Exploring the Experiment's Design

In this set of exercises, we'll get our first look at the experiment we'll be analyzing in this course; curated data from the Steinmetz et al, 2019 paper.

Today's data is focused on three CSV files, each containing sessions from a different stretch of data collection. They contain trial-level data from the experiment:

- steinmetz_winter2016.csv
- steinmetz_summer2017.csv
- steinmetz_winter2017.csv

Table of Contents

Loading and viewing data

Let's load in some csv data with MATLAB and see what we have!

Code	Description
readtable('my_datafile.csv')	read a csv file
data(row_start:row:end, :)	select rows from row_start to row_end from data
height(my_table)	count the number of rows in my_table
width(my_table)	count the number of columns in my_table
my_table.Properties.VariableNames	get the column names of my_table
[table1;table2;table3]	concatenate tables

Download datafiles

```
userpath(fullfile(fileparts(matlab.desktop.editor.getActiveFilename), "src"))
download_from_sciebo("https://uni-bonn.sciebo.de/s/QyHoxfrSF6JILQd", 'data/
steinmetz_winter2016.csv')
```

```
downloading file to data/steinmetz_winter2016.csv
Done!
```

```
download_from_sciebo("https://uni-bonn.sciebo.de/s/Z3QHxJztEueDQF8", 'data/
steinmetz_summer2017.csv')
```

```
downloading file to data/steinmetz_summer2017.csv
Done!
```

```
download_from_sciebo("https://uni-bonn.sciebo.de/s/9FxelLhARmHpw85", 'data/steinmetz_winter2017.csv')
```

```
downloading file to data/steinmetz_winter2017.csv
Done!
```

```
userpath(fullfile(fileparts(matlab.desktop.editor.getActiveFilename), "data"))
```

Example:

Load in the winter 2016 dataset and view the first 5 rows of the data

```
data_winter2016 = readtable('data/steinmetz_winter2016.csv');
data_winter2016(1:5,:)
```

```
ans = 5×15 table
```

...

	trial	active_trials	contrast_left	contrast_right	stim_onset
1	1	'True'	100	0	0.5000
2	2	'True'	0	50	0.5000
3	3	'True'	100	50	0.5000
4	4	'True'	0	0	0.5000
5	5	'True'	50	100	0.5000

The variable data is a MATLAB table, we can see that in the Workspace pannel on the right.

Exercises

Load in the summer 2017 dataset and view the first 10 rows of the data

```
data_summer2017 = readtable('data/steinmetz_summer2017.csv');
data_summer2017(1:10,:)
```

```
ans = 10×15 table
```

...

	trial	active_trials	contrast_left	contrast_right	stim_onset
1	1	'True'	0	50	0.5000
2	2	'True'	50	0	0.5000
3	3	'True'	0	0	0.5000
4	4	'True'	0	0	0.5000
5	5	'True'	0	0	0.5000

	trial	active_trials	contrast_left	contrast_right	stim_onset
6	6	'True'	0	0	0.5000
7	7	'True'	50	25	0.5000
8	8	'True'	0	25	0.5000
9	9	'True'	50	0	0.5000
10	10	'True'	0	50	0.5000

How many rows are in the summer 2017 dataset?

```
height(data_summer2017)
```

```
ans = 2747
```

How many columns are in the summer 2017 dataset?

```
width(data_summer2017)
```

```
ans = 15
```

What are the column names in the summer 2017 dataset?

```
data_summer2017.Properties.VariableNames
```

```
ans = 1×15 cell
'trial'     'active_trials''contrast_left''contrast_right''stim_onset''gocue_tim ···
```

Load in the winter 2017 dataset to an appropriately named variable

```
data_winter2017 = readtable('data/steinmetz_winter2017.csv');
```

How many rows are in the winter 2017 dataset?

```
height(data_winter2017)
```

```
ans = 7906
```

Combine the 3 datasets into one table named `data`

```
data = [data_winter2016; data_winter2017; data_summer2017];
```

How many trials are there in the combined dataset?

```
height(data)
```

```
ans = 14420
```

Are you sure that the combined dataset has all the rows of the 3 smaller datasets?

Count the rows in each to find out.

```
height(data_winter2017)+ height(data_summer2017)+ height(data_winter2016) ==
height(data)
```

```
ans = logical
   1
```

Experiment Description: Calculating Statistics on Continuous Data

Let's calculate some simple statistics from the dataset.

Code	Description
`my_table.column_A`	access column_A of my_table
`min(my_data)`	find the minimum value of my_data
`max(my_data)`	find the maximum value of my_data
`mean(my_data)`	find the mean value of my_data
`mean(my_data, "omitmissing")`	calculate the mean ignoring missing values
`median(my_data)`	find the media value of my_data
`std(my_data)`	find the standard deviation of my_data
`range(my_data)`	find the difference between largest and smallest values in my_data

Example

Find the minimum response time in the data

```
min(data.response_time)
```

```
ans = 0.4794
```

Exercises

Find the maximum response time in the data

```
max(data.response_time)
```

```
ans = 2.7136
```

Find the maximum gocue time in the data

```
max(data.gocue_time)
```

```
ans = 1.1988
```

Find the minimum gocue time in the data

```
min(data.gocue_time)
```

```
ans = 0.3951
```

Find the mean response time in the data. **Hint** - as the data contains missing values use the "omitmissing" option.

```
mean(data.response_time, "omitmissing")
```

```
ans = 1.4228
```

Calculate the mean of response time including missing values. How do missing values affect the result?

```
mean(data.response_time)
```

```
ans = NaN
```

Find the median response time in the data

```
median(data.response_time, "omitmissing")
```

```
ans = 1.1833
```

Find the standard deviation of response time

```
std(data.response_time,"omitmissing")
```

```
ans = 0.6614
```

Find the standard deviation of gocue time

```
std(data.gocue_time,"omitmissing")
```

```
ans = 0.2005
```

Find the range of gocue time

```
range(data.gocue_time)
```

```
ans = 0.8038
```

Find the range of feedback time using the `max()` and `min()` functions

```
max(data.feedback_time) - min(data.feedback_time)
```

```
ans = 2.2438
```

Experiment Description: Calculating Statistics of Across Categorical Data

In data science we often want to perform analysis on distinct separate categories, for example, analysing trials that occured on different days.

To do this, we group the data and analyse each group separately.

Code	Description
`groupsummary(data, "column_A")`	Group data according to column_A and count occurrances
groupsummary(data, "column_A", "mean", "column_B")	Group data according to column_A and calculate the mean of column_B
groupsummary(data, ["column_A", "column_C"])	Group data according to both column_A and column_C and count occurances

Example Exercise

How many trials occurred for each session date?

```
groupsummary(data,"session_date")
```

ans = 31×2 table

	session_date	GroupCount
1	14-Dec-2016	364
2	17-Dec-2016	401
3	18-Dec-2016	378
4	07-Jan-2017	554
5	08-Jan-2017	632
6	09-Jan-2017	585
7	10-Jan-2017	363
8	11-Jan-2017	252
9	12-Jan-2017	238
10	15-May-2017	357
11	16-May-2017	345
12	18-May-2017	194
13	15-Jun-2017	360

	session_date	GroupCount
14	16-Jun-2017	482
15	17-Jun-2017	557
16	18-Jun-2017	452
17	11-Oct-2017	453
18	29-Oct-2017	253
19	30-Oct-2017	347
20	31-Oct-2017	370
21	01-Nov-2017	660
22	02-Nov-2017	770
23	04-Nov-2017	400
24	05-Nov-2017	362
25	05-Dec-2017	450
26	06-Dec-2017	831
27	07-Dec-2017	746
28	08-Dec-2017	805
29	09-Dec-2017	699
30	10-Dec-2017	334
31	11-Dec-2017	426

Exercises

How many trials did each mouse participate in?

```
groupsummary(data,"mouse")
```

ans = 10×2 table

	mouse	GroupCount
1	'Cori'	1143
2	'Forssmann'	1485
3	'Hench'	1851
4	'Lederberg'	2902
5	'Moniz'	896
6	'Muller'	1112
7	'Radnitz'	1512
8	'Richards'	1677
9	'Tatum'	1389

	mouse	GroupCount
10	'Theiler'	453

What was the mean response time for each mouse?

```
groupsummary(data,"mouse", "mean", "response_time")
```

ans = 10×3 table

	mouse	GroupCount	mean_response_time
1	'Cori'	1143	1.5909
2	'Forssmann'	1485	1.4706
3	'Hench'	1851	1.5257
4	'Lederberg'	2902	1.1438
5	'Moniz'	896	1.7777
6	'Muller'	1112	1.5758
7	'Radnitz'	1512	1.5591
8	'Richards'	1677	1.3583
9	'Tatum'	1389	1.3377
10	'Theiler'	453	1.3388

What was the minimum response time for each mouse?

```
groupsummary(data,"mouse", "min", "response_time")
```

ans = 10×3 table

	mouse	GroupCount	min_response_time
1	'Cori'	1143	0.5682
2	'Forssmann'	1485	0.4949
3	'Hench'	1851	0.5522
4	'Lederberg'	2902	0.4794
5	'Moniz'	896	0.6826
6	'Muller'	1112	0.5854
7	'Radnitz'	1512	0.5838
8	'Richards'	1677	0.5059
9	'Tatum'	1389	0.5136
10	'Theiler'	453	0.4826

What was the most common (ie. mode) reaction_type for each mouse?

```
groupsummary(data,"mouse", "mode", "reaction_type")
```

ans = 10×3 table

	mouse	GroupCount	mode_reaction_type
1	'Cori'	1143	1
2	'Forssmann'	1485	-1
3	'Hench'	1851	1
4	'Lederberg'	2902	-1
5	'Moniz'	896	-1
6	'Muller'	1112	1
7	'Radnitz'	1512	-1
8	'Richards'	1677	0
9	'Tatum'	1389	1
10	'Theiler'	453	-1

What was the range of response times for each session date?

```
groupsummary(data,"session_date", "range", "response_time")
```

ans = 31×3 table

	session_date	GroupCount	range_response_time
1	14-Dec-2016	364	2.1054
2	17-Dec-2016	401	2.1227
3	18-Dec-2016	378	2.1076
4	07-Jan-2017	554	2.1245
5	08-Jan-2017	632	2.1158
6	09-Jan-2017	585	2.0917
7	10-Jan-2017	363	2.0796
8	11-Jan-2017	252	2.0306
9	12-Jan-2017	238	1.9787
10	15-May-2017	357	1.9979
11	16-May-2017	345	1.9422
12	18-May-2017	194	2.0036
13	15-Jun-2017	360	2.1031
14	16-Jun-2017	482	2.1031
15	17-Jun-2017	557	2.1477
16	18-Jun-2017	452	2.1003

	session_date	GroupCount	range_response_time
17	11-Oct-2017	453	1.8149
18	29-Oct-2017	253	1.7838
19	30-Oct-2017	347	1.7732
20	31-Oct-2017	370	1.7786
21	01-Nov-2017	660	2.0965
22	02-Nov-2017	770	2.0941
23	04-Nov-2017	400	2.1014
24	05-Nov-2017	362	2.0450
25	05-Dec-2017	450	1.8265
26	06-Dec-2017	831	1.7957
27	07-Dec-2017	746	1.7987
28	08-Dec-2017	805	1.8028
29	09-Dec-2017	699	1.7936
30	10-Dec-2017	334	1.8043
31	11-Dec-2017	426	1.8051

Rerun the last exercise replaceing "range" with "all"

```
groupsummary(data,"session_date", "all", "response_time")
```

ans = 31×14 table

...

	session_date	GroupCount	mean_response_time	sum_response_time
1	14-Dec-2016	364	1.5891	340.0590
2	17-Dec-2016	401	1.6215	407.0063
3	18-Dec-2016	378	1.5588	355.4048
4	07-Jan-2017	554	1.4704	652.8560
5	08-Jan-2017	632	1.5457	636.8091
6	09-Jan-2017	585	1.5928	581.3877
7	10-Jan-2017	363	1.5594	394.5252
8	11-Jan-2017	252	1.7116	243.0486
9	12-Jan-2017	238	1.7461	223.5022
10	15-May-2017	357	1.8110	447.3048
11	16-May-2017	345	1.7360	407.9650
12	18-May-2017	194	1.7903	221.9923

	session_date	GroupCount	mean_response_time	sum_response_time
13	15-Jun-2017	360	1.5966	399.1487
14	16-Jun-2017	482	1.5267	567.9217
15	17-Jun-2017	557	1.5365	686.8323
16	18-Jun-2017	452	1.4588	498.9053
17	11-Oct-2017	453	1.3388	459.1916
18	29-Oct-2017	253	1.5516	221.8733
19	30-Oct-2017	347	1.2720	301.4613
20	31-Oct-2017	370	1.2728	330.9329
21	01-Nov-2017	660	1.4954	657.9610
22	02-Nov-2017	770	1.5086	829.7035
23	04-Nov-2017	400	1.3697	397.2008
24	05-Nov-2017	362	1.3034	328.4642
25	05-Dec-2017	450	1.0853	369.0114
26	06-Dec-2017	831	1.1399	696.4913
27	07-Dec-2017	746	1.2797	673.1457
28	08-Dec-2017	805	1.2439	727.6932
29	09-Dec-2017	699	1.3146	629.6959
30	10-Dec-2017	334	1.1194	250.7539
31	11-Dec-2017	426	1.1431	361.2161

What was the largest number of trials that any mouse took part in? **Hint** - the `groupsummary` function returns a table, from which you can perform compuations on

```
mouse_trial_count = groupsummary(data,"mouse");
max(mouse_trial_count.GroupCount)
```

```
ans = 2902
```

How many trials did each mouse take part in on each session date?

```
groupsummary(data,["mouse","session_date"])
```

```
ans = 39×3 table
```

	mouse	session_date	GroupCount
1	'Cori'	14-Dec-2016	364
2	'Cori'	17-Dec-2016	401
3	'Cori'	18-Dec-2016	378

	mouse	session_date	GroupCount
4	'Forssmann'	01-Nov-2017	359
5	'Forssmann'	02-Nov-2017	364
6	'Forssmann'	04-Nov-2017	400
7	'Forssmann'	05-Nov-2017	362
8	'Hench'	15-Jun-2017	360
9	'Hench'	16-Jun-2017	482
10	'Hench'	17-Jun-2017	557
11	'Hench'	18-Jun-2017	452
12	'Lederberg'	05-Dec-2017	450
13	'Lederberg'	06-Dec-2017	410
14	'Lederberg'	07-Dec-2017	378
15	'Lederberg'	08-Dec-2017	514
16	'Lederberg'	09-Dec-2017	390
17	'Lederberg'	10-Dec-2017	334
18	'Lederberg'	11-Dec-2017	426
19	'Moniz'	15-May-2017	357
20	'Moniz'	16-May-2017	345
21	'Moniz'	18-May-2017	194
22	'Muller'	07-Jan-2017	554
23	'Muller'	08-Jan-2017	261
24	'Muller'	09-Jan-2017	297
25	'Radnitz'	08-Jan-2017	371
26	'Radnitz'	09-Jan-2017	288
27	'Radnitz'	10-Jan-2017	363
28	'Radnitz'	11-Jan-2017	252
29	'Radnitz'	12-Jan-2017	238
30	'Richards'	29-Oct-2017	253
31	'Richards'	30-Oct-2017	347
32	'Richards'	31-Oct-2017	370
33	'Richards'	01-Nov-2017	301
34	'Richards'	02-Nov-2017	406
35	'Tatum'	06-Dec-2017	421
36	'Tatum'	07-Dec-2017	368

	mouse	session_date	GroupCount
37	'Tatum'	08-Dec-2017	291
38	'Tatum'	09-Dec-2017	309
39	'Theiler'	11-Oct-2017	453

What was the average number of trials that each mouse participated in in a session?

```
mouse_session_count = groupsummary(data,["mouse","session_date"]);
mean(mouse_session_count.GroupCount)
```

```
ans = 369.7436
```

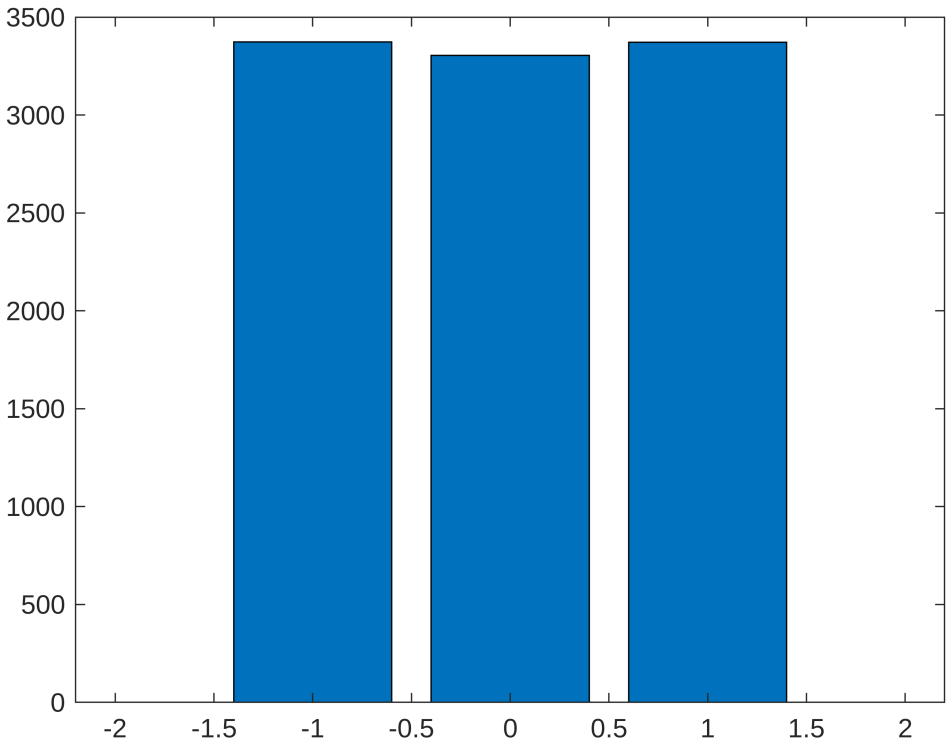
Visualizing the Experimental Design using Plots

Code	Description
`bar(x_data, y_data)`	make a bar plot of x and y data
`bar( x_data, y_data, "green")`	make a bar plot with green bars
`sortrows(table, "column_A")`	sort a table according to values in column_A
`ylabel("a new label")`	set the y label of a plot
`categorical(data_values)`	convert data_values to be categorical
`piechart(categorical_data)`	make a piechart from categorical_data
`swarmchart(categorical_data, y_data)`	make a swarmchart from categorical data and numerical y_data

Example Exercise

Make a bar plot showing how many times each response type appeared in the data

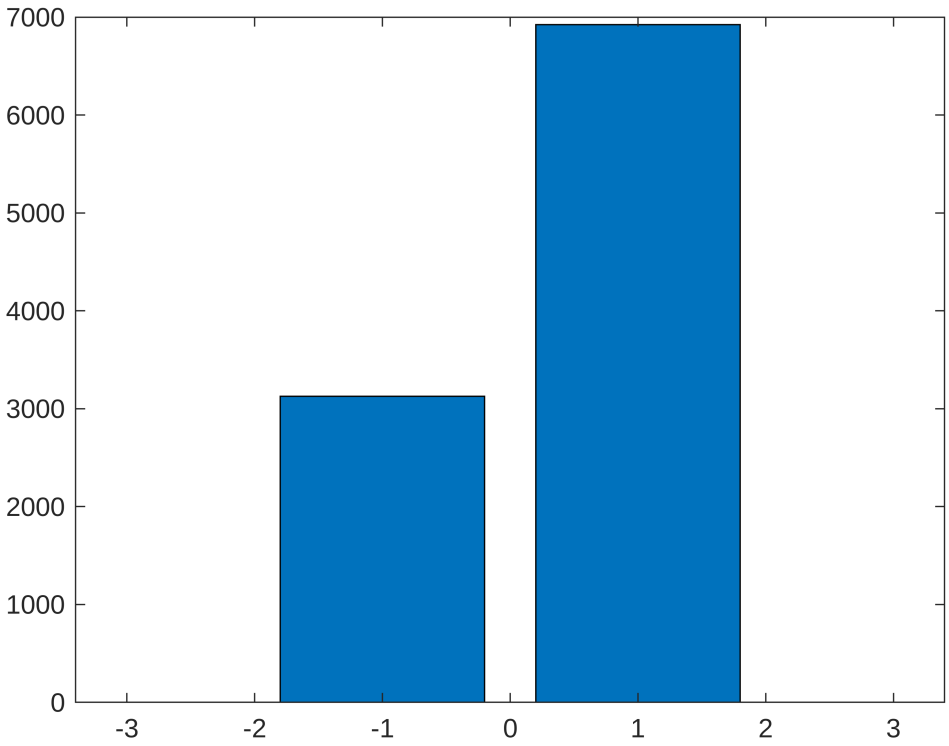
```
response_type_count = groupsummary(data, "response_type");
bar(response_type_count.response_type, response_type_count.GroupCount)
```



Exercises

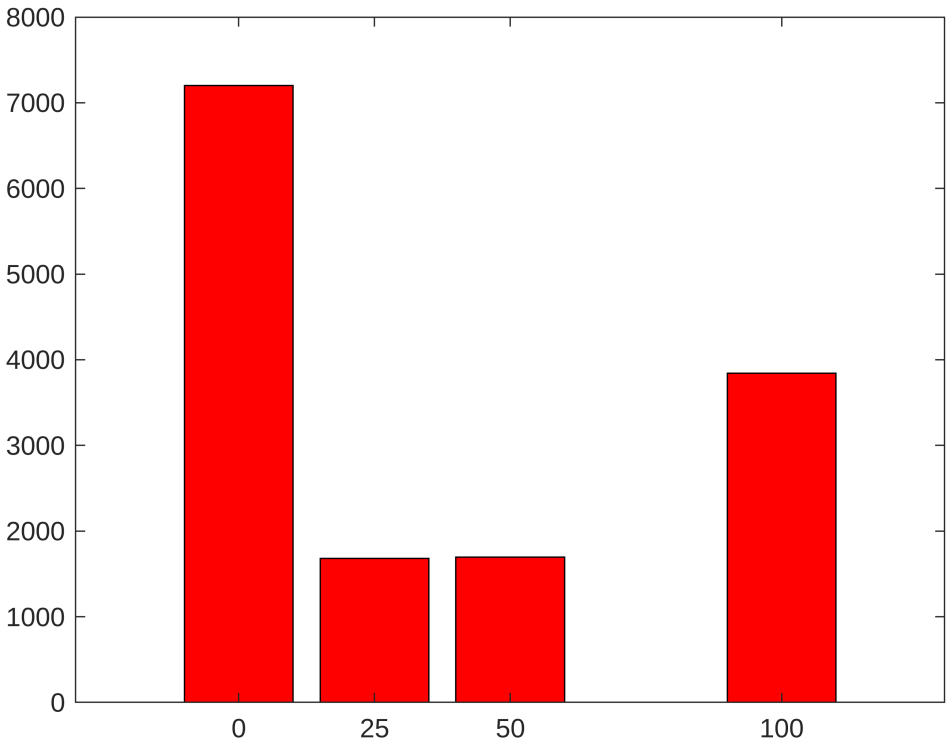
Plot the counts of feedback type from the dataset as a bar plot

```
response_type_count = groupsummary(data, "feedback_type");
bar(response_type_count.feedback_type, response_type_count.GroupCount)
```



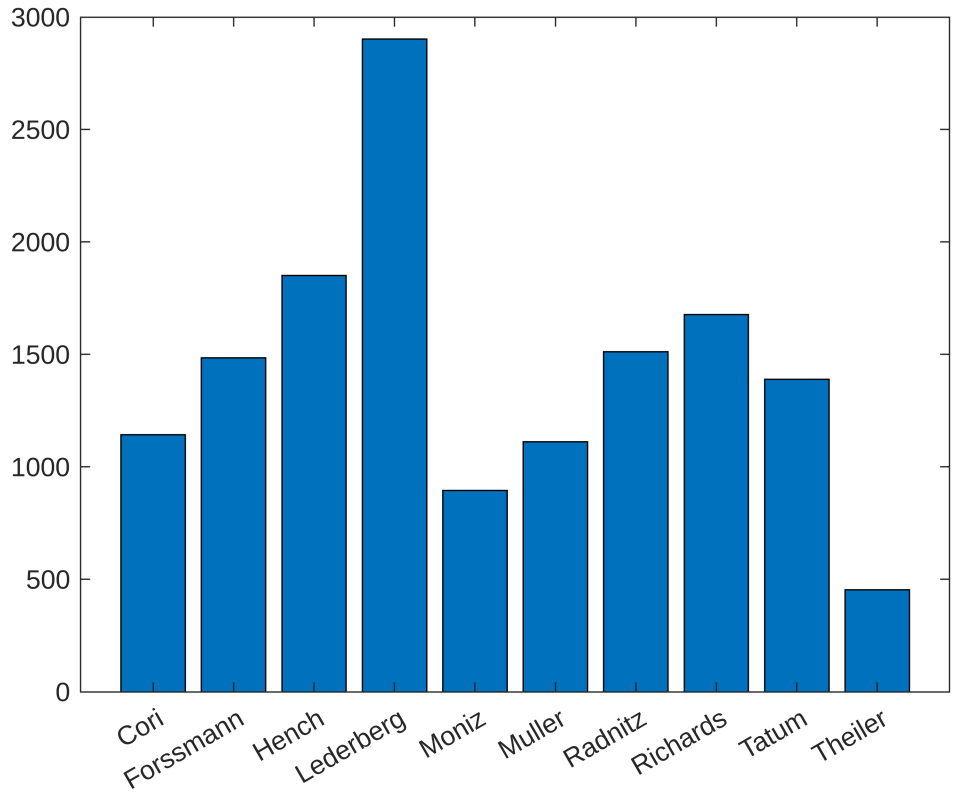
Make a bar plot showing the frequency of each `contrast_left` value with red bars

```
contrast_left_count = groupsummary(data, "contrast_left");
bar(contrast_left_count.contrast_left, contrast_left_count.GroupCount, 'red')
```



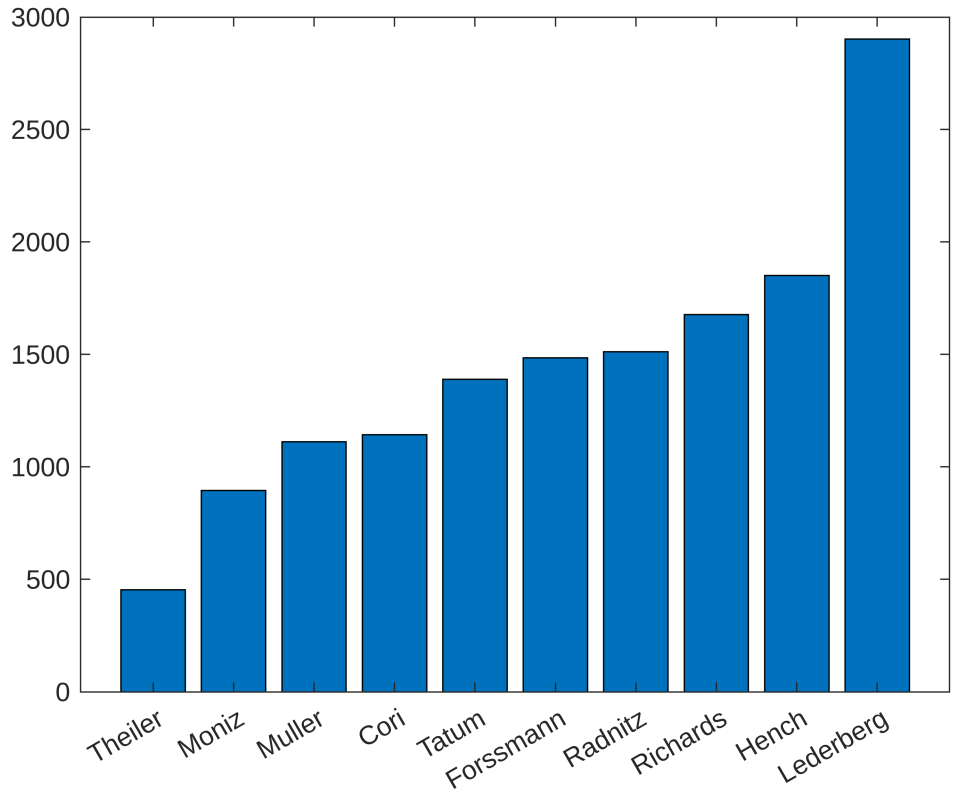
Make a bar plot showing how many trials each mouse participated in

```
trials_by_mouse = groupsummary(data, "mouse");
bar(trials_by_mouse.mouse, trials_by_mouse.GroupCount)
```



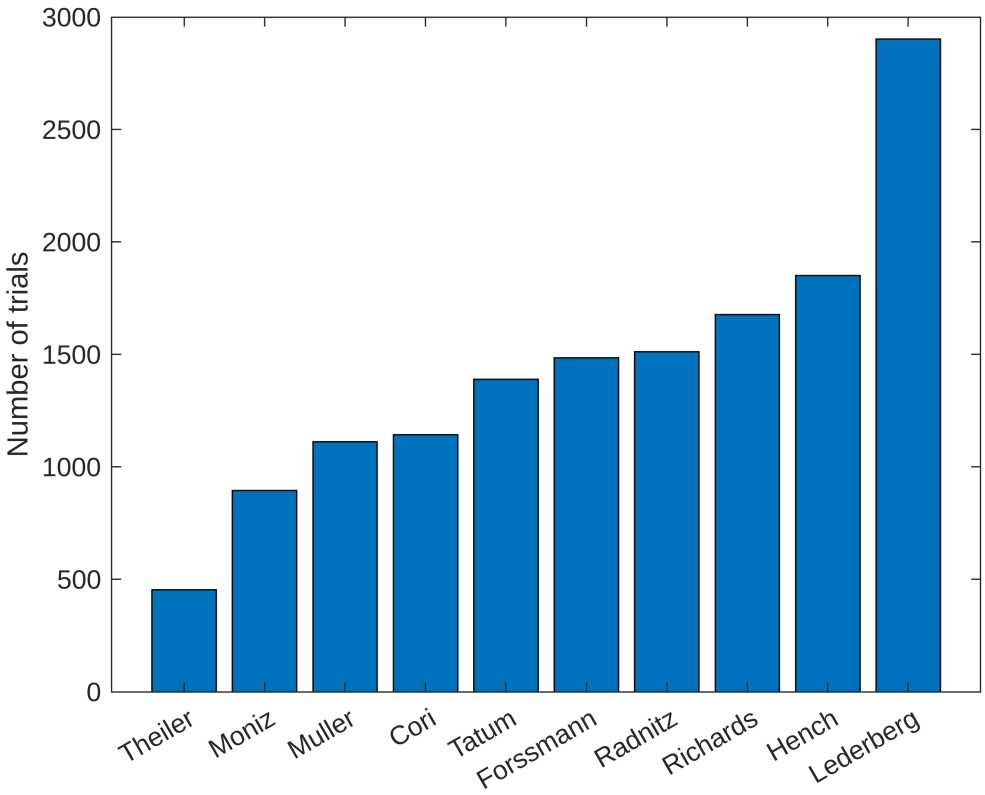
Recreate the above bar plot, but sorting the bars from smallest to largest.

```
trials_by_mouse = groupsummary(data, "mouse");
trials_by_mouse = sortrows(trials_by_mouse, "GroupCount");

bar(trials_by_mouse.mouse, trials_by_mouse.GroupCount)
```



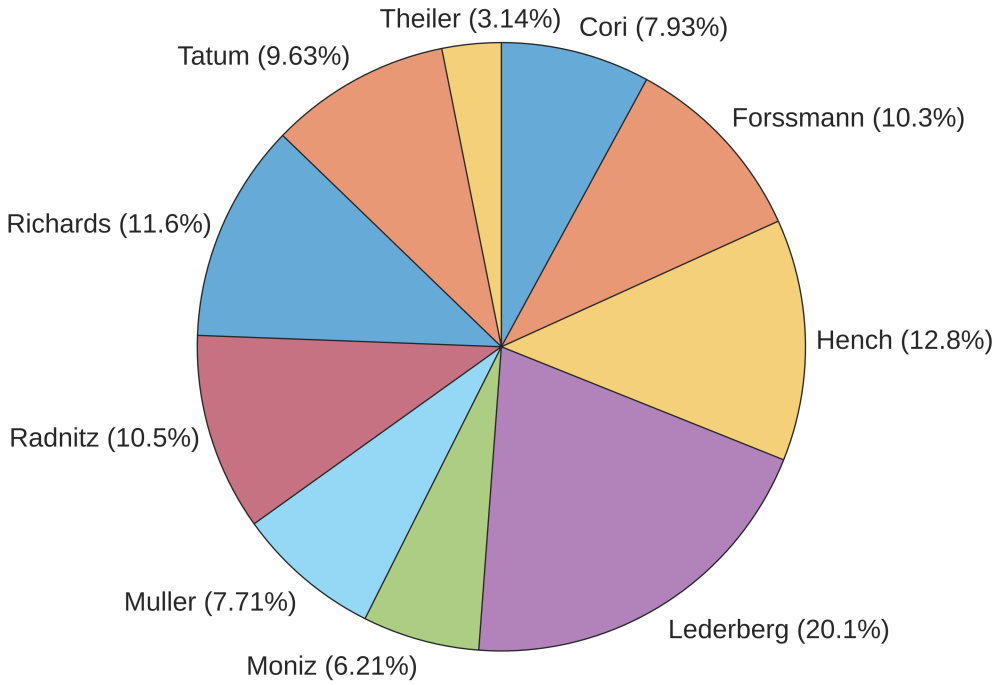
Add an appropriate y label to your plot

```
trials_by_mouse = groupsummary(data, "mouse");
trials_by_mouse = sortrows(trials_by_mouse, "GroupCount");

bar(trials_by_mouse.mouse, trials_by_mouse.GroupCount)
ylabel('Number of trials')
```



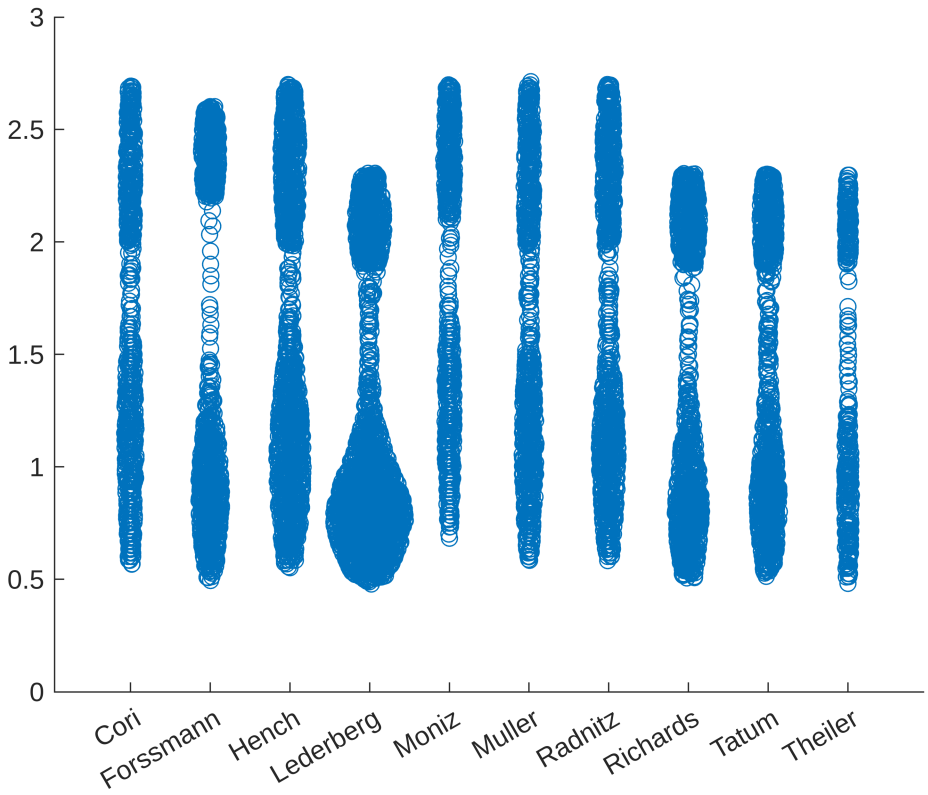
Make a pie chart showing the percentage of trials that each mouse participated in. **Hint** - the input to piechart must be categorical data.

```
mice = categorical(data.mouse);
piechart(mice)
```



Make a swarmchart showing the response time distributions for each mouse. **Hint** - the x data inputted to swarmchart must be categorical data

```
swarmchart(categorical(data.mouse), data.response_time)
```



Constructing a 3D bar plot

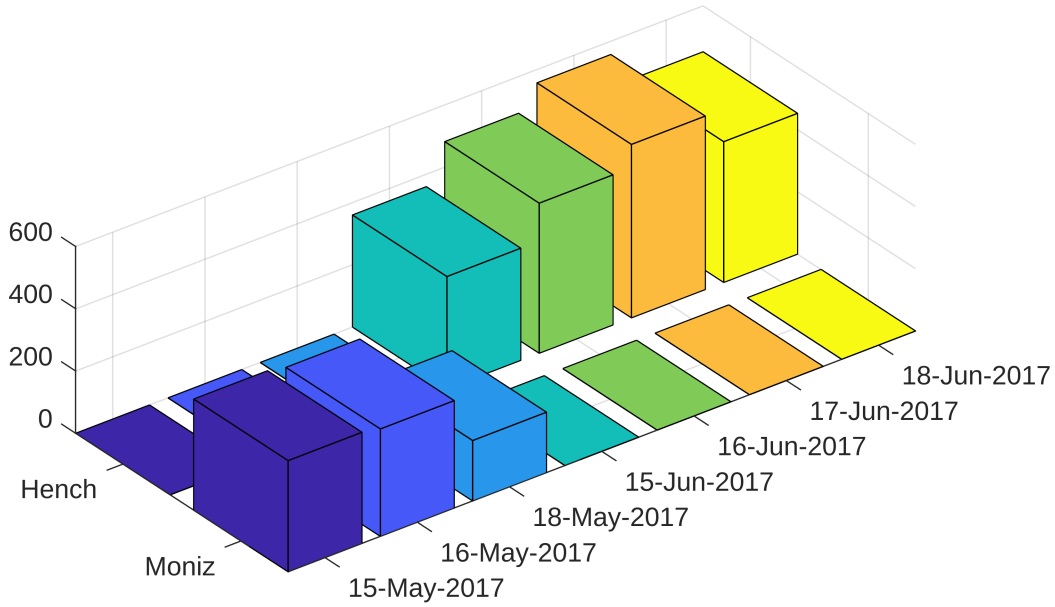
The following code makes a 3D bar plot showing how many trials each mouse underwent on each session date for the summer 2017 dataset.

You can see that several lines are "hard-coded", like the `session_dates` and y tick labels. Your challenge is to remove this hard-coding to make the plot generation generalisable.

Code	Description
`unique(my_array)`	find the unique values in `my_array`
`length(my_array)`	find the number of elements in `my_array`
`reshape(my_matrix, n_cols, n_rows)`	reshape a matrix to have `n_cols` columns and `n_rows` rows
`xticks([start: interval: end])`	put xticks at x values defined by `start`, `interval` and `end`

```
mouse_names = ["Hench", "Moniz"];
session_dates = ["15-May-2017","16-May-2017", "18-May-2017",...
    "15-Jun-2017","16-Jun-2017", "17-Jun-2017", "18-Jun-2017"];
```

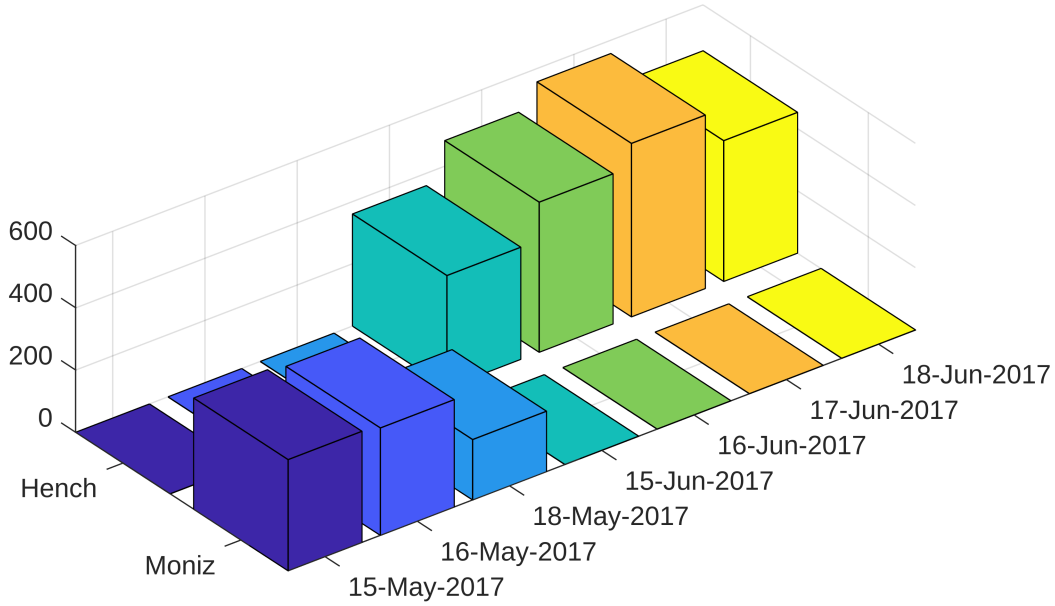
```
mouse_session_counts=groupcounts({data_summer2017.mouse,
data_summer2017.session_date}, "IncludeEmptyGroups",true);


reshaped_data_for_plot = reshape(mouse_session_counts,7,2)';
bar3(reshaped_data_for_plot)
yticklabels(["Hench","Moniz"])
xticks([1:1: 7])
xticklabels(datestr(session_dates))
```



Remake the above plot, removing the hard-coding from the variable `mouse_names`

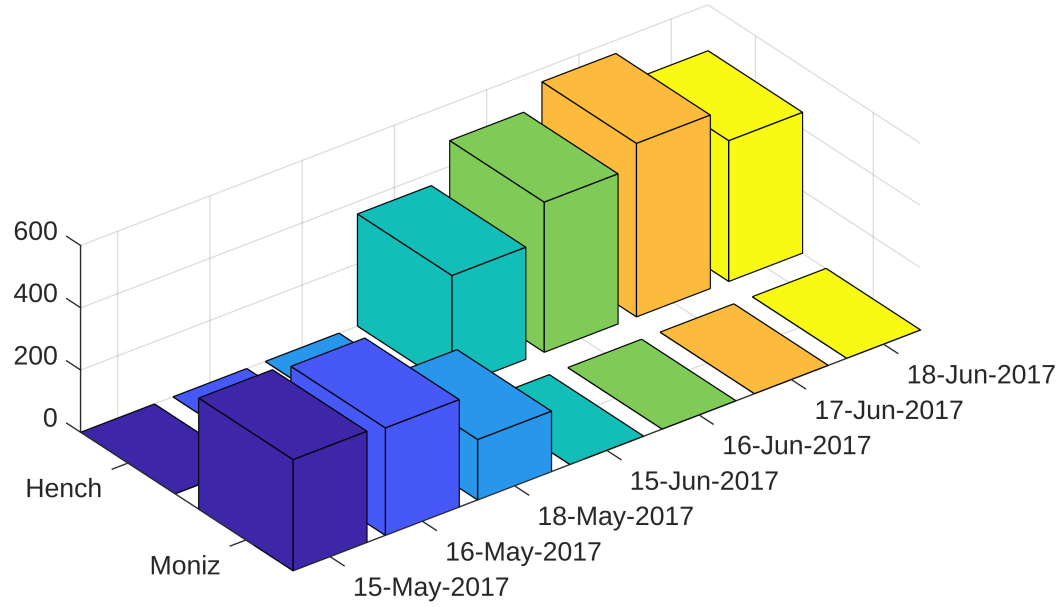
```
mouse_names = unique(data_summer2017.mouse);
session_dates = ["15-May-2017","16-May-2017", "18-May-2017",...
    "15-Jun-2017","16-Jun-2017", "17-Jun-2017", "18-Jun-2017"];

mouse_session_counts=groupcounts({data_summer2017.mouse,
data_summer2017.session_date}, "IncludeEmptyGroups",true);


reshaped_data_for_plot = reshape(mouse_session_counts,7,2)';
bar3(reshaped_data_for_plot)
yticklabels(["Hench","Moniz"])
xticks([1:1: 7])
```

```
xticklabels(datestr(session_dates))
```



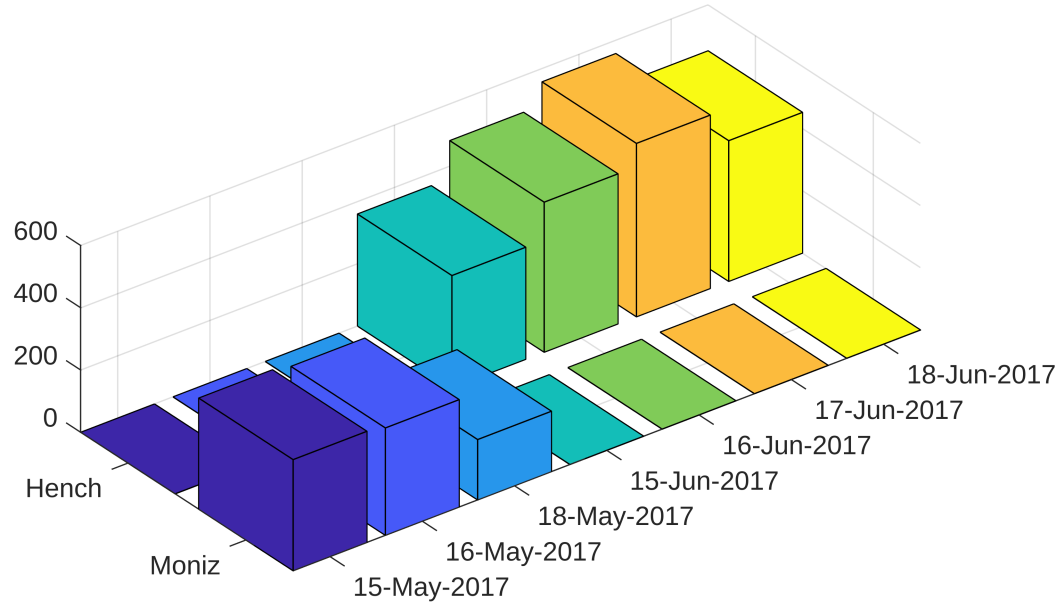
Remake the above plot, removing the hard-coding from the variable `session_dates`

```
mouse_names =unique(data_summer2017.mouse);
session_dates = unique(data_summer2017.session_date);

mouse_session_counts=groupcounts({data_summer2017.mouse,
data_summer2017.session_date}, "IncludeEmptyGroups",true);


reshaped_data_for_plot = reshape(mouse_session_counts,7,2)';
bar3(reshaped_data_for_plot)
yticklabels(["Hench","Moniz"])
xticks([1:1: 7])
xticklabels(datestr(session_dates))
```



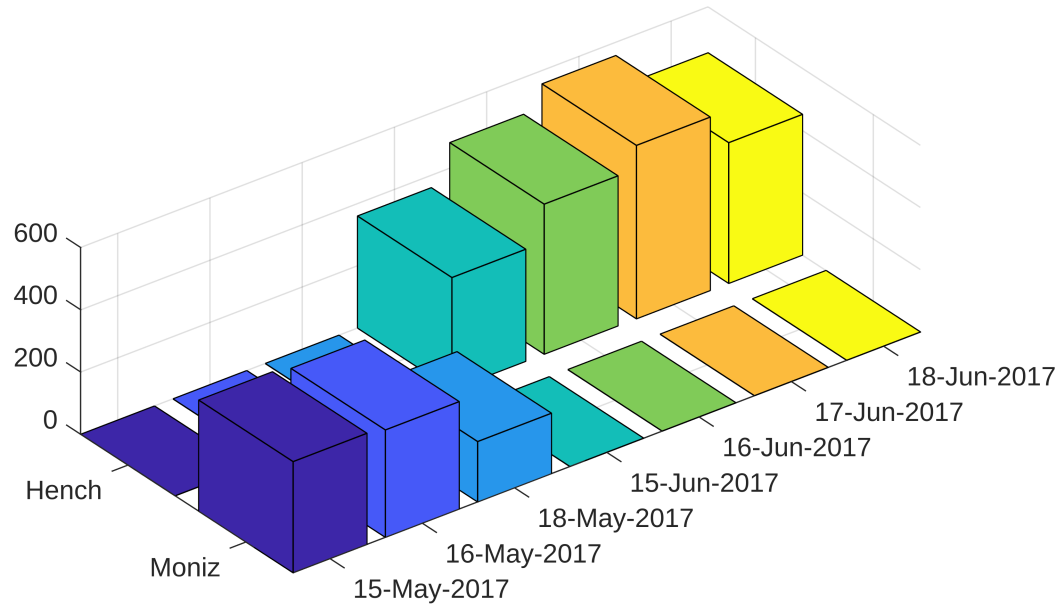
The `reshape` that produces `reshaped_data_for_plot` contains hard-coded numbers. Replace these with appropriate functions

```
mouse_names =unique(data_summer2017.mouse);
session_dates = unique(data_summer2017.session_date);

mouse_session_counts=groupcounts({data_summer2017.mouse,
data_summer2017.session_date}, "IncludeEmptyGroups",true);


reshaped_data_for_plot =
reshape(mouse_session_counts,length(session_dates),length(mouse_names))';
bar3(reshaped_data_for_plot)
yticklabels(["Hench","Moniz"])
xticks([1:1: 7])
xticklabels(datestr(session_dates))
```



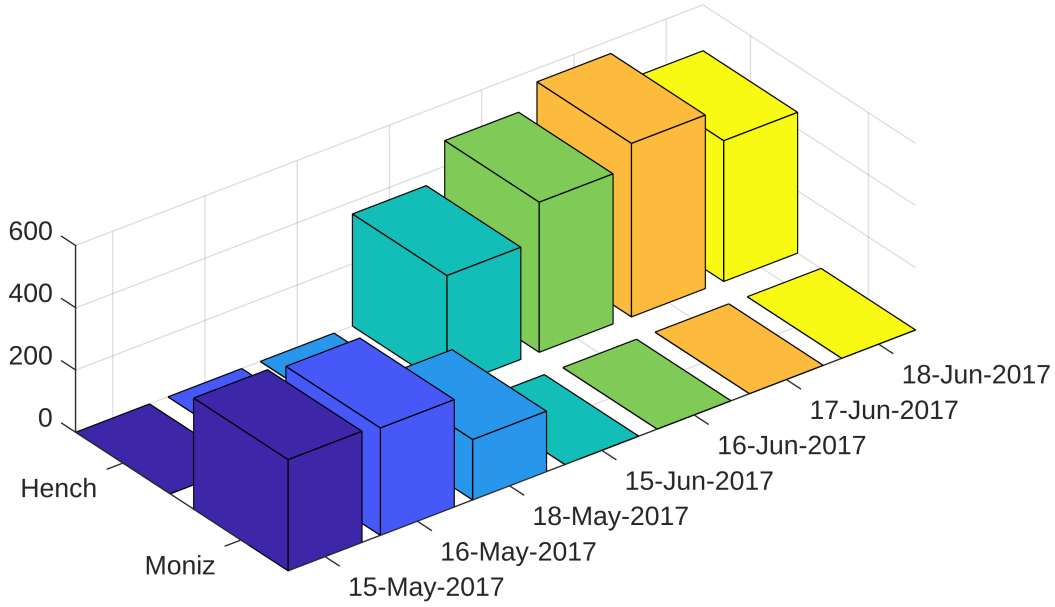
Replace the hard-coded values that set the y tick labels

```
mouse_names =unique(data_summer2017.mouse);
session_dates = unique(data_summer2017.session_date);

mouse_session_counts=groupcounts({data_summer2017.mouse,
data_summer2017.session_date}, "IncludeEmptyGroups",true);


reshaped_data_for_plot =
reshape(mouse_session_counts,length(session_dates),length(mouse_names))';
bar3(reshaped_data_for_plot)
yticklabels(mouse_names)
xticks([1:1: 7])
xticklabels(datestr(session_dates))
```



Lastly, remove the hard-coding that sets the positions of the xticks. **Hint** - replace the value 7 with a `length()` function

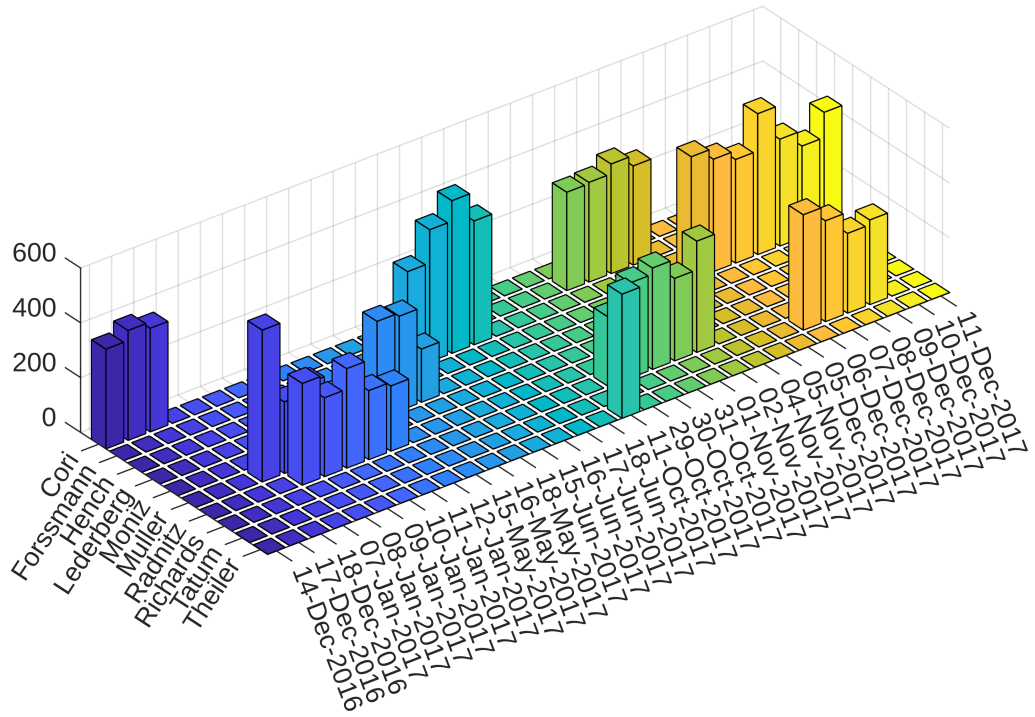
```
mouse_names =unique(data_summer2017.mouse);
session_dates = unique(data_summer2017.session_date);

mouse_session_counts=groupcounts({data_summer2017.mouse,
data_summer2017.session_date}, "IncludeEmptyGroups",true);


reshaped_data_for_plot =
reshape(mouse_session_counts,length(session_dates),length(mouse_names))';
bar3(reshaped_data_for_plot)
yticklabels(mouse_names)
xticks([1:1: length(session_dates)])
xticklabels(datestr(session_dates))
```



Now you have built a recipe that can make a similar plot for any of the datasets! Make the plot for the complete dataset, `data`

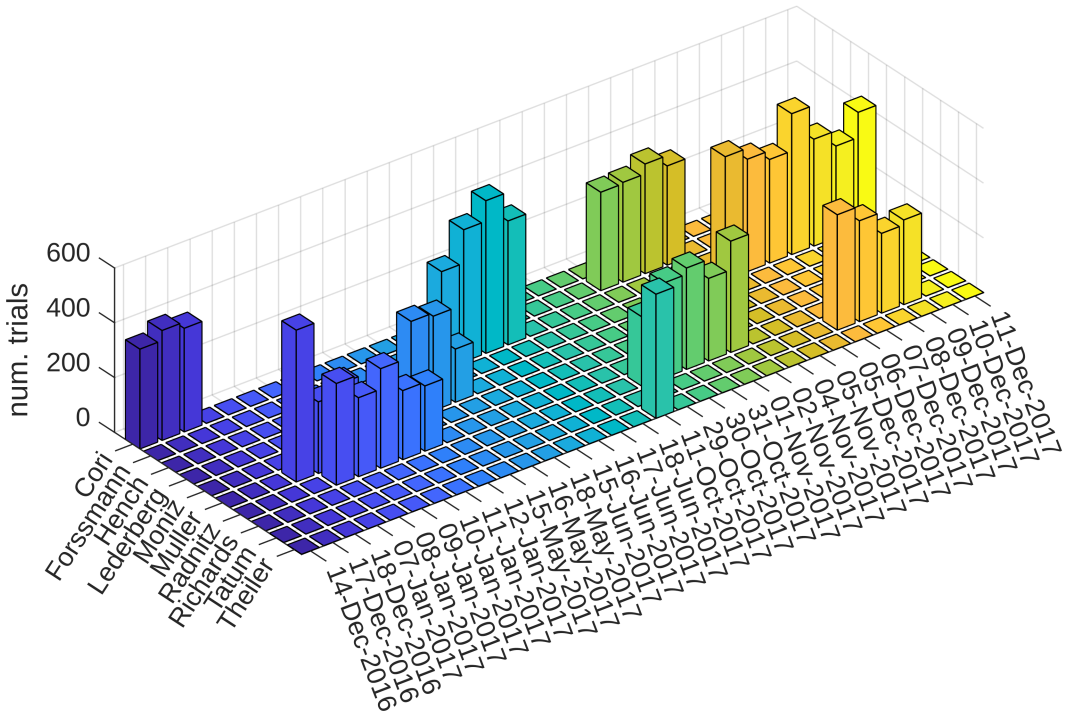
```
data = [data_winter2016; data_winter2017; data_summer2017];
```

```
mouse_names =unique(data.mouse);
session_dates = unique(data.session_date);

mouse_session_counts=groupcounts({data.mouse, data.session_date},
"IncludeEmptyGroups",true);

reshaped_data_for_plot =
reshape(mouse_session_counts,length(session_dates),length(mouse_names))';
bar3(reshaped_data_for_plot)
yticklabels(mouse_names)
xticks([1:1: length(session_dates)])
xticklabels(datestr(session_dates))
```



Add an appropriate label for the z axis to your plot

```
mouse_names =unique(data.mouse);
session_dates = unique(data.session_date);

mouse_session_counts=groupcounts({data.mouse, data.session_date},
"IncludeEmptyGroups",true);

reshaped_data_for_plot =
reshape(mouse_session_counts,length(session_dates),length(mouse_names))';
bar3(reshaped_data_for_plot)
yticklabels(mouse_names)
xticks([1:1: length(session_dates)])
xticklabels(datestr(session_dates))
zlabel('num. trials')
```


num. trials
600
400
200
0
Cori
Forssmann
Hench
Lederberg
Moniz
Muller
Radnitz
Richards
Tatum
Theiler
14-Dec-2016
17-Dec-2016
18-Dec-2016
07-Jan-2017
08-Jan-2017
09-Jan-2017
10-Jan-2017
11-Jan-2017
12-Jan-2017
15-May-2017
16-May-2017
18-May-2017
15-Jun-2017
16-Jun-2017
17-Jun-2017
18-Jun-2017
29-Oct-2017
30-Oct-2017
31-Oct-2017
01-Nov-2017
02-Nov-2017
04-Nov-2017
05-Nov-2017
06-Dec-2017
07-Dec-2017
08-Dec-2017
09-Dec-2017
10-Dec-2017
11-Dec-2017