MRC | Cognition and Brain Sciences Unit

Visualising data using MATLAB

Lydia Barnes

MRC Cognition and Brain Sciences Unit

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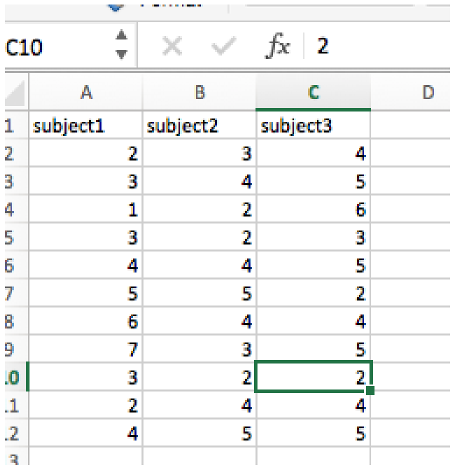
(slides from Sneha Shashidhara and Kate Storrs!)

Good practice for plotting

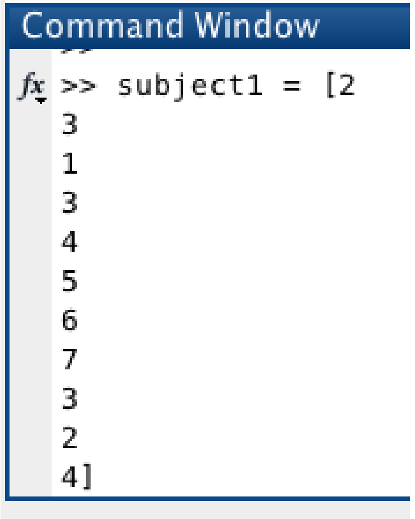
How not to use MATLAB to visualise data



C10 | fx | 2

	A	B	C	D
1	subject1	subject2	subject3	
2	2	3	4	
3	3	4	5	
4	1	2	6	
5	3	2	3	
6	4	4	5	
7	5	5	2	
8	6	4	4	
9	7	3	5	
.0	3	2	2	
.1	2	4	4	
.2	4	5	5	

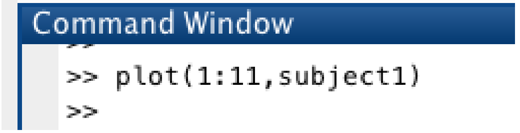
Type data into Excel…



Command Window

```
>> subject1 = [2
3
1
3
4
5
6
7
3
2
4]
```

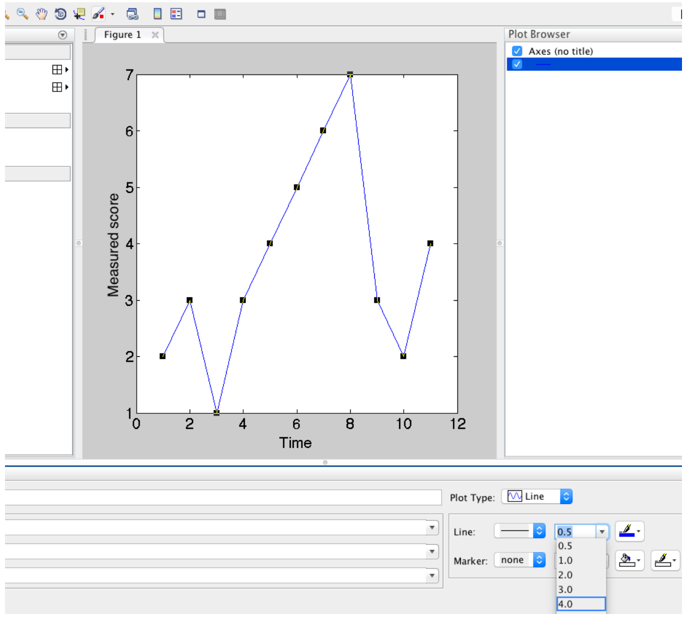
…copy-paste into Matlab…



Command Window

```
>> plot(1:11,subject1)
>>
```

…type in command line instructions to plot…



…fiddle with plot using interactive plotting interface until satisfied.

What's wrong with this?

Good practice: help your future self

- Assume you will forget everything!
- Comment
  - Intro: %this script was made to…
  - Brief note on each line or chunk: %load the data, %reformat the plot…
- Structure the code
  - clear your workspace
  - set parameters
  - load data
  - then make plots…
- Move from concrete to flexible
  - function [out] = makeMePlots(dataDirectory,plotDirectory,includePValues)

Good practice: make your process transparent

- What is Open Science?
  - Reporting what you’ve done
  - Sharing every step
- Why share scripts?
  - Limited room for explanation in a Methods section
  - Scripts hold all the detail you need!
- Reproduceable plotting
  - Script everything – including loading the data
  - Comment everything
    - Name and contact details
    - Background on the data at the top of the script, or in a ‘README’ in the script’s folder

Good practice: some resources

‘Good enough practices in scientific computing’, Wilson et al. 2017

‘Everything is f-ed’ open science syllabus, Sanjay Srivastava (@hardsci)

Starting a script

Starting a script: exercise

- open a new script
- save it
  - meaningful location, meaningful name…
  - avoid clashing with built-in function names (mean, max, plot…)
- intro
  - % for comments (things MATLAB won’t try to run)
  - your info
  - what will this script do?

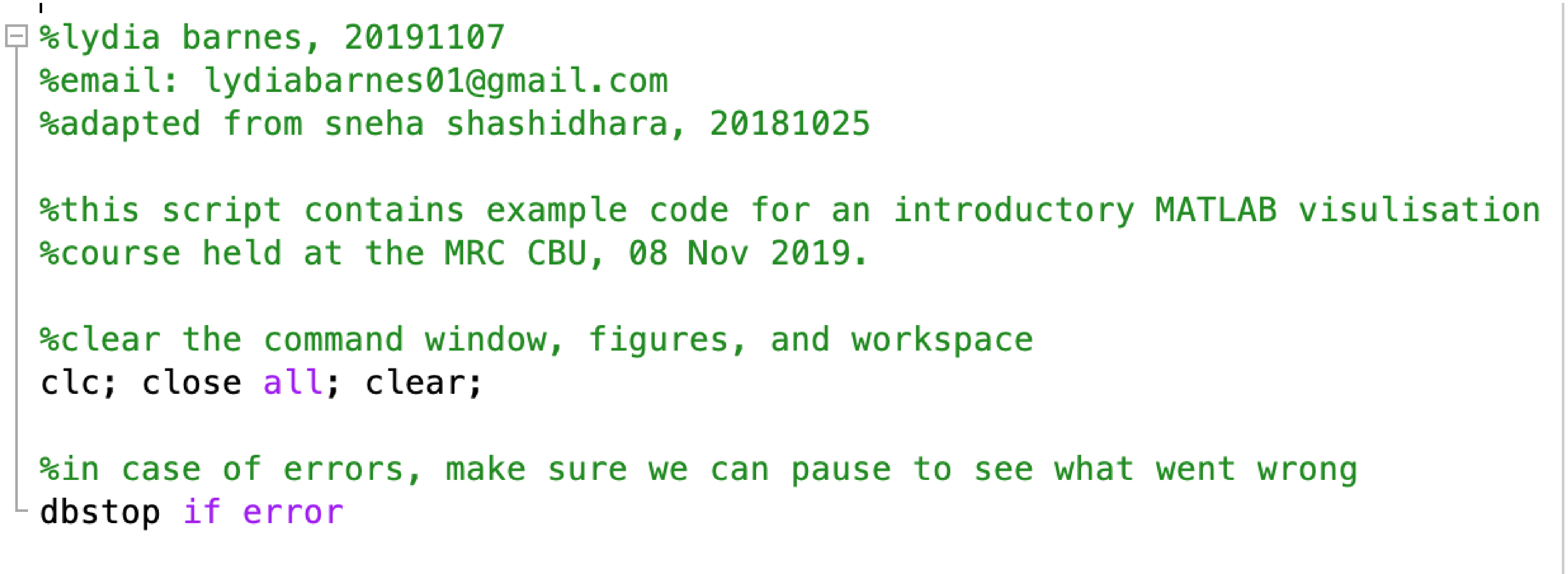
Starting a script: tips

- some safety checks
  - clean up your working environment to prevent clashes
  - prepare for errors

```
clc; close all; clear; %clear the command window, figures, and workspace
```

```
dbstop if error; %if there’s an error, pause at that line
```

Starting a script: example



```
%lydia barnes, 20191107
%email: lydiabarnes01@gmail.com
%adapted from sneha shashidhara, 20181025

%this script contains example code for an introductory MATLAB visulisation
%course held at the MRC CBU, 08 Nov 2019.

%clear the command window, figures, and workspace
clc; close all; clear;

%in case of errors, make sure we can pause to see what went wrong
dbstop if error
```

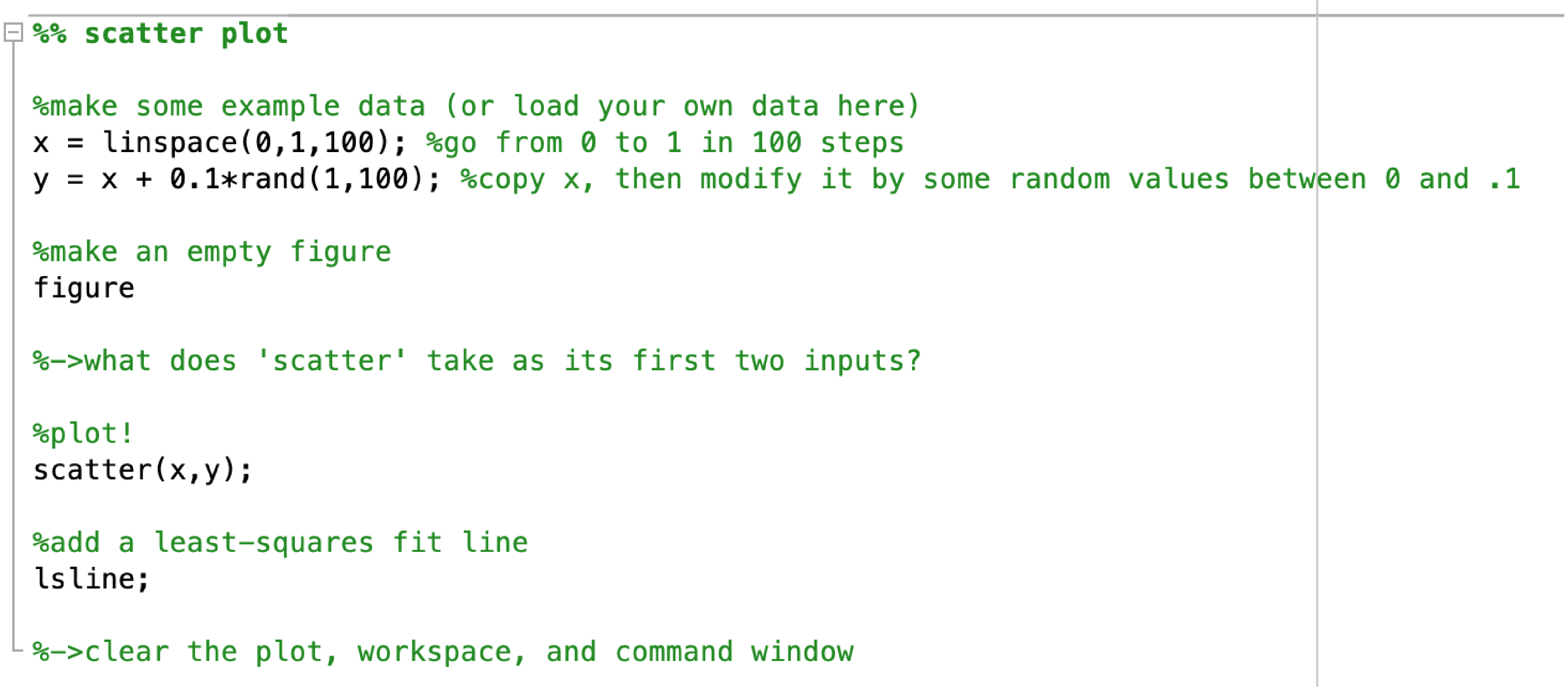
Scatter plots

Scatter plot: exercise

- make (or load) the data
  - make y relative to x
- “figure”
  - add to your script and run it!
- explore the scatter function
  - “help scatter” or “doc scatter” in the command window
- plot
  - “scatter(x,y)”
- “lsline”

```
x = linspace(0,1,100); %go from 0 to 1 in 100 steps

y = x + 0.1*rand(1,100); %copy x, then modify it by some random values between 0 and .1
```

Scatter plot: example



```
%% scatter plot

%make some example data (or load your own data here)
x = linspace(0,1,100); %go from 0 to 1 in 100 steps
y = x + 0.1*rand(1,100); %copy x, then modify it by some random values between 0 and .1

%make an empty figure
figure

%->what does 'scatter' take as its first two inputs?

%plot!
scatter(x,y);

%add a least-squares fit line
lsline;

%->clear the plot, workspace, and command window
```

Line plots

Line plot: exercise

- make (or load) the data
  - we’ll use the sine and cosine of the same data vector
- ‘figure’
- explore the ‘plot’ function
  - “help plot”
- plot
  - plot(x,y)

```
x = linspace(0,360,100); %0:360 in 100 steps
y = sind(x);
z = cosd(x);
```

Line plot: tips

- store the figure information
  - look inside the handle. what are its properties?
- make variables for different colours
  - make black
  - define your own three colours…

```
h = figure; %open a figure, and store a ‘handle’ to it in a variable
```

```
red=[1 0 0];
green=[0 1 0];
blue=[0 0 1];
black=[0 0 0];
```

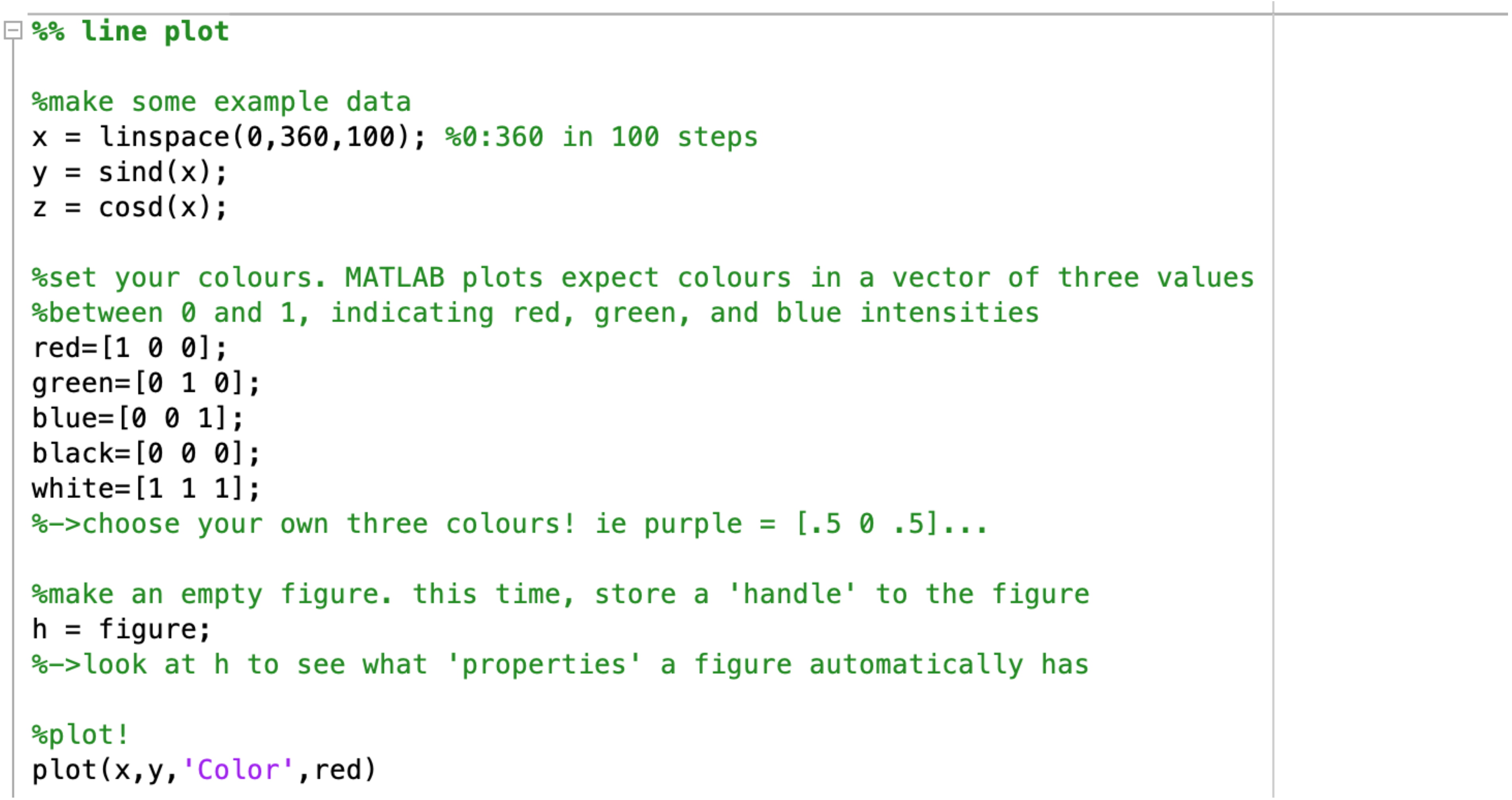
Line plot: tips

- store the figure information
  - look inside the handle. what are its properties?
- make variables for different colours
  - make black
  - define your own three colours…
- plot(x,y) again, specifying the colour
  - **Name-Value pairs**
  - go back to “help plot” if you need to!

```
h = figure; %open a figure, and store a ‘handle’ to it in a variable
```

```
red=[1 0 0];
green=[0 1 0];
blue=[0 0 1];
black=[0 0 0];
```

Line plot: example

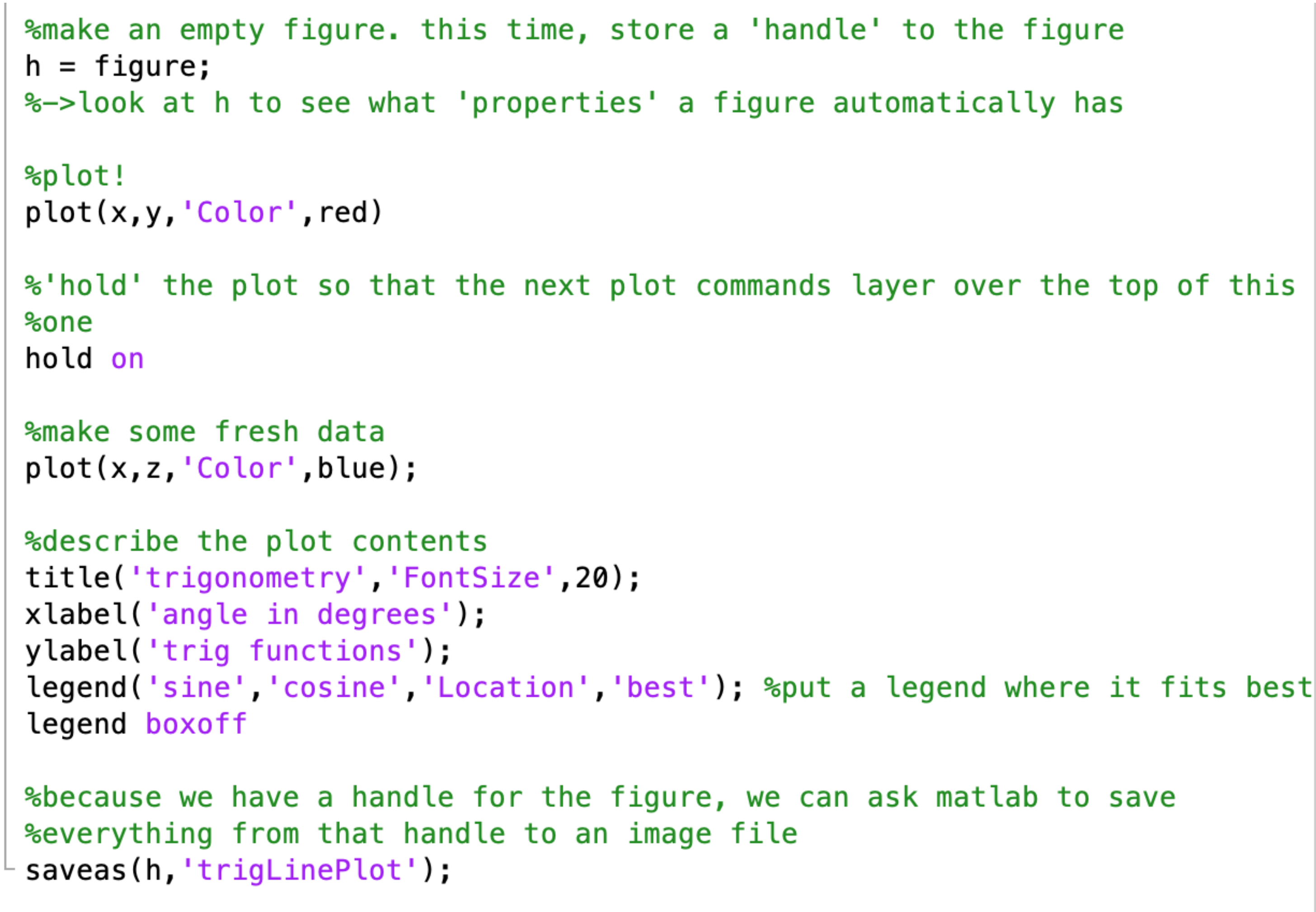


```
%% line plot

%make some example data
x = linspace(0,360,100); %0:360 in 100 steps
y = sind(x);
z = cosd(x);

%set your colours. MATLAB plots expect colours in a vector of three values
%between 0 and 1, indicating red, green, and blue intensities
red=[1 0 0];
green=[0 1 0];
blue=[0 0 1];
black=[0 0 0];
white=[1 1 1];
%->choose your own three colours! ie purple = [.5 0 .5]...

%make an empty figure. this time, store a 'handle' to the figure
h = figure;
%->look at h to see what 'properties' a figure automatically has

%plot!
plot(x,y,'Color',red)
```

Line plot: exercise

- add another plot
  - “hold on” under first plotting command
  - use x and z data variables to make another line
  - give this line a different colour
- add labels
  - try out “xlabel”, “ylabel”, and “title”
  - explore “box”, “axis”, and “legend” commands to make plot look ‘publishable’…
- save with “saveas” and the figure handle
  - see if you can work out how to save it as a jpeg!

Line plot: example



```
%make an empty figure. this time, store a 'handle' to the figure
h = figure;
%->look at h to see what 'properties' a figure automatically has

%plot!
plot(x,y,'Color',red)

%'hold' the plot so that the next plot commands layer over the top of this
%one
hold on

%make some fresh data
plot(x,z,'Color',blue);

%describe the plot contents
title('trigonometry','FontSize',20);
xlabel('angle in degrees');
ylabel('trig functions');
legend('sine','cosine','Location','best'); %put a legend where it fits best
legend boxoff

%because we have a handle for the figure, we can ask matlab to save
%everything from that handle to an image file
saveas(h,'trigLinePlot');
```

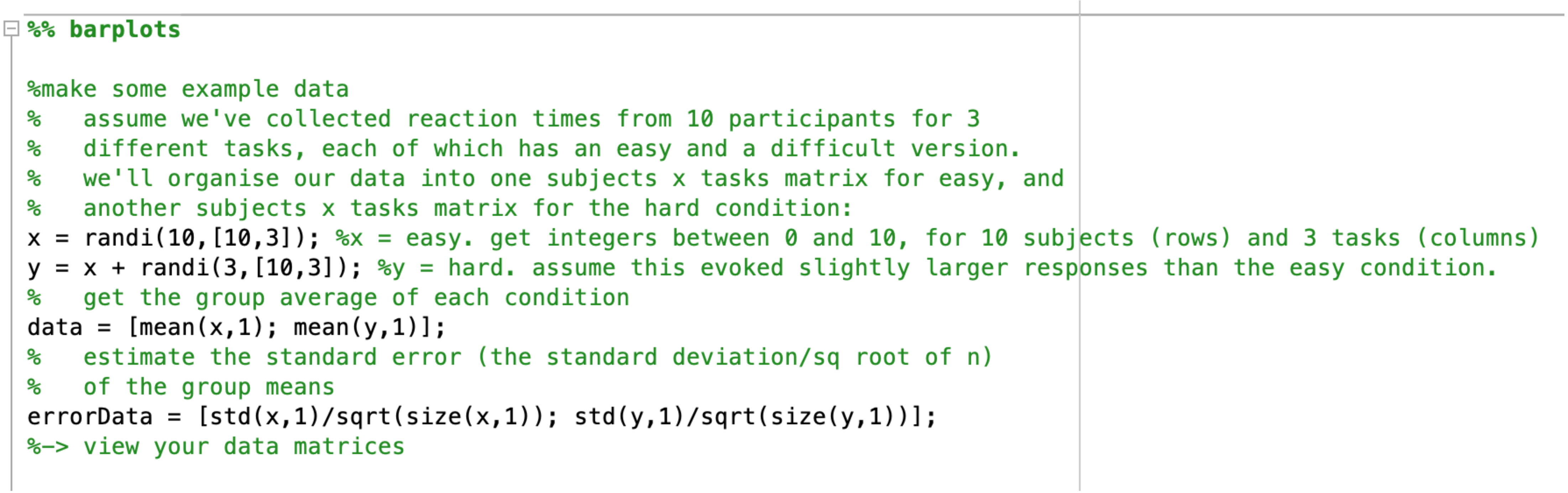
Bar plots

Bar plots: basics (exercise)

- make (or load) some data
- get the group means of x and y for each task
- store the group means in a variable
  - 2 conditions (rows), 3 tasks (columns)
- estimate the standard error of each mean (standard deviation/square root of n)
  - “std” and “sqrt”

```
x = randi(10,[10,3]); %x = easy. get random integers between 0 and 10, for 10 subjects (rows) and 3 tasks (columns)

y = x + randi(3,[10,3]); %y = hard. assume this evoked slightly larger responses than the easy condition.
```

Bar plots: basics (example)



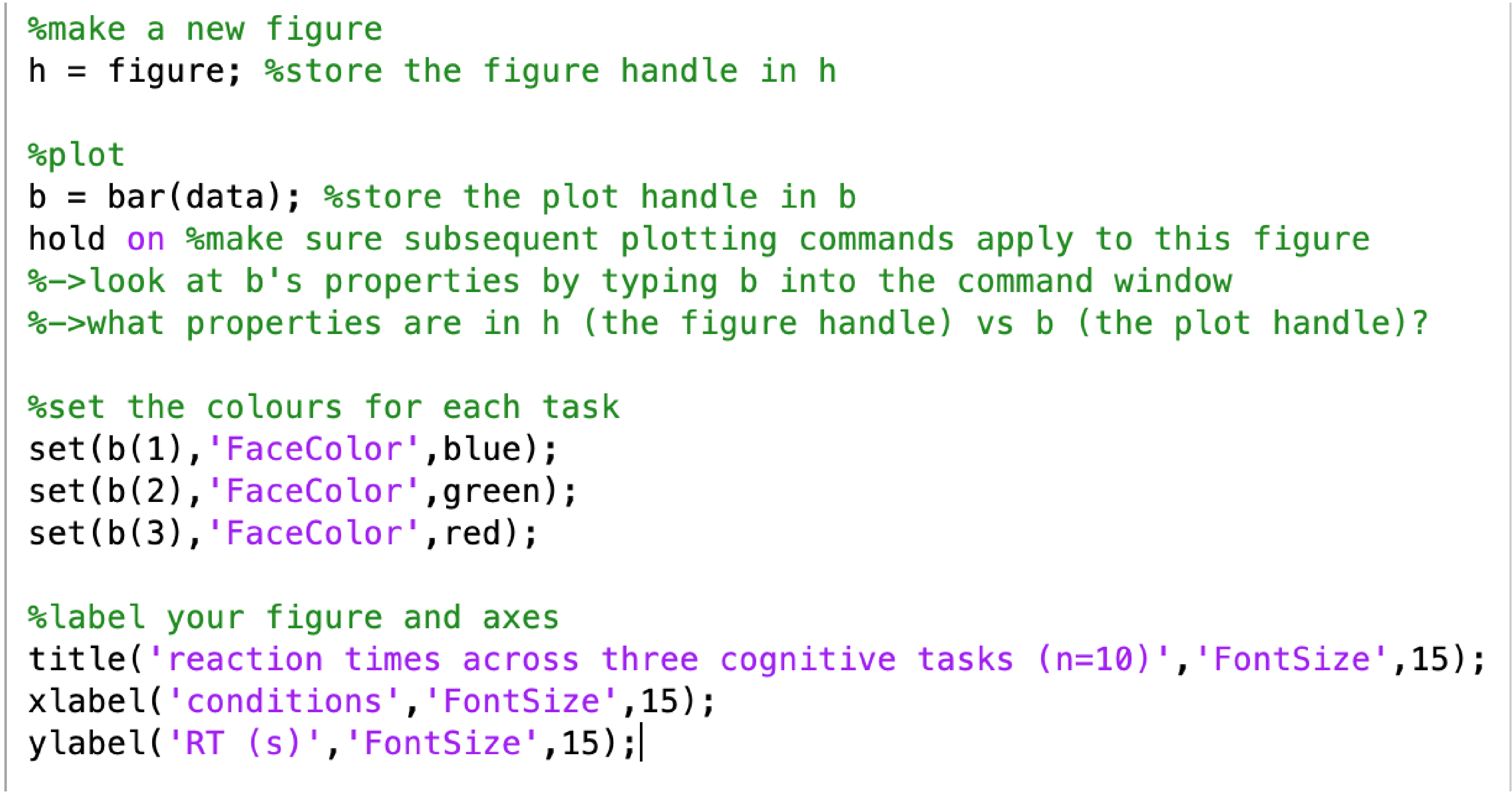
```
%% barplots

%make some example data
%   assume we've collected reaction times from 10 participants for 3
%   different tasks, each of which has an easy and a difficult version.
%   we'll organise our data into one subjects x tasks matrix for easy, and
%   another subjects x tasks matrix for the hard condition:
x = randi(10,[10,3]); %x = easy. get integers between 0 and 10, for 10 subjects (rows) and 3 tasks (columns)
y = x + randi(3,[10,3]); %y = hard. assume this evoked slightly larger responses than the easy condition.
%   get the group average of each condition
data = [mean(x,1); mean(y,1)];
%   estimate the standard error (the standard deviation/sq root of n)
%   of the group means
errorData = [std(x,1)/sqrt(size(x,1)); std(y,1)/sqrt(size(y,1))];
%-> view your data matrices
```

Bar plots: plot properties (exercise)

- h = figure;
- explore the “bar” function
- plot
- create a handle for the **plot**
    - explore the plot’s properties
- hold on
- modify the bar colours with the plot handle and “set”
- add a title and axis labels

b = bar(data);

Bar plots: plot properties (example)



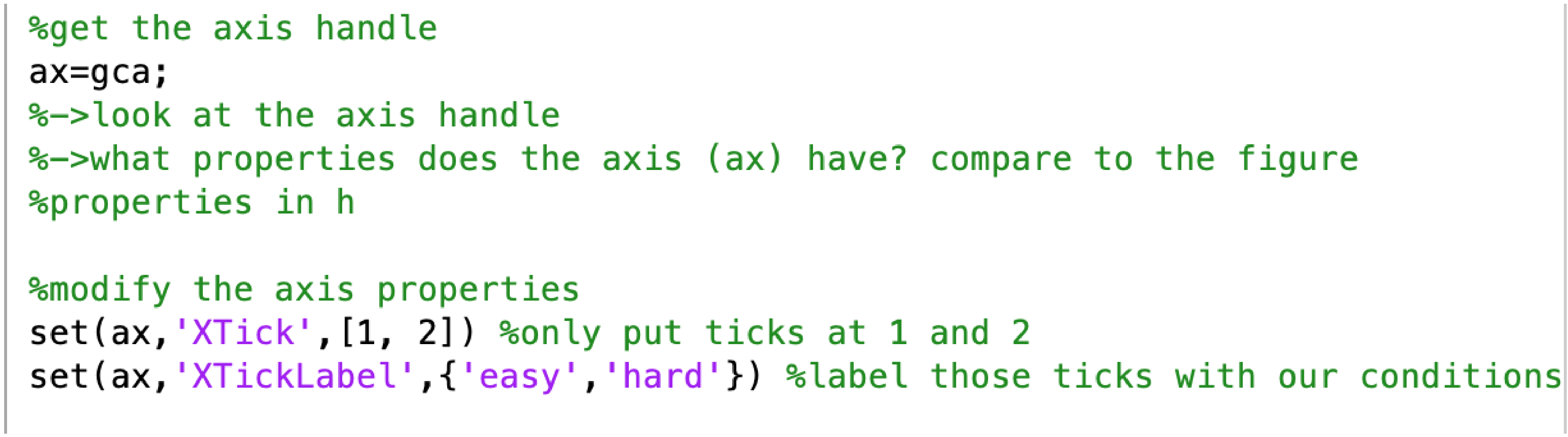
```
%make a new figure
h = figure; %store the figure handle in h

%plot
b = bar(data); %store the plot handle in b
hold on %make sure subsequent plotting commands apply to this figure
%->look at b's properties by typing b into the command window
%->what properties are in h (the figure handle) vs b (the plot handle)?

%set the colours for each task
set(b(1),'FaceColor',blue);
set(b(2),'FaceColor',green);
set(b(3),'FaceColor',red);

%label your figure and axes
title('reaction times across three cognitive tasks (n=10)','FontSize',15);
xlabel('conditions','FontSize',15);
ylabel('RT (s)','FontSize',15);
```

Bar plot: axis properties (exercise)

- get the axis handle
  - compare the properties in the figure, plot, and axis handles
- change the x-axis ticks and labels
  - hint: use ‘set’ and the axis handle

```
ax = gca; %get current axis
```

Bar plot: axis properties (example)



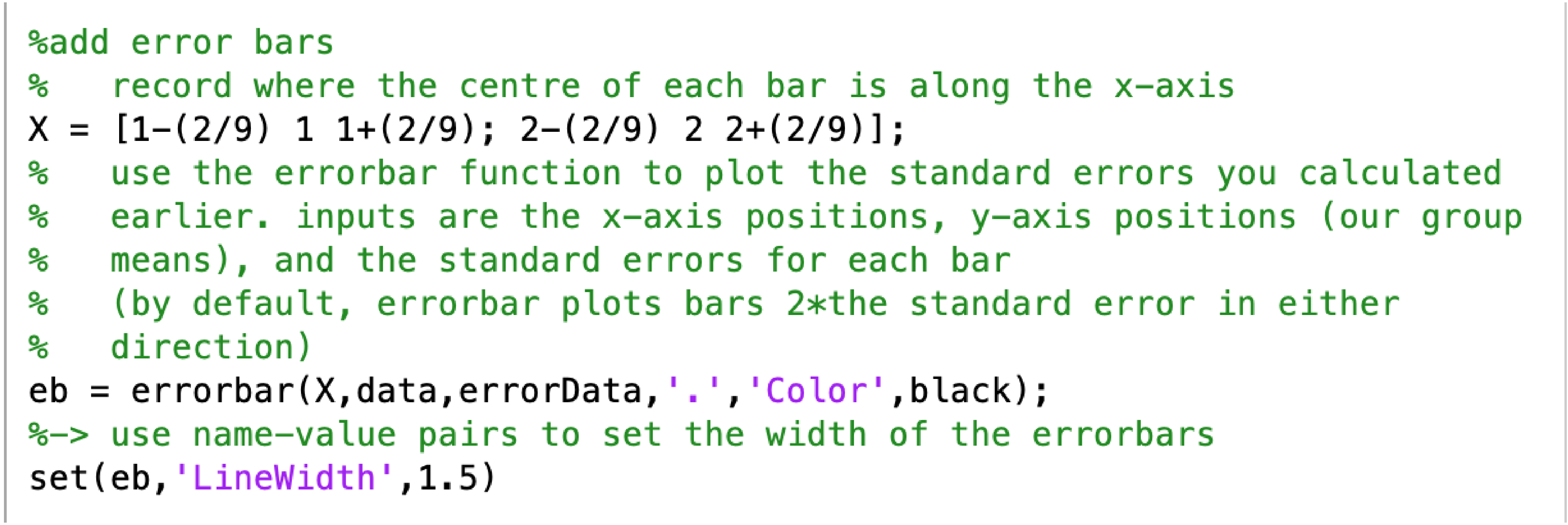
```
%get the axis handle
ax=gca;
%->look at the axis handle
%->what properties does the axis (ax) have? compare to the figure
%properties in h

%modify the axis properties
set(ax,'XTick',[1, 2]) %only put ticks at 1 and 2
set(ax,'XTickLabel',{'easy','hard'}) %label those ticks with our conditions
```

Bar plots: error bars (exercise)

- find the location of each bar on the x-axis and store it in a variable
- use “errorbar” to plot the standard error of the means
  - hint: use the errors you calculated earlier

```
X = [1-(2/9) 1 1+(2/9); 2-(2/9) 2 2+(2/9)];
```

Bar plots: error bars (example)

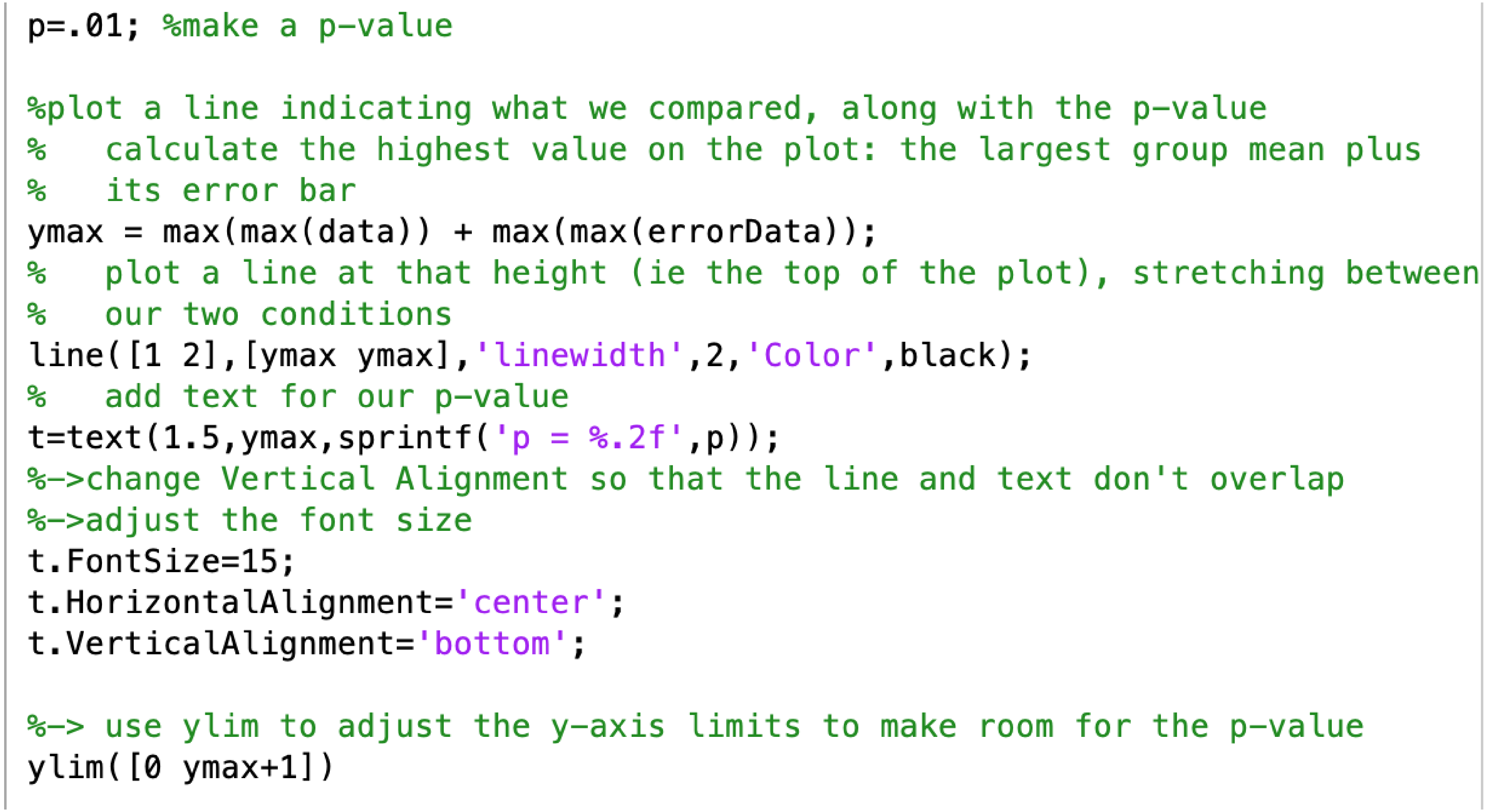


```
%add error bars
%   record where the centre of each bar is along the x-axis
X = [1-(2/9) 1 1+(2/9); 2-(2/9) 2 2+(2/9)];
%   use the errorbar function to plot the standard errors you calculated
%   earlier. inputs are the x-axis positions, y-axis positions (our group
%   means), and the standard errors for each bar
%   (by default, errorbar plots bars 2*the standard error in either
%   direction)
eb = errorbar(X,data,errorData,'.','Color',black);
%-> use name-value pairs to set the width of the errorbars
set(eb,'LineWidth',1.5)
```

Bar plots: reporting stats (exercise)

- find the highest value on the plot
    - without looking at the plot!
- “line” and “text”
    - plot a line from the easy to the hard condition along the top of the plot
    - put text in the centre showing a p-value
        - make a handle to the text
        - modify the text size and vertical alignment
- “ylim”
    - adjust the y-axis limits to give the p-value more space

Bar plots: reporting stats (example)



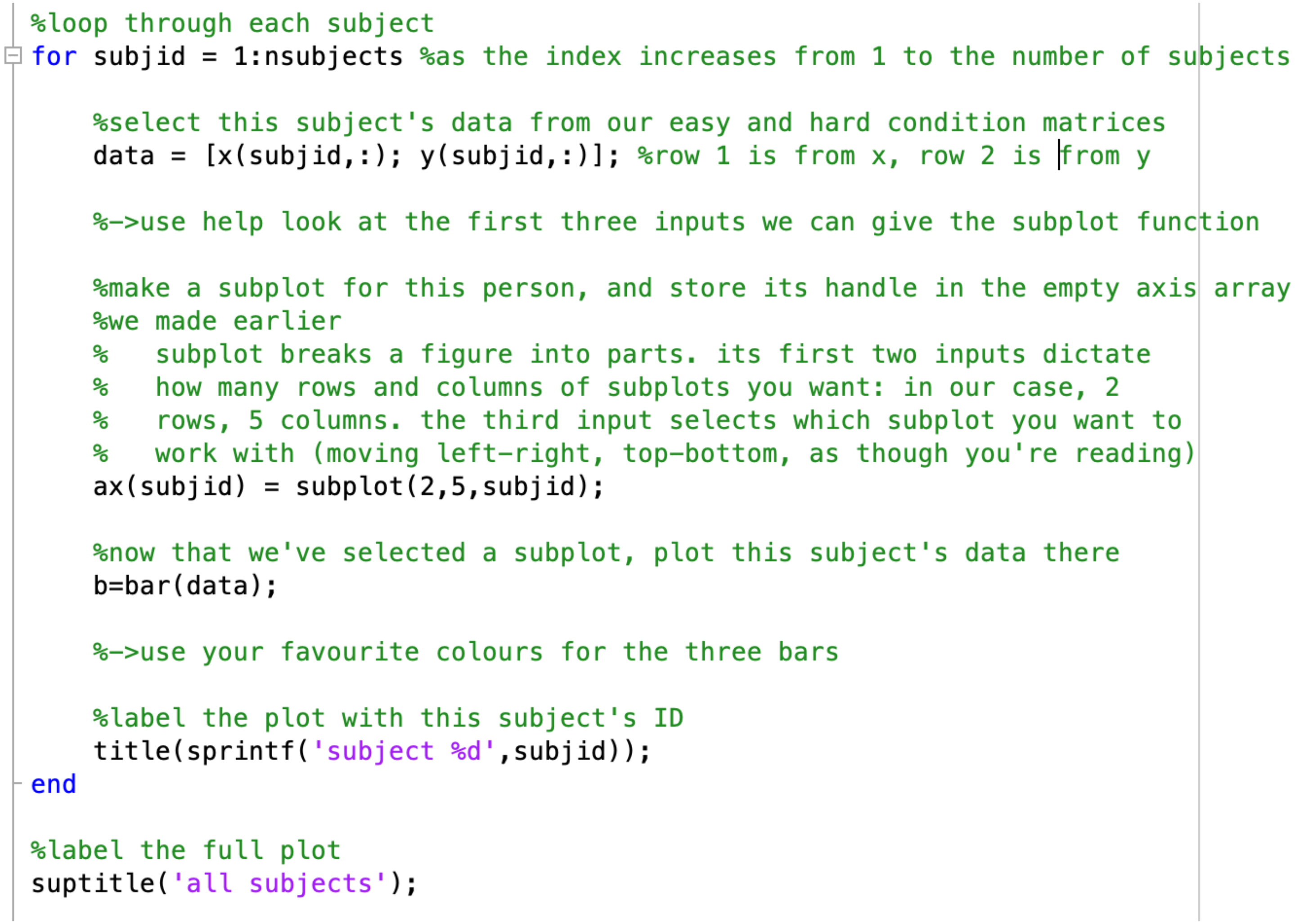
```
p=.01; %make a p-value

%plot a line indicating what we compared, along with the p-value
%   calculate the highest value on the plot: the largest group mean plus
%   its error bar
ymax = max(max(data)) + max(max(errorData));
%   plot a line at that height (ie the top of the plot), stretching between
%   our two conditions
line([1 2],[ymax ymax],'linewidth',2,'Color',black);
%   add text for our p-value
t=text(1.5,ymax,sprintf('p = %.2f',p));
%->change Vertical Alignment so that the line and text don't overlap
%->adjust the font size
t.FontSize=15;
t.HorizontalAlignment='center';
t.VerticalAlignment='bottom';

%-> use ylim to adjust the y-axis limits to make room for the p-value
ylim([0 ymax+1])
```

Subplots

Subplots (exercise)

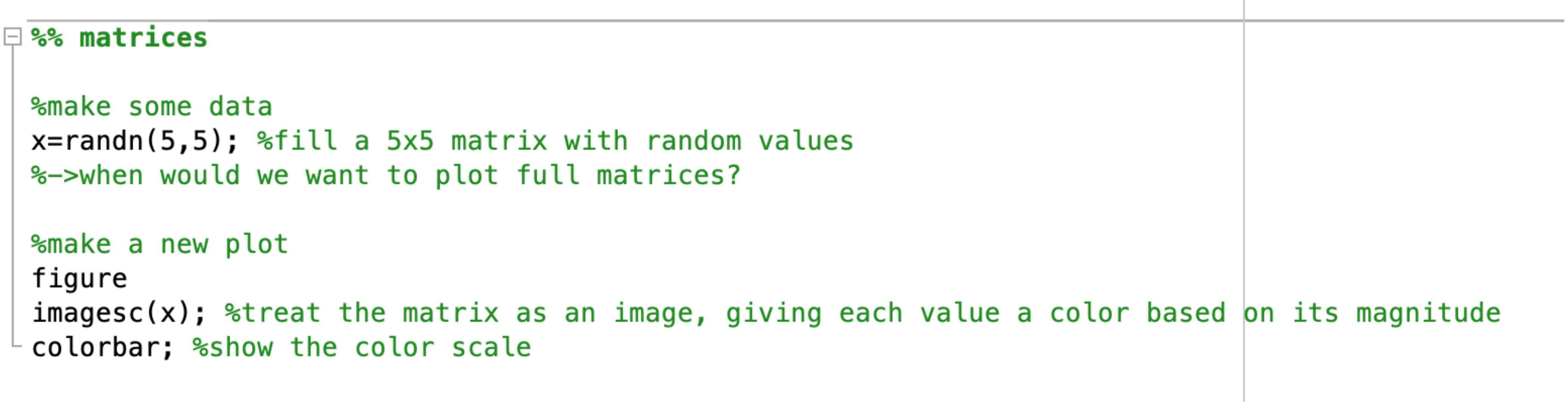
- explore the “subplot” function
- make a figure with subplots
  - 1 per person in our bar plot dataset
  - 2 rows, 5 columns
- loop through the subjects
- for each person, plot their 3 tasks and 2 conditions as you did for the group average bar plots
- give each subplot a title
- calculate the group range and use it to set the y-axis limits

Subplots (example)



```
%loop through each subject
for subjid = 1:nsubjects %as the index increases from 1 to the number of subjects

    %select this subject's data from our easy and hard condition matrices
    data = [x(subjid,:); y(subjid,:)]; %row 1 is from x, row 2 is from y

    %->use help look at the first three inputs we can give the subplot function

    %make a subplot for this person, and store its handle in the empty axis array
    %we made earlier
    %   subplot breaks a figure into parts. its first two inputs dictate
    %   how many rows and columns of subplots you want: in our case, 2
    %   rows, 5 columns. the third input selects which subplot you want to
    %   work with (moving left-right, top-bottom, as though you're reading)
    ax(subjid) = subplot(2,5,subjid);

    %now that we've selected a subplot, plot this subject's data there
    b=bar(data);

    %->use your favourite colours for the three bars

    %label the plot with this subject's ID
    title(sprintf('subject %d',subjid));
end

%label the full plot
suptitle('all subjects');
```

Just for fun



```
%% matrices

%make some data
x=randn(5,5); %fill a 5x5 matrix with random values
%->when would we want to plot full matrices?

%make a new plot
figure
imagesc(x); %treat the matrix as an image, giving each value a color based on its magnitude
colorbar; %show the color scale
```