

Matlab

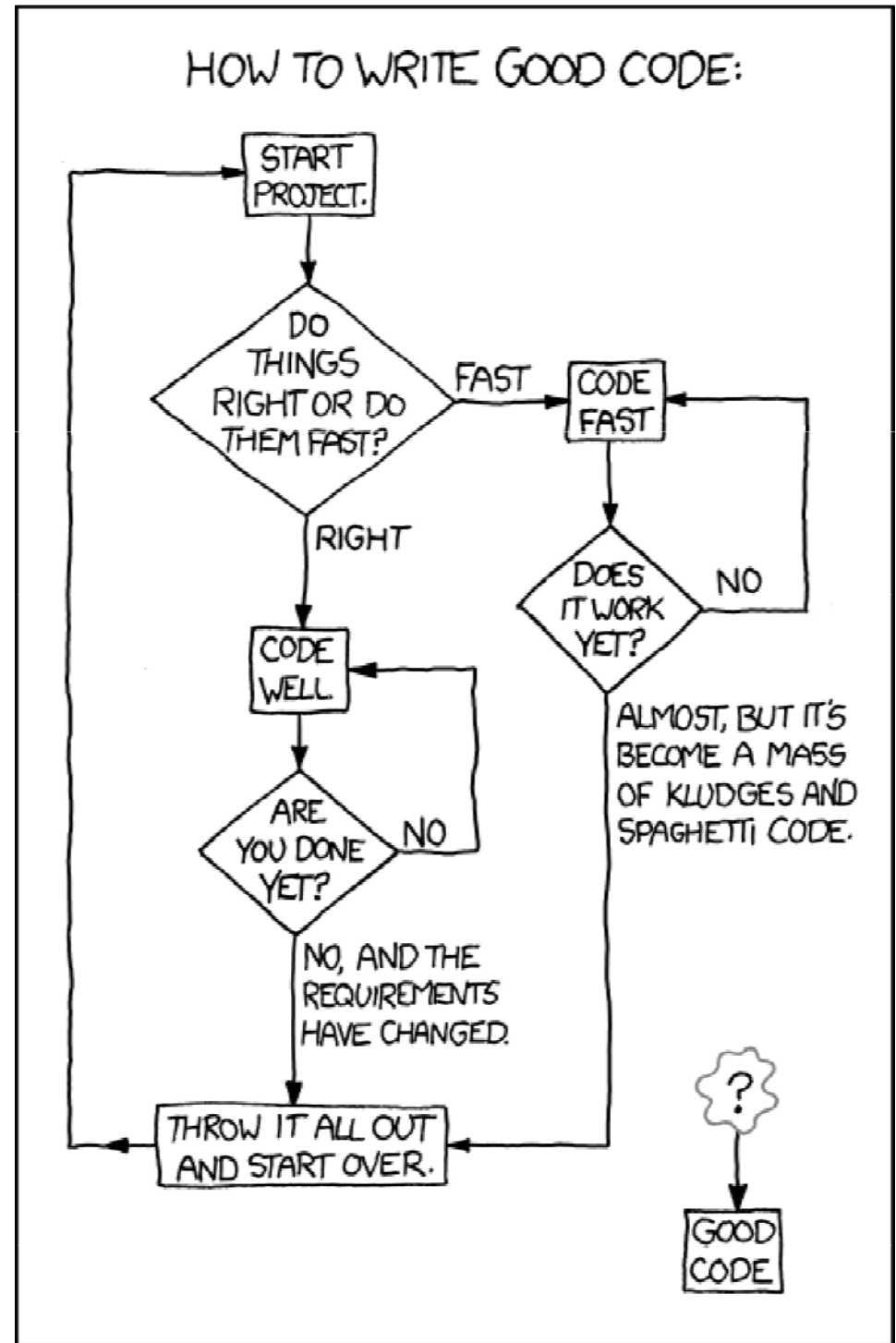
Introduction I:

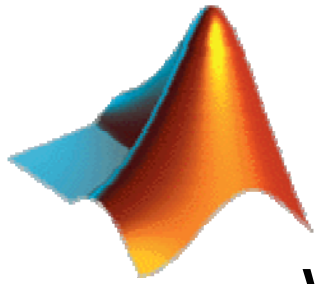
Basic concepts, commands, and structure

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Outline

- **Why Matlab?**
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 - **Path**
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 - **Numeric Variables**
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 - **An Example Script**
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 - **HELP?! (Where to get it)**
- * NOTE: All of this is available in: </imaging/jt03/demo>**



Why Matlab?

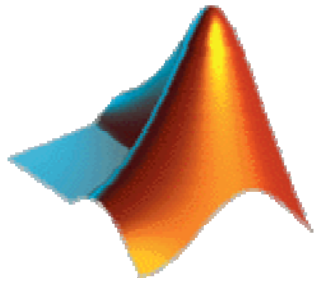
...or any other command-line software

There are distinct advantages to analysing your data using scripts and functions:

- Leave data in its original format
- Retain a complete record of all processing
- Hard work for the first subject, easy sailing for the rest
- Easily modify analysis pipeline and re-run analyses

Alternatives to Matlab:

- Octave (free!) ... matlab clone
- S-Plus (not free) or R (free!) ... stats
- Yes, you can script Excel (Visual Basic) and SPSS (syntax) too, but these are less flexible/powerful



Why Matlab?

... specifically

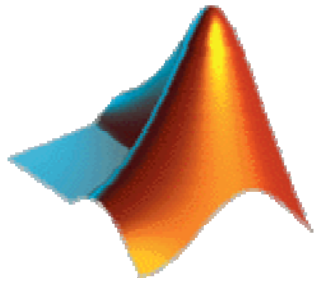
Versatility:

- Statistics
- Image Processing
- Signal Processing
- 3D Visualisation
- Custom

see: <http://www.mathworks.com/matlabcentral/fileexchange>

Neuroimaging (MRI , fMRI , DTI , M/EEG)

- SPM
- GIFT / EEGIFT
- EEGLAB / FMRLAB
- FieldTrip
- etc.



A Brief (Interactive) Introduction to Matlab

Go to demo ([brief_intro_to_matlab.m](#))

On the following slides I've simply copied the contents of [brief_intro_to_matlab.m](#), one cell per page. It's meant to be explored interactively and run line-by-line, so why not go open it in Matlab Editor and try it out?

(Otherwise, skip ahead to slide 22)

```
% A Brief Introduction to Matlab
%
% This script is intended to introduce novices to
% the Matlab environment. It is meant to be executed
% line-by-line, allowing for interactive exploration
% of data types and whatnot.
%
% Notes:
% - odd spaces between cells for demonstration purposes!
% - navigate between cells using <ctrl>+<down> <ctrl>+<up>
%
% by Jason Taylor (18 Nov 2011)
% MRC Cognition and Brain Sciences Unit
% Cambridge, UK
% email: <first>.<last>@mrc-cbu.cam.ac.uk
%
```

%% SOME TIPS:

```
%  
% GENERAL:  
% %           indicates a comment (ignored)  
% ;           (@ end of command) means don't print result  
%  
% COMMAND WINDOW:  
% >>         this is the 'prompt': type commands here!  
% <up>        scrolls through command history, last-to-first  
%             - all commands if you've typed nothing  
%             - matching commands if you've typed something  
% <tab>       completes (e.g., mea<tab> gives 'mean'...)  
% <ctrl+c>    stop command  
% clc        clears command window  
%  
% EDITOR:  
% %%         begins a new 'cell' (section of code)  
% <F9>       executes a highlighted line (or set of lines)  
% <ctrl+dn>   go to next cell  
% <ctrl+up>   go to prev cell
```

```
%% STARTING MATLAB
```

```
% Windows: Start->Matlab or double-click icon
```

```
% * Note: can set startup preferences in shortcut
```

```
%           e.g., starting dir, -nojvm, etc.
```

```
% Linux Machines:
```

```
% Type 'matlab'
```

```
% Type 'matlab <-options>'
```

```
% Type 'spm <options>'           *wrapper script @ CBU
```

```
% ... see demo ...
```



```
%% Matlab & Linux
```

```
% Within matlab, linux commands can be run:
```

```
% ! <command>
```

```
% or:
```

```
% [status,result] = unix(<command>);
```

```
% e.g.:
```

```
! hostname
```

```
[status,hname] = unix('hostname');
```

```
if ~status, fprintf(1,'You are connected to %s\n',hname); end
```

```
%% PATH
%   = search path Matlab uses to identify and execute
%     commands, functions, scripts...

% Report the contents of path:
path

% Add a directory to your path (prepend):
% >> addpath <path/to/directory>

% e.g.,
addpath /imaging/jt03/demo/scripts/
% or, append:
addpath /imaging/jt03/demo/scripts/ -END

% edit /home/<user>/matlab/startup.m

% Find the path of a particular function/script/command:
% which <command>
which mean
```

```
%% THE WORKSPACE
```

```
% = variables that are currently available to be used  
% by you (or by functions as input)
```

```
% Two ways to get the mean of a vector:
```

```
mean([4.1 3.3 4.8]) % <-this will give you the answer
```

```
% or,
```

```
x = [4.1 3.3 4.8] % <- this will store the values  
mx = mean(x) % and the answer in variables
```

```
%% ... and now you can:
```

```
% - get other summary statistics,
```

```
sx = std(x)
```

```
[min(x) max(x)]
```

```
% - plot
```

```
bar(x);
```

```
hold on;
```

```
plot(2,mx,'ko','MarkerFaceColor','r','MarkerSize',12);
```

```
% - write it to a text file:
```

```
dlmwrite('x.txt',x,'\t');
```

```
% - save as a .mat file
```

```
save('x.mat','x');
```

```
clear x
```

```
load('x.mat')
```

```
% - etc.
```

```
figure; imagesc(rand(64,64)*std(x));
```

```
%% Some WORKSPACE Commands:
```

```
% List names of all variables in the workspace:
```

```
who
```

```
% List names, size, class of all variables in the workspace:
```

```
whos
```

```
% List ... of a subset of variables in the workspace:
```

```
% whos [<variablename>]
```

```
% eg.,
```

```
whos x
```

```
whos *x*      % <- '*' = wildcard
```

```
% Clear (all or subset of) variables out of workspace:
```

```
clear x
```

```
%% NUMERIC VARIABLES:
```

```
% Scalar values:
```

```
x = 42
```

```
% Vectors:
```

```
xvec = [1 2 3 4 5 6]
```

```
xvec2 = 1:6 % equivalent
```

```
% Matrices:
```

```
xmat = [1 2 3; 4 5 6; 7 8 9]
```

```
xmat'
```

```
% N-dimensional arrays:
```

```
x3d = cat(3,xmat,xmat+10)
```

```
% Get size of each dimension:
```

```
size(xmat)
```

```
% Indexing:
```

```
xmat(:, [2 3]) % <- all rows, columns 2 and 3
```

```
%% MATHS:
```

```
% Add/subtract
```

```
42 + 10
```

```
x + 10
```

```
y = x - 10
```

```
% Multiply/divide (scalar):
```

```
y = x * 5
```

```
y = x/2
```

```
% Multiply/divide (vector):
```

```
y = xvec .* [10 100 1000 10 100 1000]
```

```
y = xvec/(xvec(1))
```

```
% etc.:
```

```
y = sqrt(x^3)
```

```
%% LOGIC & LOGICAL INDEXING:
```

```
% Logic:
```

```
v = xvec*10
```

```
v > 30
```

```
v > 30 & v ~= 60
```

```
% Find index of 'true' (or nonzero, generally):
```

```
find(v>30 & v~=60)
```

```
% Use logical index:
```

```
v(v>30 & v~=60)
```

```
v(find(v>30 & v~=60)) % equivalent
```

```
% Use logical index on a different variable:
```

```
xvec(v>30 & v~=60)
```

```
% Valid numbers:
```

```
v(end) = NaN
```

```
v(~isnan(v))
```



```
%% STRINGS AND CELLS:
```

```
% Strings:
```

```
mystring = 'hello world'
```

```
xstr = '42' % not the same as x = 42 (see 'isnumeric')
```

```
% String matching:
```

```
findstr('o',mystring)
```

```
findstr('world',mystring)
```

```
% Cell arrays (may mix types, sizes):
```

```
mycell = {'hello' 'world'}
```

```
xcell = {x xstr}
```

```
xcell(2)
```

```
xcell{2}
```

```
% Cell-string matching:
```

```
strmatch('world',mycell)
```

```
%% STRUCTURES
```

```
% ** SPM users take note **
```

```
% Struct:
```

```
S = struct()
```

```
S.subj = 's01'
```

```
S.sex = 'male'
```

```
S.age = 27
```

```
S.data = [1 2 3 4 5 6]
```

```
isfield(S, 'age')
```

```
% Adding layers:
```

```
S(2).subj = 's02';
```

```
S(2).sex = 'female';
```

```
S(2).age = 19;
```

```
S(2).data = [11 12 13 14 15 16]
```

```
% Extracting data:
```

```
[S.age]
```

```
{S.sex}
```

```
%% LOOPS:
```

```
% For loop:
```

```
for i = 1:10
```

```
    if i>3, fprintf(1,'subject %02d\n',i); end
```

```
end
```

```
% While loop:
```

```
i = 0;
```

```
while i<3
```

```
    i = i+1;
```

```
    fprintf(1,'subject %02d\n',i);
```

```
end
```

```
%% Loops continued
```

```
% Switch ... case ... otherwise ...
```

```
switch S(1).sex
```

```
    case 'male'
```

```
        fprintf(1, 'He is subject 1.\n');
```

```
    case 'female'
```

```
        fprintf(1, 'She is subject 1.\n');
```

```
    otherwise
```

```
        fprintf(1, 'Subject 1''s sex was not recorded.\n');
```

```
end
```

%% That's enough for now!

% On to scripts and functions...

% If you got here via the presentation, type 'return' +
[ENTER] at the

% command line, or highlight and <F9>:

return

Functions vs. (Batch) Scripts

Function:

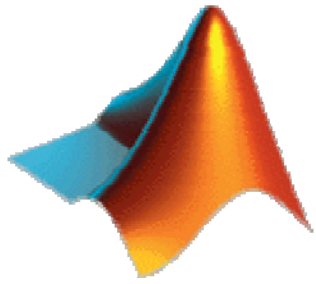
- **General**
(usually applies to any data, project)
- **Run as command**
(specify input, output arguments)
- **Variables do not stay in workspace**
(except input/output arguments, debugging environment)
- **Can get help by typing:**
`help <function name>`
- **First line of code MUST BE:**
`[<output>] = function(<input>)`

Script:

- **'Hack and Run'**
(customise to your data, project)
- **Copy&Paste (<F9>) or command**
(no arguments allowed)
- **Variables stay in workspace**

Both are text files, which you can edit in Matlab's editor (see `edit` command) or your favourite text editor (emacs, nedit, gedit, wordpad, notepad, etc.)
NOTE: These vary in terms of debugging friendliness!

You may start writing a batch script, then later find it useful to convert sections of it into functions.



An Example Batch Script

Go to demo ([demo_script_cell_by_cell.m](#))

On the following slides I've simply copied the contents of [demo_script_cell_by_cell.m](#), which shows the evolution of a simple script to analyse response time data from 15 subjects and produce a figure with a bar plot of mean RT + standard error bars. You can also view and run the resulting script – [demo_script_simple.m](#) – and the more elaborate version – [demo_script_final.m](#) – in the CBU imaging workspace.

More information is given in [demo_readme.m](#)

```
%  
% This is what I showed in the demonstration. It is meant to show  
% the evolution of demo_script_simple.m:  
%  
% - First, write description of what the script will do  
% - Second, write comments describing each step  
% - Third, flesh out each step with code  
%  
% The 'strings' at the top of each cell are annotations.  
%  
% Use <ctrl>+<down> and <ctrl>+<up> to navigate between cells.  
%  
% by Jason Taylor (21 Nov 2011)  
%
```



```
%%
```

```
'At top: What the script does, when created (updated)?'
```

```
% This is a batch script to get the median of each subject's RT data,  
% plot the grand mean and standard error for the two conditions.
```

```
%
```

```
% by Jason Taylor (17/11/2008)
```

```
% + updated (jt 17/11/2008): added error bars
```

```
%
```

```
%%
```

```
'In body: Write an outline using comments'
```

```
% (1) Define directory, filename, subject parameters
```

```
% (2) Get each subject's median RT
```

```
% (3) Compute grand mean, standard error
```

```
% (4) Plot bar graph with error bars
```

```
%%
```

```
'Then fill in with increasingly specific comments (as necessary) &  
commands'
```

```
% (1) Define directory, filename, subject parameters:
```

```
% Project directory:
```

```
projdir = '/imaging/jt03/demo/rtdata/subjects';
```

```
% Working directory: * CHANGE to a dir you have permission to write to!
```

```
wkdir = '/imaging/jt03/demo/rtdata/ga15';
```

```
% Subjects:
```

```
subjects = [1:15];
```

```
%%
```

```
'...continue to fill in ...'
```

```
% (2) Get each subject's median RT:
```

```
% Initialise variable (subjects x conditions) to collect median RTs:
```

```
mdrt = zeros(length(subjects),2);
```

```
% Loop over subjects:
```

```
for i = 1:length(subjects)
```

```
    % Get current subject label:
```

```
    subj = sprintf('s%02d',subjects(i));
```

```
    % Go to subject's directory, load data:
```

```
    cd(fullfile(projdir,subj));
```

```
    load('word_nonword.mat');
```

```
    % Put median RT for each condition into summary matrix:
```

```
    mdrt(i,1) = median(D.rt(D.event==1));
```

```
    mdrt(i,2) = median(D.rt(D.event==2));
```

```
end % i subjects
```

```
%%
```

```
'...continue to fill in ...'
```

```
% (3) Compute grand mean, standard error:
```

```
% Compute mean (collapsing over rows):
```

```
gm = mean(mdrt,1);
```

```
% Get standard error:
```

```
se = std(mdrt)/sqrt(size(mdrt,1));
```

```
% Save it as a .mat file in working directory:
```

```
cd(wkdir)
```

```
save rtdata.mat gm se
```

```
%%  
  
'...continue to fill in ...'  
  
% (4) Plot:  
  
% Open a figure, make background white:  
fig = figure;  
set(fig, 'color', [1 1 1])  
  
% Plot means:  
bar(gm);  
  
% Rescale axes:  
ymax = ceil(max(gm+se));  
set(gca, 'ylim', [0 ymax]);  
  
% Plot and format error bars:  
ebar1 = line([1 1],[gm(1) gm(1)+se(1)]);  
ebar2 = line([2 2],[gm(2) gm(2)+se(2)]);  
set([ebar1 ebar2], 'linewidth', 6);
```

```
%%
```

```
'...continue to fill in ...'
```

```
% Apply title, labels, etc.:
```

```
title('Grand Mean of Median RTs');
```

```
xlabel('Stimulus Type');
```

```
ylabel('RT + SEM (ms)');
```

```
set(gca, 'xticklab', {'word', 'nonword'});
```

```
% End gracefully:
```

```
fprintf(1, '\n++ done! ++\n\n');
```

%%

'To run the script, type at the Command Line (or highlight and <F9>):'

`demo_script_simple`

'To run a version with nicer formatting, type:'

`demo_script_final`

'If you launched this from the presentation...'

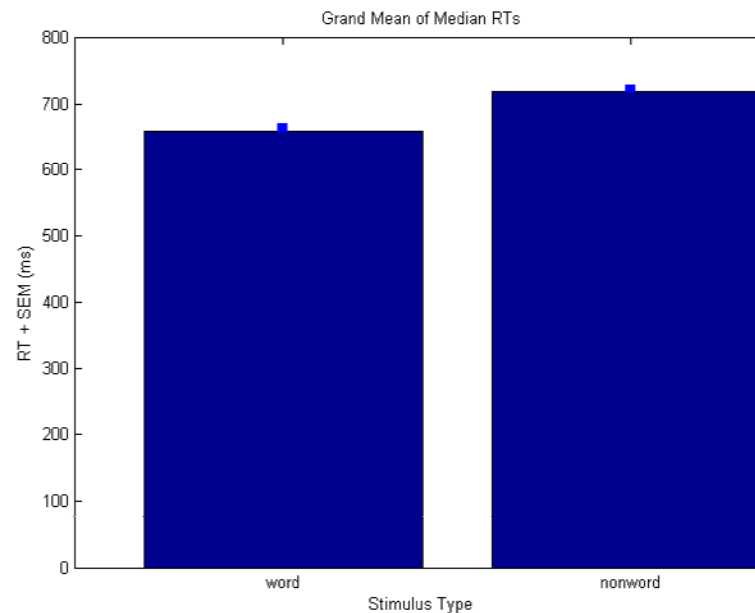
'To return to the presentation, type:'

`return`

An Example Batch Script

Running the batch script `demo_script_simple.m` should:

- Add several variables to the workspace, including
 - `gm` (grand mean of median RTs for 2 conditions)
 - `se` (standard error of the mean for 2 conditions)
 - `mdrt` (median RTs for each subject and condition, 15x2)
- Open a figure window and plot $M+SE$ for each condition



An Example Batch Script

The script `demo_script_final.m` shows how you might improve upon the simple batch script. Some improvements include:

'Adding (at top) some options to make the figure a bit more attractive'

```
%% (0) Define options:
```

```
% Plot format:
```

```
barcolor = [.5 .5 .5];
```

```
ebarcolor = [0 0 0];
```

```
ebarsize = 3;
```

```
plotfont = 12;
```

'These get called later in the call to `bar` (which plots the data):'

```
% Plot means:
```

```
bar(gm, 'facecolor', barcolor);
```

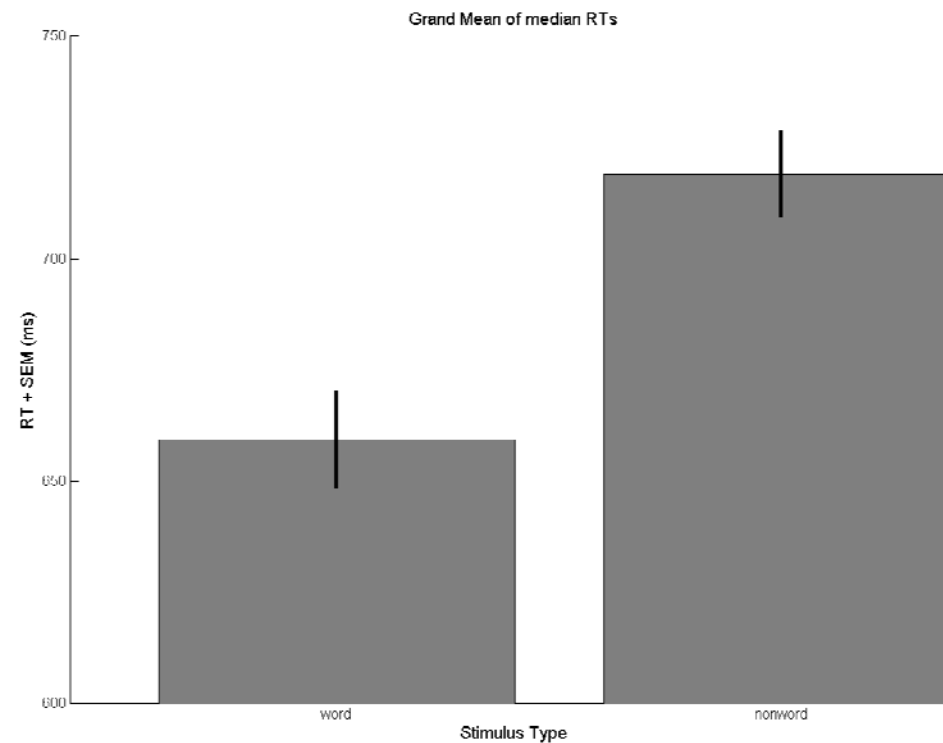
```
set([ebar1 ebar2], 'linewidth', ebarsize, 'color', ebarcolor);
```

```
set(gca, 'fontsize', plotfont);
```

An Example Batch Script

The script `demo_script_final.m` shows how you might improve upon the simple batch script. Some improvements include:

'Which results in this slightly prettier figure:'



An Example Batch Script

The script `demo_script_final.m` shows how you might improve upon the simple batch script. Some improvements include:

'Adding some processing options (Which summary statistic? Save? Plot?):'

```
% Processing options:
```

```
plotvar = 'median'; % 'median', 'mean', 'trim<N>' (N%-trimmed mean)
dosave  = 0;        % save grandmean data?
doplot  = 1;        % plot grandmean data?
```

'And some data options...'

```
% Data options:
```

```
conds      = [1 2];
condlabs   = {'word', 'nonword'};
Nevents    = [240 240];
```

'... which get looped over later'

```
% Loop over conditions
```

```
for j = 1:length(conds)
    ' ... '
    rt = D.rt(D.event==conds(j));
    ' ... '
end % j in conds
```

This loop is more flexible and more powerful than typing out the same command for each condition

In `demo_script_simple.m`, we had:

```
mdrt(i,1) = median(D.rt(D.event==1));
mdrt(i,2) = median(D.rt(D.event==2));
```

But what if we want to add more conditions?

*** Better yet, vector/matrix operations are more efficient than loops!**

An Example Function

At some point, you may find you're often typing out the same formula or set of commands. This is annoying... and inefficient!

For example: In our script, we had to compute standard error by hand:

```
% Get standard error:  
se = std(mdr_t)/sqrt(size(mdr_t,1));
```

By contrast, we don't compute the mean by hand (sum elements/number of elements), we just call the function `mean`.

So let's create a standard error function.

An Example Function

First ... what does a function look like?

To look at a function's contents, you can:

```
edit mean      % open the function's m-file in Matlab Editor
```

```
type mean      % dump the function's contents to screen
```

```
which mean     % find the function's m-file
```

```
unix(sprintf('nedit %s',which('mean'))); % edit in another editor
```

The main elements of a function are ... (next slide)

```
function y = mean(x,dim)
```

function call: function [out] = fname(in)
e.g., function y = mean(x,dim)

```
%MEAN Average or mean value.  
% For vectors, MEAN(X) is the mean value of the elements in X. For  
% matrices, MEAN(X) is a row vector containing the mean value of  
% each column. For N-D arrays, MEAN(X) is the mean value of the  
% elements along the first non-singleton dimension of X.  
%  
% MEAN(X,DIM) takes the mean along the dimension DIM of X.  
%  
% Example: If X = [0 1 2  
%                 3 4 5]  
%  
% then mean(X,1) is [1.5 2.5 3.5] and mean(X,2) is [1  
%                                                    4]  
%  
% Class support for input X:  
% float: double, single  
%  
% See also MEDIAN, STD, MIN, MAX, VAR, COV, MODE.  
%  
% Copyright 1984-2005 The MathWorks, Inc.  
% $Revision: 5.17.4.3 $ $Date: 2005/05/31 16:30:46 $  
  
if nargin==1,  
    % Determine which dimension SUM will use  
    dim = min(find(size(x)~=1));  
    if isempty(dim), dim = 1; end  
  
    y = sum(x)/size(x,dim);  
else  
    y = sum(x,dim)/size(x,dim);  
end
```

Description

-will display when
'help' is called.

-useful to include
examples

Author info

Contents of function

An Example Function

So, have a crack at a standard error function, `sem`:

```
function y = sem(x)

% Computes standard error (standard deviation divided by
% square root of N) of a vector.
%
% by Jason Taylor (18/11/2008)
% note: should be modified to handle matrices
%

% Check that input is a vector:
if nargin~=1
    help sem
    error('No input!')
elseif sum(size(x)>1)>1
    help sem
    error('Input must be a vector!')
end

% Compute SEM:
y = std(x)/sqrt(length(x));

return
```

Give it a unique name; first try: which `sem`

Describe it

Take credit/blame

Note modifications, limitations, bugs

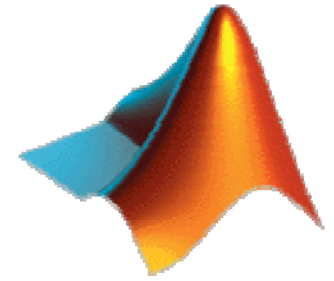
Check for proper input (here must be a vector)

Do it!

Save in your path (e.g., `/home/<user>/matlab/sem.m`)
(see `sem.m` in `/imaging/jt03/demo/scripts`)

HELP?!

(where to find it)



Obviously:

```
help <funcname>
```

For pretty, hypertext, browser-based help:

```
doc <funcname>
```

Look at the function!

```
edit <funcname>
```

```
type <funcname>
```

Online: Matlab Central:

```
http://www.mathworks.com/matlabcentral/
```

And the user file exchange:

```
http://www.mathworks.com/matlabcentral/fileexchange/
```

On the imaging wiki:

```
http://imaging.mrc-cbu.cam.ac.uk/imaging/LearningMatlab
```

Email lists (e.g., imagers+, imagerstech)