Metarate example

This script provides examples of how the functions in this repository can be used to:

- calculate rate measures using the proportional duration summation method
- conduct a scalographic analysis
- plot a scalogram and a difference of scalograms

The workflow used to conduct analyses for the paper "Parameters of unit-based measures of speech rate" is documented in `metarate_workflow.mlx`.

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Setup

To run this script you should be in the `MetaRate` repository directory.

```
if ~contains(pwd,'MetaRate')
    fprintf('WARNING: current directory should be the top-level directory of the MetaRate repository\n');
return
end
```

Add all sub-directories of the respository to the path:

```
addpath(genpath('.'));
```

Two inputs are necessary for our scalographic analyses:

- The proportional durations table.
- The targets data table.

Proportional durations table

This is table that contains the proportional duration (or proportional unit count) timeseries for each utterance. Here we use `example_propdurs_table.mat`, which is based on segmented utterances from a single speaker (F01) from the HPRC corpus. It can be found in the `examples` subdirectory of this repository.

```
load('example_propdurs_table.mat');
head(TR);
```

```
     subj      block    sent    rep    rate                         text                               words
    _______    _____    ____    ___    _____    _______________________________________________    ___________    _

    {'F01'}      1       1       1     {'F'}    {'The birch canoe slid on the smooth planks.' }    {1×10 cell}    {
    {'F01'}      1       1       1     {'N'}    {'The birch canoe slid on the smooth planks.' }    {1×10 cell}    {
    {'F01'}      1       1       2     {'N'}    {'The birch canoe slid on the smooth planks.' }    {1×11 cell}    {
    {'F01'}      1       2       1     {'F'}    {'Glue the sheet to the dark blue background.'}    {1×10 cell}    {
    {'F01'}      1       2       1     {'N'}    {'Glue the sheet to the dark blue background.'}    {1×10 cell}    {
    {'F01'}      1       2       2     {'N'}    {'Glue the sheet to the dark blue background.'}    {1×10 cell}    {
    {'F01'}      1       3       1     {'F'}    {'It's easy to tell the depth of a well.'     }    {1×11 cell}    {
    {'F01'}      1       3       1     {'N'}    {'It's easy to tell the depth of a well.'     }    {1×11 cell}    {
```

Unit-based segmentations

At least one unit-based segmentation of each utterance is needed. Here our utterances are associated with arrays of unit labels, such as phones and words:

```
list_of_phones = TR.phones{1}
```

```
list_of_phones = 1×29 cell
'sp'          'DH'          'AH0'         'B'           'ER1'         'CH'          'K ⋯
```

```
list_of_words = TR.words{1}
```

```
list_of_words = 1×10 cell
'sp'          'THE'         'BIRCH'       'CANOE'       'SLID'        'ON'          'T ⋯
```

The start and end times of each unit (here relative to the beginning of the recording) must be included as well, e.g.:

```
vector_of_phone_start_times = TR.phones_t0{1}
```

```
vector_of_phone_start_times = 1×29
         0    0.2000    0.2499    0.2898    0.3596    0.4594    0.5293    0.5991 ⋯
```

```
vector_of_phone_end_times = TR.phones_t1{1}
```

```
vector_of_phone_end_times = 1×29
    0.2000    0.2499    0.2898    0.3596    0.4594    0.5293    0.5991    0.6290 ⋯
```

In addition, maps between units at different levels must be included (if one wants to use a rate unit that differs from the target unit)

```
%the integer indices of words for each phone:
indices_of_words_byphone = TR.phones_words_ix{1}
```

```
indices_of_words_byphone = 1×29
```

```
    1     2     2     3     3     3     4     4     4     4     5     5     5⋯
```

```
%the integer indices of phones for each word:
indices_of_phones_byword = TR.words_phones_ix{1}
```

```
indices_of_phones_byword = 1×10 cell
```

...

	1	2	3	4	5	6	7	8
1	1	[2,3]	[4,5,6]	[7,8,9,10]	[11,12,13...	[15,16]	[17,18]	[19,20,21...

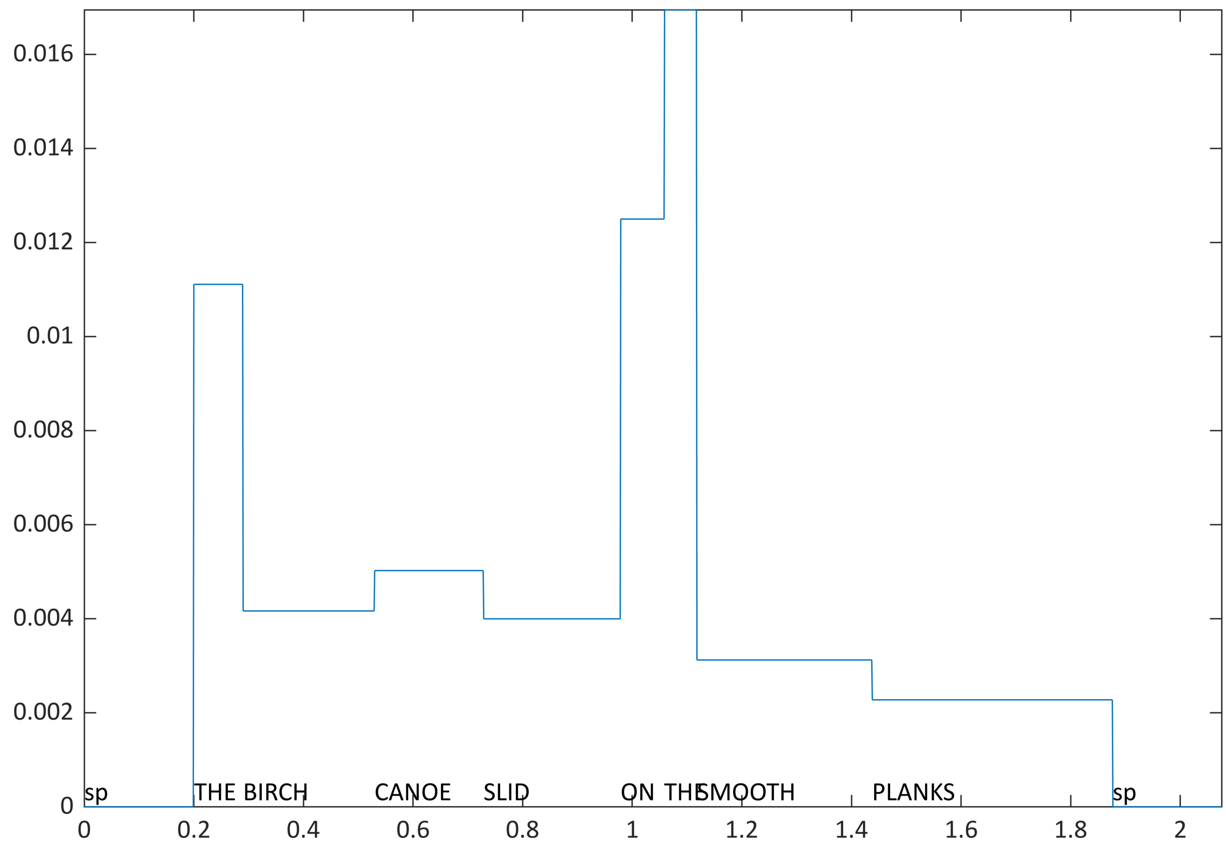
Calculating proportional the proportional duration timeseries

Use the function `metarate_calc_prop_durs` as shown below, to calculate the timeseries of proportional durations (or proportional unit counts) for a given type of unit, and add these to the proportional durations table:

```
unit = 'words';
dt = 0.001;

for i=1:height(TR)

    %calculates frame time-points, proportional counts, and indices
    [frpnts,prop_dur,UIX] = metarate_calc_prop_durs(TR(i,:),unit,dt);

    %add the outputs to the table:
    TR.frt{i} = frpnts;
    TR.([unit '_pdur']){i} = prop_dur;
    TR.([unit '_pdur_map']){i} = uint8(UIX);     %max of 256 different units in utterance
end
```

A proportional unit count timeseries looks like this:

```
figls; plot(TR.frt{1},TR.words_pdur{1});
for i=1:length(TR.words{1}), text(TR.words_t0{1}(i),0,TR.words{1}{i},'verti','bot'); end
axis tight;
```



Target data table

A table of target variables is needed.

```
load('example_targets_table.mat','D');
```

This table contains the duration of each phone, along with its start and end times, its midpoint, and its index (in the utterance):

```
info_target_phone = head(D(:,{'phones' 'dur' 't0' 't1' 'tmid' 'ix'}))
```

info_target_phone = 8×6 table

	phones	dur	t0	t1	tmid	ix
1	'B'	0.0698	0.2898	0.3596	0.3247	4
2	'P'	0.0898	1.4372	1.5270	1.4821	23
3	'B'	0.0998	0.2698	0.3696	0.3197	4
4	'P'	0.0898	1.9161	2.0059	1.9610	23
5	'B'	0.0798	0.2798	0.3596	0.3197	4
6	'P'	0.0898	1.9760	2.0658	2.0209	24

	phones	dur	t0	t1	tmid	ix
7	'B'	0.0299	1.0580	1.0880	1.0730	18
8	'B'	0.0599	1.1977	1.2576	1.2277	21

The table also contains information about the higher-level units that contain the phones:

```
head(D(:,{'words' 'words_t0' 'words_t1'}))
```

```
       words         words_t0    words_t1
    _____________    ________    ________

    {'BIRCH'     }     0.2898     0.52925
    {'PLANKS'    }     1.4372      1.8762
    {'BIRCH'     }    0.26984     0.61905
    {'PLANKS'    }     1.9161       2.405
    {'BIRCH'     }    0.27982     0.59909
    {'PLANKS'    }      1.976      2.4549
    {'BLUE'      }      1.058      1.1977
    {'BACKGROUND'}     1.1977      1.6667
```

Scalographic analysis

Required inputs

The function `metarate_scalographic_analysis` conducts a scalographic analysis. It requires a table of proportional durations and a table of targets (both described above).

Analysis parameters

The function takes the following parameters:

data_selection

- 'bytarget' (default): use only datapoints that fit in all rate-estimation windows
- 'bywindow': for a given rate-estimation window, use whatever datapoints fit in that window

target_exclusion

- true (default): exclude from the rate-estimation window the rate-unit that contains the target
- false: do not exclude the target-containing rate unit

window_method

- 'centered' (default): windows are centered on target units
- 'beginanchored': windows are left-aligned to ends of target units

- 'endanchored': windows are right-aligned to beginnings of target units
- 'extendwin': centered windows which are extended to compensate for exclusion
- 'adaptivewin': windows which are shifted to remain within utterance

Please see ./metarate_windef_methods.mlx for examples of the above window methods.

unit

This is the unit used for calculating rate. The default is "phones". The name of the unit must correspond to fields in both the proportional durations table and the targets table.

Specifically:

- The proportional durations table must contain a field with the unit name suffixed by '_pdur'. For example if "words" is the rate unit, the proportional durations table must contain a column named 'words_pdur'.
- The targets data table must contain columns that indicated start/end times of the rate unit. For example if "words" is the rate unit, the targets data table must contain columns named 'words_t0' and words_t1'.

```
head(D(:,{'phones' 'fname' 'words_t0', 'words_t1'}));
```

phones	fname	words_t0	words_t1
{'B'}	{'F01_B01_S01_R01_F'}	0.2898	0.52925
{'P'}	{'F01_B01_S01_R01_F'}	1.4372	1.8762
{'B'}	{'F01_B01_S01_R01_N'}	0.26984	0.61905
{'P'}	{'F01_B01_S01_R01_N'}	1.9161	2.405
{'B'}	{'F01_B01_S01_R02_N'}	0.27982	0.59909
{'P'}	{'F01_B01_S01_R02_N'}	1.976	2.4549
{'B'}	{'F01_B01_S02_R01_F'}	1.058	1.1977
{'B'}	{'F01_B01_S02_R01_F'}	1.1977	1.6667

The function checks whether these conditions hold and returns an error otherwise.

inverse_rate

- 2 (default): return correlations from both proper and inverse rates
- 0: return correlations based on proper rates
- 1: return correlations based on inverse rates

Additional parameters:

- frame_per (default = 0.001 s): the frame period. This must match the period of the proportional duration timeseries in the proportional durations table.
- scale_range: the range of scales to analyze. By default, these are defined differently for different window methods within the function.

- center_range: the range of centers to analyze. By default, these are defined differently for different window methods within the function.
- scale_step (default = 0.050 s): the step sizes for defining window sizes to analyze.
- center_step (default = 0.025 s): the step size for defining window centers to analyze.
- target_ident_field (default = 'phones'): the name of the targets data table column that encodes the identity of the target units
- target_variable (default = 'dur'): the name of the targets data table column that encodes the dependent variable of the partial correlation
- return_datasets (default = 'false'): returns extra data for debugging
- use_parallel (default = 'false'): parallelizes some aspects of the scalographic analysis. currently only provides minor speedups.
- n_threads (default = 6): number of threads to use for parallelized analysis.

Running the function

Here is an example of how the function is run

```
datasel = 'bytarget';  %use the same data-points across windows
target_exclusion = true;
winmethod = 'extendwin'; %extend windows to compensate for excluded rate unit
unit = 'words';

T = metarate_scalographic_analysis(TR,D,...
    'unit',unit,...
    'target_exclusion',true,...
    'data_selection',datasel,...
    'window_method',winmethod);
```

The output of `metarate_scalographic_analysis` is a table that contains various information about each analysis.

Included in the output is the partial correlation (rho), the p-value of the partial correlation, the rate measure used, the target variable name, the data selection strategy, the target exclusion parameter, the ratio expression (1 for inverse, 0 for proper), the number of tokens in the analysis, the number for which the rate measure was non-finite, the number for which an NaN value was observed, and the total number of valid tokens in the analysis:

```
head(T(:,{'rho' 'pval' 'target' 'unit' 'scale' 'center' 'winmethod'}))
```

rho	pval	target	unit	scale	center	winmethod
-0.12695	0.0070074	{'phones'}	{'words'}	0.05	-0.475	{'extendwin'}
-0.08038	0.088188	{'phones'}	{'words'}	0.05	-0.45	{'extendwin'}
-0.098098	0.037082	{'phones'}	{'words'}	0.1	-0.45	{'extendwin'}
-0.055062	0.24269	{'phones'}	{'words'}	0.05	-0.425	{'extendwin'}
-0.10044	0.032764	{'phones'}	{'words'}	0.1	-0.425	{'extendwin'}
-0.1448	0.0020271	{'phones'}	{'words'}	0.15	-0.425	{'extendwin'}

```
-0.097698     0.037865    {'phones'}    {'words'}    0.05        -0.4    {'extendwin'}
 -0.12803    0.0064163    {'phones'}    {'words'}     0.1        -0.4    {'extendwin'}
```

```
head(T(:,{'datasel' 'exclusion' 'inversion' 'N_tokens' 'N_inf' 'N_nan' 'N_valid'}))
```

datasel	exclusion	inversion	N_tokens	N_inf	N_nan	N_valid
{'bytarget'}	true	0	453	2	0	451
{'bytarget'}	true	0	453	1	0	452
{'bytarget'}	true	0	453	0	0	453
{'bytarget'}	true	0	453	0	0	453
{'bytarget'}	true	0	453	0	0	453
{'bytarget'}	true	0	453	0	0	453
{'bytarget'}	true	0	453	0	0	453
{'bytarget'}	true	0	453	0	0	453

Plotting a scalogram

First prepare the scalographic information for plotting:

```
S = params_from_scalographs(T);
S(1)
```

```
ans = struct with fields:
       target: 'phones'
         unit: 'words'
      datasel: 'bytarget'
    winmethod: 'extendwin'
    exclusion: 1
    inversion: 0
```

The function "prep_subsets" takes a cell array of structures with analysis parameters as input:

```
G = prep_subsets({S(1)});
G(1).subset
```

```
ans = struct with fields:
       target: 'phones'
         unit: 'words'
      datasel: 'bytarget'
    winmethod: 'extendwin'
    exclusion: 1
    inversion: 0
```

The function `prep_scalographs` generates a structure (with one element for each scalograph) with the centers (XX), scales (YY), and scalogram values (ZZ).

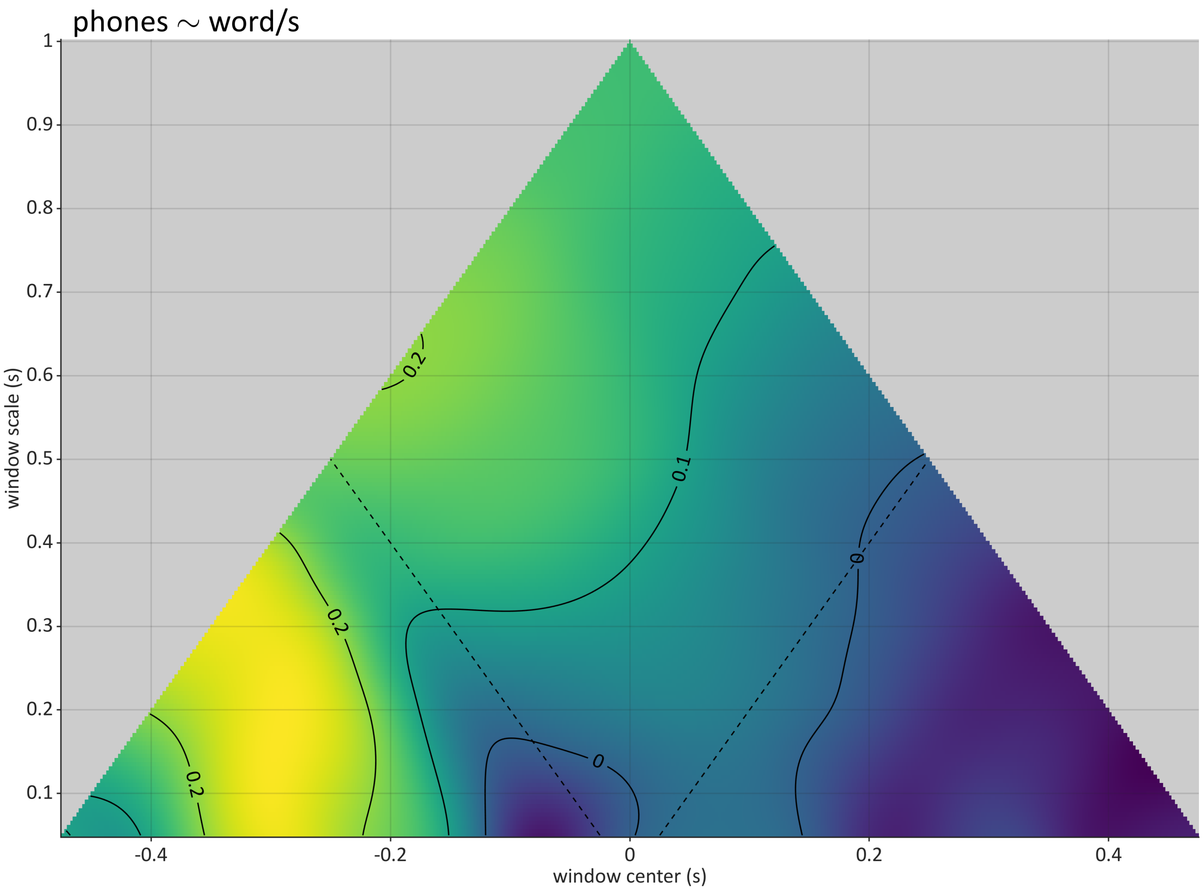
```
SC = prep_scalographs(T,G)
```

```
SC = struct with fields:
        XX: [951×1 double]
        YY: [191×1 double]
    varlab: '{\it{r}}^{\prime}'
        ZZ: [191×951 double]
```

```
 rho_range: [-0.1212 0.2642]
     clims: [-0.1222 0.2652]
      cmap: [5001×3 double]
rho_levels: [0 0.1000 0.2000 0.3000 0.4000 0.5000 0.6000 0.7000 0.8000 0.9000 1]
    panlab: 'phones \sim word/s'
     ax_ix: 1
```

Plot scalographs can be used to plot a set of scalographs in a set of axes:

```
figls; plot_scalographs(SC,gca);
```



Plotting a difference scalogram

First, let's conduct separate scalographic analyses on the /p/ and /b/ phones from our example dataset:

```
% make separate data tables
D_p = D(ismember(D.phones,{'P'}),:);
D_b = D(ismember(D.phones,{'B'}),:);

%define analysis parameters
params = {...
    'unit','words',...
    'target_exclusion',true,...
```

```
    'window_method','extendwin',...
    'inverse_rate',0};

%conduct scalographic analyses
T_p = metarate_scalographic_analysis(TR,D_p,params{:});
T_b = metarate_scalographic_analysis(TR,D_b,params{:});

%rename target fields and combine:
T_p.target = repmat({'phone_p'},height(T_p),1);
T_b.target = repmat({'phone_b'},height(T_b),1);

T = [T_p; T_b];
```

Now let's prepare all three scalograms and plot:

```
S = params_from_scalographs(T);

S(1)
```

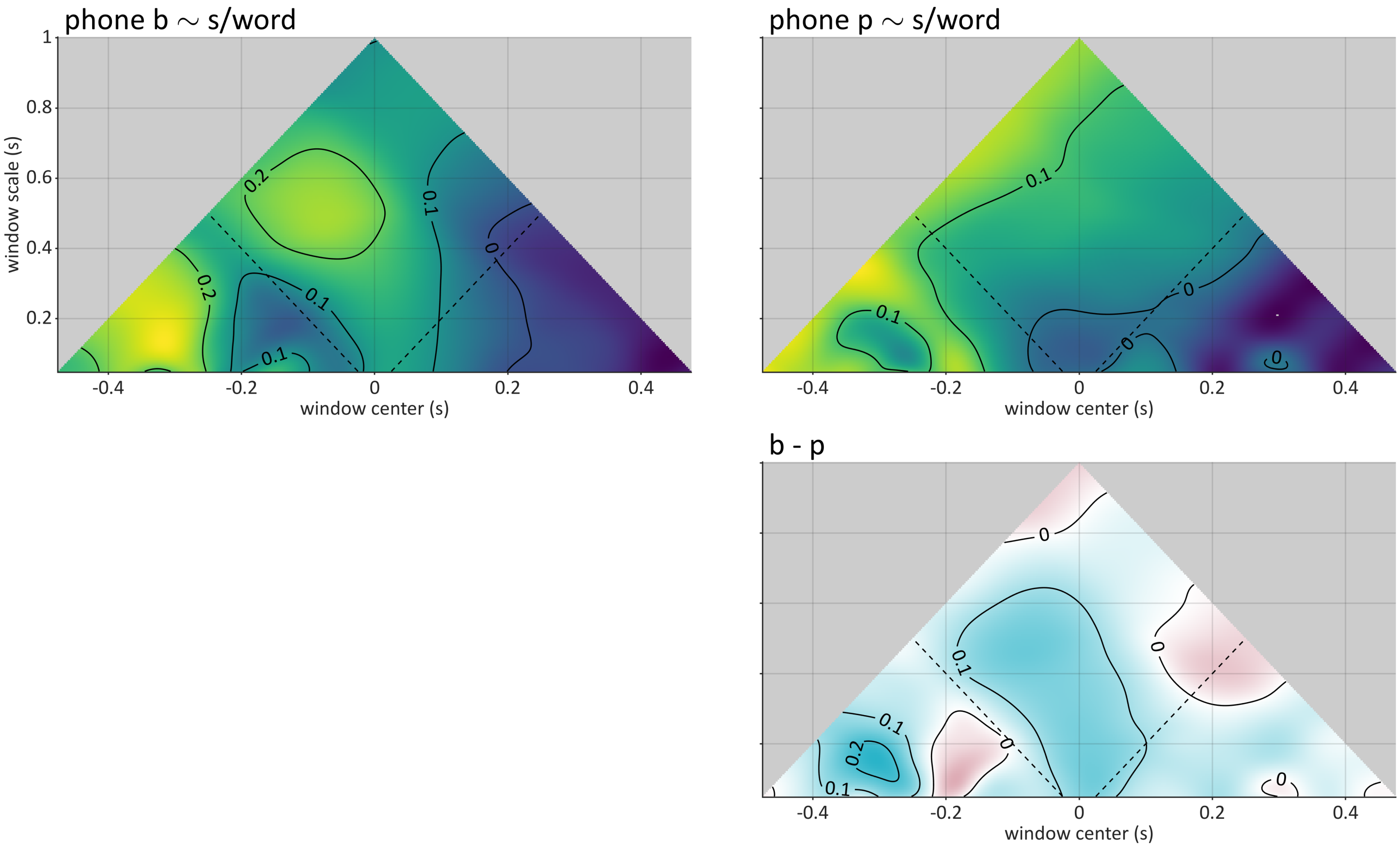
```
ans = struct with fields:
       target: 'phone_b'
         unit: 'words'
      datasel: 'bytarget'
    winmethod: 'extendwin'
    exclusion: 1
    inversion: 1
```

```
S(2)
```

```
ans = struct with fields:
       target: 'phone_p'
         unit: 'words'
      datasel: 'bytarget'
    winmethod: 'extendwin'
    exclusion: 1
    inversion: 1
```

```
G = prep_subsets({S(1),S(2),S});
SC = prep_scalographs(T,G);
```

```
figls; ax = stf([1 2; nan 3],[0.05 0.10 0.01 0.05],[0.05 0.10],'parent',gcf); %creates a figure with some axes
handles = plot_scalographs(SC,ax);
handles.th(end).String = 'b - p';
```




```
function [] = figls()
figure('units','pixels','outerposition',[0 0 750 500]);
end
```