

# Package ‘mixtur’

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**Title** Modelling Continuous Report Visual Short-Term Memory Studies

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**Description** A set of utility functions for analysing and modelling data from continuous report short-term memory experiments using either the 2-component mixture model of Zhang and Luck (2008) <[doi:10.1038/nature06860](https://doi.org/10.1038/nature06860)> or the 3-component mixture model of Bays et al. (2009) <[doi:10.1167/9.10.7](https://doi.org/10.1167/9.10.7)>. Users are also able to simulate from these models.

**Depends** R (>= 4.0)

**Imports** dplyr, ggplot2, rlang, tidyr, RColorBrewer

**Suggests** knitr, rmarkdown

**License** GPL-3

**LazyData** true

**URL** <https://github.com/JimGrange/mixtur>

**BugReports** <https://github.com/JimGrange/mixtur/issues>

**Encoding** UTF-8

**RoxygenNote** 7.1.1

**Copyright** Some functions have been adapted from Matlab code written by Paul Bays (<https://bayslab.com>) published under GNU General Public License.

**NeedsCompilation** no

**Author** Jim Grange [aut, cre] (<<https://orcid.org/0000-0002-8352-8390>>),  
Stuart B. Moore [aut] (<<https://orcid.org/0000-0002-0747-9304>>),  
Ed D. J. Berry [ctb]

**Maintainer** Jim Grange <[grange.jim@gmail.com](mailto:grange.jim@gmail.com)>

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## R topics documented:

bays2009_full . . . . .	2
bays2009_sample . . . . .	3
berry_2019 . . . . .	4
fit_mixtur . . . . .	4
get_summary_statistics . . . . .	6
oberauer_2017 . . . . .	7
plot_error . . . . .	8
plot_model_fit . . . . .	10
plot_model_parameters . . . . .	11
plot_summary_statistic . . . . .	12
simulate_mixtur . . . . .	13
<b>Index</b>	<b>16</b>

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bays2009_full	<i>Full data set from Bays et al. (2009)</i>
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### Description

A full data set including data from 12 participants in a continuous report visual short-term memory experiment. The stimuli were coloured squares in the range radians  $-\pi$  to  $\pi$ . The experiment had various set sizes and an additional manipulation of duration of the sample array presentation.

### Usage

```
bays2009_full
```

### Format

A data frame with 7271 rows and 10 variables:

**id** participant identification

**set\_size** the set size of each trial

**duration** the duration of the sample array (in milliseconds, ms), with levels 100ms, 500ms, 2000ms

**response** the participant's recollection of the target orientation in radians ( $-\pi$  to  $\pi$ )

**target** the feature value of the target in radians ( $-\pi$  to  $\pi$ )

**non\_target\_1** the feature value of the first non-target in radians ( $-\pi$  to  $\pi$ )

**non\_target\_2** the feature value of the second non-target in radians ( $-\pi$  to  $\pi$ )

**non\_target\_3** the feature value of the third non-target in radians ( $-\pi$  to  $\pi$ )

**non\_target\_4** the feature value of the fourth non-target in radians ( $-\pi$  to  $\pi$ )

**non\_target\_5** the feature value of the fifth non-target in radians ( $-\pi$  to  $\pi$ )

**Source**

The data set is publicly available on the Open Science Framework, with thanks to Paul Bays:  
<https://osf.io/c2yx5/>

**References**

Bays, P.M., Catalao, R.F.G., & Husain, M. (2009). The precision of visual working memory is set by allocation of a shared resource. *Journal of Vision*, 9(10), Article 7.

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bays2009_sample	<i>Sample data set from Bays et al. (2009)</i>
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**Description**

A sample data set including data from 12 participants in a continuous report visual short-term memory experiment. The stimuli were coloured squares in the range radians  $-\pi$  to  $\pi$ . The sample data set only consists of trials with a set size of 4 and a sample array duration of 500ms.

**Usage**

bays2009\_sample

**Format**

A data frame with 7271 rows and 10 variables:

**id** participant identification

**response** the participant's recollection of the target orientation in radians ( $-\pi$  to  $\pi$ )

**target** the feature value of the target in radians ( $-\pi$  to  $\pi$ )

**non\_target\_1** the feature value of the first non-target in radians ( $-\pi$  to  $\pi$ )

**non\_target\_2** the feature value of the second non-target in radians ( $-\pi$  to  $\pi$ )

**non\_target\_3** the feature value of the third non-target in radians ( $-\pi$  to  $\pi$ )

**Source**

The data set is publicly available on the Open Science Framework, with thanks to Paul Bays:  
<https://osf.io/c2yx5/>

**References**

Bays, P.M., Catalao, R.F.G., & Husain, M. (2009). The precision of visual working memory is set by allocation of a shared resource. *Journal of Vision*, 9(10), Article 7.

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berry\_2019

*Data set from Berry et al. (2019)*

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### Description

A data set including data from 30 participants in a continuous report visual short-term memory experiment. The stimuli were oriented bars within the range 1-180 degrees. The experiment had a set size of 3.

### Usage

berry\_2019

### Format

A data frame with 3600 rows and 6 variables:

**id** participant identification

**condition** condition of experiment: whether the task was completed under single-task or dual-task conditions

**target\_ori** the orientation of the target in degrees (1-180)

**response\_ori** the participant's recollection of the target orientation in degrees (1-180)

**non\_target\_1** the orientation of the first non-target in degrees (1-180)

**non\_target\_2** the orientation of the second non-target in degrees (1-180)

### Source

The data set is publicly available on the Open Science Framework: <https://osf.io/59c4g/>

### References

Berry, E.D.J., Allen, R.J., Waterman, A.H., & Logie, R.H. (2019). The effect of a verbal concurrent task on visual precision in working memory. *Experimental Psychology*, 66, (77-85).

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fit\_mixtur

*Fit the mixture model.*

---

### Description

This is the function called by the user to fit either the two- or three- component mixture model.

**Usage**

```
fit_mixtur(
  data,
  model = "3_component",
  unit = "degrees",
  id_var = "id",
  response_var = "response",
  target_var = "target",
  non_target_var = NULL,
  set_size_var = NULL,
  condition_var = NULL,
  return_fit = FALSE
)
```

**Arguments**

data	A data frame with columns containing (at the very least) trial-level participant response and target values. This data can either be in degrees (1-360 or 1-180) or radians. If the 3-component mixture model is to be fitted to the data, the data frame also needs to contain the values of all non-targets. In addition, the model can be fit to individual individual participants, individual set-sizes, and individual additional conditions; if the user wishes for this, then the data frame should have columns coding for this information.
model	A string indicating the model to be fit to the data. Currently the options are "2_component", "3_component", "slots", and "slots_averaging".
unit	A string indicating the unit of measurement in the data frame: "degrees" (measurement is in degrees, from 1 to 360); "degrees_180" (measurement is in degrees, but limited to 1 to 180); or "radians" (measurement is in radians, from $2 * \pi$ to $2 * \pi$ , but could also be already in the range $-\pi$ to $\pi$ ).
id_var	The quoted column name coding for participant id. If the data is from a single participant (i.e., there is no id column) set to NULL.
response_var	The quoted column name coding for the participants' responses
target_var	The quoted column name coding for the target value.
non_target_var	The quoted variable name common to all columns (if applicable) storing non-target values. If the user wishes to fit the 3-component mixture model, the user should have one column coding for each non-target's value in the data frame. If there is more than one non-target, each column name should begin with a common term (e.g., the "non_target" term is common to the non-target columns "non_target_1", "non_target_2" etc.), which should then be passed to the function via the non_target_var variable.
set_size_var	The quoted column name (if applicable) coding for the set size of each response.
condition_var	The quoted column name (if applicable) coding for the condition of each response.
return_fit	If set to TRUE, the function will return the log-likelihood of the model fit, Akaike's Information Criterion (AIC), Bayesian Information Criterion (BIC), as well as the number of trials used in the fit.

**Value**

Returns a data frame with best-fitting parameters per participant (if applicable), set-size (if applicable), and condition (if applicable). If `return_fit` was set to `TRUE`, the data frame will also include the log-likelihood value and information criteria of the model fit.

**Source**

The code for the 3-component model has been adapted from Matlab code written by Paul Bays (<https://bayslab.com>) published under GNU General Public License.

**Examples**

```
# load the example data
data <- bays2009_full

# fit the 3-component mixture model ignoring condition

fit <- fit_mixture(data = data,
                  model = "3_component",
                  unit = "radians",
                  id_var = "id",
                  response_var = "response",
                  target_var = "target",
                  non_target_var = "non_target",
                  set_size_var = "set_size",
                  condition_var = NULL)
```

---

get\_summary\_statistics

*Obtain summary statistics of response error*

---

**Description**

Returns participant-level summary statistic data of response error estimates ready for inferential analysis. Note that the function does not actually conduct the analysis.

**Usage**

```
get_summary_statistics(
  data,
  unit = "degrees",
  id_var = "id",
  response_var = "response",
  target_var = "target",
  set_size_var = NULL,
  condition_var = NULL
)
```

**Arguments**

<code>data</code>	A data frame with columns containing: participant identifier (declared via variable <code>'id_var'</code> ); the participants' response per trial ( <code>'response_var'</code> ); the target value ( <code>'target_var'</code> ); and, if applicable, the set size of each response ( <code>'set_size_var'</code> ), and the condition of each response ( <code>'condition_var'</code> ).
<code>unit</code>	The unit of measurement in the data frame: "degrees" (measurement is in degrees, from 0 to 360); "degrees_180" (measurement is in degrees, but limited to 0 to 180); or "radians" (measurement is in radians, from $\pi$ to $2 * \pi$ , but could also be already in $-\pi$ to $\pi$ ).
<code>id_var</code>	The quoted column name coding for participant id. If the data is from a single participant (i.e., there is no id column) set to NULL.
<code>response_var</code>	The quoted column name coding for the participants' responses
<code>target_var</code>	The quoted column name coding for the target value.
<code>set_size_var</code>	The quoted column name (if applicable) coding for the set size of each response.
<code>condition_var</code>	The quoted column name (if applicable) coding for the condition of each response.

**Value**

Returns a data frame containing the summary statistics `mean_absolute_error`, `resultant_vector_length`, `precision`, and `bias` per participant (if applicable), `set-size` (if applicable), and `condition` (if applicable).

**Examples**

```
# load an example data frame
data(bays2009_full)

# calculate the summary statistics per condition and per set size
summary_data <- get_summary_statistics(data = bays2009_full,
                                     unit = "radians",
                                     condition_var = "duration",
                                     set_size_var = "set_size")
```

---

 oberauer\_2017

*Data set from Oberauer & Lin (2017)*


---

**Description**

A data set including data from 19 participants in a continuous report visual short-term memory experiment. The stimuli were coloured patches within the range 1-360 degrees. The experiment had a set sizes ranging from 1 to 8.

**Usage**

```
oberauer_2017
```

**Format**

A data frame with 15,200 rows and 11 variables:

**id** participant identification

**set\_size** the set size of each trial

**response** the participant's recollection of the target colour in degrees (1-360)

**target** the orientation of the target colour in degrees (1-360)

**non\_target\_1** the orientation of the first non-target in degrees (1-360)

**non\_target\_2** the orientation of the first non-target in degrees (1-360)

**non\_target\_3** the orientation of the second non-target in degrees (1-360)

**non\_target\_4** the orientation of the third non-target in degrees (1-360)

**non\_target\_5** the orientation of the fourth non-target in degrees (1-360)

**non\_target\_6** the orientation of the fifth non-target in degrees (1-360)

**non\_target\_7** the orientation of the sixth non-target in degrees (1-360)

**Source**

The data set is publicly available on the Open Science Framework: <https://osf.io/j24wb/>

**References**

Oberauer, K. & Lin, H-Y. (2017). An interference model of visual working memory. *Psychological Review*, 124, 21-59.

---

plot\_error

*Plot response error of behavioural data relative to target values.*

---

**Description**

Function to plot the response error in behavioural data relative to target values. Requires a data frame that (at least) has target value data and participant response data.

**Usage**

```
plot_error(  
  data,  
  unit = "degrees",  
  id_var = "id",  
  response_var = "response",  
  target_var = "target",  
  set_size_var = NULL,  
  condition_var = NULL,  
  n_bins = 18,  
  n_col = 2,  
  return_data = FALSE,  
  palette = "Dark2"  
)
```



## Arguments

data	A data frame with columns containing: participant identifier ('id_var'); the participants' response per trial ('response_var'); the target value ('target_var'); and, if applicable, the set size of each response ('set_size_var'), and the condition of each response ('condition_var').
unit	The unit of measurement in the data frame: "degrees" (measurement is in degrees, from 0 to 360); "degrees_180" (measurement is in degrees, but limited to 0 to 180); or "radians" (measurement is in radians, from $\pi$ to $2 * \pi$ , but could also be already in $-\pi$ to $\pi$ ).
id_var	The column name coding for participant id. If the data is from a single participant (i.e., there is no id column) set to "NULL".
response_var	The column name coding for the participants' responses.
target_var	The column name coding for the target value.
set_size_var	The column name (if applicable) coding for the set size of each response.
condition_var	The column name (if applicable) coding for the condition of each response.
n_bins	An integer controlling the number of cells / bins used in the plot.
n_col	An integer controlling the number of columns in the resulting plot.
return_data	A boolean (TRUE or FALSE) indicating whether the data for the plot should be returned.
palette	A character stating the preferred colour palette to use. To see all available palettes, type <code>display.brewer.all()</code> into the console.

## Value

If `return_data` is set to `FALSE` (which it is by default), the function returns a `ggplot2` object visualising the density distribution of response error averaged across participants (if applicable) per set-size (if applicable) and condition (if applicable).

If `return_data` is set to `TRUE`, the function returns a list with two components:

- `plot`: The `ggplot2` object.
- `data`: A data frame with the data used to generate the plot.

## Examples

```
plot_error(bays2009_full,
           unit = "radians",
           set_size_var = "set_size")
```

---

plot_model_fit	<i>Plot model fit against human error data (target errors)</i>
----------------	--

---

## Description

Plot model fit against human error data (target errors)

## Usage

```
plot_model_fit(
  participant_data,
  model_fit,
  model,
  unit = "degrees",
  id_var = "id",
  response_var = "response",
  target_var = "target",
  set_size_var = NULL,
  condition_var = NULL,
  n_bins = 18,
  n_col = 2,
  palette = "Dark2"
)
```

## Arguments

participant_data	A data frame of the participant data, with columns containing: participant identifier ('id_var'); the participants' response per trial ('response_var'); the target value ('target_var'); and, if applicable, the set size of each response ('set_size_var'), and the condition of each response ('condition_var').
model_fit	The model fit object to be plotted against participant data.
model	A string indicating the model that was fit to the data. Currently the options are "2_component", "3_component", "slots", and "slots_averaging".
unit	The unit of measurement in the data frame: "degrees" (measurement is in degrees, from 0 to 360); "degrees_180" (measurement is in degrees, but limited to 0 to 180); or "radians" (measurement is in radians, from pi to 2 * pi, but could also be already in -pi to pi).
id_var	The column name coding for participant id. If the data is from a single participant (i.e., there is no id column) set to "NULL".
response_var	The column name coding for the participants' responses
target_var	The column name coding for the target value
set_size_var	The column name (if applicable) coding for the set size of each response
condition_var	The column name (if applicable) coding for the condition of each response

n_bins	An integer controlling the number of cells / bins used in the plot of the behavioural data.
n_col	An integer controlling the number of columns in the resulting plot.
palette	A character stating the preferred colour palette to use. To see all available palettes, type <code>display.brewer.all()</code> into the console.

### Value

The function returns a ggplot2 object visualising the mean observed response error density distribution across participants (if applicable) per set-size (if applicable) and condition (if applicable) together with the model predictions superimposed.

---

`plot_model_parameters` *Plot best-fitting parameters of model fit*

---

### Description

Function to plot the best-fitting parameters of either the 2-component or 3-component model. .

### Usage

```
plot_model_parameters(
  model_fit,
  model,
  id_var = "id",
  set_size_var = NULL,
  condition_var = NULL,
  n_col = 2,
  return_data = FALSE,
  palette = "Dark2"
)
```

### Arguments

model_fit	The model fit object containing the parameters to be plotted.
model	A string indicating the model that was fit to the data. Currently the options are "2_component", "3_component", "slots", and "slots_averaging".
id_var	The column name coding for participant id.
set_size_var	The column name (if applicable) coding for the set size of each response.
condition_var	The column name (if applicable) coding for the condition of each response.
n_col	An integer controlling the number of columns in the resulting plot.
return_data	A boolean (TRUE or FALSE) indicating whether the data for the plot should be returned.
palette	A character stating the preferred colour palette to use. To see all available palettes, type <code>display.brewer.all()</code> into the console.

**Value**

If `return_data` is set to `FALSE` (which it is by default), the function returns a `ggplot2` object visualising the mean model parameters across participants (if applicable) per set-size (if applicable) and condition (if applicable).

If `return_data` is set to `TRUE`, the function returns a list with two components:

- `plot`: The `ggplot2` object.
- `data`: A data frame with the data used to generate the plot.

---

`plot_summary_statistic`

*Plot summary statistics of behavioural data*

---

**Description**

Function to plot model-free summary statistics of behavioural data. Users can plot mean absolute error, resultant vector length, and precision of the behavioural data.

**Usage**

```
plot_summary_statistic(
  data,
  statistic = "precision",
  unit = "degrees",
  id_var = "id",
  response_var = "response",
  target_var = "target",
  set_size_var = NULL,
  condition_var = NULL,
  return_data = FALSE,
  palette = "Dark2"
)
```

**Arguments**

<code>data</code>	A data frame with columns containing: participant identifier ( <code>'id_var'</code> ); the participants' response per trial ( <code>'response_var'</code> ); the target value ( <code>'target_var'</code> ); and, if applicable, the set size of each response ( <code>'set_size_var'</code> ), and the condition of each response ( <code>'condition_var'</code> ).
<code>statistic</code>	The summary statistic to plot. This can be set to <code>"mean_absolute_error"</code> , <code>"resultant_vector_length"</code> , or <code>"precision"</code> .
<code>unit</code>	The unit of measurement in the data frame: <code>"degrees"</code> (measurement is in degrees, from 0 to 360); <code>"degrees_180"</code> (measurement is in degrees, but limited to 0 to 180); or <code>"radians"</code> (measurement is in radians, from $\pi$ to $2 * \pi$ , but could also be already in $-\pi$ to $\pi$ ).

id_var	The column name coding for participant id. If the data is from a single participant (i.e., there is no id column) set to "NULL".
response_var	The column name coding for the participants' responses.
target_var	The column name coding for the target value.
set_size_var	The column name (if applicable) coding for the set size of each response.
condition_var	The column name (if applicable) coding for the condition of each response.
return_data	A boolean (TRUE or FALSE) indicating whether the data for the plot should be returned.
palette	A character stating the preferred colour palette to use. To see all available palettes, type <code>display.brewer.all()</code> into the console.

### Value

If `return_data` is set to `FALSE` (which it is by default), the function returns a `ggplot2` object visualising the summary statistic averaged across participants (if applicable) per set-size (if applicable) and condition (if applicable).

If `return_data` is set to `TRUE`, the function returns a list with two components:

- `plot`: The `ggplot2` object.
- `data`: A data frame with the data used to generate the plot.

### Examples

```
plot_summary_statistic(bays2009_full,
  unit = "radians",
  statistic = "precision",
  set_size_var = "set_size",
  condition_var = "duration")
```

---

simulate_mixtur	<i>Generate simulated data from mixture models</i>
-----------------	--

---

### Description

Generate simulated data from mixture models

### Usage

```
simulate_mixtur(n_trials, model, kappa, p_u, p_n, K, set_size)
```

**Arguments**

n_trials	an integer indicating how many trials to simulate
model	a string indicating the model to be fit to the data. Currently the options are "2_component", "3_component", "slots", and "slots_averaging".
kappa	a numeric value indicating the concentration parameter of the von Mises distribution to use in the simulations. Note, when simulating from the 2_component or 3_component model, if multiple values are provided to the set_size argument, kappa must be a vector of parameter values to use for each set size).
p_u	a numeric value indicating the probability of uniform guessing to use when simulating from the 2_component and 3_component models. Note, when simulating from the 2_component or 3_component model, if multiple values are provided to the set_size argument, p_u must be a vector of parameter values to use for each set size).
p_n	a numeric value indicating the probability of a non-target response when simulating from the 3_component model. Note, when simulating from the 2_component or 3_component model, if multiple values are provided to the set_size argument, p_n must be a vector of parameter values to use for each set size).
K	a numeric value indicating the capacity value to use when simulating from the slots and slots_averaging models.
set_size	a numeric value (or vector) indicating the set size(s) to use in the simulations

**Value**

Returns a data frame containing simulated responses from the requested model per set-size (if applicable).

**Examples**

```
# simulate from the slots model

slots_data <- simulate_mixtur(n_trials = 1000,
                             model = "slots",
                             kappa = 8.2,
                             K = 2.5,
                             set_size = c(2, 4, 6, 8))

# simulate one set size from the 3_component model

component_data <- simulate_mixtur(n_trials = 1000,
                                  model = "3_component",
                                  kappa = 8.2,
                                  p_u = .1,
                                  p_n = .15,
                                  set_size = 4)
```



# Index

## \* datasets

- bays2009\_full, [2](#)
- bays2009\_sample, [3](#)
- berry\_2019, [4](#)
- oberauer\_2017, [7](#)

- bays2009\_full, [2](#)
- bays2009\_sample, [3](#)
- berry\_2019, [4](#)

- fit\_mixtur, [4](#)

- get\_summary\_statistics, [6](#)

- oberauer\_2017, [7](#)

- plot\_error, [8](#)
- plot\_model\_fit, [10](#)
- plot\_model\_parameters, [11](#)
- plot\_summary\_statistic, [12](#)

- simulate\_mixtur, [13](#)