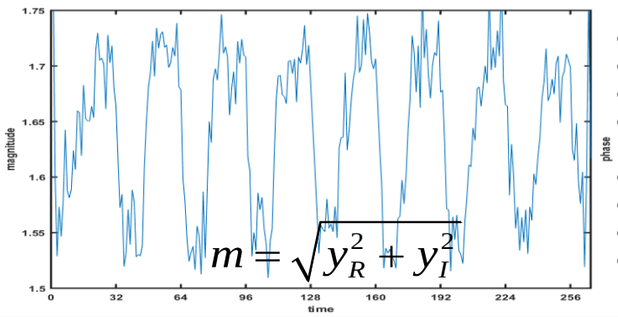
$$\rho_t = \beta_0 + \beta_1 x_{1t} + \cdots + \beta_{q_1} x_{q_1 t}$$

More advanced model applied to experimental data.

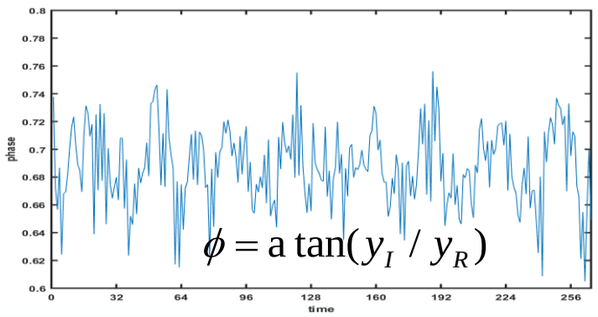


a) Magnitude Model b) Complex Model

5% FDR Threshold



$$m = \sqrt{y_R^2 + y_I^2}$$



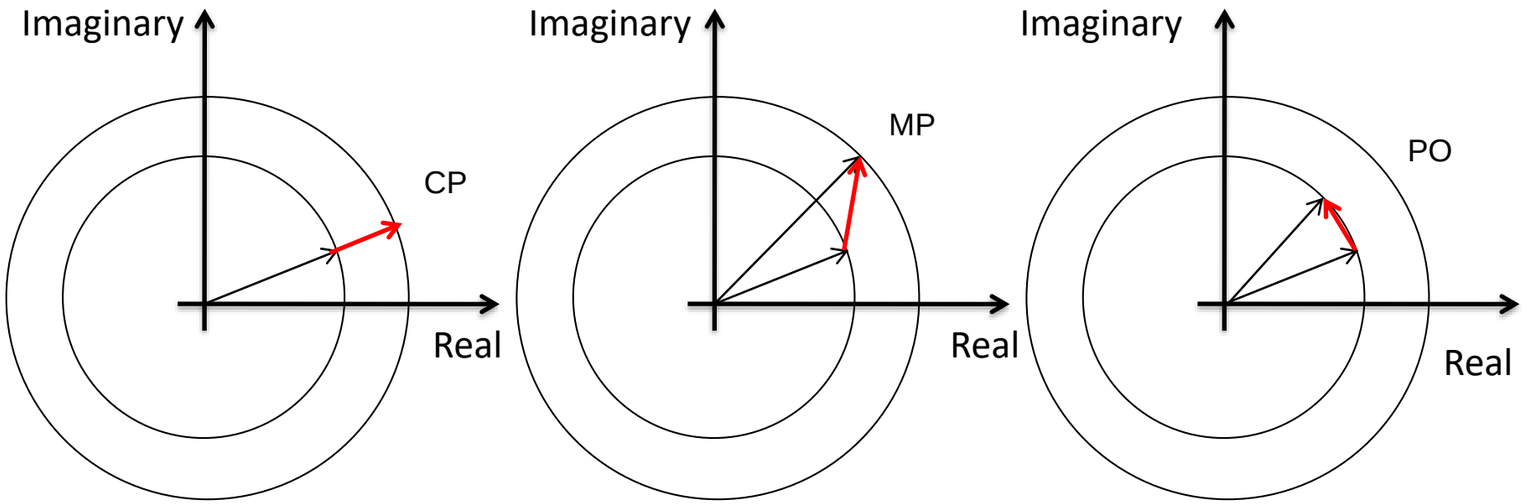
$$\phi = \mathrm{a}\tan(y_I / y_R)$$

II.2. Measured Data

In each voxel at time t:

$$\begin{pmatrix} y_{Rt} \\ y_{It} \end{pmatrix} = \begin{pmatrix} \rho_t \cos\theta_t \\ \rho_t \sin\theta_t \end{pmatrix} + \begin{pmatrix} \eta_{Rt} \\ \eta_{It} \end{pmatrix}$$

$$(\eta_{Rt}, \eta_{It})' \sim N(0, \Sigma)$$



$$\left.\begin{aligned} \rho_t &= \beta_0 + \beta_1 x_{1t} + \cdots + \beta_{q_1} x_{q_1 t} \\ \theta_t &= \theta \end{aligned}\right\}$$

$$\left.\begin{aligned} \rho_t &= \beta_0 + \beta_1 x_{1t} + \cdots + \beta_{q_1} x_{q_1 t} \\ \theta_t &\neq \theta_{t'} \end{aligned}\right\}$$

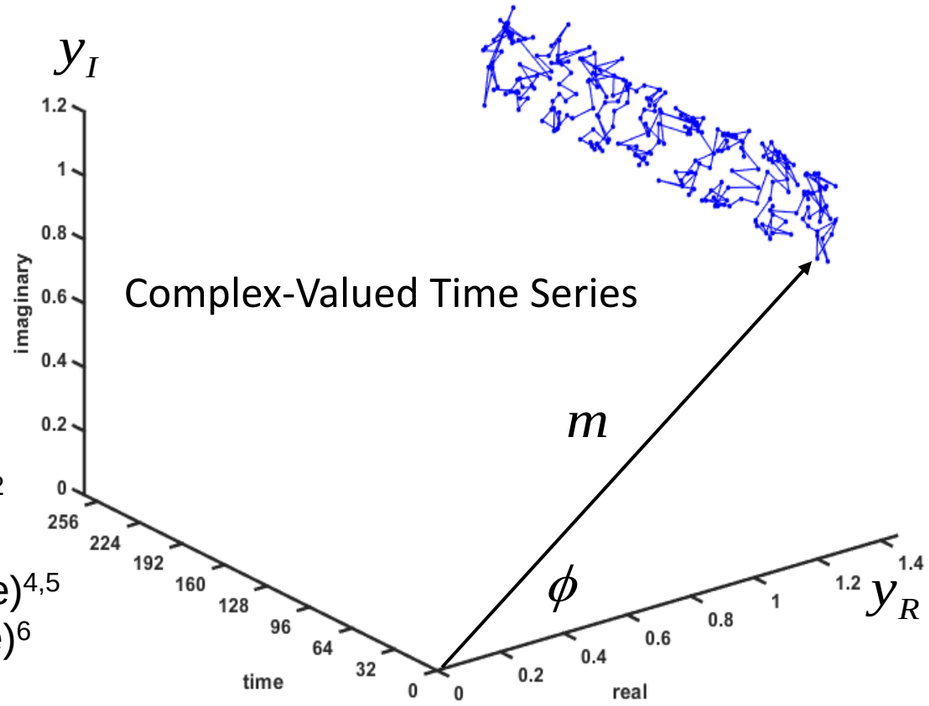
$$\left.\begin{aligned} \rho_t &= \beta_0 + \beta_1 x_{1t} + \cdots + \beta_{q_1} x_{q_1 t} \\ \theta_t &= \gamma_0 + \gamma_1 u_{1t} + \cdots + \gamma_{q_2} u_{q_2 t} \end{aligned}\right\}$$

$$\left.\begin{aligned} \beta_t &\neq \beta_{t'} \\ \theta_t &= \gamma_0 + \gamma_1 u_{1t} + \cdots + \gamma_{q_2} u_{q_2 t} \end{aligned}\right\}$$

Three possible changes.

[1]Rowe and Logan: NIMG, 23:1078-1092, 2004.
[2]Rowe: NIMG 25:1124-1132, 2005a.
[3]Rowe: NIMG, 25:1310-1324, 2005b.
[4]Bandettini et al.: MRM, 30:161-173, 1993.
[5]Rowe and Logan: NIMG 24:603-606, 2005.
[6]Rowe, et al.: JNSM, 161:331-341, 2007.
[7]Rowe: MRM, 62:1356-1357, 2009.

- Magnitude w/ Constant Phase (CP) Activation[1,2]
- Magnitude and/or Phase (MP) Activation[3,7]
- Magnitude-Only (MO) Activation (Discard Phase)[4,5]
- Phase-Only (PO) Activation (Discard Magnitude)[6]

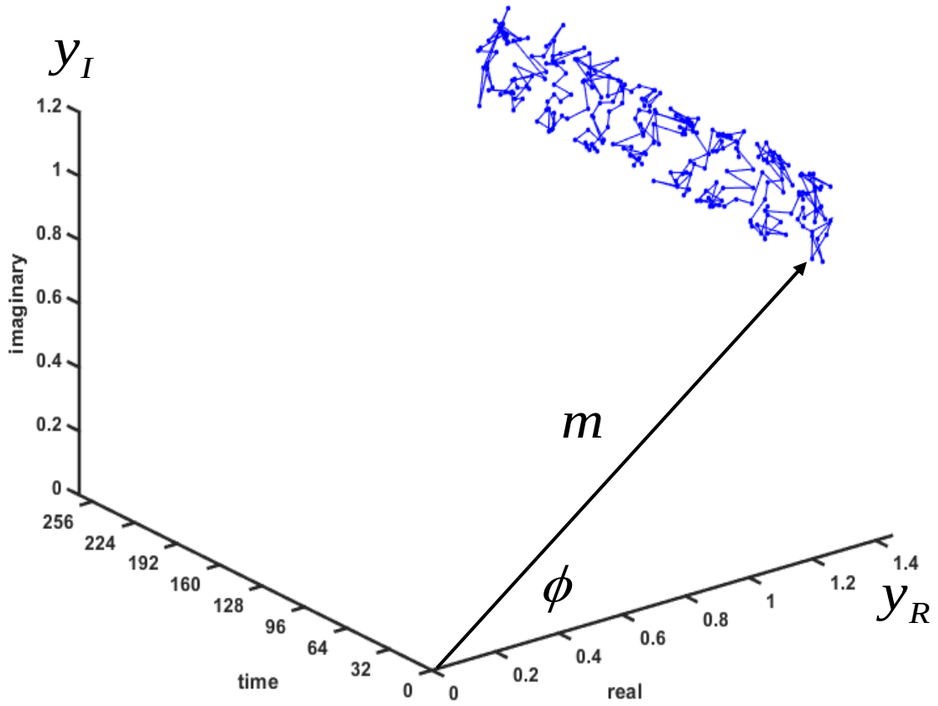


II.2. Measured Data

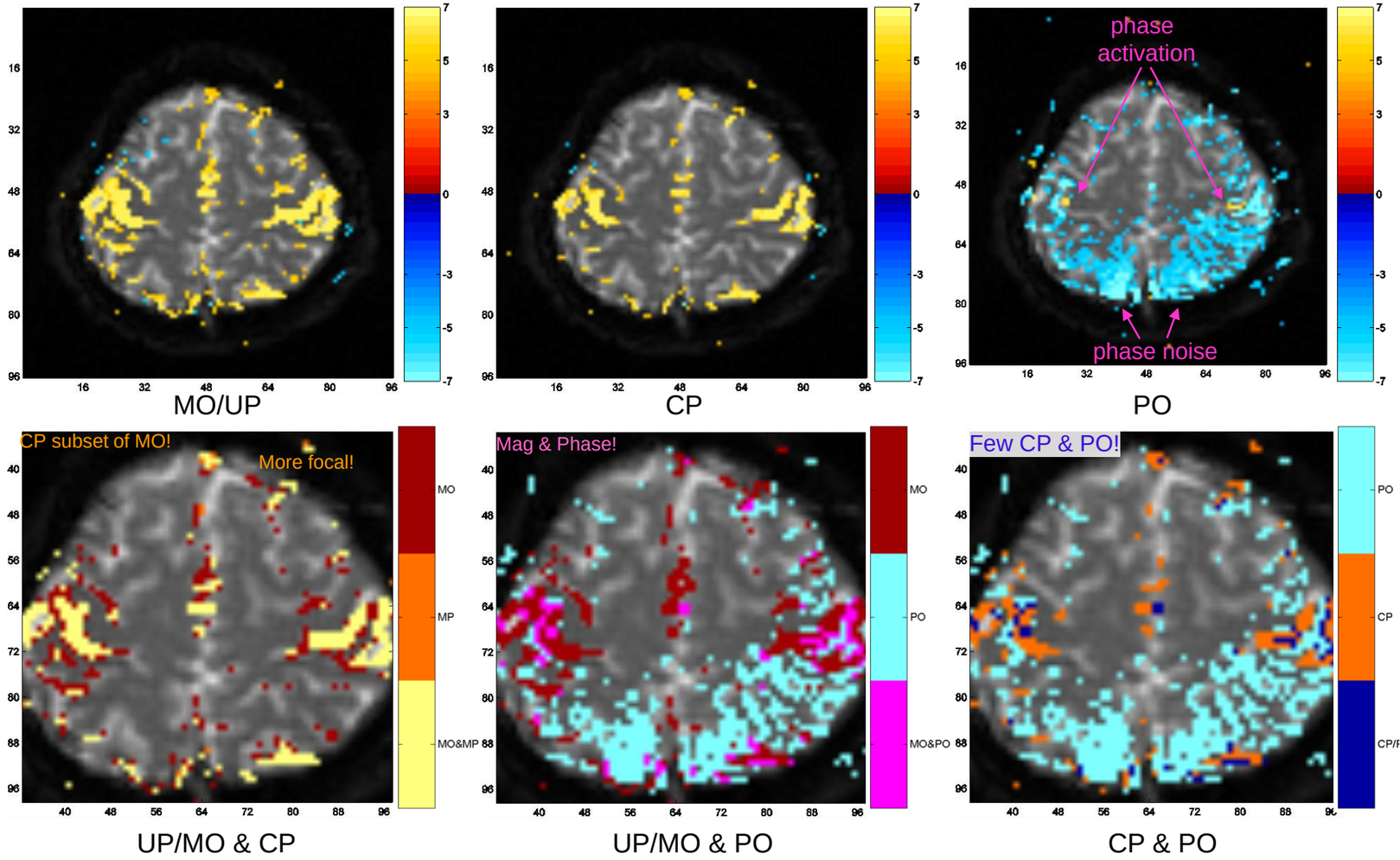
1.5T GE Signa

Results from various activation models.

$$\begin{pmatrix} y_{Rt} \\ y_{It} \end{pmatrix} = \begin{pmatrix} \rho_t \cos\theta_t \\ \rho_t \sin\theta_t \end{pmatrix} + \begin{pmatrix} \eta_{Rt} \\ \eta_{It} \end{pmatrix}$$



Presented at 2005 JSM



Rowe and Logan: NIMG, 23:1078-1092, 2004.

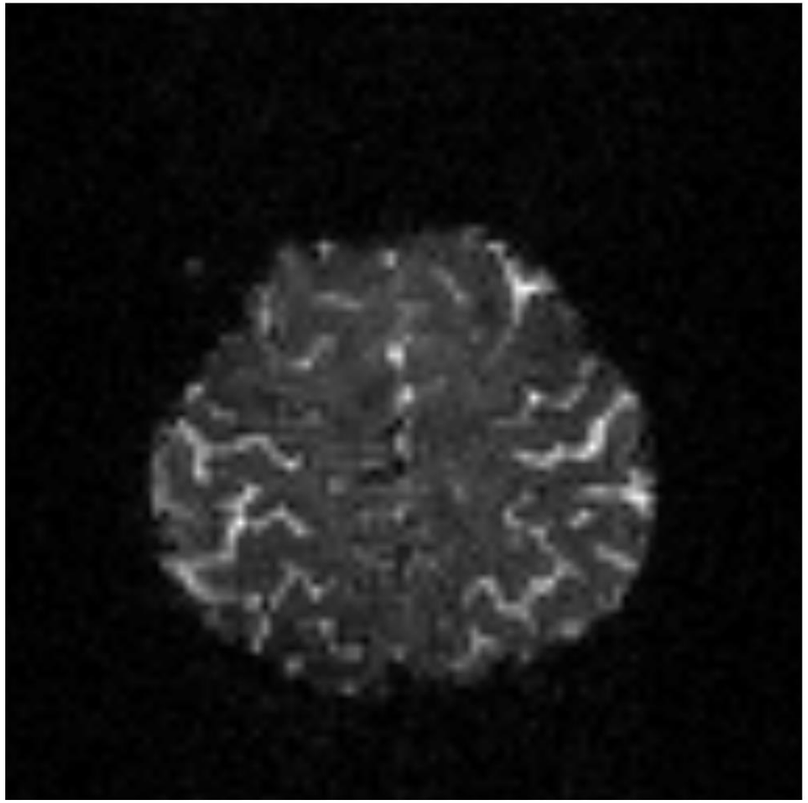
Rowe: NIMG, 25:1310-1324, 2005b.

II.2. Measured Data

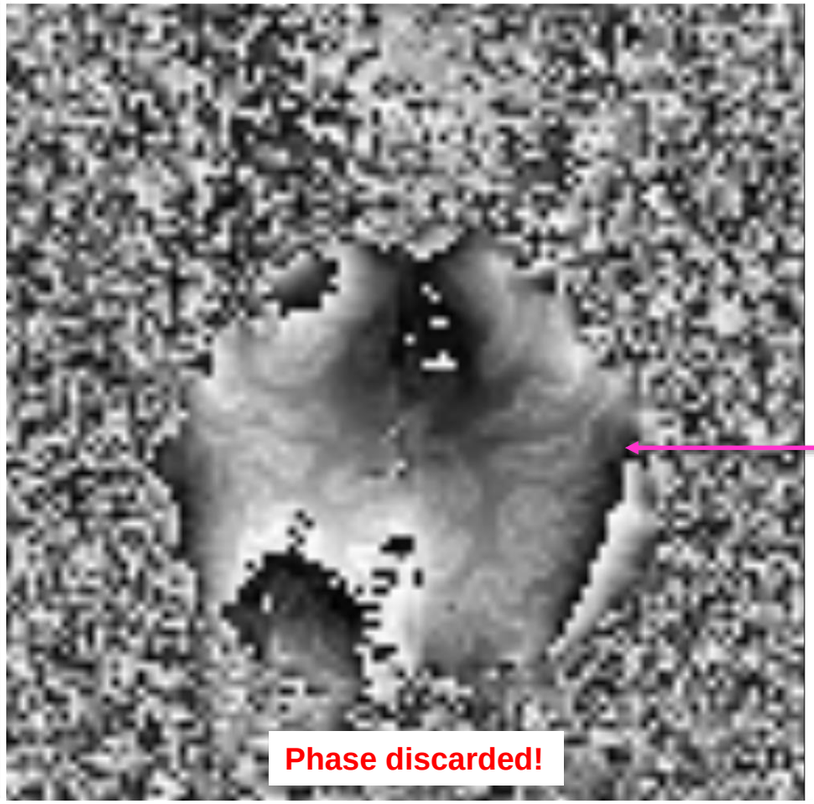
Rowe: NIMG, 25:1310-1324, 2005b.
Rowe, et al.: JNSM, 161:331-341, 2007.

As it turns out, there is biological info in the phase trough space.

T2* GRE EPI Image



Magnitude Image



Phase Image

Biological structure through space

$\Delta B(x, y)$

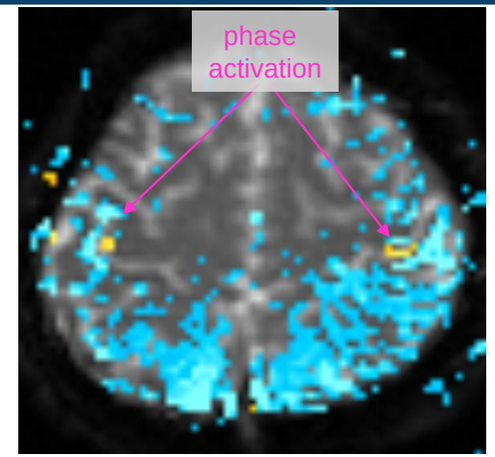
Signal Eqn.

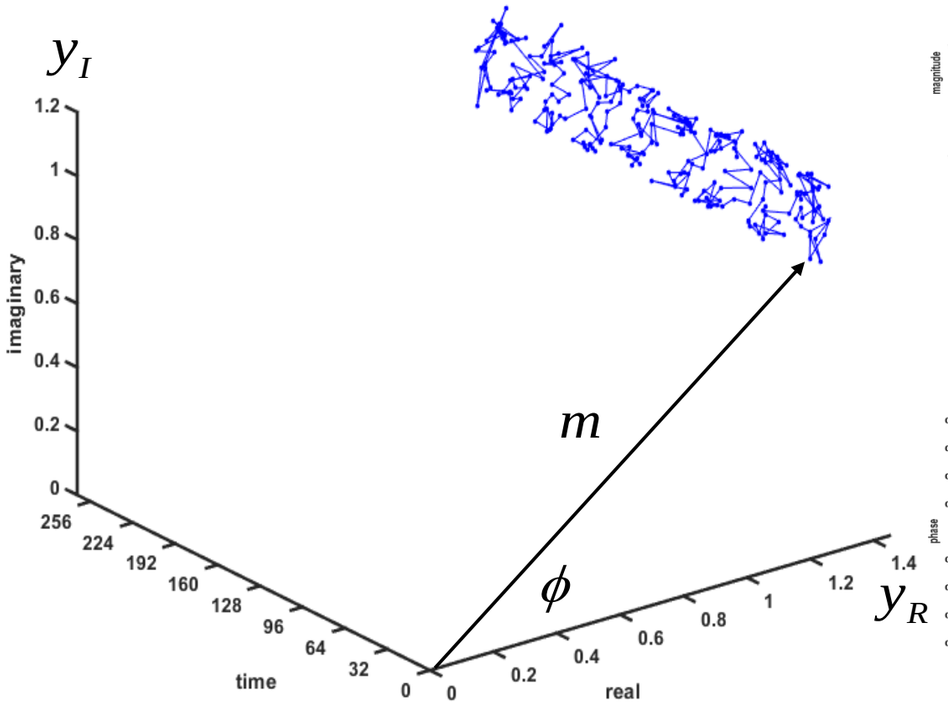
$$\mathcal{S}(t) = \int_{-\infty}^{+\infty}\int_{-\infty}^{+\infty} \rho(x,y)\left(1 - e^{-TR/T_1(x,y)}\right) e^{-t/T_2^*(x,y)} e^{-i\gamma\Delta B(x,y)t} e^{-i2\pi(k_x x + k_y y)}\, dxdy$$

II.2. Measured Data

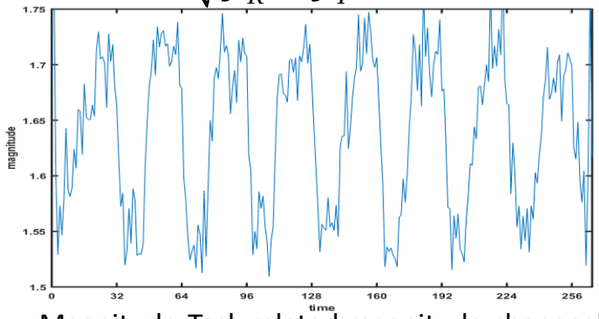
As it turns out, there is biological info in the phase through time.

$$\begin{pmatrix} y_{Rt} \\ y_{It} \end{pmatrix} = \begin{pmatrix} \rho_t \cos\theta_t \\ \rho_t \sin\theta_t \end{pmatrix} + \begin{pmatrix} \eta_{Rt} \\ \eta_{It} \end{pmatrix}$$



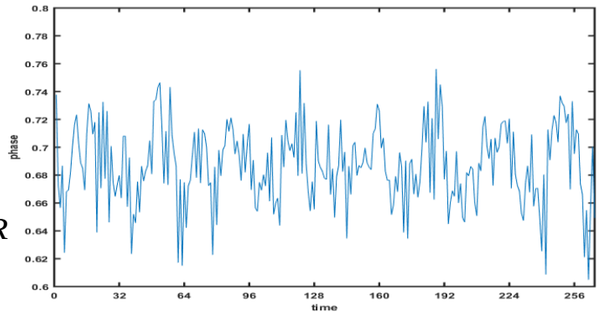


$$m = \sqrt{y_R^2 + y_I^2}$$

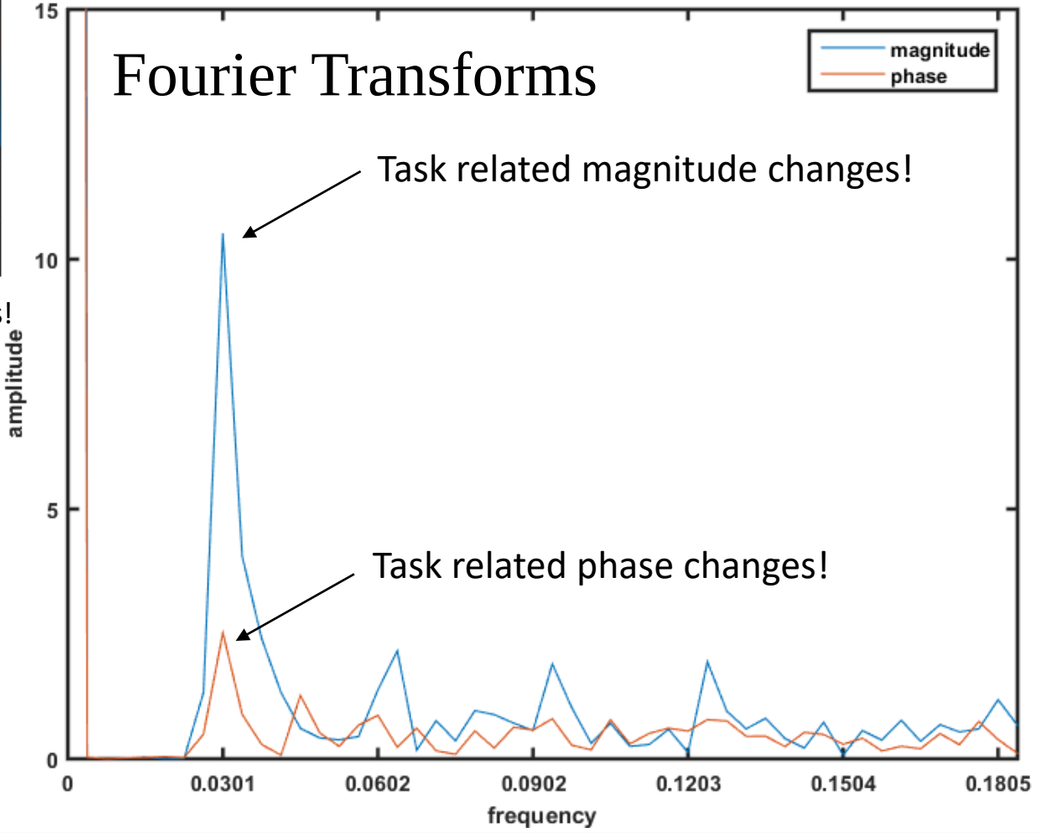


Magnitude:Task related magnitude changes!

$$\phi = \mathrm{a}\tan(y_I / y_R)$$

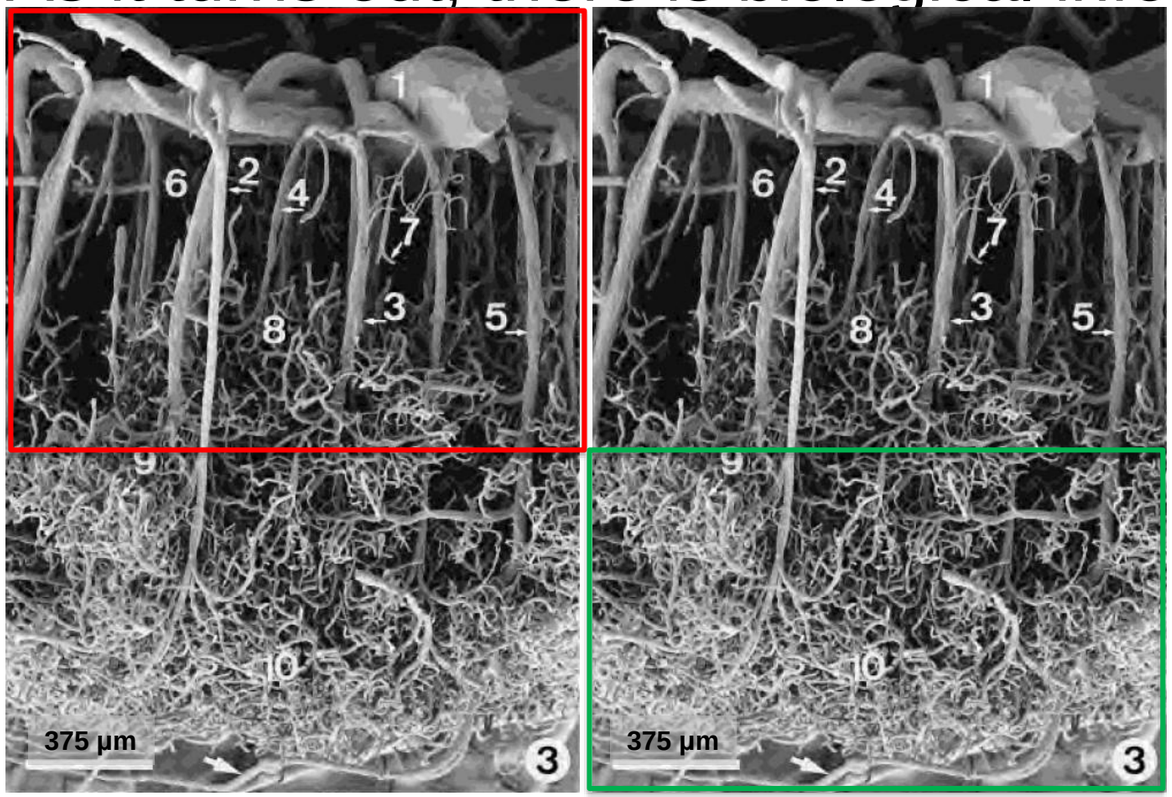


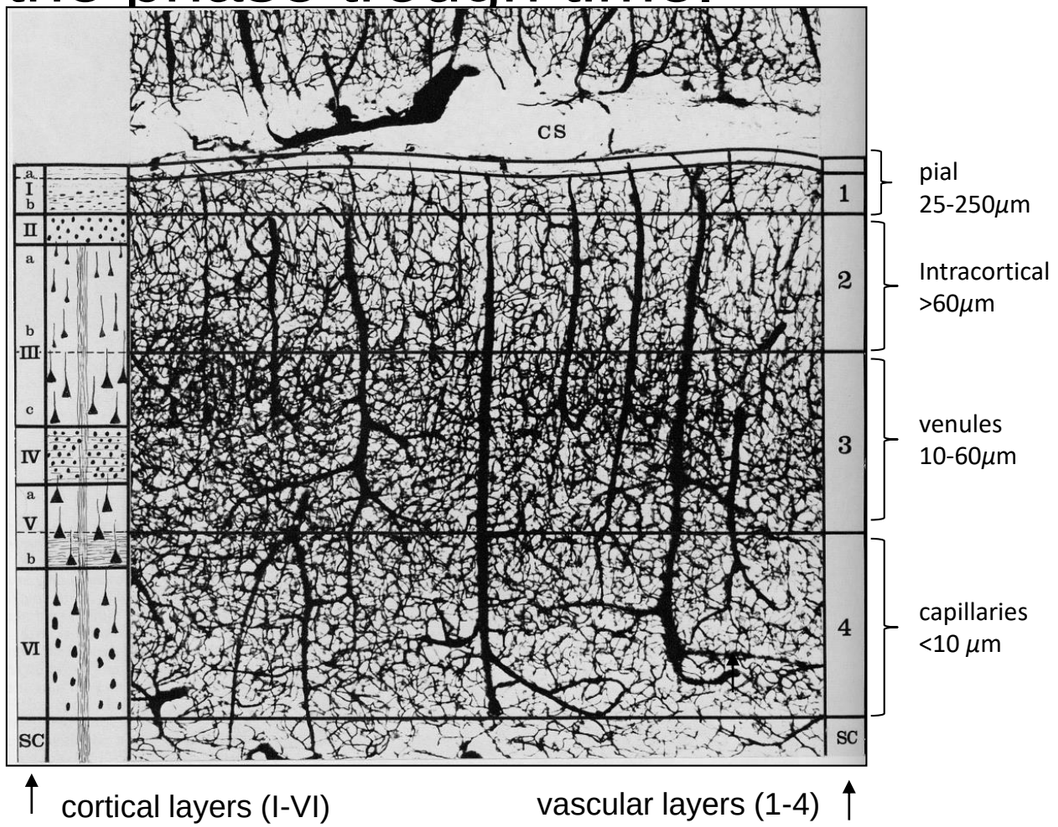
Phase: Task related phase changes!



II.2. Measured Data

As it turns out, there is biological info in the phase trough time.





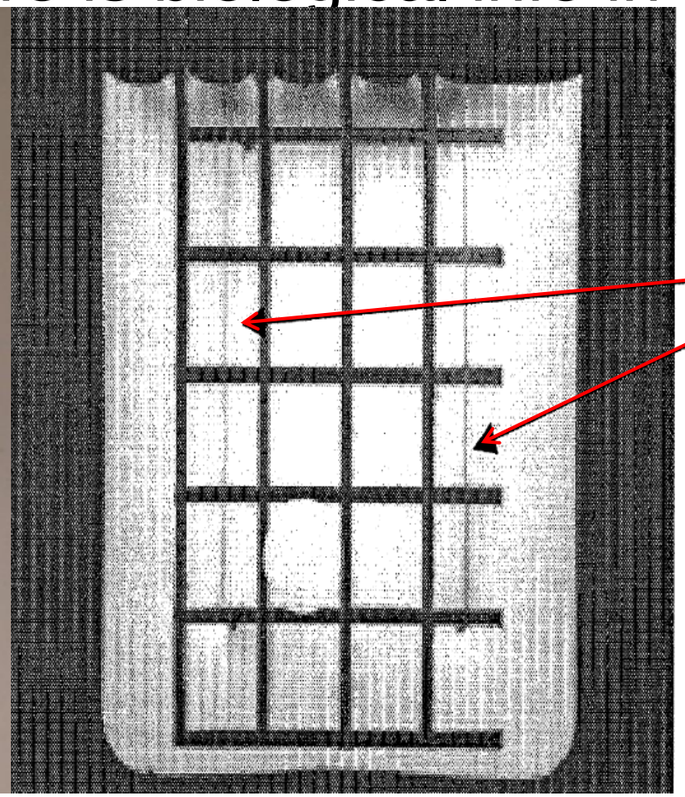
1. pial artery
2. long cortical artery
3. middle cortical artery
4. short cortical artery
5. cortical vein
6. subpial zone
7. precapillary vessels
8. superficial capillary zone
9. middle capillary zone
10. deep capillary zone

Figure (left,center) Reina-de la Torre et al.: The Anatomical Record, 1998.
Figure (right) Duvernoy et al. Brain Res Bull 7:519-579, 1981.
Data (right) Yamaguchi et al. Int J Microcirc Clin Exp 1992.

[1]Menon: MRM, 47:1-9, 2002.,
[2]Nencka, Rowe: NIMG, 177-88, 2007.

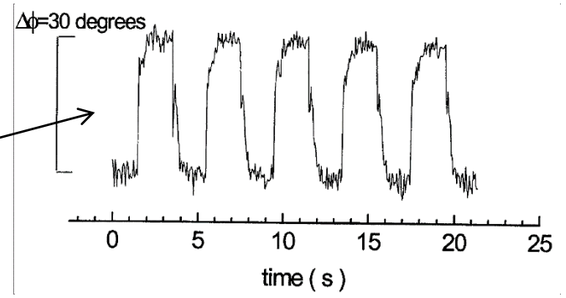
II.2. Measured Data

As it turns out, there is biological info in the phase through time.



Bodurka et al.: JMR, 1999.

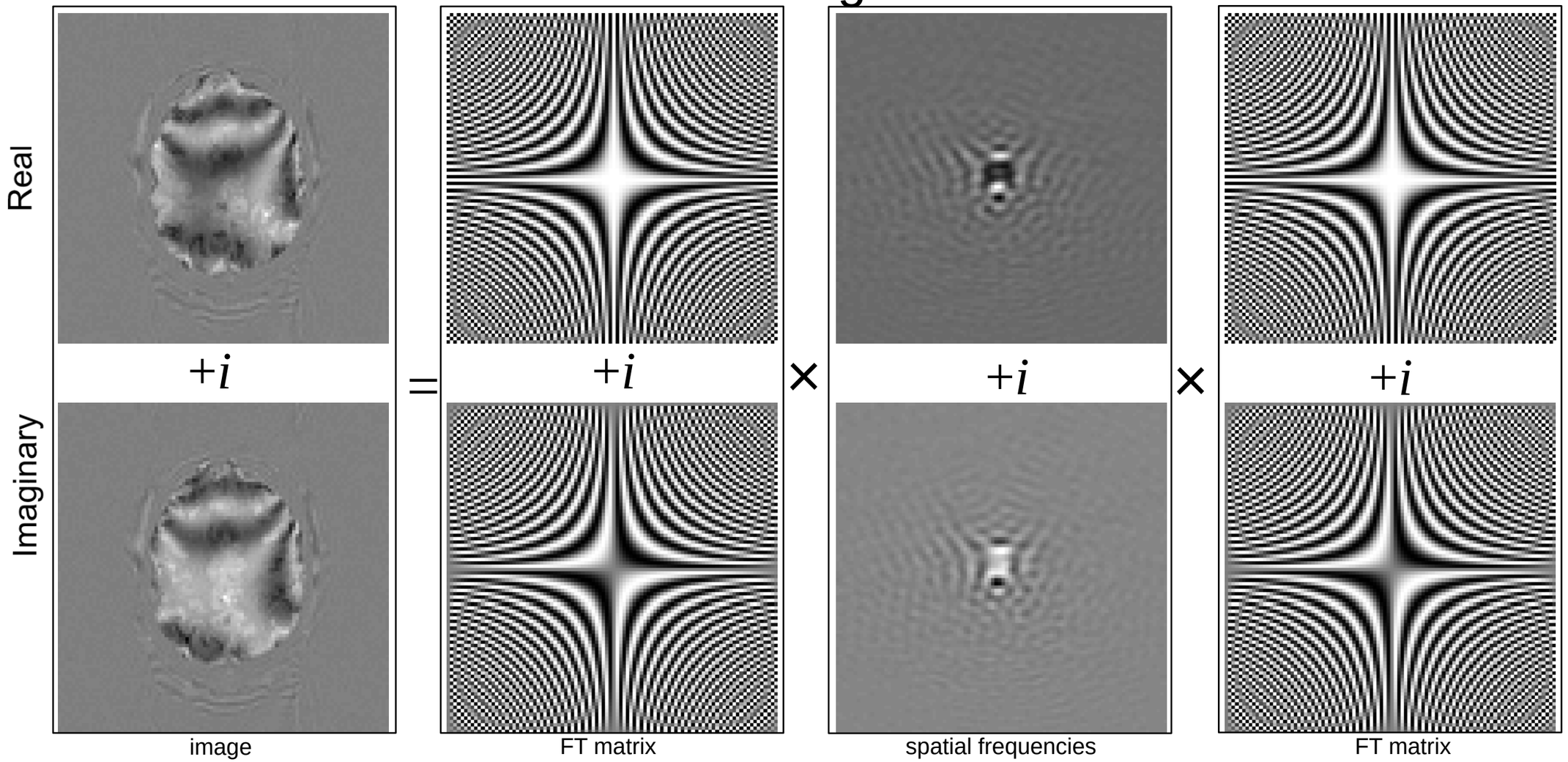
Chow et al.: NIMG, 2006.



Phase contains other magnetic field change info: respiration, motion!

II.2. Measured Data

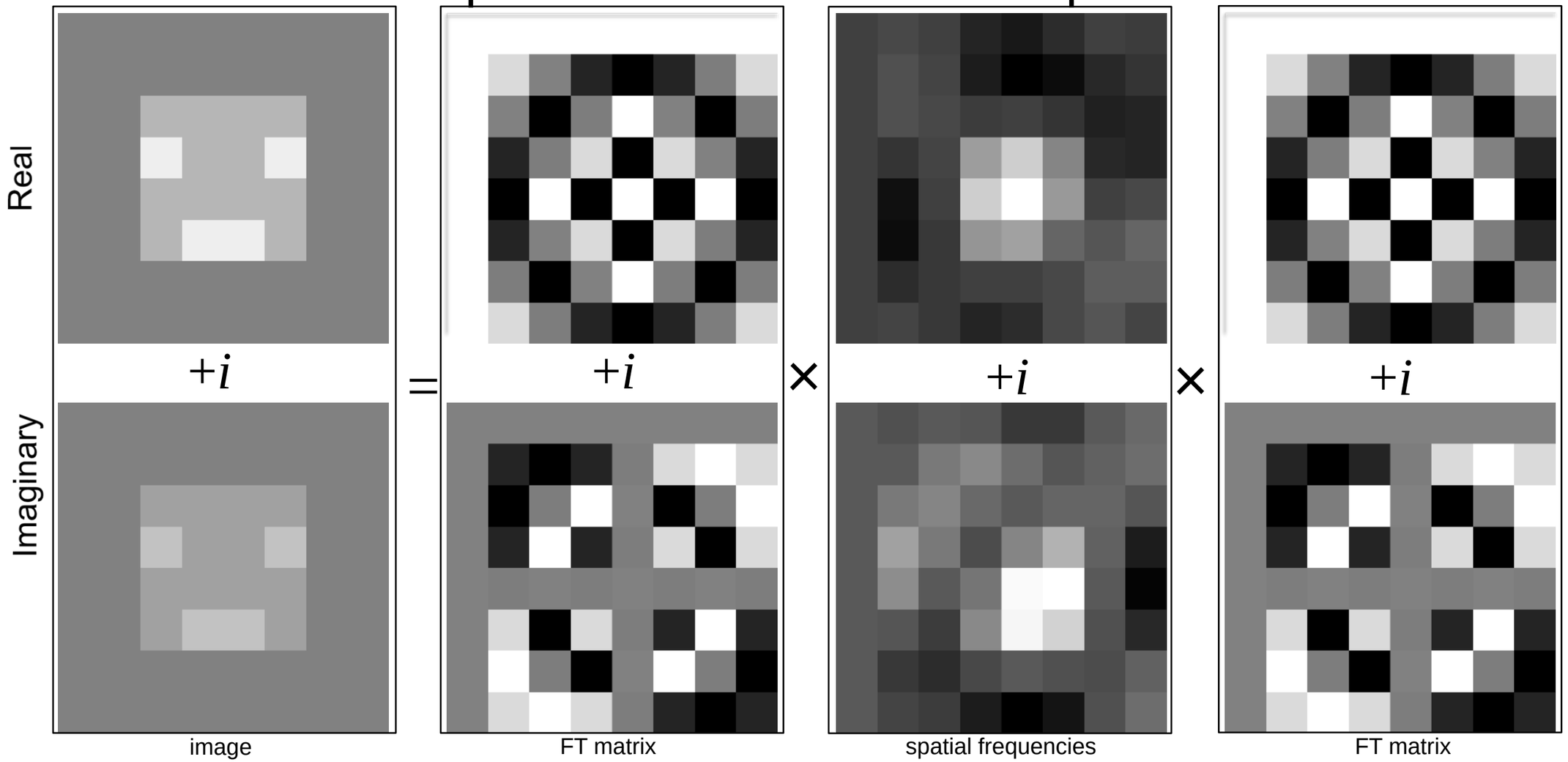
As statisticians we should be starting with the actual measured data.



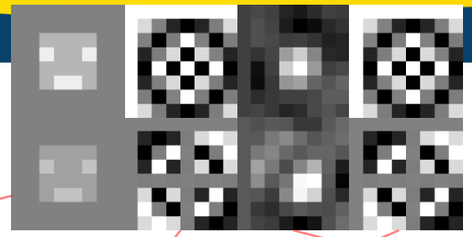
II.2. Measured Data

*Similar presented at 2006 JSM

An illustrative example of the DFT as a linear process.



II.2. Measured Data



We can write the 2D DFT as a matrix multiplication & include other processes.

$$\begin{bmatrix} y_R \\ y_I \end{bmatrix} = O_I \times \Omega \times O_k \times \begin{bmatrix} f_R \\ f_I \end{bmatrix}$$

$$y = Of$$

$$E(f) = \delta$$

$$cov(f) = \Gamma$$

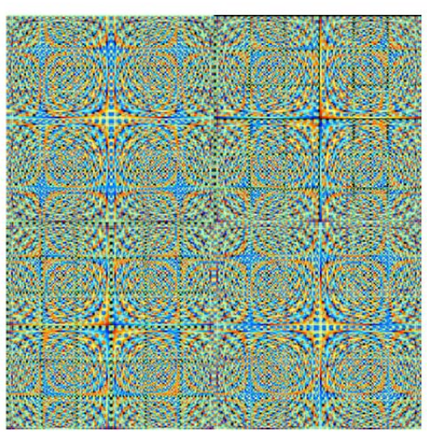
$$E(y) = O\delta$$

$$cov(f) = O\Gamma O^T$$

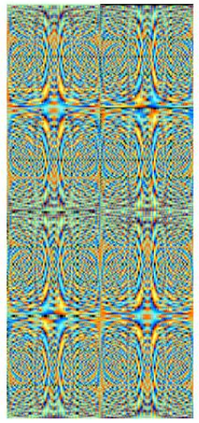
II.2. Measured Data

Rowe DB: Image Reconstruction in Functional MRI. (205-232) In Handbook of Statistical Methods for Brain Signals and Images, Chapman & Hall/CRC Press.

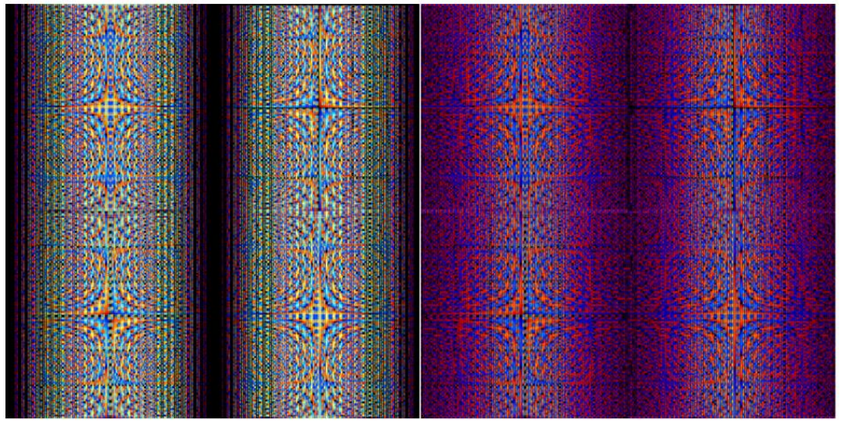
Examples of matrix pre-multiplication reconstruction/processing operators.



a) $O=\Omega$

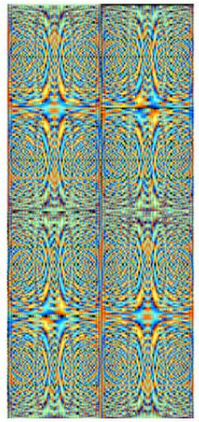


b) $O=\Omega Z$

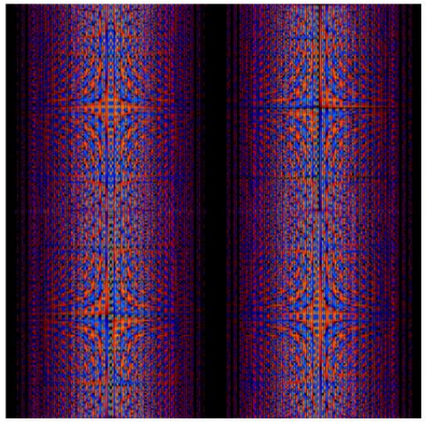


c) $O=\Omega A$

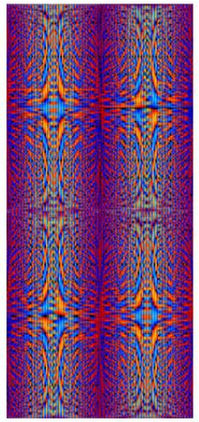
d) $O=S\Omega$



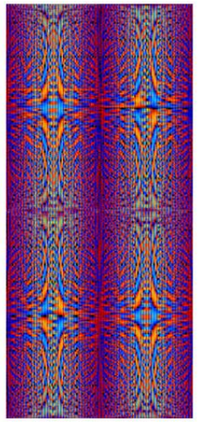
e) $O=\Omega AZ$



f) $O=S\Omega A$



g) $O=S\Omega Z$



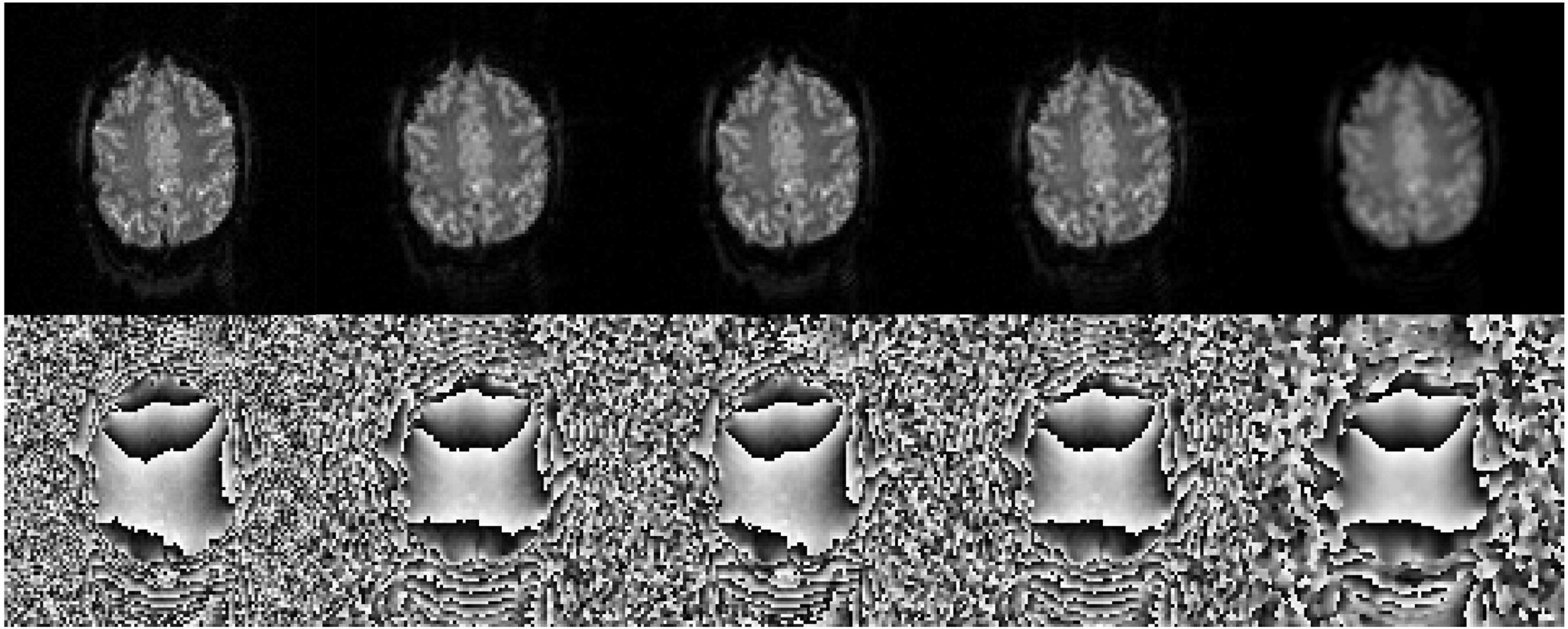
h) $O=S\Omega AZ$

18482 rows for
96 × 96 image

II.2. Measured Data

Rowe DB: Image Reconstruction in Functional MRI. (205-232) In Handbook of Statistical Methods for Brain Signals and Images, Chapman & Hall/CRC Press.

Effects of image operations on image mean.

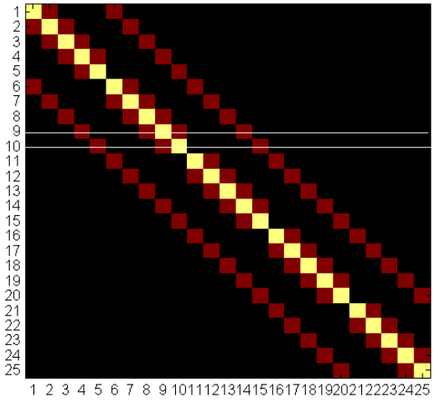


II.2. Measured Data

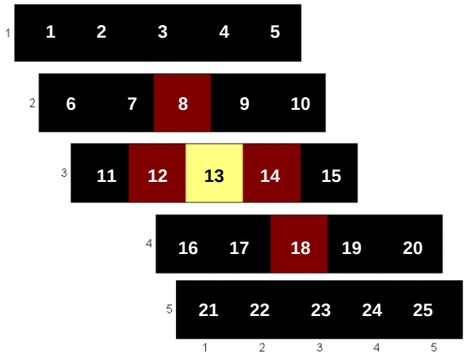
Rowe DB: Image Reconstruction in Functional MRI. (205-232) In Handbook of Statistical Methods for Brain Signals and Images, Chapman & Hall/CRC Press.

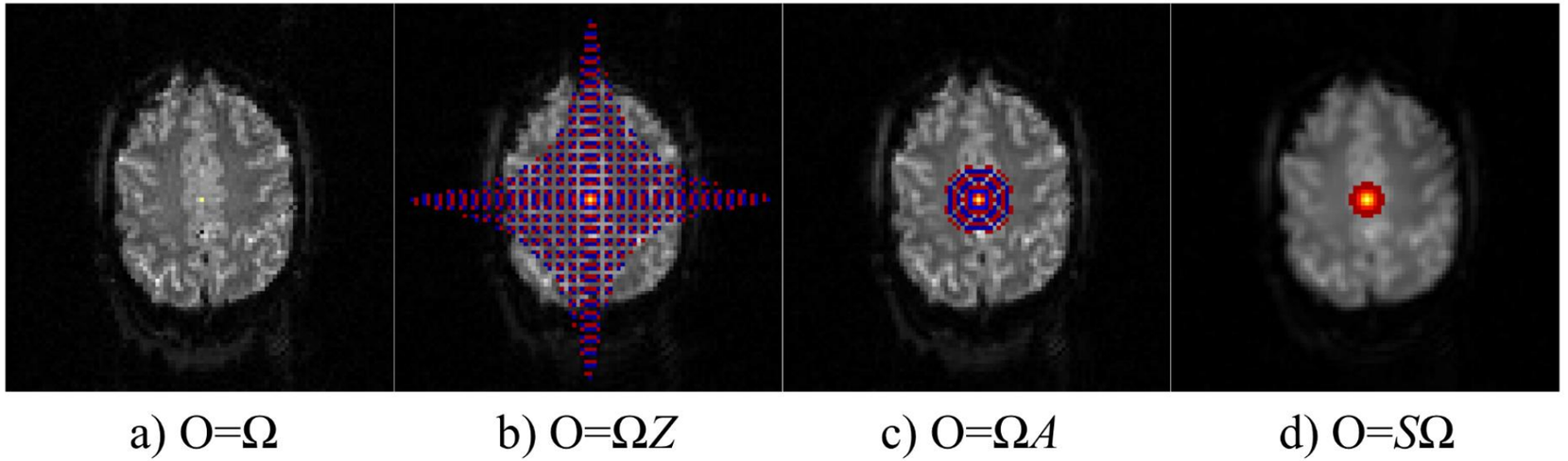
Effects of image operations on image correlation.

25×25 correlation matrix



5×5 image





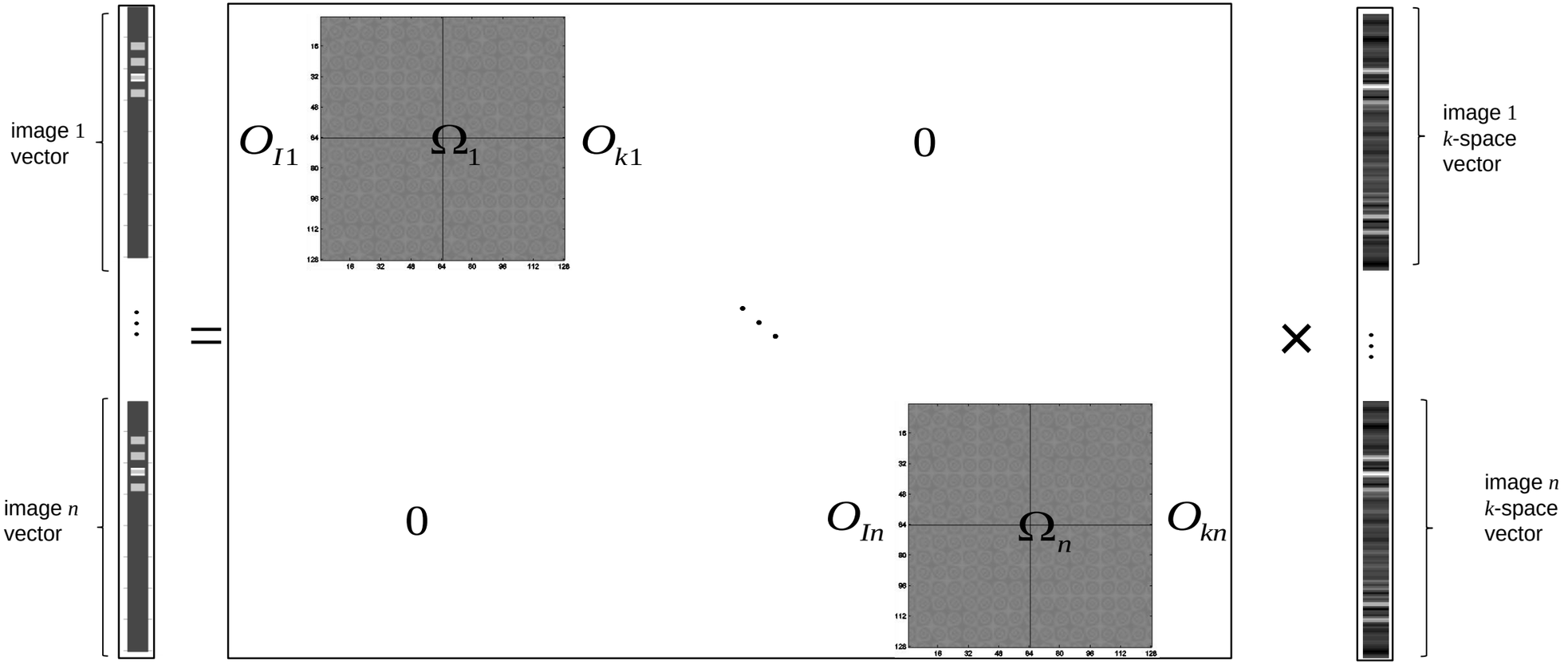
a) O=Ω b) O=ΩZ c) O=ΩA d) O=SΩ

e) O=ΩAZ f) O=SΩA g) O=SΩZ h) O=SΩAZ

II.2. Measured Data

Can look at induced time series correlation.

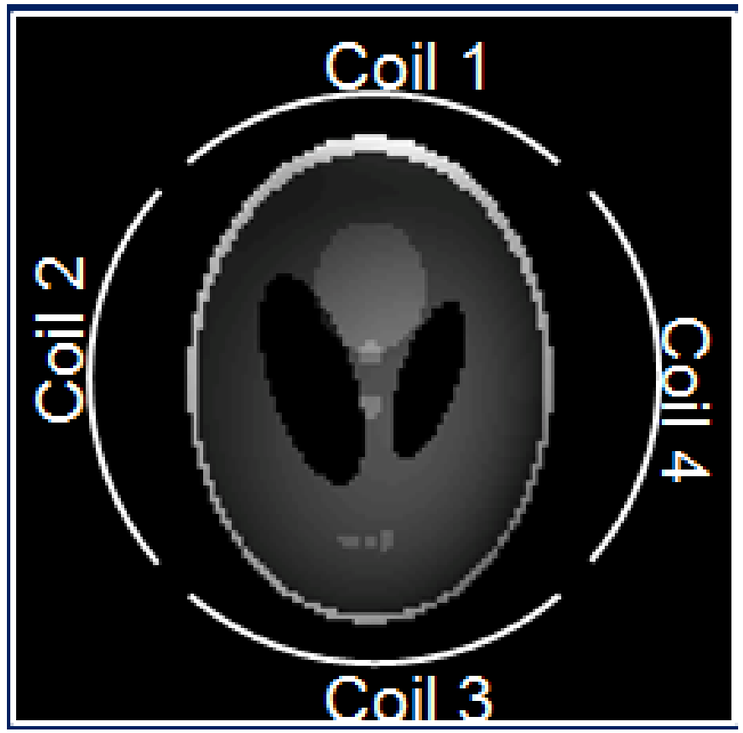
We can generalize this to n k-space arrays/images.

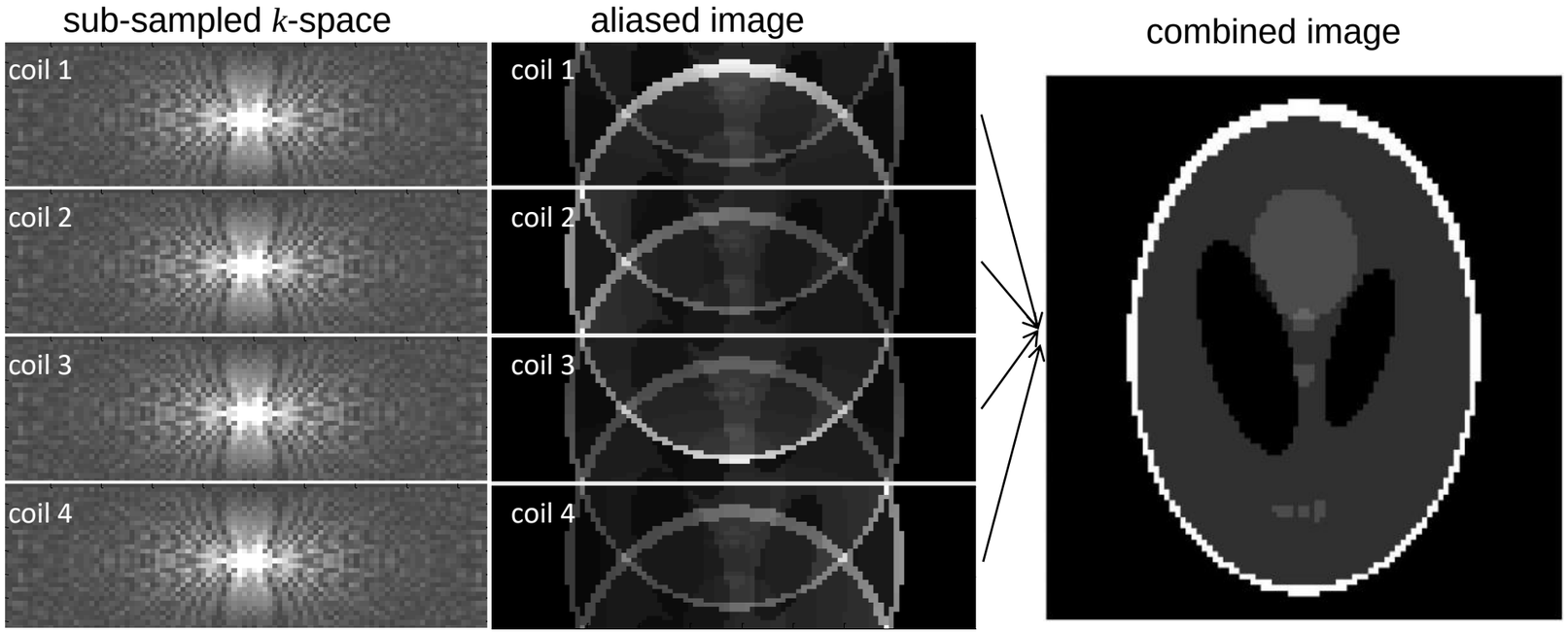


This allows us to directly link the measured k-space data to images.

II.2. Measured Data

Can look at the effects of multicoil imaging

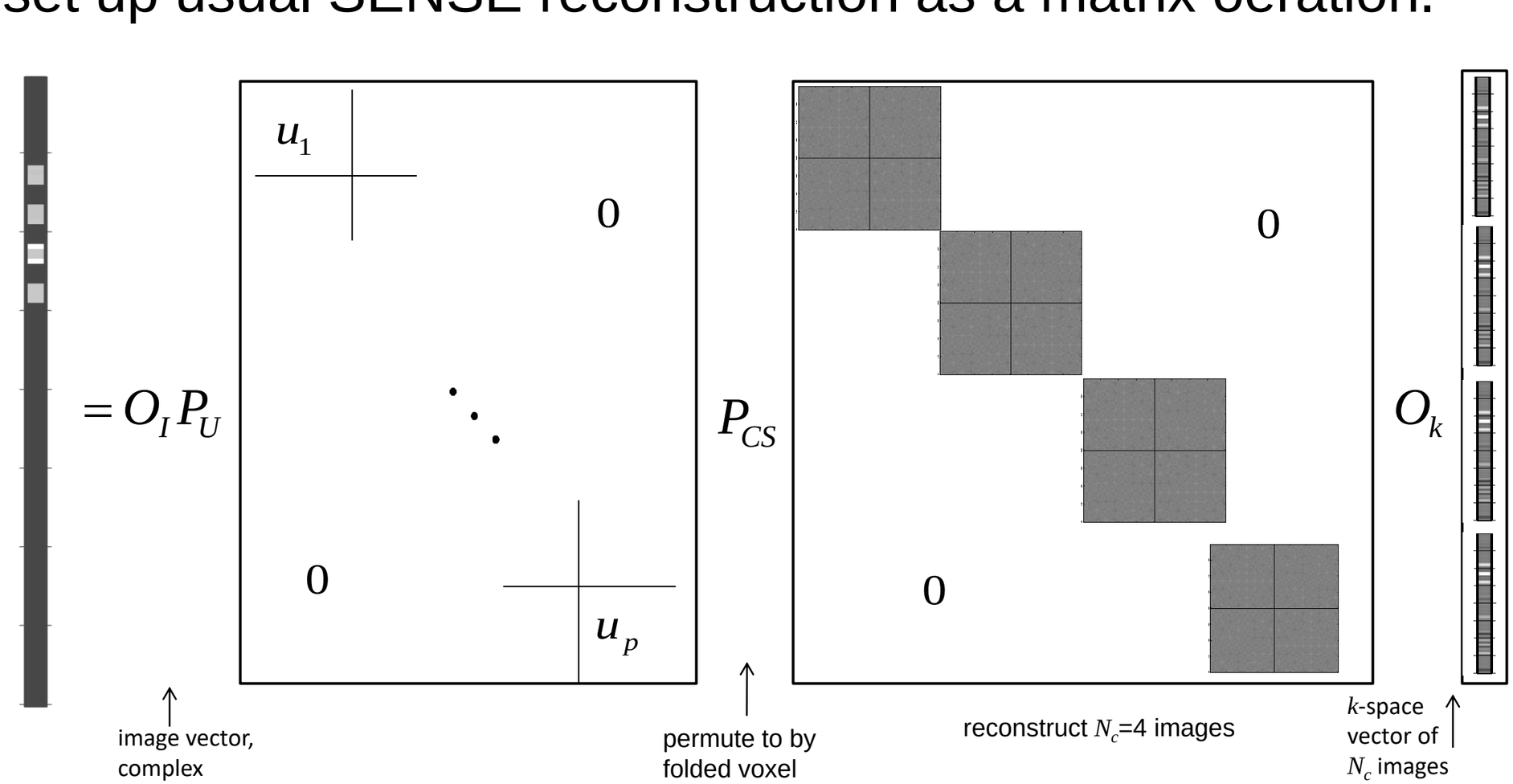




Bruce et al, MRI 2011.

II.2. Measured Data

Can set up usual SENSE reconstruction as a matrix oeration.



Bruce et al, MRI 2011.

II.2. Measured Data

Usual SENSE reconstruction induces long range correlations.

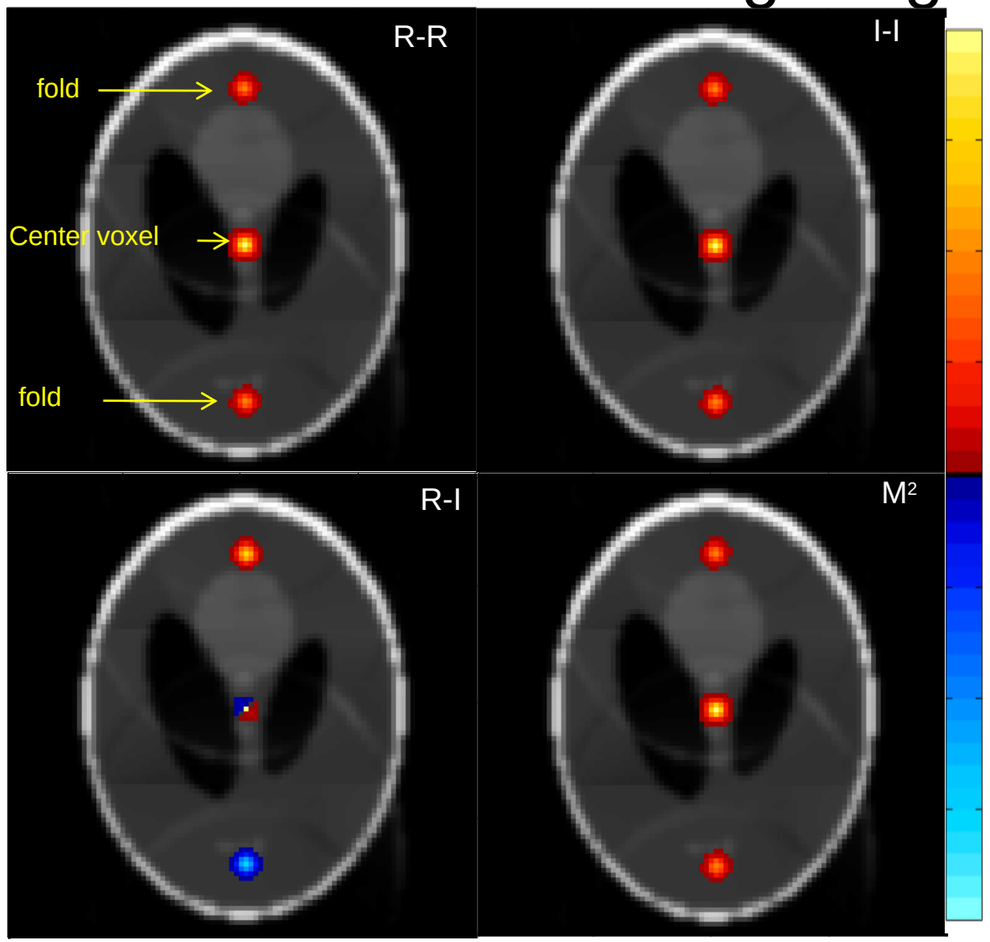
$$y = Of$$

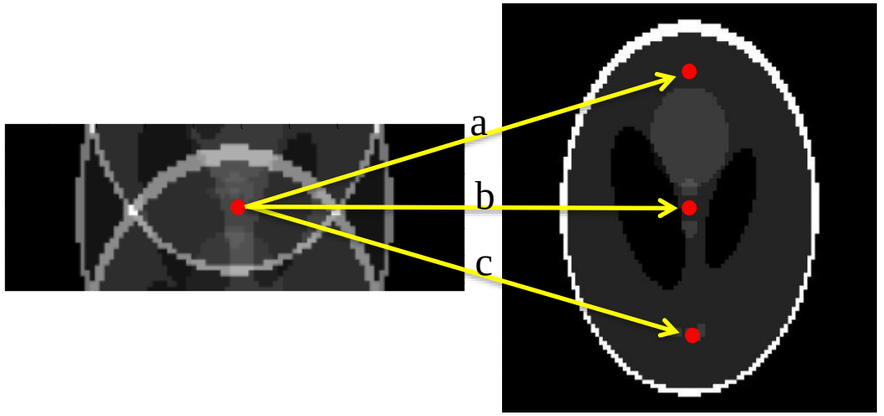
$$E(f) = \delta$$

$$cov(f) = \Gamma$$

$$E(y) = O\delta$$

$$cov(f) = O\Gamma O^T$$

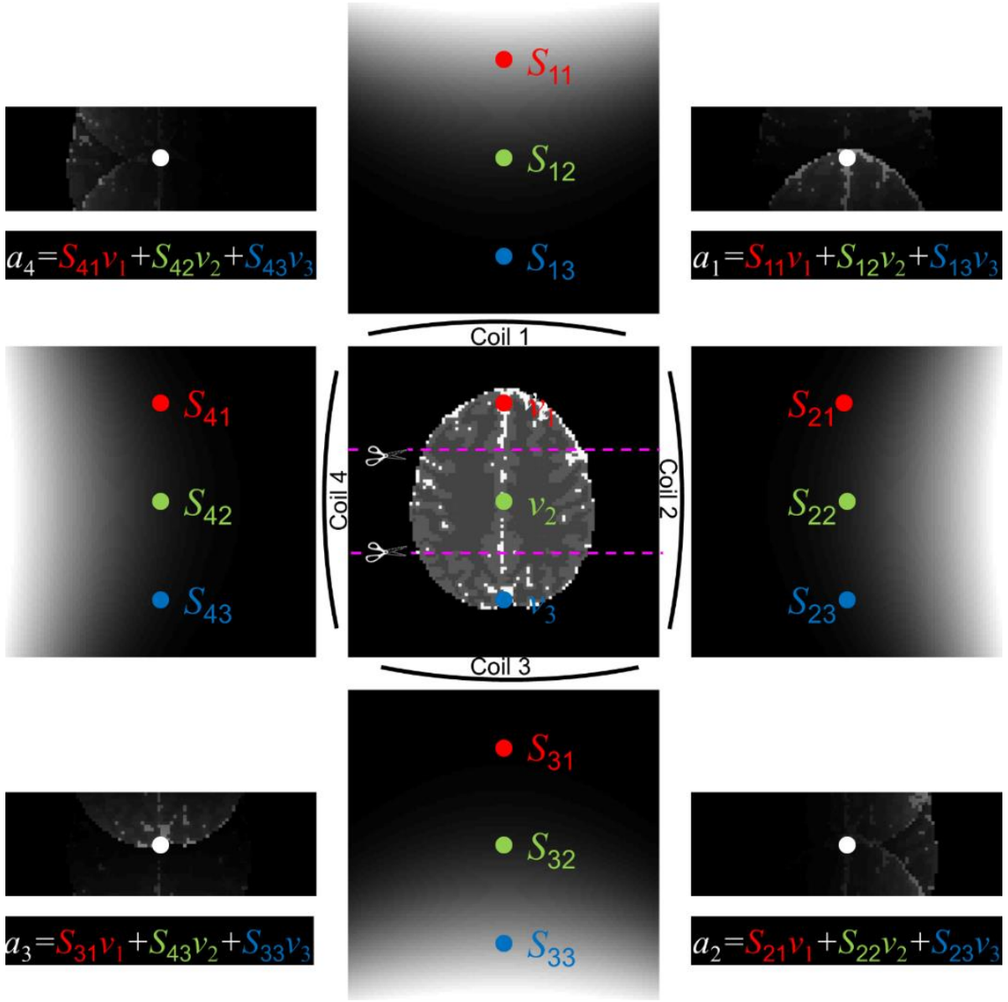




Bruce et al, MRI 2011.

II.3. Opportunities in FMRI

Opportunities in Bayesian image reconstruction.



Posterior PDF

$$p(S, v, \sigma^2 \mid a)$$

Sakitis et al. SMI 2022.

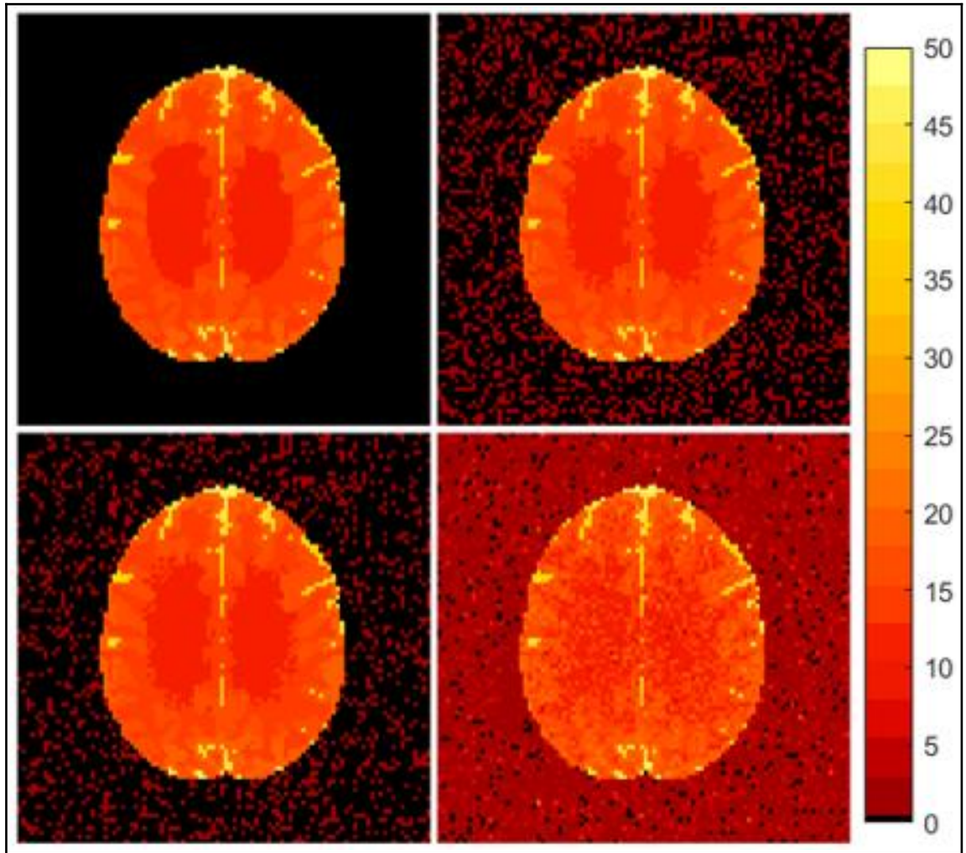


Figure 4: True non-task unaliased image (top left), BSENSE MAP unaliased non-task magnitude image (top right) using ICM, Mean BSENSE unaliased non-task magnitude image (bottom left) using Gibbs sampling, and SENSE non-task magnitude image (bottom right).

II.3. Opportunities in FMRI

Opportunities still exist.

Digging deeper to properly model measured data.

Potential for increased biological knowledge.

Think about the biology and not fitting a model to data.

Discussion

Part I. Founding of Section on Statistics in Imaging

Dear Dan,

The deadline for the Council of Sections to vote on the proposed new Section on Statistics in Imaging was last Friday, September 29. I am very pleased to report to you that the Council of Sections approved the formation of this section. Congratulations!

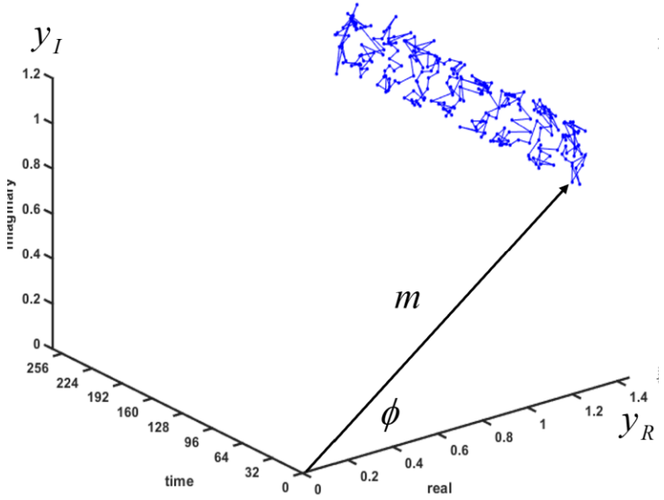
⋮

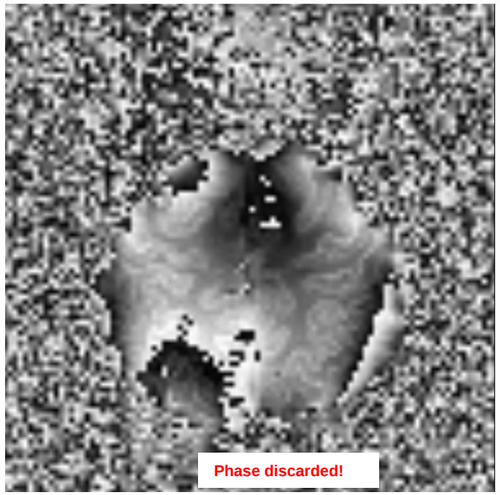
Once again, congratulations. As the ASA sections staff liaison, please do not hesitate if ever there is anything I can do for you and the Section on Statistics in Imaging.

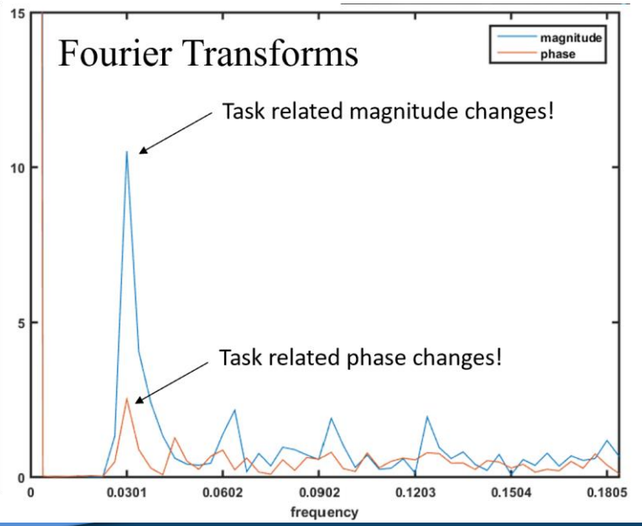
Best regards,

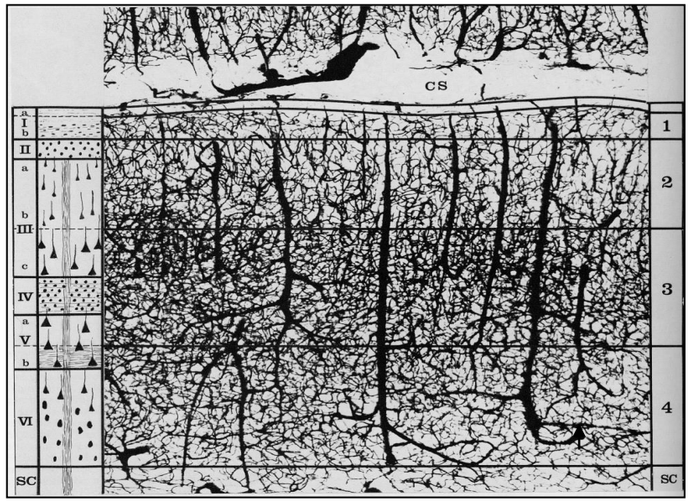
Rick

Part II. Foundations of Functional MRI









Thank You

Questions?