CCBER - Software Description Document

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Overview of Software

`ccber` is an `R` package (see cran.r-project.org) for the estimation of behavioral entropy rate, developed for the Conte Center @ UCI. The package reads in an individual, or set of, excel files and processes the file to estimate the entropy rate from the supplied data. This document describes usage and input formats that are expected with this software.

See reference: Davis, E.P., Stout, S.A., Molet, J., Vegetabile, B., Glynn, L.M., Sandman, C.A., Heins, K., Stern, H., Baram, T.Z. (2017). **Exposure to unpredictable maternal sensory signals influences cognitive development across-species**. *Proceedings of the National Academy of Sciences*. September 26, 2017. 114 (39) 10390-10395

An overview of behavioral entropy rate estimation in the context of human behavior is found in the supporting information (SI) for the reference above.

The source files for `ccber` are found at github.com/bvegetabile/ccber

Installation of `ccber`

The package `devtools` is required to install this `R` package from this Github repository. Install this package first if it is not already installed.

From within an `R` console, enter the following:

```
install.packages('devtools', dependencies = TRUE)
```

Once that package has been installed, use the following to install `ccber`

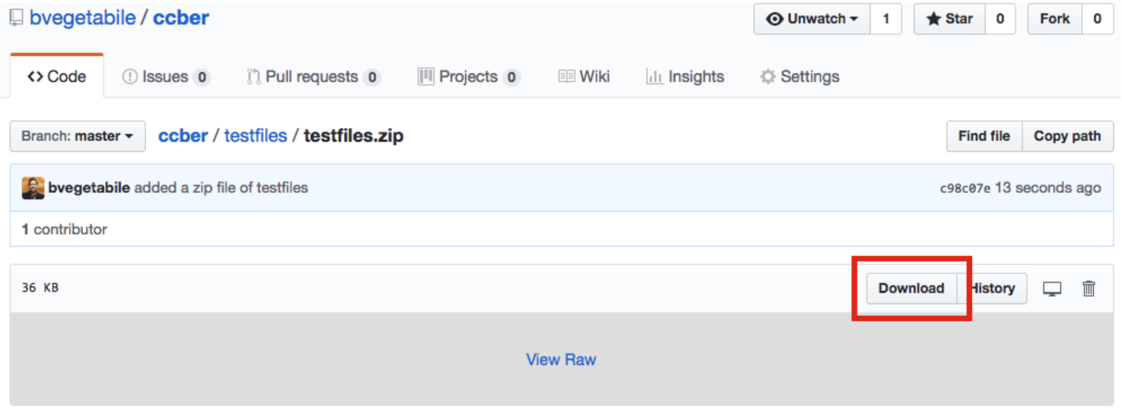
```
devtools::install_github('bvegetabile/ccber')
```

Load the package to begin analysis!

```
library('ccber')
```

Quick Start

Download files from github.com/bvegetabile/ccber/tree/master/testfiles/testfiles.zip.



Screenshot of the download location for testfiles.zip"

Navigate to the directory where the files are located using the following R command. The setwd command sets the working directory for R. (*Note in the below, the path should be changed to the location of where the files have been uncompressed. The following examples have beend developed on a Mac and will vary for use on a Windows machine.*)

```
setwd('~/git/ccber/testfiles/')
```

Then run the following,

```
test_output <- ccber::ber_analyze_dir('.')
```

By setting the working directory in the first step, any output files will be put in the directory specified.

If successful, you will see the following:

```
> ccber::ber_analyze_dir('.')
Completed without issue    :  Entropy_6m - 88888HE - Event Logs.xlsx
Completed without issue    :  Entropy_6m - 99999LE - Event Logs.xlsx
Script total run time:  0.013 minutes
-------------------- Check the log for files below --------------------
```

The object `test_output` contains the entropy rates and some additional measures. The output will look as follows after typing `test_output` in the terminal to view the object:

```
> test_output
  SubjectID CanEstimateEntropy EntropyRate
1   88888HE               TRUE   1.2755499
2   99999LE               TRUE   0.6442886
  TotalNumberOfTransitions CombinedVideoDuration PercentMissing
1                      119               600.027              0
2                       69               600.027              0
  AuditoryCounts AuditoryTotalTime AuditoryAverageTime
1             23            25.001               1.087
2             15            15.000               1.000
  VisualCounts VisualTotalTime VisualAverageTime TactileCounts
```

```
1           16        309.9636          19.37273             21
2           11        185.0270          16.82064             10
  TactileTotalTime TactileAverageTime
1         362.9628           17.28394
2         285.0273           28.50273
```

To save the output data to a `.csv` file to be read into excel later, use the following:

```
write.csv(test_output,
          file = file = paste(Sys.Date(),
                              '-ber-estimates.csv',
                              sep=''),
          row.names = F)
```

The command `Sys.Date()` prepends the date to document when the data was created

Function Overviews

Ordinary use of the package would not require any of the information below this point in the description.

These function overviews provide additional information that may be helpful if there is a need to modify the settings (e.g., an error has occurred, there is a new data type or you want to try an alternative padding in event definitions).

Function : `ber_analyze_file`

The following function from `ccber` is one of the primary functions for the estimation of entropy rate:

```
ber_analyze_file(f_loc,
                 plot_all=F,
                 plots_to_file=F,
                 tactile_padding = 1.0,
                 auditory_padding = 1.0,
                 behavior_types=list(
                   "mom_auditory_types" = c('Vocal'),
                   "mom_tactile_types" = c('TouchBaby',
                                           'HoldingBaby'),
                   "mom_visual_types" = c('ManipulatingObject'),
                   "baby_visual_types" = c('LookAtMomActivity'),
                   "missing_types" = c('CantTellHolding',
                                       'ActivityNotVisible',
                                       'CantTellLooking')),
                 missing_threshold = 0.1)
```

Below is a more detailed description of each input:

Input	Input Type	Description

f_loc	String	String indicating the location of the file of interest
plot_all	Logical	Indicator of whether to provide visualization to the user. Values : True or False
plots_to_file	Logical	Indicator of whether or not to save visuals. Currently not implemented.
tactile_padding	Numeric	Value (in seconds) to right pad each tactile point event
auditory_padding	Numeric	Value (in seconds) to right pad each auditory point event
behavior_types	List	List outlining the behavioral states expected. Required : mom_auditory_types, mom_tactile_types, mom_visual_types, baby_visual_types, missing_types. These categories define the sensory domains as in the original paper. See the example code above for the default values expected in each category.
missing_threshold	Numeric	Value (a proportion) that indicators how much missingness is acceptable. This threshold is defined to be the percentage of the behavioral sequence that is represented by missing types defined in missing_types.

Example Usage

```
ber_analyze_file('./testfiles/Entropy_6m - 88888HE - Event Logs.xlsx')
```

Output

ber_analyze_file returns an R list whose first element is a data.frame named estimates and a second element that is a list called file_checks. The element estimates is the primary object of interest and has the following column headings

Column Header	Description
SubjectID	Subject ID found during analysis of file
CanEstimateEntropy	Indicator of success or failure in estimating entropy rate
EntropyRate	Estimate of entropy rate between 0 and $log_2(K)$ where K is the total number of states
TotalNumberOfTransitions	The total number of events considered in the final event sequence
CombinedVideoDuration	Total duration of the video (endtime + final duration)
PercentMissing	Proportion of time represented by missing_types category
AuditoryCounts	Total number of events in auditory category
AuditoryTotalTime	Total time representing events in auditory category
AuditoryAverageTime	Average duration of events in auditory category
VisualCounts	Total number of events in visual category
VisualTotalTime	Total time representing events in visual category
VisualAverageTime	Average duration of events in visual category

`TactileCounts`	Total number of events in tactile category
`TactileTotalTime`	Total time representing events in tactile category
`TactileTotalTime`	Average duration of events in tactile category

During the course of running, the script performs a series of quality assurance tests of the file that has been input. Specifically it performs the following tests:

Test Name	Description
`header_pass`	Checks for the following column headers : `c('Observation', 'Behavior', 'Time_Relative_sf', 'Duration_sf', 'Event_Type')`
`subjid_pass`	Checks for an entry in the first cell of the column `Observation`. Does not check format of subject IDs
`misdat_pass`	Checks for empty cells in the columns list above using `sum(is.na(behavior_data$Behavior)) > 0`
`blabel_pass`	Finds the unique entries in the column `Behavior`, then compares that with the labels in `behavior_types`. Reports unused labels, i.e., labels found in `Behavior` that were not including in `behavior_types`.
`elabel_pass`	Finds the unique entries in the column `Event_Type`, then compares with the following list : `c('State start', 'State point', 'Point', 'State stop', 'State Stop')`. These are currently supported events types.
`misnes_pass`	Checks the proportion of time representing missing data based off of the inputs to `missing_types` within `behavior_types`.

Example output from script:

When running `ber_analyze_file` by itself, the following is an example of what is printed to the console at runtime to help diagnose issues with files:

```
-----------------------------------------------------------------------
Filename:         Entropy_6m - 88888HE - Event Logs.xlsx
Time of Analysis: 2018-06-04 10:33:12
-----------------------------------------------------------------------
*************************** Performing File Check *********************
- Checking for required Columns:
    Observation      : First cell used to set "SubjectID"
    Behavior         : Set of used behavior labels
    Time_Relative_sf : Sets the start point for each action
    Duration_sf      : Time_Relative_sf + Duration_sf sets end points
    Event_Type       : Defines point events and states
--- PASSED : Found all Required Column Headers
- Checking "Observation" Column For Subject ID
--- PASSED: Using Subject ID from Column J, Cell 1: 88888HE
- Checking for Missing Data in Columns
--- "Behavior"         : PASSED
--- "Time_Relative_sf" : PASSED
--- "Duration_sf"      : PASSED
--- "Event_Type"       : PASSED
- Checking "Behavior" Column For Unused Labels:
--- WARNING : Unused Labels in "Behavior" Column, See Below:
    Expected Label  : "NotHoldingBaby", not used in analysis
    Expected Label  : "NoObjectInHand", not used in analysis
--- NOTE: Investigate this if these do not look familar
- Checking "Event_Type" Column For Labels:
--- PASSED : No Unused Labels in "Event_Type" Column
- Checking Missingness based on "missing_types"
--- Percent Missingness: 0
--- PASSED : Percent missing less than threshold
-----------------------------------------------------------------------
************************ File Completed Successfully ******************
-----------------------------------------------------------------------
```

Function : ber_analyze_dir

The following function is another primary functions for the estimation of entropy rate. Given a directory, the function makes multiple calls to ber_analyze_file to analyze the excel files within that directory. Note that there is no plotting capability currently included when operating on directories.

```
ber_analyze_dir(dir_loc,
                tactile_padding = 1.0,
                auditory_padding = 1.0,
                behavior_types=list(
                  "mom_auditory_types" = c('Vocal'),
                  "mom_tactile_types" = c('TouchBaby',
                                          'HoldingBaby'),
                  "mom_visual_types" = c('ManipulatingObject'),
                  "baby_visual_types" = c('LookAtMomActivity'),
                  "missing_types" = c('CantTellHolding',
                                      'ActivityNotVisible',
                                      'CantTellLooking')),
                missing_threshold = 0.1,
                log_file = paste(Sys.Date(), '-ber-logfile.txt', sep=''))
```

Input	Input Type	Description
dir_loc	String	String indicating the location of the directory of interest
tactile_padding	Numeric	Value (in seconds) to right pad each tactile point event
auditory_padding	Numeric	Value (in seconds) to right pad each auditory point event
behavior_types	List	List outlining the behavioral states expected. Required : mom_auditory_types, mom_tactile_types, mom_visual_types, baby_visual_types, missing_types. These categories define the sensory domains as in the

		original paper. See the example code above for the default values expected in each category.
missing_threshold	Numeric	Value (a proportion) that indicators how much missingness is acceptable. This threshold is defined to be the percentage of the behavioral sequence that is represented by missing types defined in missing_types
log_file	String	String indicating the location for where to save the diagnostic information from each run of ber_analyze_file

Example Usage

From the directory where the files of interest are located type the following:

```
ber_analyze_dir('.')
```

Output

`ber_analyze_dir` returns a `R` `data.frame` with column headings as in `ber_analyze_file`. Each row of the `data.frame` represents the results from calling `ber_analyze_file` on a file.

Input file formats

This section describes the expected input file format required for the software. It is also identifies important columns utilized in the estimation of entropy rate.

File Format Type

At the moment, the required format is an Excel `.xlsx` file.

Note: In the future this may be modifed to include `.csv` files, by altering specific lines of code in `ber.R`. Specifically, line 37 within `ber_analyze_dir` should be altered to accept different string patterns:

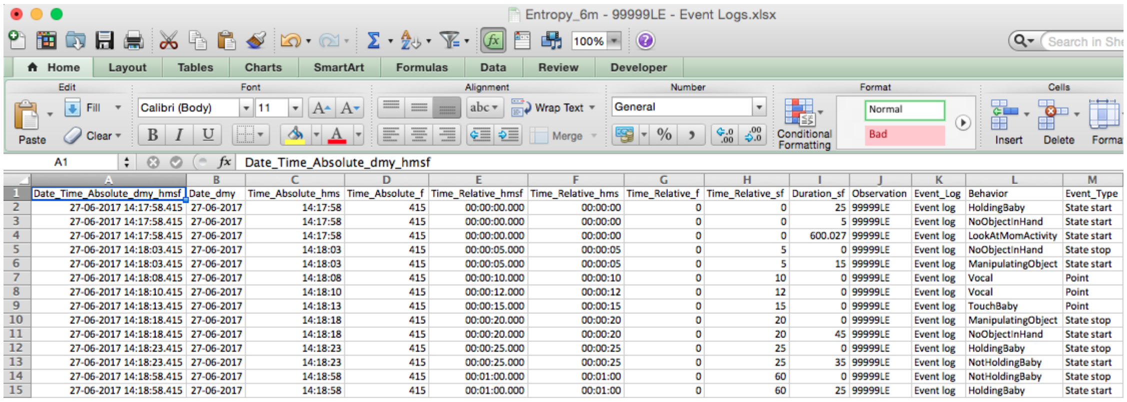
```
    all_files = list.files(dir_loc, pattern="*.xlsx")
```

and line 116 within `ber_analyze_file` should be changed read `.csv` files:

```
    behavior_data <- data.frame(readxl::read_xlsx(f_loc))
```

File Organization

Below is a visualization of a current input file that is located within the `testfiles` subdirectory of the source files and was used earlier in the software demonstration:



	A	B	C	D	E	F	G	H	I	J	K	L	M
1	Date_Time_Absolute_dmy_hmsf	Date_dmy	Time_Absolute_hms	Time_Absolute_f	Time_Relative_hmsf	Time_Relative_hms	Time_Relative_f	Time_Relative_sf	Duration_sf	Observation	Event_Log	Behavior	Event_Type
2	27-06-2017 14:17:58.415	27-06-2017	14:17:58	415	00:00:00.000	00:00:00	0	0	25	99999LE	Event log	HoldingBaby	State start
3	27-06-2017 14:17:58.415	27-06-2017	14:17:58	415	00:00:00.000	00:00:00	0	0	5	99999LE	Event log	NoObjectInHand	State start
4	27-06-2017 14:17:58.415	27-06-2017	14:17:58	415	00:00:00.000	00:00:00	0	0	600.027	99999LE	Event log	LookAtMomActivity	State start
5	27-06-2017 14:18:03.415	27-06-2017	14:18:03	415	00:00:05.000	00:00:05	0	5	0	99999LE	Event log	NoObjectInHand	State stop
6	27-06-2017 14:18:03.415	27-06-2017	14:18:03	415	00:00:05.000	00:00:05	0	5	15	99999LE	Event log	ManipulatingObject	State start
7	27-06-2017 14:18:08.415	27-06-2017	14:18:08	415	00:00:10.000	00:00:10	0	10	0	99999LE	Event log	Vocal	Point
8	27-06-2017 14:18:10.415	27-06-2017	14:18:10	415	00:00:12.000	00:00:12	0	12	0	99999LE	Event log	Vocal	Point
9	27-06-2017 14:18:13.415	27-06-2017	14:18:13	415	00:00:15.000	00:00:15	0	15	0	99999LE	Event log	TouchBaby	Point
10	27-06-2017 14:18:18.415	27-06-2017	14:18:18	415	00:00:20.000	00:00:20	0	20	0	99999LE	Event log	ManipulatingObject	State stop
11	27-06-2017 14:18:18.415	27-06-2017	14:18:18	415	00:00:20.000	00:00:20	0	20	45	99999LE	Event log	NoObjectInHand	State start
12	27-06-2017 14:18:23.415	27-06-2017	14:18:23	415	00:00:25.000	00:00:25	0	25	0	99999LE	Event log	HoldingBaby	State stop
13	27-06-2017 14:18:23.415	27-06-2017	14:18:23	415	00:00:25.000	00:00:25	0	25	35	99999LE	Event log	NotHoldingBaby	State start
14	27-06-2017 14:18:58.415	27-06-2017	14:18:58	415	00:01:00.000	00:01:00	0	60	0	99999LE	Event log	NotHoldingBaby	State stop
15	27-06-2017 14:18:58.415	27-06-2017	14:18:58	415	00:01:00.000	00:01:00	0	60	25	99999LE	Event log	HoldingBaby	State start

Screenshot of the test file "Entropy_6m - 99999LE - Event Logs.xlsx"

The expected column headings are:

Column Heading	Used?	Description
`Date_Time_Absolute_dmy_hmsf`	No	Absolute Time - Day-Month-Year Hour:Min:Sec.Millisec (Military Time)
`Date_dmy`	No	Absolute Time - Day-Month-Year
`Time_Absolute_hms`	No	Absolute Time - Hour:Min:Sec
`Time_Absolute_f`	No	??? Appears to be millisecond part ???
`Time_Relative_hmsf`	No	Relative Time - Hour:Min:Sec.Millisec
`Time_Relative_hms`	No	Relative Time - Hour:Min:Sec.Millisec
`Time_Relative_f`	No	??? Appears to be millisecond part ???
`Time_Relative_sf`	Yes	Relative Time - Seconds. Used as starting point for each instance in the video
`Duration_sf`	Yes	Relative Time - Seconds. Duration of the the instance. The time of an event is `Time_Relative_sf` + `Duration_sf`
`Observation`	Yes	Typically Subject ID. Cell `J1` is used as the Subject ID that is reported from `ber_analyze_dir` and `ber_analyze_file`
`Event_Log`	No	Unknown
`Behavior`	Yes	Used to find and match against `behavior_types` specified in `ber_analyze_dir` and `ber_analyze_file`
`Event_Type`	Yes	`State start` indicates cells which will be used as *events*. `Point` instances that are included will be right padded to become events. `State stop` rows are ignored.

The order of the rows should **not** matter, but it is best to be safe and keep the organization that is above for ease of processing.

Input File Tests

As stated above the following tests are run using `ber_analyze_file` and are shown again below:

Test Name	Description
`header_pass`	Checks for the following column headers : `c('Observation', 'Behavior', 'Time_Relative_sf', 'Duration_sf', 'Event_Type')`
`subjid_pass`	Checks for an entry in the first cell of the column `Observation`. Does not check format of subject IDs
`misdat_pass`	Checks for empty cells in the columns list above using `sum(is.na(behavior_data$Behavior)) > 0`
`blabel_pass`	Finds the unique entries in the column `Behavior`, then compares that with the labels in `behavior_types`. Reports unused labels, i.e., labels found in `Behavior` that were not including in `behavior_types`.
`elabel_pass`	Finds the unique entries in the column `Event_Type`, then compares with the following list : `c('State start', 'State point', 'Point', 'State stop', 'State Stop')`. These are currently supported events types.
`misnes_pass`	Checks the proportion of time representing missing data based off of the inputs to `missing_types` within `behavior_types`.

Be sure to check the log files and output using `ber_analyze_dir` to ensure that the files are processed correctly.