

# Open-visualizations tutorial for repeated measures in R

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## Background

This tutorial is partly inspired by work from [Allen et al. \(2019\)](#) and was initially created to contribute to a GitHub repository called ‘[open-visualizations](#)’. The idea behind the ‘[open-visualizations](#)’ repository stems from the fact that (open) science - in general - lacks ‘fully’ transparent and robust visualizations, i.e., figures have always some form of ‘hidden-data’. To overcome this issue, I started experimenting with some code in Python and R and after posting a [Tweet](#), in which I stated that I was working on ‘[open-visualizations](#)’, Neuroscientist Micah Allen [replied](#) and advised me to check out his work on Rainclouds. After performing two of their tutorials, in [R](#) and [Python](#) respectively, I thought of a way to combine the raincloud approach with my own work performed in [Python](#). Shortly after posting another [Tweet](#), which included some figures that I produced in [R](#), I received a huge amount of encouraging feedback which led me to writing this markdown document. Next to this markdown document, I have created two other tutorials in Python. Both tutorials are available in my repository [open-visualizations](#).

If you have any questions, suggestions for improvement or identify bugs, please open an issue in the GitHub repository [open-visualizations](#).

If you use my repository for your research, please reference it.

## R-version check

```
R.version$version.string
```

```
## [1] "R version 3.6.1 (2019-07-05)"
```

## Package dependencies

Make sure you have the packages that are needed for this tutorial.

- Install **plyr** before **dplyr** - which is included in **tidyverse**. If you need functions from both **plyr** and **dplyr**, please load **plyr** first, then **dplyr**, otherwise error messages might occur (source: R console). **Rmisc** also depends on this package.
- Install **lattice** since **Rmisc** depends on this package.
- Install **tidyverse** since it includes **ggplot2**, **dplyr**, and **readr**.
- Install **rmarkdown** to convert this .Rmd template into a variety of formats including HTML, MS Word, PDF, and Beamer (Only required if you do not work in Rstudio).
- Install **Rmisc** to perform some basic statistical computations (e.g., calculate mean, median, sd, se, ci).
- Install **gghalves** from their GitHub repository since it features the newest options as opposed to the version on CRAN. To install from GitHub, the **devtools** package needs to be installed first. **gghalves** is a **ggplot2** extension for easy plotting of half-half geom combinations. Think half boxplot and half jitterplot, or half violinplot and half dotplot.

## Package references

- `plyr` - [Wickham, 2019](#)
- `lattice` - [Sarkar, 2019](#)
- `tidyverse` - [Wickham, Rstudio, 2019](#)
- `rmarkdown` - [Allaire & Xie, 2020](#)
- `Rmisc` - [Hope, 2013](#)
- `devtools` - [Wickham & Hester, 2020](#)
- `gghalves` - [Tiedemann, 2020](#)

## Install packages

```
packages <- c("plyr", "lattice", "tidyverse", "rmarkdown", "Rmisc")

if (length(setdiff(packages, rownames(installed.packages()))) > 0) {
  install.packages(setdiff(packages, rownames(installed.packages())))
}

if (!require(devtools)) {
  install.packages("devtools")
}
devtools::install_github('erocoar/gghalves')
```

## Load packages

```
library("plyr")
library("lattice")
library("tidyverse")
library("rmarkdown")
library("Rmisc")
library("devtools")
library("gghalves")

# width and height variables for saved plots
w = 6
h = 4

# Define limits of y-axis
y_lim_min = 4
y_lim_max = 7.5

# Make the figure folder if it doesn't exist yet
dir.create('../tutorial_R/figs_repmes/', showWarnings = FALSE)
```

For this tutorial, we make use of the package `gghalves`.

The main idea behind `gghalves` is that standard `geom`'s aggregate data e.g., `geom_boxplot`, `geom_violin` and `geom_dotplot` who all tend to be an approximation of symmetry. Given that the space to display information is limited, we can make better use of it by cutting the `geoms` in half and displaying additional `geoms` that e.g. give information about the sample size [Tiedemann, 2020](#).

## Figure 1

For this example, we make use of the *iris* dataset, which is freely available in R.

We manipulate the dataset by creating two variables (1) `before` and (2) `after`. Specify the variable `n` and create a dataframe `d` which includes the variables `y`, `x` and `id`.

```
before = iris$Sepal.Length[1:50]
after = iris$Sepal.Length[51:100]
n <- length(before)
d <- data.frame(y = c(before, after),
               x = rep(c(1,2), each=n),
               id = factor(rep(1:n,2)))
```

Let's create a first very basic figure only showing the individual datapoints.

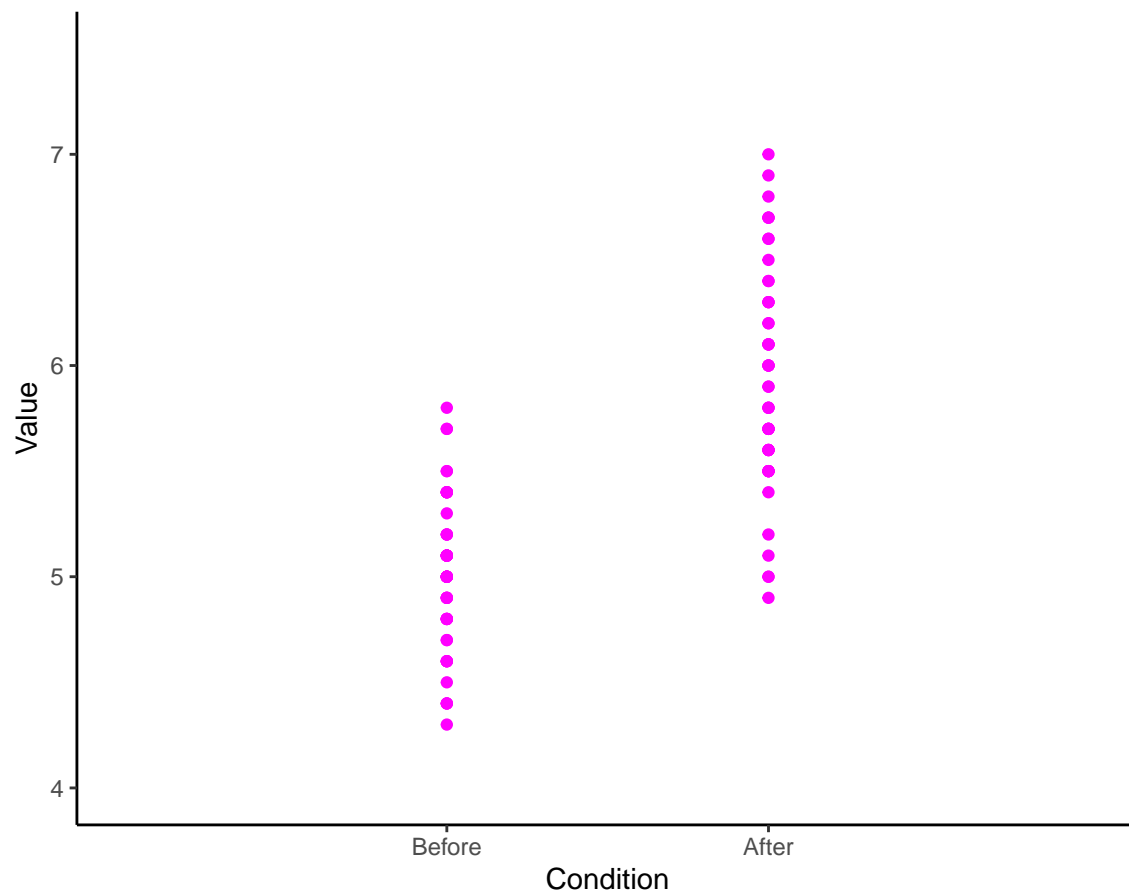
```
f1 <- ggplot(data=d, aes(y=y)) +

  #Add geom_() objects
  geom_point(aes(x=x), color = "magenta", size = 1.5) +

  #Define additional settings
  scale_x_continuous(breaks=c(1,2), labels=c("Before", "After"), limits=c(0, 3)) +
  xlab("Condition") + ylab("Value") +
  ggtitle('Figure 1: Repeated measures individual datapoints') +
  theme_classic() +
  coord_cartesian(ylim=c(y_lim_min, y_lim_max))

f1
```

Figure 1: Repeated measures individual datapoints



```
ggsave('../tutorial_R/figs_repmes/figure1.png', width = w, height = h)
```

Figure 2

Let's again create a simple figure, but now with the datapoints connected (i.e., intra-individual trends).

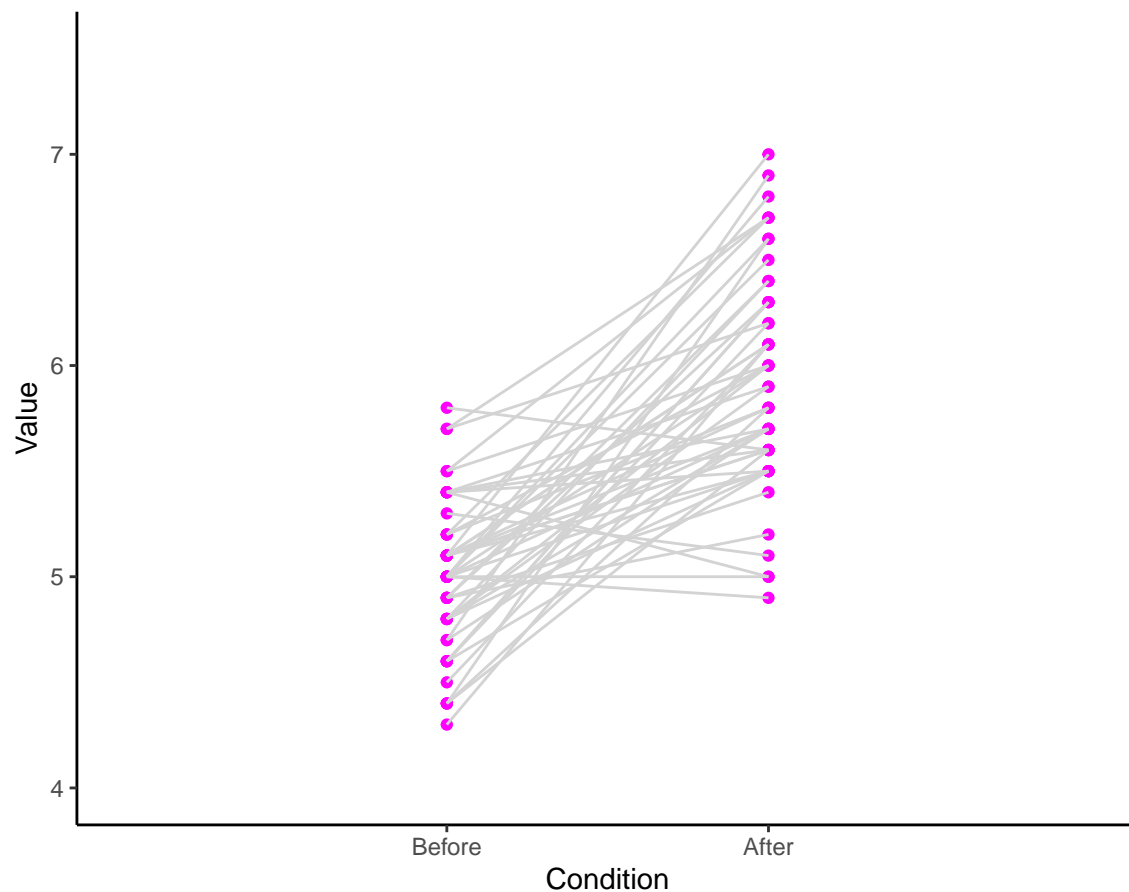
```
f2 <- ggplot(data=d, aes(y=y)) +

  #Add geom_() objects
  geom_point(aes(x=x), color = "magenta", size = 1.5) +
  geom_line(aes(x=x, group=id), color = 'lightgray') +

  #Define additional settings
  scale_x_continuous(breaks=c(1,2), labels=c("Before", "After"), limits=c(0, 3)) +
  xlab("Condition") + ylab("Value") +
  ggtitle('Figure 2: Repeated measures with connecting lines') +
  theme_classic()+
  coord_cartesian(ylim=c(y_lim_min, y_lim_max))
```

f2

Figure 2: Repeated measures with connecting lines



```
ggsave('../tutorial_R/figs_repmes/figure2.png', width = w, height = h)
```

Figure 3

Let's add some jitter to avoid that datapoints overlap.

```
set.seed(321)
d$xj <- jitter(d$x, amount=.09)
```

Now we create the the figure again, including jitter.

```
f3 <- ggplot(data=d, aes(y=y)) +

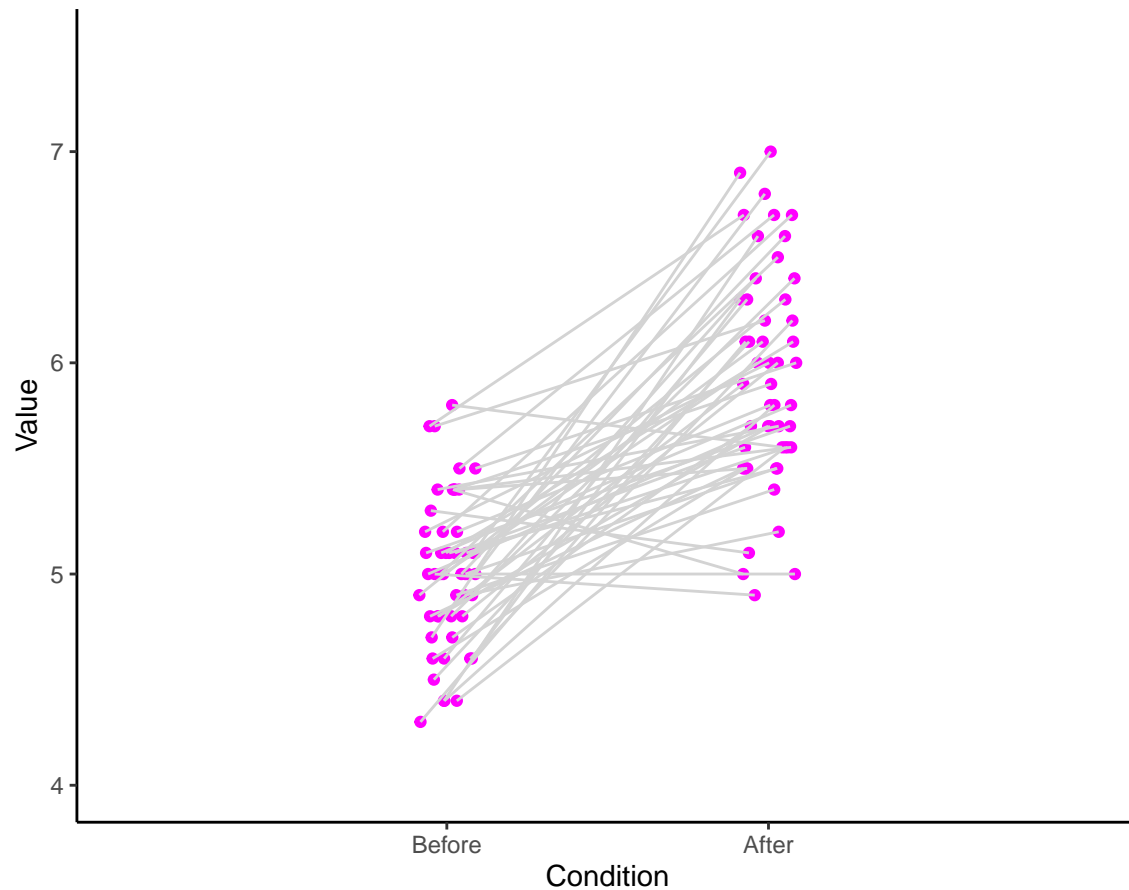
  #Add geom_() objects
  geom_point(aes(x=xj), color = "magenta", size = 1.5) +
  geom_line(aes(x=xj, group=id), color = 'lightgray') +

  #Define additional settings
  scale_x_continuous(breaks=c(1,2), labels=c("Before", "After"), limits=c(0, 3)) +
  xlab("Condition") + ylab("Value") +
  ggtitle('Figure 3: Repeated measures with jitter and connections') +
```

```
theme_classic()+
coord_cartesian(ylim=c(y_lim_min, y_lim_max))
```

f3

Figure 3: Repeated measures with jitter and connections



```
ggsave('../tutorial_R/figs_repmes/figure3.png', width = w, height = h)
```

Figure 4

Produce another figure, but now defined by different colors for Before and After. Just for illustrative purposes, alpha was used in geom\_line.

```
f4 <- ggplot(data=d, aes(y=y)) +

  #Add geom_() objects
  geom_point(data = d %>% filter(x=="1"), aes(x=xj), color = 'dodgerblue', size = 1.5,
            alpha = .6) +
  geom_point(data = d %>% filter(x=="2"), aes(x=xj), color = 'darkorange', size = 1.5,
            alpha = .6) +
  geom_line(aes(x=xj, group=id), color = 'lightgray', alpha = .3) +
```

```
#Define additional settings
scale_x_continuous(breaks=c(1,2), labels=c("Before", "After"), limits=c(0, 3)) +
xlab("Condition") + ylab("Value") +
ggtitle('Figure 4: Repeated measures with jittered datapoints and connections') +
theme_classic()+
coord_cartesian(ylim=c(y_lim_min, y_lim_max))
```

f4

Figure 4: Repeated measures with jittered datapoints and connections



```
ggsave('..\\tutorial_R\\figs_repmes\\figure4.png', width = w, height = h)
```

## Figure 5

Let's add box- and violinplots to create raincloud like plots.

```
f5 <- ggplot(data = d, aes(y = y)) +

#Add geom_() objects
geom_point(data = d %>% filter(x == "1"), aes(x = xj), color = 'dodgerblue', size = 1.5,
          alpha = .6) +
geom_point(data = d %>% filter(x == "2"), aes(x = xj), color = 'darkorange', size = 1.5,
```

```

      alpha = .6) +
geom_line(aes(x = xj, group = id), color = 'lightgray', alpha = .3) +

geom_half_boxplot(
  data = d %>% filter(x=="1"), aes(x=x, y = y), position = position_nudge(x = -.25),
  side = "r", outlier.shape = NA, center = TRUE, errorbar.draw = FALSE, width = .2,
  fill = 'dodgerblue') +

geom_half_boxplot(
  data = d %>% filter(x=="2"), aes(x=x, y = y), position = position_nudge(x = .15),
  side = "r", outlier.shape = NA, center = TRUE, errorbar.draw = FALSE, width = .2,
  fill = 'darkorange') +

geom_half_violin(
  data = d %>% filter(x=="1"), aes(x = x, y = y), position = position_nudge(x = -.3),
  side = "l", fill = 'dodgerblue') +

geom_half_violin(
  data = d %>% filter(x=="2"), aes(x = x, y = y), position = position_nudge(x = .3),
  side = "r", fill = "darkorange") +

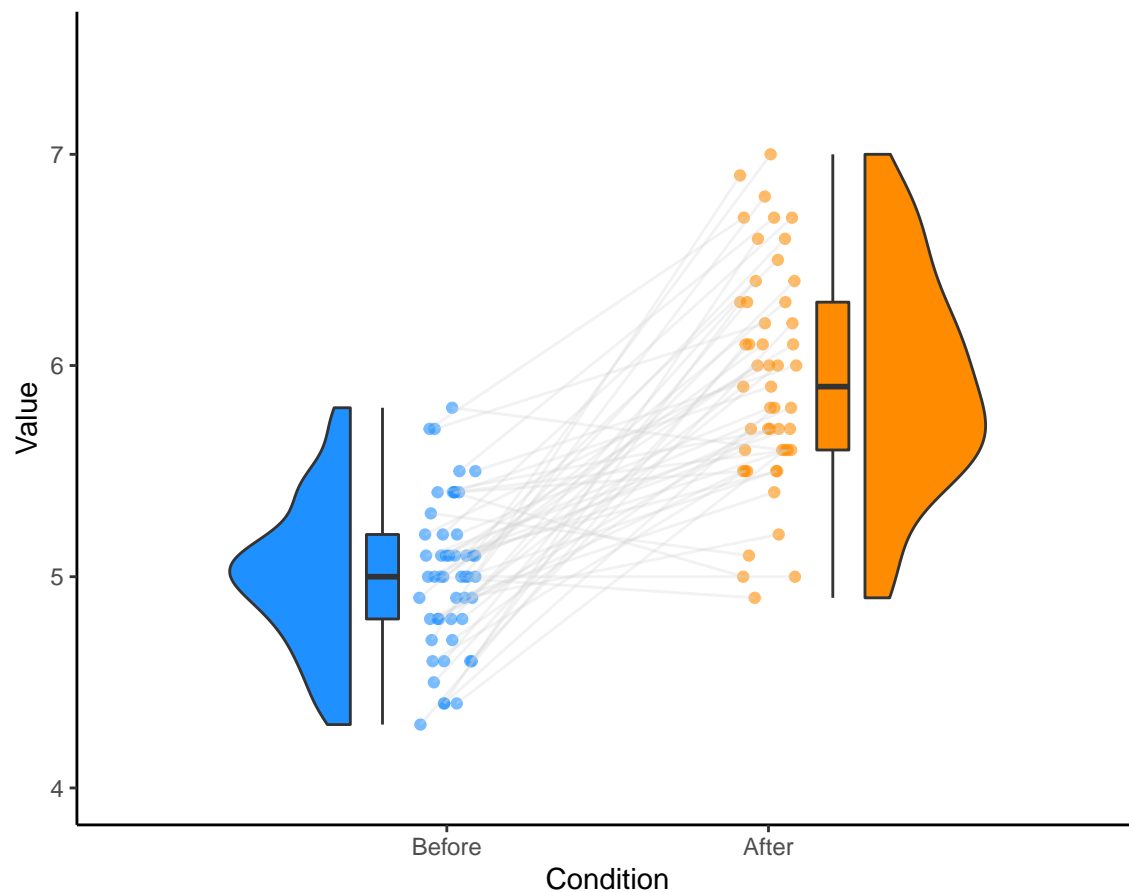
#Define additional settings
scale_x_continuous(breaks=c(1,2), labels=c("Before", "After"), limits=c(0, 3)) +
xlab("Condition") + ylab("Value") +
ggtitle('Figure 5: Repeated measures with box- and violin plots') +
theme_classic()+
coord_cartesian(ylim=c(y_lim_min, y_lim_max))

```

f5



Figure 5: Repeated measures with box- and violin plots



```
ggsave('../tutorial_R/figs_repmes/figure5.png', width = w, height = h)
```

## Note

A potential downside of the current approach is that it uses a lot of filtering and a lot of `geoms`.

## Add descriptive statistics

- Create a dataframe including:
  - Mean
  - Median
  - Standard deviation
  - Standard error
  - Confidence interval (95 %)

```
score_mean_1 <- mean(d$y[1:50])
score_mean_2 <- mean(d$y[51:100])
score_median1 <- median(d$y[1:50])
score_median2 <- median(d$y[51:100])
score_sd_1 <- sd(d$y[1:50])
```

```

score_sd_2 <- sd(d$y[51:100])
score_se_1 <- score_sd_1/sqrt(n) #-> adjust your n
score_se_2 <- score_sd_2/sqrt(n) #-> adjust your n
score_ci_1 <- CI(d$y[1:50], ci = 0.95)
score_ci_2 <- CI(d$y[51:100], ci = 0.95)

#Create data frame with 2 rows and 7 columns containing the descriptives
group <- c("x", "z")
N <- c(50, 50)
score_mean <- c(score_mean_1, score_mean_2)
score_median <- c(score_median1, score_median2)
sd <- c(score_sd_1, score_sd_2)
se <- c(score_se_1, score_se_2)
ci <- c((score_ci_1[1] - score_ci_1[3]), (score_ci_2[1] - score_ci_2[3]))

#Create the dataframe
summary_df <- data.frame(group, N, score_mean, score_median, sd, se, ci)

```

**Figure 6**

Let's add the items calculated in `summary_df` to the figure

```

f6 <- ggplot(data = d, aes(y = y)) +

  #Add geom() objects
  geom_point(data = d %>% filter(x == "1"), aes(x = xj), color = 'dodgerblue', size = 1.5,
    alpha = .6) +
  geom_point(data = d %>% filter(x == "2"), aes(x = xj), color = 'darkorange', size = 1.5,
    alpha = .6) +
  geom_line(aes(x = xj, group = id), color = 'lightgray', alpha = .3) +

  geom_half_boxplot(
    data = d %>% filter(x == "1"), aes(x = x, y = y), position = position_nudge(x = -.28),
    side = "r", outlier.shape = NA, center = TRUE, errorbar.draw = FALSE, width = .2,
    fill = 'dodgerblue') +

  geom_half_boxplot(
    data = d %>% filter(x == "2"), aes(x = x, y = y), position = position_nudge(x = .18),
    side = "r", outlier.shape = NA, center = TRUE, errorbar.draw = FALSE, width = .2,
    fill = 'darkorange') +

  geom_half_violin(
    data = d %>% filter(x == "1"), aes(x = x, y = y), position = position_nudge(x = -.3),
    side = "l", fill = 'dodgerblue') +

  geom_half_violin(
    data = d %>% filter(x == "2"), aes(x = x, y = y), position = position_nudge(x = .3),
    side = "r", fill = "darkorange") +

  geom_point(data = d %>% filter(x == "1"), aes(x = x, y = score_mean[1]),
    position = position_nudge(x = -.13), color = "dodgerblue", alpha = .6, size = 1.5) +

```

```

geom_errorbar(data = d %>% filter(x=="1"), aes(x = x, y = score_mean[1],
  ymin = score_mean[1]-ci[1], ymax = score_mean[1]+ci[1]),
  position = position_nudge(-.13),
  color = "dodgerblue", width = 0.05, size = 0.4, alpha = .5) +

geom_point(data = d %>% filter(x=="2"), aes(x = x, y = score_mean[2]),
  position = position_nudge(x = .13), color = "darkorange", alpha = .6, size = 1.5)+

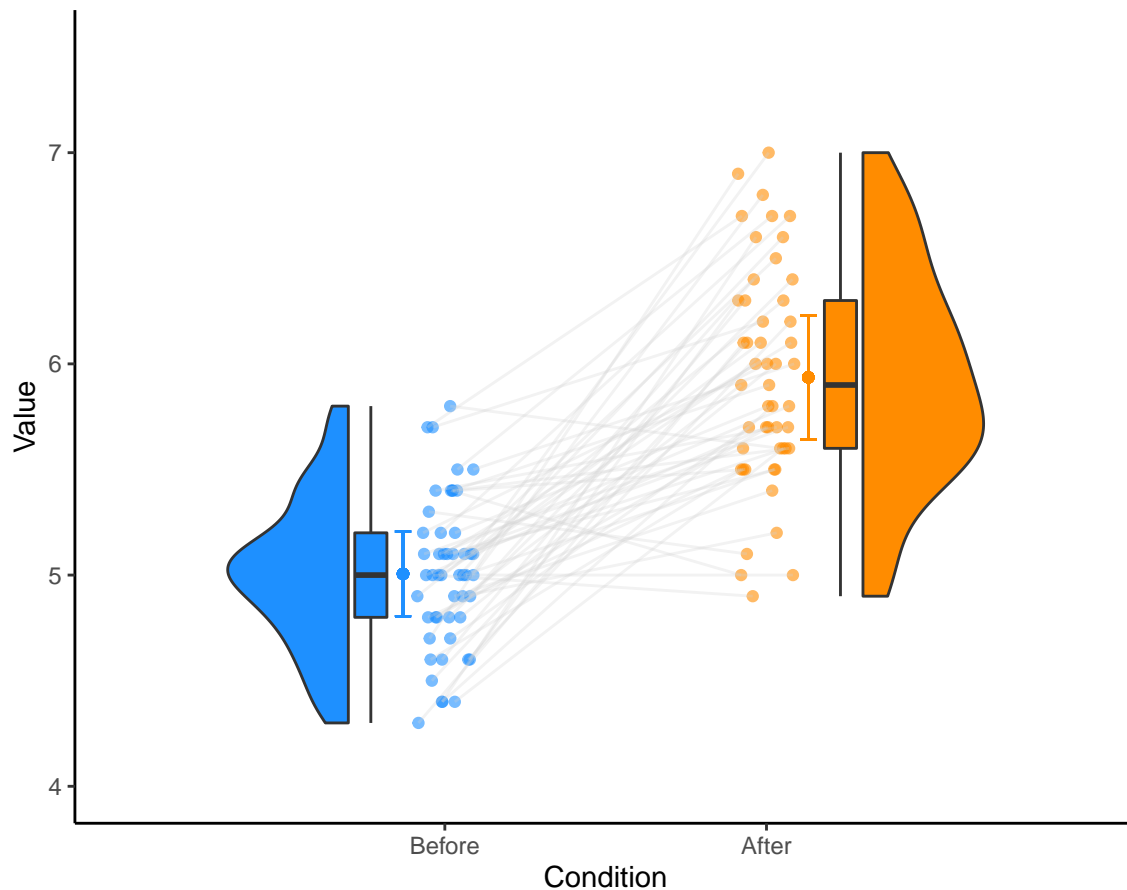
geom_errorbar(data = d %>% filter(x=="2"), aes(x = x, y = score_mean[2],
  ymin = score_mean[2]-ci[2],
  ymax = score_mean[2]+ci[2]), position = position_nudge(.13), color = "darkorange",
  width = 0.05, size = 0.4, alpha = .5) +

#Define additional settings
scale_x_continuous(breaks=c(1,2), labels=c("Before", "After"), limits=c(0, 3)) +
xlab("Condition") + ylab("Value") +
ggtitle('Figure 6: Repeated measures with box- and violin plots') +
theme_classic()+
coord_cartesian(ylim=c(y_lim_min, y_lim_max))

```

f6

Figure 6: Repeated measures with box- and violin plots



```
ggsave('.../tutorial_R/figs_repmes/figure6.png', width = w, height = h)
```

## Figure 7

Optionally you could add a line between the two means. Define the x-coordinates where the line needs to be drawn. Note these coordinates can be calculated as  $1 - \text{position\_nudge}()$  for the first variable and  $2 + \text{position\_nudge}()$  for the second variable, which in our case is  $1 - .13 = .87$  and  $2 + .13 = 2.13$ .

```
x_tick_means <- c(.87, 2.13)

f7 <- ggplot(data = d, aes(y = y)) +

  #Add geom_() objects
  geom_point(data = d %>% filter(x == "1"), aes(x = xj), color = 'dodgerblue', size = 1.5,
            alpha = .6) +
  geom_point(data = d %>% filter(x == "2"), aes(x = xj), color = 'darkorange', size = 1.5,
            alpha = .6) +
  geom_line(aes(x = xj, group = id), color = 'lightgray', alpha = .3) +

  geom_half_boxplot(
    data = d %>% filter(x=="1"), aes(x=x, y = y), position = position_nudge(x = -.28),
    side = "r", outlier.shape = NA, center = TRUE, errorbar.draw = FALSE, width = .2,
    fill = 'dodgerblue') +

  geom_half_boxplot(
    data = d %>% filter(x=="2"), aes(x=x, y = y), position = position_nudge(x = .18),
    side = "r", outlier.shape = NA, center = TRUE, errorbar.draw = FALSE, width = .2,
    fill = 'darkorange') +

  geom_half_violin(
    data = d %>% filter(x=="1"), aes(x = x, y = y), position = position_nudge(x = -.3),
    side = "l", fill = 'dodgerblue') +

  geom_half_violin(
    data = d %>% filter(x=="2"), aes(x = x, y = y), position = position_nudge(x = .3),
    side = "r", fill = "darkorange") +

  geom_point(data = d %>% filter(x=="1"), aes(x = x, y = score_mean[1]),
            position = position_nudge(x = -.13), color = "dodgerblue", alpha = .6, size = 1.5) +

  geom_errorbar(data = d %>% filter(x=="1"), aes(x = x, y = score_mean[1],
            ymin = score_mean[1]-ci[1], ymax = score_mean[1]+ci[1]),
            position = position_nudge(-.13),
            color = "dodgerblue", width = 0.05, size = 0.4, alpha = .6) +

  geom_point(data = d %>% filter(x=="2"), aes(x = x, y = score_mean[2]),
            position = position_nudge(x = .13), color = "darkorange", alpha = .6, size = 1.5)+

  geom_errorbar(data = d %>% filter(x=="2"), aes(x = x, y = score_mean[2],
            ymin = score_mean[2]-ci[2],
            ymax = score_mean[2]+ci[2]), position = position_nudge(.13), color = "darkorange",
            width = 0.05, size = 0.4, alpha = .6) +
```

```

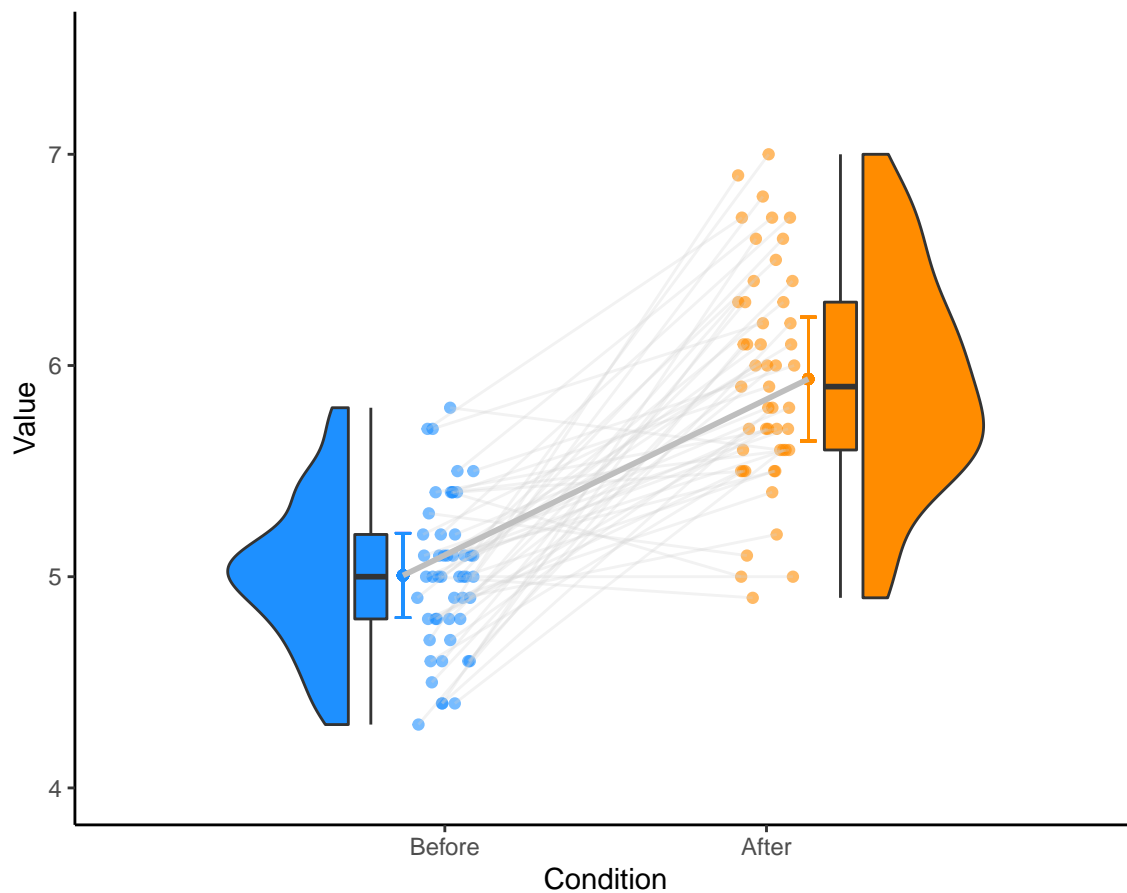
#Add a line connecting the two means
geom_line(data = summary_df, aes(x = x_tick_means, y = score_mean), color = 'gray',
  size = 1) +

#Define additional settings
scale_x_continuous(breaks=c(1,2), labels=c("Before", "After"), limits=c(0, 3)) +
xlab("Condition") + ylab("Value") +
ggtitle('Figure 7: Repeated measures with box- and violin plots and means + ci ') +
theme_classic()+
coord_cartesian(ylim=c(y_lim_min, y_lim_max))

```

f7

Figure 7: Repeated measures with box- and violin plots and means + ci



```

ggsave('../tutorial_R/figs_repmes/figure7.png', width = w, height = h)

```

## 2 x 2 repeated measures rainclouds in a #butterfly fashion

As a last step, let's create these figures for a 2 x 2 repeated measures study.

Define an additional variable *z* which has two categories 3 and 4 and create a second jittered variable.

```

before = iris$Sepal.Length[1:50]
after = iris$Sepal.Length[51:100]
n <- length(before)
d <- data.frame(y = c(before, after),
                x = rep(c(1,2), each=n),
                z = rep(c(3,4), each=n),
                id = factor(rep(1:n,2)))

set.seed(321)
d$xj <- jitter(d$x, amount = .09)
d$xj_2 <- jitter(d$z, amount = .09)

```

```

f8 <- ggplot(data = d, aes(y = y)) +

  #Add geom_() objects
  geom_point(data = d %>% filter(x == "1"), aes(x = xj), color = 'dodgerblue', size = 1.5,
            alpha = .6) +
  geom_point(data = d %>% filter(x == "2"), aes(x = xj), color = 'darkorange', size = 1.5,
            alpha = .6) +
  geom_point(data = d %>% filter(z == "3"), aes(x = xj_2), color = 'dodgerblue', size = 1.5,
            alpha = .6) +
  geom_point(data = d %>% filter(z == "4"), aes(x = xj_2), color = 'darkorange', size = 1.5,
            alpha = .6) +
  geom_line(aes(x = xj, group = id), color = 'lightgray', alpha = .3) +
  geom_line(aes(x = xj_2, group = id), color = 'lightgray', alpha = .3) +

  geom_half_boxplot(
    data = d %>% filter(x=="1"), aes(x=x, y = y), position = position_nudge(x = -.35),
    side = "r", outlier.shape = NA, center = TRUE, errorbar.draw = FALSE, width = .2,
    fill = 'dodgerblue', alpha = .6) +

  geom_half_boxplot(
    data = d %>% filter(x=="2"), aes(x=x, y = y), position = position_nudge(x = -1.16),
    side = "l", outlier.shape = NA, center = TRUE, errorbar.draw = FALSE, width = .2,
    fill = 'darkorange', alpha = .6) +

  geom_half_boxplot(
    data = d %>% filter(z=="3"), aes(x=z, y = y), position = position_nudge(x = 1.3),
    side = "r", outlier.shape = NA, center = TRUE, errorbar.draw = FALSE, width = .2,
    fill = 'dodgerblue', alpha = .6) +

  geom_half_boxplot(
    data = d %>% filter(z=="4"), aes(x=z, y = y), position = position_nudge(x = .2),
    side = "r", outlier.shape = NA, center = TRUE, errorbar.draw = FALSE, width = .2,
    fill = 'darkorange', alpha = .6) +

  geom_half_violin(
    data = d %>% filter(x=="1"), aes(x = x, y = y), position = position_nudge(x = -.40),
    side = "l", fill = 'dodgerblue', alpha = .6) +

  geom_half_violin(
    data = d %>% filter(x=="2"), aes(x = x, y = y), position = position_nudge(x = -1.40),
    side = "l", fill = "darkorange", alpha = .6) +

```

```

geom_half_violin(
  data = d %>% filter(z=="3"), aes(x = z, y = y), position = position_nudge(x = 1.45),
  side = "r", fill = 'dodgerblue', alpha = .6) +

geom_half_violin(
  data = d %>% filter(z=="4"), aes(x = z, y = y), position = position_nudge(x = .45),
  side = "r", fill = "darkorange", alpha = .6) +

geom_point(data = d %>% filter(x=="1"), aes(x = x, y = score_mean[1]),
  position = position_nudge(x = -.13), color = "dodgerblue", alpha = .6, size = 1.5) +

geom_errorbar(data = d %>% filter(x=="1"), aes(x = x, y = score_mean[1],
  ymin = score_mean[1]-ci[1], ymax = score_mean[1]+ci[1]),
  position = position_nudge(-.13),
  color = "dodgerblue", width = 0.05, size = 0.4, alpha = .6) +

geom_point(data = d %>% filter(x=="2"), aes(x = x, y = score_mean[2]),
  position = position_nudge(x = -1.1), color = "darkorange", alpha = .6, size = 1.5)+

geom_errorbar(data = d %>% filter(x=="2"), aes(x = x, y = score_mean[2],
  ymin = score_mean[2]-ci[2],
  ymax = score_mean[2]+ci[2]), position = position_nudge(x = -1.1), color = "darkorange",
  width = 0.05, size = 0.4, alpha = .6) +

geom_point(data = d %>% filter(z=="3"), aes(x = z, y = score_mean[1]),
  position = position_nudge(x = 1.15), color = "dodgerblue", alpha = .5) +

geom_errorbar(data = d %>% filter(z=="3"), aes(x = z, y = score_mean[1],
  ymin = score_mean[1]-ci[1],
  ymax = score_mean[1]+ci[1]), position = position_nudge(1.15),
  color = "dodgerblue", width = 0.05, size = 0.4, alpha = .5)+

geom_point(data = d %>% filter(z=="4"), aes(x = z, y = score_mean[2]),
  position = position_nudge(x = .15), color = "darkorange", alpha = .5)+

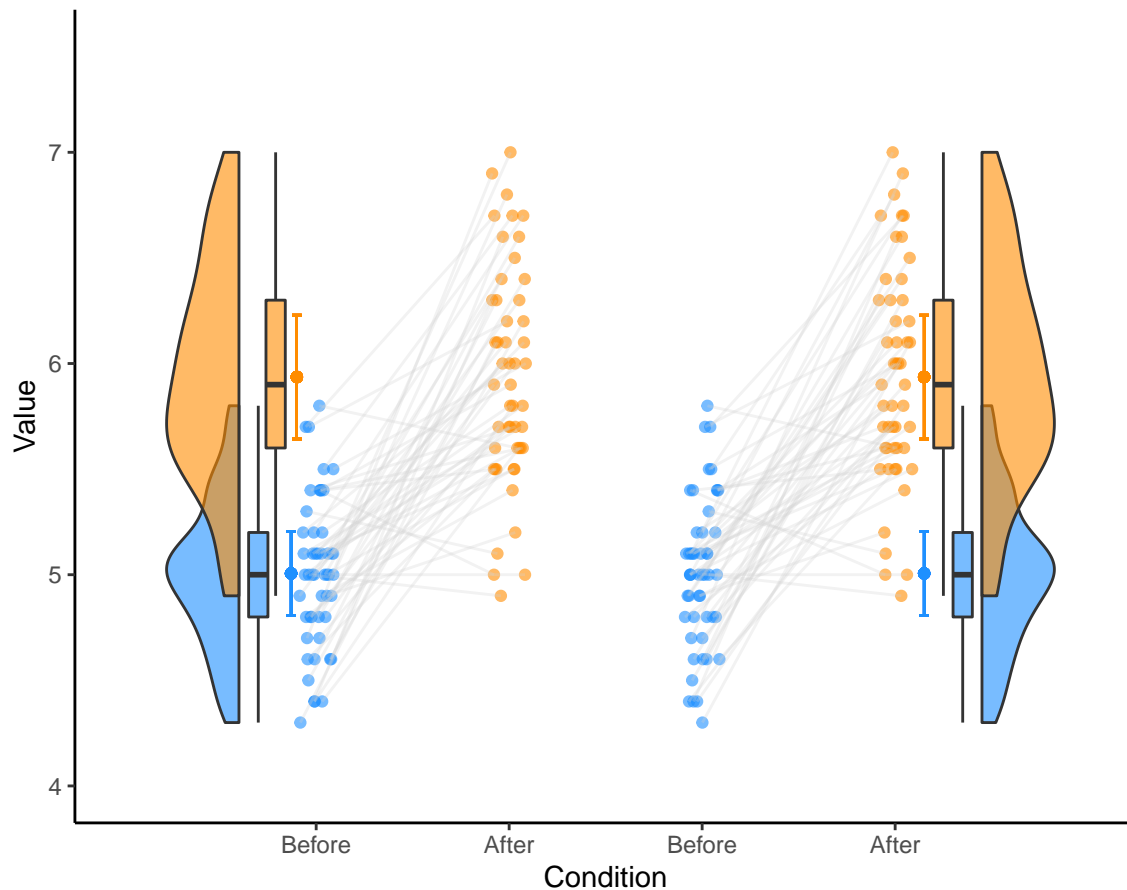
geom_errorbar(data = d %>% filter(z=="4"), aes(x = z, y = score_mean[2],
  ymin = score_mean[2]-ci[2], ymax = score_mean[2]+ci[2]), position = position_nudge(.15),
  color = "darkorange", width = 0.05, size = 0.4, alpha = .5)+

#Define additional settings
scale_x_continuous(breaks=c(1,2,3,4), labels=c("Before", "After", "Before", "After"),
  limits=c(0, 5))+
xlab("Condition") + ylab("Value") +
ggtitle('Figure 8: 2 x 2 Repeated measures with box- and violin plots') +
theme_classic()+
coord_cartesian(ylim=c(y_lim_min, y_lim_max))

```

f8

Figure 8: 2 x 2 Repeated measures with box- and violin plots



```
ggsave('../tutorial_R/figs_repmes/figure8.png', width = w, height = h)
```

Figure 9

Finally, let's add lines that connect the means of each group.

```
#First we must again define the x-coordinates of the means.
x_tick_means_x <- c(.87, 2.13) #same as above
x_tick_means_z <- c(2.87, 4.13) #just add 2 for each tick

f9 <- ggplot(data = d, aes(y = y)) +

  #Add geom_() objects
  geom_point(data = d %>% filter(x == "1"), aes(x = xj), color = 'dodgerblue', size = 1.5,
            alpha = .6) +
  geom_point(data = d %>% filter(x == "2"), aes(x = xj), color = 'darkorange', size = 1.5,
            alpha = .6) +
  geom_point(data = d %>% filter(z == "3"), aes(x = xj_2), color = 'dodgerblue', size = 1.5,
            alpha = .6) +
  geom_point(data = d %>% filter(z == "4"), aes(x = xj_2), color = 'darkorange', size = 1.5,
            alpha = .6) +
  geom_line(aes(x = xj, group = id), color = 'lightgray', alpha = .3) +
```



```

geom_line(aes(x = xj_2, group = id), color = 'lightgray', alpha = .3) +

geom_half_boxplot(
  data = d %>% filter(x=="1"), aes(x=x, y = y), position = position_nudge(x = -.35),
  side = "r", outlier.shape = NA, center = TRUE, errorbar.draw = FALSE, width = .2,
  fill = 'dodgerblue', alpha = .6) +

geom_half_boxplot(
  data = d %>% filter(x=="2"), aes(x=x, y = y), position = position_nudge(x = -1.16),
  side = "l", outlier.shape = NA, center = TRUE, errorbar.draw = FALSE, width = .2,
  fill = 'darkorange', alpha = .6) +

geom_half_boxplot(
  data = d %>% filter(z=="3"), aes(x=z, y = y), position = position_nudge(x = 1.3),
  side = "r", outlier.shape = NA, center = TRUE, errorbar.draw = FALSE, width = .2,
  fill = 'dodgerblue', alpha = .6) +

geom_half_boxplot(
  data = d %>% filter(z=="4"), aes(x=z, y = y), position = position_nudge(x = .2),
  side = "r", outlier.shape = NA, center = TRUE, errorbar.draw = FALSE, width = .2,
  fill = 'darkorange', alpha = .6) +

geom_half_violin(
  data = d %>% filter(x=="1"), aes(x = x, y = y), position = position_nudge(x = -.40),
  side = "l", fill = 'dodgerblue', alpha = .6) +

geom_half_violin(
  data = d %>% filter(x=="2"), aes(x = x, y = y), position = position_nudge(x = -1.40),
  side = "l", fill = "darkorange", alpha = .6) +

geom_half_violin(
  data = d %>% filter(z=="3"), aes(x = z, y = y), position = position_nudge(x = 1.45),
  side = "r", fill = 'dodgerblue', alpha = .6) +

geom_half_violin(
  data = d %>% filter(z=="4"), aes(x = z, y = y), position = position_nudge(x = .45),
  side = "r", fill = "darkorange", alpha = .6) +

geom_point(data = d %>% filter(x=="1"), aes(x = x, y = score_mean[1]),
  position = position_nudge(x = -.13), color = "dodgerblue", alpha = .6, size = 1.5) +

geom_errorbar(data = d %>% filter(x=="1"), aes(x = x, y = score_mean[1],
  ymin = score_mean[1]-ci[1], ymax = score_mean[1]+ci[1]),
  position = position_nudge(-.13),
  color = "dodgerblue", width = 0.05, size = 0.4, alpha = .6) +

geom_point(data = d %>% filter(x=="2"), aes(x = x, y = score_mean[2]),
  position = position_nudge(x = .13), color = "darkorange", alpha = .6, size = 1.5) +

geom_errorbar(data = d %>% filter(x=="2"), aes(x = x, y = score_mean[2],
  ymin = score_mean[2]-ci[2],
  ymax = score_mean[2]+ci[2]), position = position_nudge(x = .13), color = "darkorange",
  width = 0.05, size = 0.4, alpha = .6) +

```

```

geom_point(data = d %>% filter(z=="3"), aes(x = z, y = score_mean[1]),
  position = position_nudge(x = -.13), color = "dodgerblue", alpha = .5) +

geom_errorbar(data = d %>% filter(z=="3"), aes(x = z, y = score_mean[1],
  ymin = score_mean[1]-ci[1],
  ymax = score_mean[1]+ci[1]), position = position_nudge(-.13),
  color = "dodgerblue", width = 0.05, size = 0.4, alpha = .5)+

geom_point(data = d %>% filter(z=="4"), aes(x = z, y = score_mean[2]),
  position = position_nudge(x = .13), color = "darkorange", alpha = .5)+

geom_errorbar(data = d %>% filter(z=="4"), aes(x = z, y = score_mean[2],
  ymin = score_mean[2]-ci[2], ymax = score_mean[2]+ci[2]),
  position = position_nudge(.13),
  color = "darkorange", width = 0.05, size = 0.4, alpha = .5)+

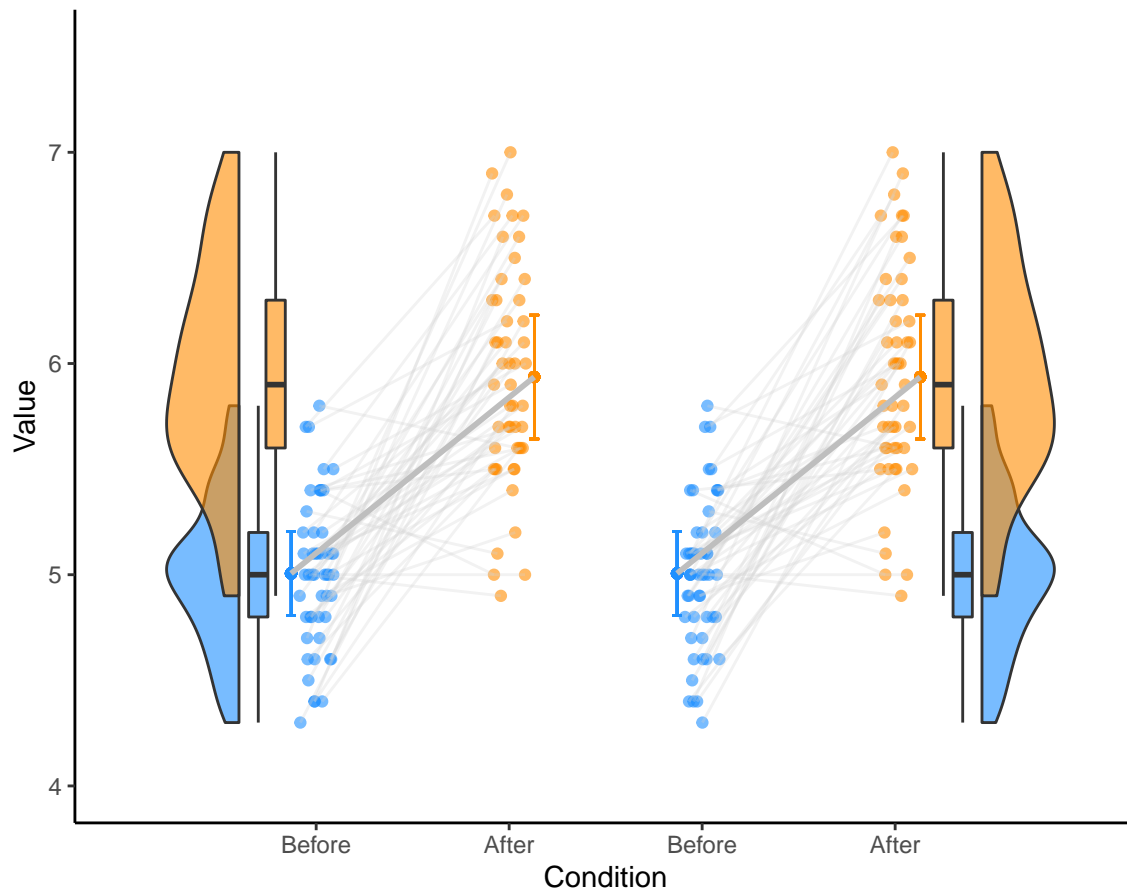
#Add lines connecting the two means
geom_line(data = summary_df, aes(x = x_tick_means_x, y = score_mean),
  color = 'gray', size = 1) +
geom_line(data = summary_df, aes(x = x_tick_means_z, y = score_mean),
  color = 'gray', size = 1) +

#Define additional settings
scale_x_continuous(breaks=c(1,2,3,4), labels=c("Before", "After","Before", "After"),
  limits=c(0, 5))+
xlab("Condition") + ylab("Value") +
ggtitle('Figure 9: 2 x 2 Repeated measures with box- and violin plots') +
theme_classic()+
coord_cartesian(ylim=c(y_lim_min, y_lim_max))

```

f9

Figure 9: 2 x 2 Repeated measures with box- and violin plots



```
ggsave('../tutorial_R/figs_repmes/figure9.png', width = w, height = h)
```

## General remarks / tips

- To be more flexible in assigning labels to your figures, the **ggtext** package by [Wilke, 2020](#) might be worthwhile .
- If you would like to be flexible in plotting multiple figures next to each other, check-out the **patchwork** package by [Pedersen, 2020](#).
- If you want to save your figures in a high-quality manner (> GB) for e.g., publications, you could save your figure with a **.tiff** extension and add **dpi=** as used in the following line of code:

```
ggsave("figure.tiff", height=h, width=w, units='in', dpi=600)
```

- If for some reason your code does not work due to e.g., an update in a package, you could use the following line of code to unload and load that package again.

```
if("package_name" %in% (.packages())){
  detach('package:package_name', unload=TRUE)}

library("package_name")
```

You have reached the end of this document.

I hope you'll be able to use this tutorial to create more **open-visualizations** for your research!

If you use this tutorial, please cite it in your work.

[open-visualizations](#) for repeated measures in R by **Jordy van Langen**