The relationship between mindset and academic achievement: A reanalysis of Sisk et al. (2018) meta-analysis

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1. Prepare environment

```r
# Load packages -----------------------------------------------------------
library(tidyverse)
```

```
## -- Attaching packages --------------------------------------- tidyverse 1.3.0 --

## v ggplot2 3.3.5     v purrr   0.3.4
## v tibble  3.1.6     v dplyr   1.0.8
## v tidyr   1.1.2     v stringr 1.4.0
## v readr   2.1.2     v forcats 0.5.0

## Warning: package 'readr' was built under R version 4.0.5

## -- Conflicts ------------------------------------------ tidyverse_conflicts() --
## x dplyr::filter() masks stats::filter()
## x dplyr::lag()    masks stats::lag()
```

```r
library(metafor)
```

```
## Loading required package: Matrix

##
## Attaching package: 'Matrix'

## The following objects are masked from 'package:tidyr':
##
##     expand, pack, unpack

##
## Loading the 'metafor' package (version 3.0-2). For an
## introduction to the package please type: help(metafor)
```

```r
library(readxl)
library(gridExtra) # for arranging qqplots
```

```
##
## Attaching package: 'gridExtra'

## The following object is masked from 'package:dplyr':
##
##     combine
```

```r
library(multcomp) # for multiple comparisons
```

```
## Loading required package: mvtnorm
## Loading required package: survival
## Loading required package: TH.data
## Loading required package: MASS
##
## Attaching package: 'MASS'
## The following object is masked from 'package:dplyr':
##
##     select
##
## Attaching package: 'TH.data'
## The following object is masked from 'package:MASS':
##
##     geyser
```

```r
# Local function(s) -------------------------------------------------------

# * Function to calculate I^2 in multilevel model -------------------------
# Formulae:
# Sampling variance: Chen(2015), formula (4.29), Higgins and Thompson statistics
# Multilevel I^2: Cheung(2014), formulae (10), (11)

# Function Inputs:
# tau2_level2: multilevel within-study study variance
# tau2_level3: multilevel between-study variance
# vect_var: vector of variances (e.g. df$vi)

multilevel_i2 <- function (tau2_level2, tau2_level3, vect_var) {
  k <- length(vect_var)
  numerator <- (k-1)*sum(1/vect_var)
  denominator <- (sum(1/vect_var)^2) - sum(1/(vect_var)^2)
  v <- numerator / denominator

  i2_denominator <- tau2_level2 + tau2_level3 + v

  i2_level1 <- v / i2_denominator

  i2_level2 <- tau2_level2 / i2_denominator

  i2_level3 <- tau2_level3 / i2_denominator

  I2_1 <- round((amountvariancelevel1 <- i2_level1 * 100),2)
  I2_2 <- round((amountvariancelevel2 <- i2_level2 * 100),2)
  I2_3 <- round((amountvariancelevel3 <- i2_level3 * 100),2)

  col1 <- rbind(I2_1, I2_2, I2_3)
  col2 <- rbind('Level 1', 'Level 2', 'Level 3')
  I2_partition <- data.frame(col1, col2)
  names(I2_partition) <- c('I2', 'Level')
  print(I2_partition)
```

```r
  # Barplot
  ggplot(I2_partition, aes(x="", y=I2, fill=Level))+
    geom_bar(width = 1, stat = "identity") +
    labs(title = "Distribution of variance across levels") +
    theme_light()

}

# Import data -------------------------------------------------------------
df1 <- read_excel('../mindset/data/mindset.xlsx', sheet = 'Meta-analysis 1')
```

2. Data cleaning

```r
# Data cleaning ------------------------------------------------------------
# Glimpse data
glimpse(df1)
```

```
## Rows: 273
## Columns: 35
## $ `Document #`                          <dbl> 1, 2, 2, 2, 3, 3, 3, 3, 4, 5, 6, 6~
## $ `Study #`                             <dbl> 1, 2, 2, 2, 3, 3, 3, 3, 4, 5, 6, 6~
## $ `Sample #`                            <dbl> 1, 2, 3, 4, 5, 81, 81, 81, 6, 7, 8~
## $ `Sample Country`                      <chr> "Indonesia", "USA", "USA", "USA", ~
## $ `ES #`                                <dbl> 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11,~
## $ Reference                             <chr> "Adatitomo (2015)", "Bagley (2016)~
## $ N                                     <dbl> 123, 400, 1019, 710, 250, 272, 279~
## $ `Adjusted N`                          <dbl> 123.000000, 400.000000, 1019.00000~
## $ `Student Description`                 <chr> "second semester university studen~
## $ `School Level`                        <chr> "post-secondary", "post-secondary"~
## $ `Development Stage`                   <chr> "Adults", "Adults", "Adults", "Adu~
## $ `Risk status`                         <chr> "low", "moderate", "moderate", "mo~
## $ SES                                   <chr> "not reported", "not reported", "n~
## $ `MS Measure`                          <chr> "Mindset about intelligence", "Dwe~
## $ `MS Measure Description`              <chr> "6 items, 3 growth and 3 fixed fro~
## $ `Mindset Type`                        <chr> "Intelligence", "Personal attribut~
## $ `Achievement Measure Description`     <chr> "Statistics final exam grade", "De~
## $ `Academic Achievement Measure Type`   <chr> "Course exam", "Course grade", "Co~
## $ `Lab-based`                           <chr> "no", "no", "no", "no", "no", "no"~
## $ Published                             <chr> "yes", "no", "no", "no", "no", "no~
## $ `ES type`                             <chr> "continuous", "continuous", "conti~
## $ Calculation                           <chr> "Pearson's r", "sqrt of bivariate ~
## $ Variance                              <dbl> 0.0079425749, 0.0024188215, 0.0009~
## $ `Adjusted Variance`                   <dbl> 0.0079425749, 0.0024188215, 0.0009~
## $ `Significant?`                        <chr> "N", "Y", "Y", "Y", "Y", "Y", "Y",~
## $ r                                     <dbl> -0.12500000, 0.13266499, 0.1972308~
## $ `Growth M`                            <dbl> NA, NA, NA, NA, NA, NA, NA, NA, NA~
## $ `Growth SD`                           <dbl> NA, NA, NA, NA, NA, NA, NA, NA, NA~
## $ `Other M`                             <dbl> NA, NA, NA, NA, NA, NA, NA, NA, NA~
## $ `Other SD`                            <dbl> NA, NA, NA, NA, NA, NA, NA, NA, NA~
## $ `Cohen's d`                           <dbl> NA, NA, NA, NA, NA, NA, NA, NA, NA~
## $ rpb                                   <dbl> NA, NA, NA, NA, NA, NA, NA, NA, NA~
## $ rb                                    <dbl> NA, NA, NA, NA, NA, NA, NA, NA, NA~
## $ `Calculated r`                        <dbl> NA, NA, NA, NA, NA, NA, NA, NA, NA~
## $ Notes                                 <chr> "the authors of the study also mea~
```

```r
# Rename columns
df2 <- rename(df1,
              document_id = 'Document #',
              study_id = 'Study #',
              sample_id = 'Sample #',
              sample_country = 'Sample Country',
              es_id = 'ES #',
              reference = 'Reference',
              n = N,
              adjusted_n = 'Adjusted N',
```

```r
              student_description = 'Student Description',
              school_level = 'School Level',
              development_stage = 'Development Stage',
              risk_status = 'Risk status',
              ses = SES,
              ms_measure = 'MS Measure',
              ms_measure_description = 'MS Measure Description',
              mindset_type = 'Mindset Type',
              achievement_measure_description = 'Achievement Measure Description',
              academic_achievement_measure_type = 'Academic Achievement Measure Type',
              lab_based = 'Lab-based',
              published = 'Published',
              es_type = 'ES type',
              calculation = 'Calculation',
              variance = 'Variance',
              adjusted_variance = 'Adjusted Variance',
              is_significant = 'Significant?',
              growth_m = 'Growth M',
              growth_sd = 'Growth SD',
              other_m = 'Other M',
              other_sd = 'Other SD',
              cohen_d = "Cohen's d",
              calculated_r = 'Calculated r',
              notes = Notes)

# Check that variable types is correct
glimpse(df2)
```

```
## Rows: 273
## Columns: 35
## $ document_id                       <dbl> 1, 2, 2, 2, 3, 3, 3, 3, 4, 5, 6, 6, ~
## $ study_id                          <dbl> 1, 2, 2, 2, 3, 3, 3, 3, 4, 5, 6, 6, ~
## $ sample_id                         <dbl> 1, 2, 3, 4, 5, 81, 81, 81, 6, 7, 8, ~
## $ sample_country                    <chr> "Indonesia", "USA", "USA", "USA", "U~
## $ es_id                             <dbl> 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 1~
## $ reference                         <chr> "Adatitomo (2015)", "Bagley (2016) --~
## $ n                                 <dbl> 123, 400, 1019, 710, 250, 272, 279, ~
## $ adjusted_n                        <dbl> 123.000000, 400.000000, 1019.000000,~
## $ student_description               <chr> "second semester university students~
## $ school_level                      <chr> "post-secondary", "post-secondary", ~
## $ development_stage                 <chr> "Adults", "Adults", "Adults", "Adult~
## $ risk_status                       <chr> "low", "moderate", "moderate", "mode~
## $ ses                               <chr> "not reported", "not reported", "not~
## $ ms_measure                        <chr> "Mindset about intelligence", "Dweck~
## $ ms_measure_description            <chr> "6 items, 3 growth and 3 fixed from ~
## $ mindset_type                      <chr> "Intelligence", "Personal attributes~
## $ achievement_measure_description   <chr> "Statistics final exam grade", "Deve~
## $ academic_achievement_measure_type <chr> "Course exam", "Course grade", "Cour~
## $ lab_based                         <chr> "no", "no", "no", "no", "no", "no", ~
## $ published                         <chr> "yes", "no", "no", "no", "no", "no",~
## $ es_type                           <chr> "continuous", "continuous", "continu~
## $ calculation                       <chr> "Pearson's r", "sqrt of bivariate R^~
## $ variance                          <dbl> 0.0079425749, 0.0024188215, 0.000907~
## $ adjusted_variance                 <dbl> 0.0079425749, 0.0024188215, 0.000907~
```

```
## $ is_significant                     <chr> "N", "Y", "Y", "Y", "Y", "Y", "Y", "~
## $ r                                  <dbl> -0.12500000, 0.13266499, 0.19723083,~
## $ growth_m                           <dbl> NA, NA, NA, NA, NA, NA, NA, NA, NA, ~
## $ growth_sd                          <dbl> NA, NA, NA, NA, NA, NA, NA, NA, NA, ~
## $ other_m                            <dbl> NA, NA, NA, NA, NA, NA, NA, NA, NA, ~
## $ other_sd                           <dbl> NA, NA, NA, NA, NA, NA, NA, NA, NA, ~
## $ cohen_d                            <dbl> NA, NA, NA, NA, NA, NA, NA, NA, NA, ~
## $ rpb                                <dbl> NA, NA, NA, NA, NA, NA, NA, NA, NA, ~
## $ rb                                 <dbl> NA, NA, NA, NA, NA, NA, NA, NA, NA, ~
## $ calculated_r                       <dbl> NA, NA, NA, NA, NA, NA, NA, NA, NA, ~
## $ notes                              <chr> "the authors of the study also measu~
```

```r
# Change school_level from character to factor
df2$school_level <- as.factor(df2$school_level)
levels(df2$school_level)
```

```
##  [1] "elementary, middle and high"
##  [2] "graduate"
##  [3] "middle"
##  [4] "middle and secondary"
##  [5] "middle and secondary (mostly secondary)"
##  [6] "post-secondary"
##  [7] "primary"
##  [8] "primary and middle"
##  [9] "secondary"
## [10] "vocational courses"
```

```r
# Change development_stage from character to factor
df2$development_stage <- as.factor(df2$development_stage)
levels(df2$development_stage)
```

```
## [1] "Adolescents" "Adults"      "Children"    "Wide range"  "Wide Range"
```

```r
# Convert all "Wide range" level to "Wide Range"
df2$development_stage <- recode_factor(df2$development_stage,
                                       'Wide range' = 'Wide Range')
levels(df2$development_stage)
```

```
## [1] "Wide Range"  "Adolescents" "Adults"      "Children"
```

```r
# Change risk_status from character to factor
df2$risk_status <- as.factor(df2$risk_status)
levels(df2$risk_status)
```

```
## [1] "."        "high"     "low"      "moderate"
```

```r
## Note: The category '.' applies to 4 rows
## These are studies from which it was not possible to determine the risk status
## df2 %>%
##   filter(risk_status == '.')

# Change ses from character to factor
df2$ses <- as.factor(df2$ses)
levels(df2$ses)
```

```
## [1] "low SES"      "not low"      "not reported"
```

```r
# Change mindset_type from character to factor
df2$mindset_type <- as.factor(df2$mindset_type)
levels(df2$mindset_type)
```

```
##  [1] "Ability"
##  [2] "Ability and Intelligence"
##  [3] "Ability and Performance"
##  [4] "Ability to learn"
##  [5] "Art Ability"
##  [6] "Biology Ability"
##  [7] "English Ability"
##  [8] "Intelligence"
##  [9] "Intelligence and Reading Ability"
## [10] "Intelligence and Talent"
## [11] "Intelligence, Math Ability, and Effort"
## [12] "Math ability"
## [13] "Math Ability"
## [14] "Math intelligence"
## [15] "Math Intelligence"
## [16] "Performance and Intelligence"
## [17] "Personal attributes"
## [18] "Personality"
## [19] "Physics Intelligence"
## [20] "Reading Ability"
## [21] "School Ability"
## [22] "Science ability"
## [23] "Science Ability"
## [24] "Talent for School"
## [25] "Verbal Intelligence"
```

```r
# Change academic_achievement_measure_type from character to factor
df2$academic_achievement_measure_type <- as.factor(df2$academic_achievement_measure_type)
levels(df2$academic_achievement_measure_type)
```

```
## [1] "Course exam"       "Course grade"      "GPA"
## [4] "Standardized test"
```

```r
# Change lab_based from character to factor
df2$lab_based <- as.factor(df2$lab_based)
levels(df2$lab_based)
```

```
## [1] "no"  "yes"
```

```r
# Change published from character to factor
df2$published <- as.factor(df2$published)
levels(df2$published)
```

```
## [1] "no"  "yes"
```

```r
# Change es_type from character to factor
df2$es_type <- as.factor(df2$es_type)
levels(df2$es_type)
```

```
## [1] "categorical" "continuous"
```

```r
# Change is_significant from character to factor
df2$is_significant <- as.factor(df2$is_significant)
```

```r
levels(df2$is_significant)
```

```
## [1] "N" "Y"
```

```r
# Create dataframe for metafor:
# Calculate r-to-z transformed correlations and corresponding sampling variances
df3 <- escalc(measure="ZCOR", ri=r, ni=n, data=df2)
```

3. Exploratory Data Analysis

```
# Exploratory Data Analysis ----------------------------------------------
# How many effect sizes?
length(df3$study_id)
```

```
## [1] 273
```

```
# How many studies?
length(unique(df3$study_id))
```

```
## [1] 129
```

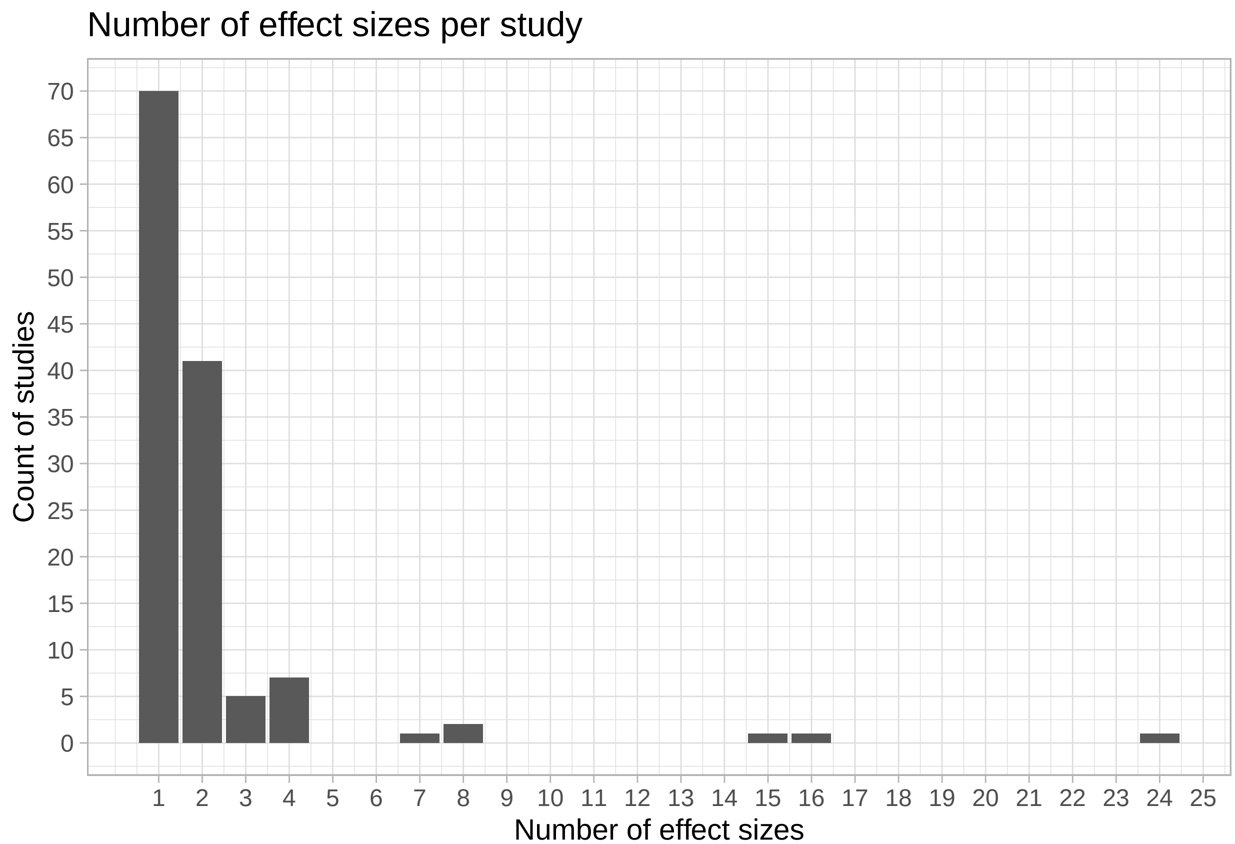
```
# How many samples?
length(unique(df3$sample_id))
```

```
## [1] 162
```

```
# * Count effect sizes per study ------------------------------------------
# How many effect sizes per study?
df_groub_by_study <- df3 %>%
  group_by(study_id) %>%
  summarize(n_es = n())

summarize(df_groub_by_study,
          min_n_es = min(n_es),
          max_n_es = max(n_es),
          median_n_es = median(n_es))
```

```
## # A tibble: 1 x 3
##   min_n_es max_n_es median_n_es
##      <int>    <int>       <int>
## 1        1       24           1
```

```
ggplot(df_groub_by_study, aes(x=n_es)) +
  geom_bar() +
  labs(title = 'Number of effect sizes per study',
       x = 'Number of effect sizes',
       y = 'Count of studies') +
  scale_x_continuous(breaks = seq(0:27)) +
  scale_y_continuous(breaks = seq(from = 0, to =80, by=5)) +
  theme_light()
```




```r
## Percentage of studies reporting 1 effect size
df_percentage_es <- df_groub_by_study %>%
  group_by(n_es) %>%
  summarize(total = n()) %>%
  mutate(percentage = round(total/sum(total), 3))

# Check that sums to 100
sum(df_percentage_es$percentage)
```

```
## [1] 1.002
```

```r
## Percentage of studies with more than 2 effect sizes
df_percentage_es %>%
  filter(n_es > 2 ) %>%
  mutate(sum = sum(percentage))
```

```
## # A tibble: 7 x 4
##    n_es total percentage   sum
##   <int> <int>      <dbl> <dbl>
## 1     3     5      0.039 0.141
## 2     4     7      0.054 0.141
## 3     7     1      0.008 0.141
## 4     8     2      0.016 0.141
## 5    15     1      0.008 0.141
## 6    16     1      0.008 0.141
## 7    24     1      0.008 0.141
```

```r
# Sample sizes
## Minimum sample size
min(df3$n)
```

```
## [1] 6
```

```r
## Maximum sample size
max(df3$n)
```

```
## [1] 167605
```

```r
## Mean sample size
mean(df3$n)
```

```
## [1] 1537.927
```

```r
## Median sample size
median(df3$n)
```

```
## [1] 165
```

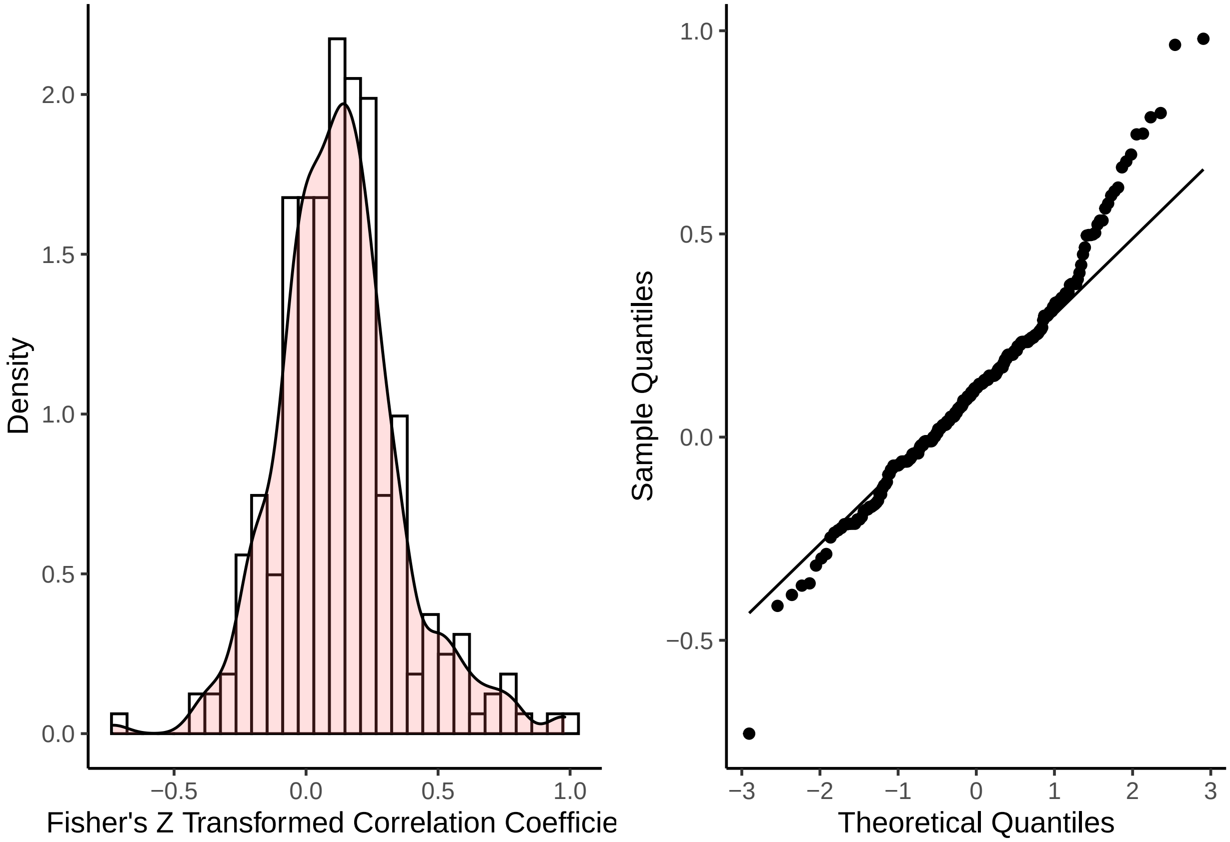
```r
# Which study has the largest sample size?
df3 %>%
  filter(n == max(df3$n))
```

```
##   document_id study_id sample_id sample_country es_id           reference
## 1          17       18        29          Chile    55 Claro et al. (2016)
##        n adjusted_n                        student_description school_level
## 1 167605     167605 10th grade public school students in Chile    secondary
##   development_stage risk_status     ses                   ms_measure
## 1       Adolescents         low low SES Theory of Intelligence Scale
##       ms_measure_description mindset_type
## 1 2 items on a 6-point scale Intelligence
##                achievement_measure_description
## 1 Average standardized language and math tests
##   academic_achievement_measure_type lab_based published    es_type calculation
## 1                 Standardized test        no       yes continuous Pearson's r
##       variance adjusted_variance is_significant     r growth_m growth_sd
## 1 4.645135e-06      4.645135e-06              Y 0.343       NA        NA
##   other_m other_sd cohen_d rpb rb calculated_r notes     yi     vi
## 1      NA       NA      NA  NA NA           NA  <NA> 0.3575 0.0000
```

```r
# Claro et al. (2016)


# * Fisher's Z vs Correlation Coefficient ---------------------------------
# Explore graphically Fisher's Z
density_z <- ggplot(df3, aes(x=yi)) +
  geom_histogram(aes(y=..density..), colour = 'black', fill = "white") +
  geom_density(alpha=.2, fill="#FF6666") +
  labs(x = "Fisher's Z Transformed Correlation Coefficient",
       y = "Density") +
  theme_classic()

# Fisher's Z
qqplot_z <- ggplot(df3, aes(sample=yi)) +
  stat_qq(distribution = stats::qnorm) +
  stat_qq_line(distribution = stats::qnorm,) +
```

```
  labs(x = "Theoretical Quantiles",
       y = "Sample Quantiles") +
  theme_classic()

grid.arrange(density_z, qqplot_z, ncol=2)
```

```
## `stat_bin()` using `bins = 30`. Pick better value with `binwidth`.
```



3. Random Effect Model meta-analysis

```r
# Meta-analysis 1: Random-effects model (REM) ------------------------------
meta1 <- rma (yi = yi,
              vi = vi,
              measure = 'ZCOR',
              data = df3,
              slab = es_id,
              method = 'REML')
summary(meta1, digits = 3)
```

```
##
## Random-Effects Model (k = 273; tau^2 estimator: REML)
##
##   logLik  deviance       AIC       BIC      AICc
##   60.314  -120.628  -116.628  -109.416  -116.583
##
## tau^2 (estimated amount of total heterogeneity): 0.019 (SE = 0.002)
## tau (square root of estimated tau^2 value):      0.137
## I^2 (total heterogeneity / total variability):   95.68%
## H^2 (total variability / sampling variability):  23.13
##
## Test for Heterogeneity:
## Q(df = 272) = 8958.240, p-val < .001
##
## Model Results:
##
## estimate     se    zval   pval  ci.lb  ci.ub
##    0.107  0.010  10.411  <.001  0.087  0.127  ***
##
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```r
# Confidence interval around tau^2
## Interval for tau^2 is obtained iteratively either via the Q-profile method
## or via the generalized Q-statistic method
## The square root of the interval bounds is also returned for easier interpretation.
## Confidence intervals for I2 and H2 are also provided (Higgins & Thompson, 2002).
## Since I2 and H2 are just monotonic transformations of tau2 the confidence intervals
## for I2 and H2 are also exact.
confint.rma.uni(meta1, digits = 2)
```

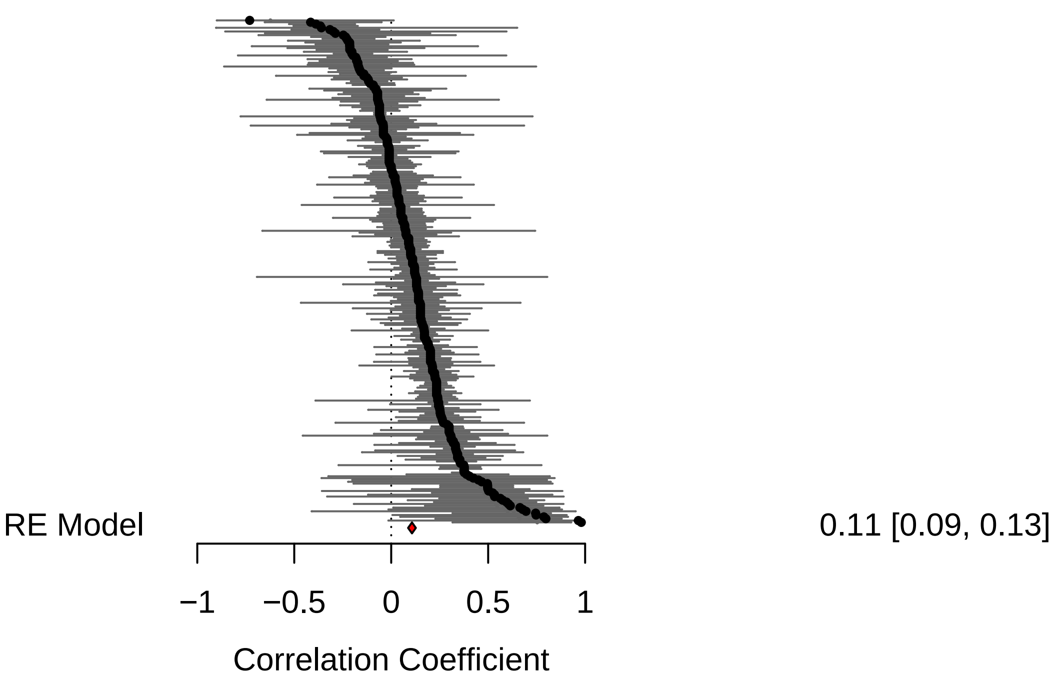
```
##
##         estimate ci.lb ci.ub
## tau^2       0.02  0.02  0.03
## tau         0.14  0.13  0.17
## I^2(%)     95.68 95.08 97.10
## H^2        23.13 20.31 34.52
```

```r
# Transform from z to r
predict(meta1, digits=2, transf=transf.ztor)
```

```
##
##  pred ci.lb ci.ub pi.lb pi.ub
##  0.11  0.09  0.13 -0.16  0.36
```

3.1 Caterpillar plot

```r
# Caterpillar plot ------------------------------------------------------------
# Open jpeg file
# jpeg("caterpillar.jpeg", quality = 100)

# Source code:
# http://www.metafor-project.org/doku.php/plots:caterpillar_plot
### create plot
forest(df3$yi, df3$vi,
       xlim=c(-2.5,3.5),         ### adjust horizontal plot region limits
       order="obs",              ### order by size of yi
       slab=NA, annotate=FALSE, ### remove study labels and annotations
       efac=0,                   ### remove vertical bars at end of CIs
       pch=19,                   ### changing point symbol to filled circle
       col="gray40",             ### change color of points/CIs
       psize=2,                  ### increase point size
       cex.lab=1, cex.axis=1,    ### increase size of x-axis title/labels
       lty=c("solid","blank"),   ### remove horizontal line at top of plot
       transf = transf.ztor)

### draw points one more time to make them easier to see
points(sort(df3$yi), length(df3$vi):1, pch=19, cex=0.5)

### add summary polygon at bottom and text
addpoly(meta1, mlab="", cex=1, col = 'red')
text(-2, -2, "RE Model", pos=4, offset=0, cex=1)
```




```r
# Close jpeg file
# dev.off()

# Find minimum and maximum value of point estimates
min(df2$r)
```

```
## [1] -0.6228928
```

```r
max(df2$r)
```

```
## [1] 0.7531611
```

3.2 Subgroup analysis

```
# Subgroup analysis ----------------------------------------------------
# Prepare dataset
levels(df3$development_stage)
```

```
## [1] "Wide Range"  "Adolescents" "Adults"      "Children"
```

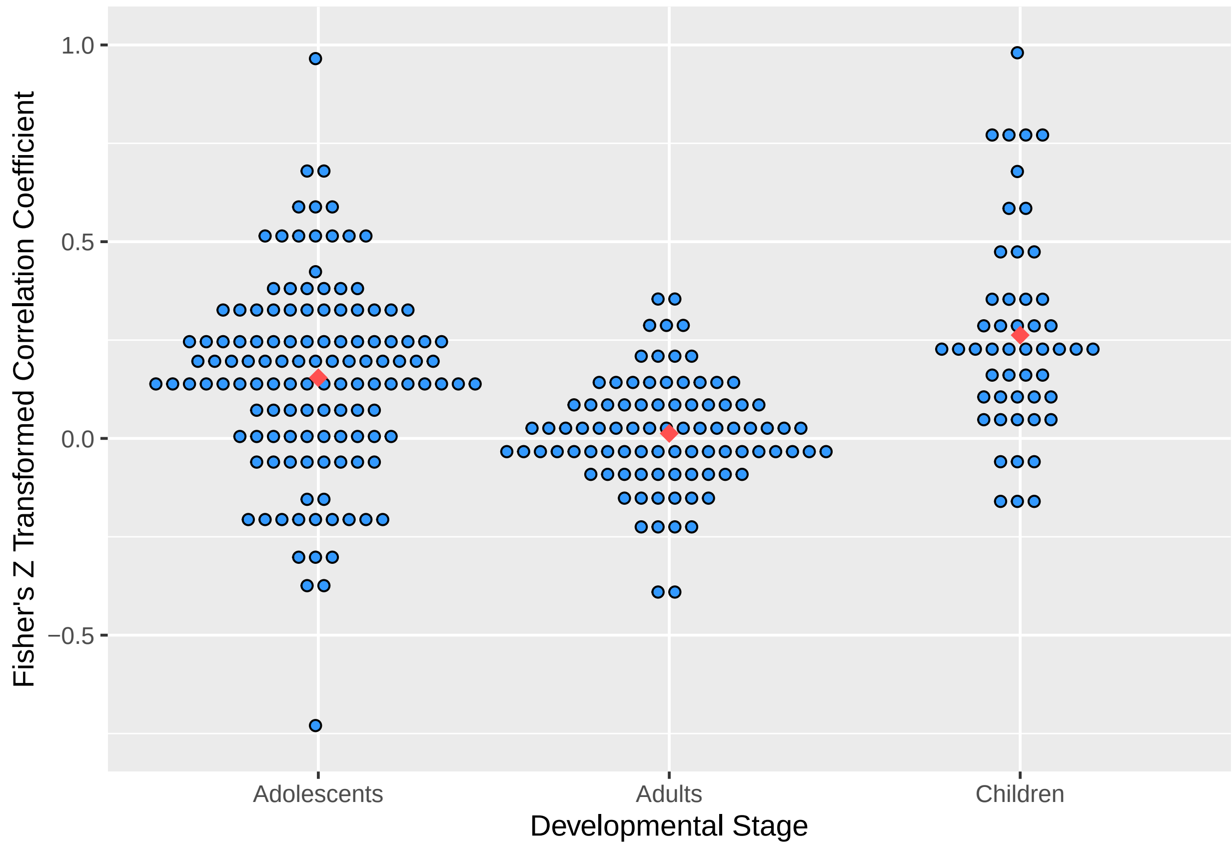
```
# Subset to exclude "Wide Range"
df3_develop <- filter(df3,
                      (development_stage == "Adolescents") |
                        (development_stage == "Adults") |
                        (development_stage == "Children"))
# Adjust labels
df3_develop$development_stage <- droplevels(df3_develop$development_stage)
levels(df3_develop$development_stage)
```

```
## [1] "Adolescents" "Adults"      "Children"
```

```
# Open a jpeg file
## jpeg("subgroup.jpeg", width = 800, height = 400, quality = 100)
# Inspect visually the relationship between Fisher's z and the categories
# x = developmental_stage y = Fisher's z
ggplot(data=df3_develop, mapping = aes(x=development_stage, y = yi)) +
  geom_dotplot(binaxis='y',
               stackdir='center',
               stackratio=1.5,
               dotsize=0.5,
               fill="#3399ff") +
  stat_summary(fun.y=mean, geom="point", shape=18,
               size=3, color="#ff5050")+
  labs(x = "Developmental Stage",
       y = "Fisher's Z Transformed Correlation Coefficient")
```

```
## Warning: `fun.y` is deprecated. Use `fun` instead.
```

```
## Bin width defaults to 1/30 of the range of the data. Pick better value with `binwidth`.
```




```r
theme_classic()
```

```
## List of 93
##  $ line                      :List of 6
##   ..$ colour       : chr "black"
##   ..$ size         : num 0.5
##   ..$ linetype     : num 1
##   ..$ lineend      : chr "butt"
##   ..$ arrow        : logi FALSE
##   ..$ inherit.blank: logi TRUE
##   ..- attr(*, "class")= chr [1:2] "element_line" "element"
##  $ rect                      :List of 5
##   ..$ fill         : chr "white"
##   ..$ colour       : chr "black"
##   ..$ size         : num 0.5
##   ..$ linetype     : num 1
##   ..$ inherit.blank: logi TRUE
##   ..- attr(*, "class")= chr [1:2] "element_rect" "element"
##  $ text                      :List of 11
##   ..$ family       : chr ""
##   ..$ face         : chr "plain"
##   ..$ colour       : chr "black"
##   ..$ size         : num 11
##   ..$ hjust        : num 0.5
##   ..$ vjust        : num 0.5
##   ..$ angle        : num 0
##   ..$ lineheight   : num 0.9
```

```
##   ..$ margin       : 'margin' num [1:4] 0points 0points 0points 0points
##   .. ..- attr(*, "unit")= int 8
##   ..$ debug        : logi FALSE
##   ..$ inherit.blank: logi TRUE
##   ..- attr(*, "class")= chr [1:2] "element_text" "element"
##  $ title                     : NULL
##  $ aspect.ratio              : NULL
##  $ axis.title                : NULL
##  $ axis.title.x              :List of 11
##   ..$ family       : NULL
##   ..$ face         : NULL
##   ..$ colour       : NULL
##   ..$ size         : NULL
##   ..$ hjust        : NULL
##   ..$ vjust        : num 1
##   ..$ angle        : NULL
##   ..$ lineheight   : NULL
##   ..$ margin       : 'margin' num [1:4] 2.75points 0points 0points 0points
##   .. ..- attr(*, "unit")= int 8
##   ..$ debug        : NULL
##   ..$ inherit.blank: logi TRUE
##   ..- attr(*, "class")= chr [1:2] "element_text" "element"
##  $ axis.title.x.top          :List of 11
##   ..$ family       : NULL
##   ..$ face         : NULL
##   ..$ colour       : NULL
##   ..$ size         : NULL
##   ..$ hjust        : NULL
##   ..$ vjust        : num 0
##   ..$ angle        : NULL
##   ..$ lineheight   : NULL
##   ..$ margin       : 'margin' num [1:4] 0points 0points 2.75points 0points
##   .. ..- attr(*, "unit")= int 8
##   ..$ debug        : NULL
##   ..$ inherit.blank: logi TRUE
##   ..- attr(*, "class")= chr [1:2] "element_text" "element"
##  $ axis.title.x.bottom       : NULL
##  $ axis.title.y              :List of 11
##   ..$ family       : NULL
##   ..$ face         : NULL
##   ..$ colour       : NULL
##   ..$ size         : NULL
##   ..$ hjust        : NULL
##   ..$ vjust        : num 1
##   ..$ angle        : num 90
##   ..$ lineheight   : NULL
##   ..$ margin       : 'margin' num [1:4] 0points 2.75points 0points 0points
##   .. ..- attr(*, "unit")= int 8
##   ..$ debug        : NULL
##   ..$ inherit.blank: logi TRUE
##   ..- attr(*, "class")= chr [1:2] "element_text" "element"
##  $ axis.title.y.left         : NULL
##  $ axis.title.y.right        :List of 11
##   ..$ family       : NULL
```

```
##   ..$ face         : NULL
##   ..$ colour       : NULL
##   ..$ size         : NULL
##   ..$ hjust        : NULL
##   ..$ vjust        : num 0
##   ..$ angle        : num -90
##   ..$ lineheight   : NULL
##   ..$ margin       : 'margin' num [1:4] 0points 0points 0points 2.75points
##   .. ..- attr(*, "unit")= int 8
##   ..$ debug        : NULL
##   ..$ inherit.blank: logi TRUE
##   ..- attr(*, "class")= chr [1:2] "element_text" "element"
##  $ axis.text                 :List of 11
##   ..$ family       : NULL
##   ..$ face         : NULL
##   ..$ colour       : chr "grey30"
##   ..$ size         : 'rel' num 0.8
##   ..$ hjust        : NULL
##   ..$ vjust        : NULL
##   ..$ angle        : NULL
##   ..$ lineheight   : NULL
##   ..$ margin       : NULL
##   ..$ debug        : NULL
##   ..$ inherit.blank: logi TRUE
##   ..- attr(*, "class")= chr [1:2] "element_text" "element"
##  $ axis.text.x               :List of 11
##   ..$ family       : NULL
##   ..$ face         : NULL
##   ..$ colour       : NULL
##   ..$ size         : NULL
##   ..$ hjust        : NULL
##   ..$ vjust        : num 1
##   ..$ angle        : NULL
##   ..$ lineheight   : NULL
##   ..$ margin       : 'margin' num [1:4] 2.2points 0points 0points 0points
##   .. ..- attr(*, "unit")= int 8
##   ..$ debug        : NULL
##   ..$ inherit.blank: logi TRUE
##   ..- attr(*, "class")= chr [1:2] "element_text" "element"
##  $ axis.text.x.top           :List of 11
##   ..$ family       : NULL
##   ..$ face         : NULL
##   ..$ colour       : NULL
##   ..$ size         : NULL
##   ..$ hjust        : NULL
##   ..$ vjust        : num 0
##   ..$ angle        : NULL
##   ..$ lineheight   : NULL
##   ..$ margin       : 'margin' num [1:4] 0points 0points 2.2points 0points
##   .. ..- attr(*, "unit")= int 8
##   ..$ debug        : NULL
##   ..$ inherit.blank: logi TRUE
##   ..- attr(*, "class")= chr [1:2] "element_text" "element"
##  $ axis.text.x.bottom        : NULL
```

```
##  $ axis.text.y               :List of 11
##   ..$ family       : NULL
##   ..$ face         : NULL
##   ..$ colour       : NULL
##   ..$ size         : NULL
##   ..$ hjust        : num 1
##   ..$ vjust        : NULL
##   ..$ angle        : NULL
##   ..$ lineheight   : NULL
##   ..$ margin       : 'margin' num [1:4] 0points 2.2points 0points 0points
##   .. ..- attr(*, "unit")= int 8
##   ..$ debug        : NULL
##   ..$ inherit.blank: logi TRUE
##   ..- attr(*, "class")= chr [1:2] "element_text" "element"
##  $ axis.text.y.left          : NULL
##  $ axis.text.y.right         :List of 11
##   ..$ family       : NULL
##   ..$ face         : NULL
##   ..$ colour       : NULL
##   ..$ size         : NULL
##   ..$ hjust        : num 0
##   ..$ vjust        : NULL
##   ..$ angle        : NULL
##   ..$ lineheight   : NULL
##   ..$ margin       : 'margin' num [1:4] 0points 0points 0points 2.2points
##   .. ..- attr(*, "unit")= int 8
##   ..$ debug        : NULL
##   ..$ inherit.blank: logi TRUE
##   ..- attr(*, "class")= chr [1:2] "element_text" "element"
##  $ axis.ticks                :List of 6
##   ..$ colour       : chr "grey20"
##   ..$ size         : NULL
##   ..$ linetype     : NULL
##   ..$ lineend      : NULL
##   ..$ arrow        : logi FALSE
##   ..$ inherit.blank: logi TRUE
##   ..- attr(*, "class")= chr [1:2] "element_line" "element"
##  $ axis.ticks.x              : NULL
##  $ axis.ticks.x.top          : NULL
##  $ axis.ticks.x.bottom       : NULL
##  $ axis.ticks.y              : NULL
##  $ axis.ticks.y.left         : NULL
##  $ axis.ticks.y.right        : NULL
##  $ axis.ticks.length         : 'simpleUnit' num 2.75points
##   ..- attr(*, "unit")= int 8
##  $ axis.ticks.length.x       : NULL
##  $ axis.ticks.length.x.top   : NULL
##  $ axis.ticks.length.x.bottom: NULL
##  $ axis.ticks.length.y       : NULL
##  $ axis.ticks.length.y.left  : NULL
##  $ axis.ticks.length.y.right : NULL
##  $ axis.line                 :List of 6
##   ..$ colour       : chr "black"
##   ..$ size         : 'rel' num 1
```

```
##   ..$ linetype     : NULL
##   ..$ lineend      : NULL
##   ..$ arrow        : logi FALSE
##   ..$ inherit.blank: logi TRUE
##   ..- attr(*, "class")= chr [1:2] "element_line" "element"
##  $ axis.line.x               : NULL
##  $ axis.line.x.top           : NULL
##  $ axis.line.x.bottom        : NULL
##  $ axis.line.y               : NULL
##  $ axis.line.y.left          : NULL
##  $ axis.line.y.right         : NULL
##  $ legend.background         :List of 5
##   ..$ fill         : NULL
##   ..$ colour       : logi NA
##   ..$ size         : NULL
##   ..$ linetype     : NULL
##   ..$ inherit.blank: logi TRUE
##   ..- attr(*, "class")= chr [1:2] "element_rect" "element"
##  $ legend.margin             : 'margin' num [1:4] 5.5points 5.5points 5.5points 5.5points
##   ..- attr(*, "unit")= int 8
##  $ legend.spacing            : 'simpleUnit' num 11points
##   ..- attr(*, "unit")= int 8
##  $ legend.spacing.x          : NULL
##  $ legend.spacing.y          : NULL
##  $ legend.key                : list()
##   ..- attr(*, "class")= chr [1:2] "element_blank" "element"
##  $ legend.key.size           : 'simpleUnit' num 1.2lines
##   ..- attr(*, "unit")= int 3
##  $ legend.key.height         : NULL
##  $ legend.key.width          : NULL
##  $ legend.text               :List of 11
##   ..$ family       : NULL
##   ..$ face         : NULL
##   ..$ colour       : NULL
##   ..$ size         : 'rel' num 0.8
##   ..$ hjust        : NULL
##   ..$ vjust        : NULL
##   ..$ angle        : NULL
##   ..$ lineheight   : NULL
##   ..$ margin       : NULL
##   ..$ debug        : NULL
##   ..$ inherit.blank: logi TRUE
##   ..- attr(*, "class")= chr [1:2] "element_text" "element"
##  $ legend.text.align         : NULL
##  $ legend.title              :List of 11
##   ..$ family       : NULL
##   ..$ face         : NULL
##   ..$ colour       : NULL
##   ..$ size         : NULL
##   ..$ hjust        : num 0
##   ..$ vjust        : NULL
##   ..$ angle        : NULL
##   ..$ lineheight   : NULL
##   ..$ margin       : NULL
```

```
##   ..$ debug        : NULL
##   ..$ inherit.blank: logi TRUE
##   ..- attr(*, "class")= chr [1:2] "element_text" "element"
##  $ legend.title.align        : NULL
##  $ legend.position           : chr "right"
##  $ legend.direction          : NULL
##  $ legend.justification      : chr "center"
##  $ legend.box                : NULL
##  $ legend.box.just           : NULL
##  $ legend.box.margin         : 'margin' num [1:4] 0cm 0cm 0cm 0cm
##   ..- attr(*, "unit")= int 1
##  $ legend.box.background     : list()
##   ..- attr(*, "class")= chr [1:2] "element_blank" "element"
##  $ legend.box.spacing        : 'simpleUnit' num 11points
##   ..- attr(*, "unit")= int 8
##  $ panel.background          :List of 5
##   ..$ fill         : chr "white"
##   ..$ colour       : logi NA
##   ..$ size         : NULL
##   ..$ linetype     : NULL
##   ..$ inherit.blank: logi TRUE
##   ..- attr(*, "class")= chr [1:2] "element_rect" "element"
##  $ panel.border              : list()
##   ..- attr(*, "class")= chr [1:2] "element_blank" "element"
##  $ panel.spacing             : 'simpleUnit' num 5.5points
##   ..- attr(*, "unit")= int 8
##  $ panel.spacing.x           : NULL
##  $ panel.spacing.y           : NULL
##  $ panel.grid                :List of 6
##   ..$ colour       : chr "grey92"
##   ..$ size         : NULL
##   ..$ linetype     : NULL
##   ..$ lineend      : NULL
##   ..$ arrow        : logi FALSE
##   ..$ inherit.blank: logi TRUE
##   ..- attr(*, "class")= chr [1:2] "element_line" "element"
##  $ panel.grid.major          : list()
##   ..- attr(*, "class")= chr [1:2] "element_blank" "element"
##  $ panel.grid.minor          : list()
##   ..- attr(*, "class")= chr [1:2] "element_blank" "element"
##  $ panel.grid.major.x        : NULL
##  $ panel.grid.major.y        : NULL
##  $ panel.grid.minor.x        : NULL
##  $ panel.grid.minor.y        : NULL
##  $ panel.ontop               : logi FALSE
##  $ plot.background           :List of 5
##   ..$ fill         : NULL
##   ..$ colour       : chr "white"
##   ..$ size         : NULL
##   ..$ linetype     : NULL
##   ..$ inherit.blank: logi TRUE
##   ..- attr(*, "class")= chr [1:2] "element_rect" "element"
##  $ plot.title                :List of 11
##   ..$ family       : NULL
```

```
##   ..$ face         : NULL
##   ..$ colour       : NULL
##   ..$ size         : 'rel' num 1.2
##   ..$ hjust        : num 0
##   ..$ vjust        : num 1
##   ..$ angle        : NULL
##   ..$ lineheight   : NULL
##   ..$ margin       : 'margin' num [1:4] 0points 0points 5.5points 0points
##   .. ..- attr(*, "unit")= int 8
##   ..$ debug        : NULL
##   ..$ inherit.blank: logi TRUE
##   ..- attr(*, "class")= chr [1:2] "element_text" "element"
##  $ plot.title.position       : chr "panel"
##  $ plot.subtitle             :List of 11
##   ..$ family       : NULL
##   ..$ face         : NULL
##   ..$ colour       : NULL
##   ..$ size         : NULL
##   ..$ hjust        : num 0
##   ..$ vjust        : num 1
##   ..$ angle        : NULL
##   ..$ lineheight   : NULL
##   ..$ margin       : 'margin' num [1:4] 0points 0points 5.5points 0points
##   .. ..- attr(*, "unit")= int 8
##   ..$ debug        : NULL
##   ..$ inherit.blank: logi TRUE
##   ..- attr(*, "class")= chr [1:2] "element_text" "element"
##  $ plot.caption              :List of 11
##   ..$ family       : NULL
##   ..$ face         : NULL
##   ..$ colour       : NULL
##   ..$ size         : 'rel' num 0.8
##   ..$ hjust        : num 1
##   ..$ vjust        : num 1
##   ..$ angle        : NULL
##   ..$ lineheight   : NULL
##   ..$ margin       : 'margin' num [1:4] 5.5points 0points 0points 0points
##   .. ..- attr(*, "unit")= int 8
##   ..$ debug        : NULL
##   ..$ inherit.blank: logi TRUE
##   ..- attr(*, "class")= chr [1:2] "element_text" "element"
##  $ plot.caption.position     : chr "panel"
##  $ plot.tag                  :List of 11
##   ..$ family       : NULL
##   ..$ face         : NULL
##   ..$ colour       : NULL
##   ..$ size         : 'rel' num 1.2
##   ..$ hjust        : num 0.5
##   ..$ vjust        : num 0.5
##   ..$ angle        : NULL
##   ..$ lineheight   : NULL
##   ..$ margin       : NULL
##   ..$ debug        : NULL
##   ..$ inherit.blank: logi TRUE
```

```
##   ..- attr(*, "class")= chr [1:2] "element_text" "element"
##  $ plot.tag.position         : chr "topleft"
##  $ plot.margin               : 'margin' num [1:4] 5.5points 5.5points 5.5points 5.5points
##   ..- attr(*, "unit")= int 8
##  $ strip.background          :List of 5
##   ..$ fill         : chr "white"
##   ..$ colour       : chr "black"
##   ..$ size         : 'rel' num 2
##   ..$ linetype     : NULL
##   ..$ inherit.blank: logi TRUE
##   ..- attr(*, "class")= chr [1:2] "element_rect" "element"
##  $ strip.background.x        : NULL
##  $ strip.background.y        : NULL
##  $ strip.placement           : chr "inside"
##  $ strip.text                :List of 11
##   ..$ family       : NULL
##   ..$ face         : NULL
##   ..$ colour       : chr "grey10"
##   ..$ size         : 'rel' num 0.8
##   ..$ hjust        : NULL
##   ..$ vjust        : NULL
##   ..$ angle        : NULL
##   ..$ lineheight   : NULL
##   ..$ margin       : 'margin' num [1:4] 4.4points 4.4points 4.4points 4.4points
##   .. ..- attr(*, "unit")= int 8
##   ..$ debug        : NULL
##   ..$ inherit.blank: logi TRUE
##   ..- attr(*, "class")= chr [1:2] "element_text" "element"
##  $ strip.text.x              : NULL
##  $ strip.text.y              :List of 11
##   ..$ family       : NULL
##   ..$ face         : NULL
##   ..$ colour       : NULL
##   ..$ size         : NULL
##   ..$ hjust        : NULL
##   ..$ vjust        : NULL
##   ..$ angle        : num -90
##   ..$ lineheight   : NULL
##   ..$ margin       : NULL
##   ..$ debug        : NULL
##   ..$ inherit.blank: logi TRUE
##   ..- attr(*, "class")= chr [1:2] "element_text" "element"
##  $ strip.switch.pad.grid     : 'simpleUnit' num 2.75points
##   ..- attr(*, "unit")= int 8
##  $ strip.switch.pad.wrap     : 'simpleUnit' num 2.75points
##   ..- attr(*, "unit")= int 8
##  $ strip.text.y.left         :List of 11
##   ..$ family       : NULL
##   ..$ face         : NULL
##   ..$ colour       : NULL
##   ..$ size         : NULL
##   ..$ hjust        : NULL
##   ..$ vjust        : NULL
##   ..$ angle        : num 90
```

```
##   ..$ lineheight   : NULL
##   ..$ margin       : NULL
##   ..$ debug        : NULL
##   ..$ inherit.blank: logi TRUE
##   ..- attr(*, "class")= chr [1:2] "element_text" "element"
##  - attr(*, "class")= chr [1:2] "theme" "gg"
##  - attr(*, "complete")= logi TRUE
##  - attr(*, "validate")= logi TRUE
```

```r
# Close jpeg file
## dev.off()

# How many studies and how many effect sizes not included?
check <- df3 %>%
  filter(development_stage == "Wide Range")
# Number of studies
length(unique(check$study_id))
```

```
## [1] 6
```

```r
# Number of effect sizes
length(unique(check$es_id))
```

```
## [1] 8
```

3.2.1 Estimate

τ^2

: 2 approaches

```r
# * Common tau^2 ---------------------------------------------------------
## Same between-study variance within each subgroup (Adolescents, Adults, Children)
meta1_develop1 <- rma (yi = yi,
                       vi = vi,
                       measure = 'ZCOR',
                       data = df3_develop,
                       mods = ~ development_stage-1)
summary(meta1_develop1, digits = 3)
```

```
##
## Mixed-Effects Model (k = 265; tau^2 estimator: REML)
##
##   logLik  deviance       AIC       BIC      AICc
##   78.298  -156.597  -148.597  -134.323  -148.441
##
## tau^2 (estimated amount of residual heterogeneity):     0.014 (SE = 0.002)
## tau (square root of estimated tau^2 value):             0.119
## I^2 (residual heterogeneity / unaccounted variability): 94.13%
## H^2 (unaccounted variability / sampling variability):   17.03
##
## Test for Residual Heterogeneity:
## QE(df = 262) = 5395.403, p-val < .001
##
## Test of Moderators (coefficients 1:3):
## QM(df = 3) = 184.782, p-val < .001
##
## Model Results:
##
##                                 estimate     se    zval   pval   ci.lb  ci.ub
## development_stageAdolescents      0.151  0.014  10.649  <.001   0.123  0.179
## development_stageAdults           0.021  0.015   1.370  0.171  -0.009  0.050
## development_stageChildren         0.201  0.024   8.337  <.001   0.154  0.248
##
## development_stageAdolescents  ***
## development_stageAdults
## development_stageChildren     ***
##
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```r
# Transform the estimates of the differences from z to r
estimate <- round(transf.ztor(meta1_develop1$b),2)
stand_er <- round(transf.ztor(meta1_develop1$se),2)
cilb <- round(transf.ztor(meta1_develop1$ci.lb),2)
ciup <- round(transf.ztor(meta1_develop1$ci.ub),2)

(groups <- data.frame(cbind(estimate, stand_er,cilb, ciup)))
```

```
##                                V1 stand_er  cilb ciup
## development_stageAdolescents 0.15     0.01  0.12 0.18
## development_stageAdults      0.02     0.01 -0.01 0.05
```

```
## development_stageChildren    0.20     0.02  0.15 0.24
```

```r
# Multiple comparisons
# https://wviechtb.github.io/metafor/reference/rma.uni.html
multcomp_develop1 <- glht(meta1_develop1,
                          linfct=contrMat(c("Adolescents"=1,"Adults"=1,"Children"=1),
                                          type="Tukey"),test=adjusted("bonferroni"))

summary(multcomp_develop1)
```

```
##
##   Simultaneous Tests for General Linear Hypotheses
##
## Multiple Comparisons of Means: Tukey Contrasts
##
##
## Fit: rma(yi = yi, vi = vi, mods = ~development_stage - 1, measure = "ZCOR",
##     data = df3_develop)
##
## Linear Hypotheses:
##                              Estimate Std. Error z value Pr(>|z|)
## Adults - Adolescents == 0   -0.13025    0.02061  -6.321   <1e-04 ***
## Children - Adolescents == 0  0.05042    0.02798   1.802    0.166
## Children - Adults == 0       0.18066    0.02840   6.362   <1e-04 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
## (Adjusted p values reported -- single-step method)
```

```r
# Note that the estimate of the differences in the output are Fisher z
# So I need to transform them
estimate <- round(transf.ztor(c(-0.13025, 0.05042, 0.18066)),2)
stand_er <- round(transf.ztor(c(0.02061, 0.02798, 0.02840)),2)
(groups <- data.frame(cbind(estimate, stand_er)))
```

```
##   estimate stand_er
## 1    -0.13     0.02
## 2     0.05     0.03
## 3     0.18     0.03
```

```r
# Confidence intervals for tau^2
confint.rma.uni(meta1_develop1, digits = 3)
```

```
##
##        estimate  ci.lb  ci.ub
## tau^2     0.014  0.012  0.022
## tau       0.119  0.111  0.150
## I^2(%)   94.129 93.231 96.185
## H^2      17.034 14.773 26.212
```

```r
# * Different tau^2 per subgroup ------------------------------------------
## Different between-study variance within each subgroup (Adolescents, Adults, Children)
# https://wviechtb.github.io/metafor/reference/rma.uni.html

# We have to fit 3 models: ado, adu, chi
meta1_develop2_ado <- rma (yi = yi,
                           vi = vi,
                           measure = 'ZCOR',
                           data = df3_develop,
                           mods = ~ development_stage-1,
                           subset = (development_stage=="Adolescents"))
```

```
## Warning: Redundant predictors dropped from the model.
```

```r
summary(meta1_develop2_ado, digits = 3)
```

```
##
## Random-Effects Model (k = 126; tau^2 estimator: REML)
##
##   logLik  deviance       AIC       BIC      AICc
##   20.075   -40.150   -36.150   -30.493   -36.051
##
## tau^2 (estimated amount of total heterogeneity): 0.019 (SE = 0.004)
## tau (square root of estimated tau^2 value):      0.139
## I^2 (total heterogeneity / total variability):   97.43%
## H^2 (total variability / sampling variability):  38.85
##
## Test for Heterogeneity:
## Q(df = 125) = 4868.986, p-val < .001
##
## Model Results:
##
## estimate     se    zval    pval   ci.lb   ci.ub
##    0.150  0.016   9.467   <.001   0.119   0.181   ***
##
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```r
confint.rma.uni(meta1_develop2_ado, digits = 3)
```

```
##
##        estimate  ci.lb  ci.ub
## tau^2     0.019  0.014  0.032
## tau       0.139  0.117  0.179
## I^2(%)   97.426 96.424 98.436
## H^2      38.852 27.967 63.943
```

```r
meta1_develop2_adu <- rma (yi = yi,
                           vi = vi,
                           measure = 'ZCOR',
                           data = df3_develop,
                           mods = ~ development_stage-1,
                           subset = (development_stage=="Adults"))
```

```
## Warning: Redundant predictors dropped from the model.
```

```r
summary(meta1_develop2_adu,  digits = 3)
```

```
##
## Random-Effects Model (k = 89; tau^2 estimator: REML)
##
##   logLik  deviance       AIC       BIC      AICc
##   52.299  -104.599  -100.599   -95.644  -100.457
##
## tau^2 (estimated amount of total heterogeneity): 0.011 (SE = 0.002)
## tau (square root of estimated tau^2 value):      0.104
## I^2 (total heterogeneity / total variability):   81.25%
## H^2 (total variability / sampling variability):  5.33
##
## Test for Heterogeneity:
## Q(df = 88) = 394.676, p-val < .001
##
## Model Results:
##
## estimate     se   zval   pval   ci.lb  ci.ub
##    0.021  0.014  1.564  0.118  -0.005  0.048
##
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```r
confint.rma.uni(meta1_develop2_adu, digits = 3)
```

```
##
##        estimate  ci.lb  ci.ub
## tau^2     0.011  0.007  0.018
## tau       0.104  0.085  0.135
## I^2(%)   81.249 74.506 87.947
## H^2       5.333  3.922  8.297
```

```r
meta1_develop2_chi <- rma (yi = yi,
                           vi = vi,
                           measure = 'ZCOR',
                           data = df3_develop,
                           mods = ~ development_stage-1,
                           subset = (development_stage=="Children"))
```

```
## Warning: Redundant predictors dropped from the model.
```

```r
summary(meta1_develop2_chi, digits =3)
```

```
##
## Random-Effects Model (k = 50; tau^2 estimator: REML)
##
##   logLik  deviance       AIC       BIC      AICc
##    8.434   -16.869   -12.869    -9.085   -12.608
##
## tau^2 (estimated amount of total heterogeneity): 0.008 (SE = 0.003)
## tau (square root of estimated tau^2 value):      0.090
## I^2 (total heterogeneity / total variability):   68.25%
## H^2 (total variability / sampling variability):  3.15
##
## Test for Heterogeneity:
```

```
## Q(df = 49) = 131.742, p-val < .001
##
## Model Results:
##
## estimate     se    zval    pval   ci.lb   ci.ub
##    0.198  0.020  9.862  <.001  0.159  0.237  ***
##
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
confint.rma.uni(meta1_develop2_chi, digits = 3)
```

```
##
##         estimate  ci.lb   ci.ub
## tau^2      0.008  0.006   0.048
## tau        0.090  0.078   0.219
## I^2(%)    68.253 61.855  92.740
## H^2        3.150  2.622  13.775
```

```
# Compare tau^2
tau2_comp <- data.frame(rbind(meta1_develop1$tau2,
                              meta1_develop2_ado$tau2,
                              meta1_develop2_adu$tau2,
                              meta1_develop2_chi$tau2))
names(tau2_comp) <- 'tau^2'
rownames(tau2_comp) <- c('Common', 'Adolescents', 'Adults', 'Children')
round(tau2_comp, 3)
```

```
##             tau^2
## Common      0.014
## Adolescents 0.019
## Adults      0.011
## Children    0.008
```

```
# Compare I^2
i2_comp <- data.frame(rbind(meta1_develop1$I2,
                            meta1_develop2_ado$I2,
                            meta1_develop2_adu$I2,
                            meta1_develop2_chi$I2))
names(i2_comp) <- 'I^2'
rownames(i2_comp) <- c('Common', 'Adolescents', 'Adults', 'Children')
round(i2_comp,2)
```

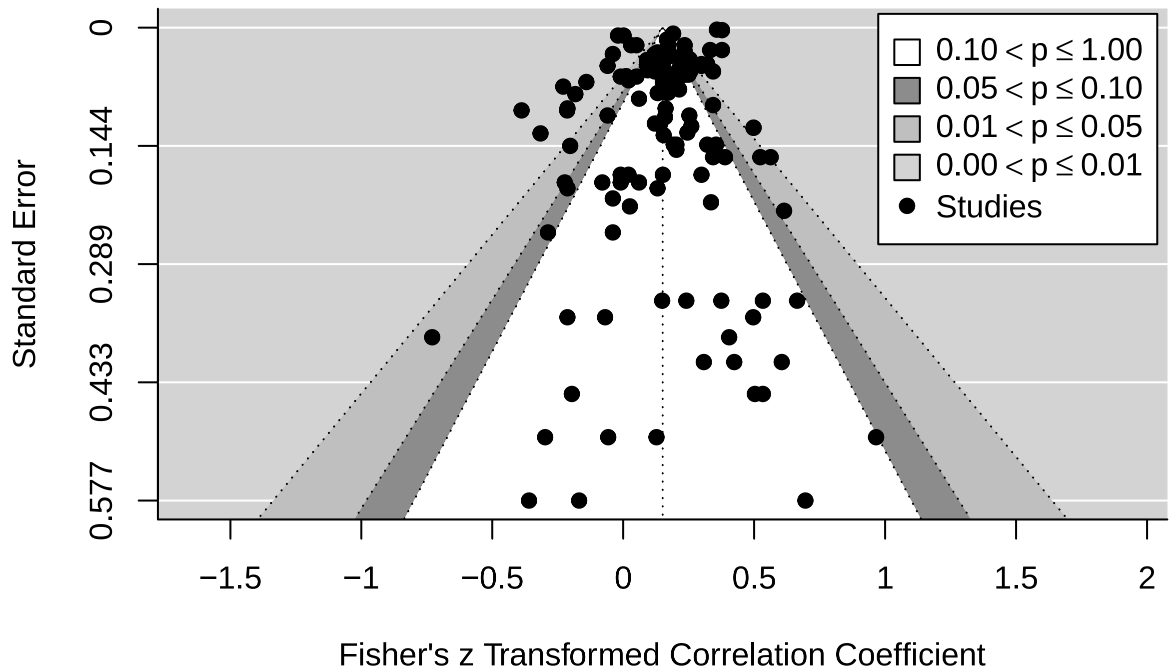
```
##               I^2
## Common      94.13
## Adolescents 97.43
## Adults      81.25
## Children    68.25
```

3.3 Publication bias (REM)

```
# * Funnel plot adolescents ------------------------------------------------
# How many studies arethere in the adolescents group?
meta1_develop2_ado$k
```

```
## [1] 126
```

```
funnel(meta1_develop2_ado,
       level=c(90, 95, 99),
       shade=c("white", "gray55", "gray75"),
       legend=TRUE)
```




```
# * Egger's regression test adolescents ----------------------------------
meta1_regtst_ado_rma <- regtest(meta1_develop2_ado,
                                model = 'rma',
                                predictor = 'sei',
                                ret.fit = TRUE)
meta1_regtst_ado_rma
```

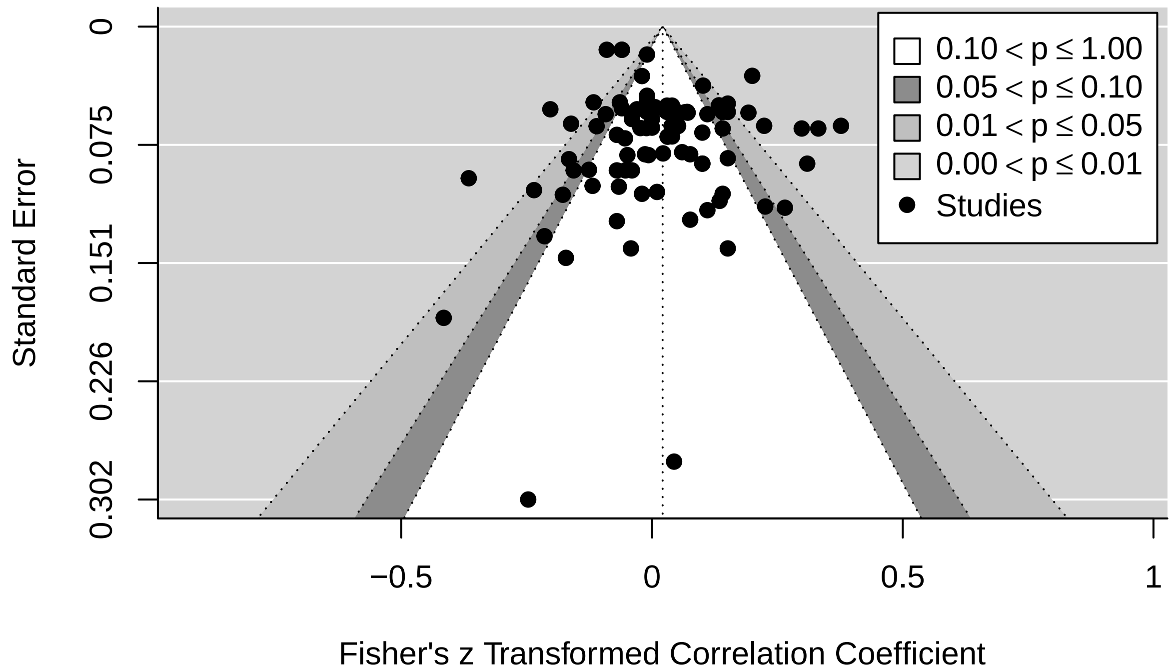
```
##
## Regression Test for Funnel Plot Asymmetry
##
## Model:     mixed-effects meta-regression model
## Predictor: standard error
##
## Mixed-Effects Model (k = 126; tau^2 estimator: REML)
##
## tau^2 (estimated amount of residual heterogeneity):     0.0193 (SE = 0.0036)
## tau (square root of estimated tau^2 value):             0.1388
## I^2 (residual heterogeneity / unaccounted variability): 97.35%
## H^2 (unaccounted variability / sampling variability):   37.69
## R^2 (amount of heterogeneity accounted for):            0.00%
##
```

```
## Test for Residual Heterogeneity:
## QE(df = 124) = 3987.3836, p-val < .0001
##
## Test of Moderators (coefficient 2):
## QM(df = 1) = 0.0391, p-val = 0.8432
##
## Model Results:
##
##          estimate      se     zval    pval    ci.lb   ci.ub
## intrcpt    0.1534  0.0228   6.7187  <.0001   0.1086  0.1981  ***
## sei       -0.0404  0.2041  -0.1979  0.8432  -0.4405  0.3597
##
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Test for Funnel Plot Asymmetry: z = -0.1979, p = 0.8432
## Limit Estimate (as sei -> 0):   b = 0.1534 (CI: 0.1086, 0.1981)
```

```r
# * Funnel plot adults ---------------------------------------------------
# How many studies arethere in the adults group?
meta1_develop2_adu$k
```

```
## [1] 89
```

```r
funnel(meta1_develop2_adu,
       level=c(90, 95, 99),
       shade=c("white", "gray55", "gray75"),
       legend=TRUE)
```




```r
# * Egger's regression test adults  --------------------------------------
meta1_regtst_adu_rma <- regtest(meta1_develop2_adu,
                                model = 'rma',
                                predictor = 'sei',
                                ret.fit = TRUE)
meta1_regtst_adu_rma
```

```
##
## Regression Test for Funnel Plot Asymmetry
##
## Model:     mixed-effects meta-regression model
## Predictor: standard error
##
## Mixed-Effects Model (k = 89; tau^2 estimator: REML)
##
## tau^2 (estimated amount of residual heterogeneity):     0.0110 (SE = 0.0024)
## tau (square root of estimated tau^2 value):             0.1051
## I^2 (residual heterogeneity / unaccounted variability): 81.03%
## H^2 (unaccounted variability / sampling variability):   5.27
## R^2 (amount of heterogeneity accounted for):            0.00%
##
## Test for Residual Heterogeneity:
```

```
## QE(df = 87) = 363.0890, p-val < .0001
##
## Test of Moderators (coefficient 2):
## QM(df = 1) = 1.3454, p-val = 0.2461
##
## Model Results:
##
##          estimate      se     zval    pval    ci.lb   ci.ub
## intrcpt    0.0555  0.0326   1.7013  0.0889  -0.0084  0.1193  .
## sei       -0.5102  0.4399  -1.1599  0.2461  -1.3724  0.3519
##
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Test for Funnel Plot Asymmetry: z = -1.1599, p = 0.2461
## Limit Estimate (as sei -> 0):   b = 0.0555 (CI: -0.0084, 0.1193)
```

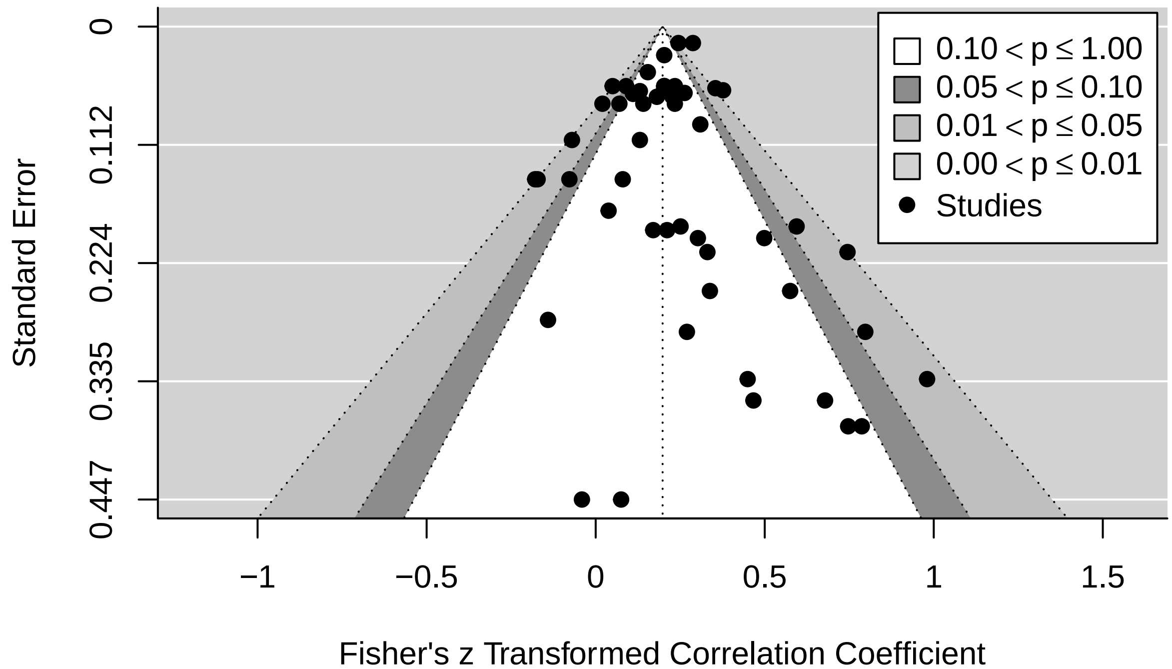
```r
## The code below shows that the regtest with rma is equivalent to
## a meta-regression with the standard error as predictor
rma (yi = yi,
     vi = vi,
     measure = 'ZCOR',
     data = df3_develop,
     subset = (development_stage=="Adults"),
     mods = ~ sqrt(vi))
```

```
##
## Mixed-Effects Model (k = 89; tau^2 estimator: REML)
##
## tau^2 (estimated amount of residual heterogeneity):     0.0110 (SE = 0.0024)
## tau (square root of estimated tau^2 value):             0.1051
## I^2 (residual heterogeneity / unaccounted variability): 81.03%
## H^2 (unaccounted variability / sampling variability):   5.27
## R^2 (amount of heterogeneity accounted for):            0.00%
##
## Test for Residual Heterogeneity:
## QE(df = 87) = 363.0890, p-val < .0001
##
## Test of Moderators (coefficient 2):
## QM(df = 1) = 1.3454, p-val = 0.2461
##
## Model Results:
##
##           estimate      se     zval    pval    ci.lb   ci.ub
## intrcpt     0.0555  0.0326   1.7013  0.0889  -0.0084  0.1193  .
## sqrt(vi)   -0.5102  0.4399  -1.1599  0.2461  -1.3724  0.3519
##
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```r
# * Funnel plot children -------------------------------------------------------
# How many studies are there in the children group?
meta1_develop2_chi$k
```

```
## [1] 50
```

```r
funnel(meta1_develop2_chi,
       level=c(90, 95, 99),
       shade=c("white", "gray55", "gray75"),
       legend=TRUE)
```




```r
# * Egger's regression test children --------------------------------------
meta1_regtst_chi_rma <- regtest(meta1_develop2_chi,
                                model = 'rma',
                                predictor = 'sei',
                                ret.fit = TRUE)
meta1_regtst_chi_rma
```

```
##
## Regression Test for Funnel Plot Asymmetry
##
## Model:     mixed-effects meta-regression model
## Predictor: standard error
##
## Mixed-Effects Model (k = 50; tau^2 estimator: REML)
##
## tau^2 (estimated amount of residual heterogeneity):     0.0102 (SE = 0.0040)
## tau (square root of estimated tau^2 value):             0.1011
## I^2 (residual heterogeneity / unaccounted variability): 72.30%
## H^2 (unaccounted variability / sampling variability):   3.61
## R^2 (amount of heterogeneity accounted for):            0.00%
##
## Test for Residual Heterogeneity:
```

```
## QE(df = 48) = 129.5107, p-val < .0001
##
## Test of Moderators (coefficient 2):
## QM(df = 1) = 4.4693, p-val = 0.0345
##
## Model Results:
##
##          estimate      se    zval    pval   ci.lb   ci.ub
## intrcpt    0.1431  0.0341  4.1933  <.0001  0.0762  0.2100  ***
## sei        0.6293  0.2977  2.1141  0.0345  0.0459  1.2127    *
##
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Test for Funnel Plot Asymmetry: z = 2.1141, p = 0.0345
## Limit Estimate (as sei -> 0):   b = 0.1431 (CI: 0.0762, 0.2100)
```

```r
## The code below shows that the regtest with rma is equivalent to
## a meta-regression with the standard error as predictor
rma (yi = yi,
     vi = vi,
     measure = 'ZCOR',
     data = df3_develop,
     subset = (development_stage=="Children"),
     mods = ~ sqrt(vi))
```

```
##
## Mixed-Effects Model (k = 50; tau^2 estimator: REML)
##
## tau^2 (estimated amount of residual heterogeneity):     0.0102 (SE = 0.0040)
## tau (square root of estimated tau^2 value):             0.1011
## I^2 (residual heterogeneity / unaccounted variability): 72.30%
## H^2 (unaccounted variability / sampling variability):   3.61
## R^2 (amount of heterogeneity accounted for):            0.00%
##
## Test for Residual Heterogeneity:
## QE(df = 48) = 129.5107, p-val < .0001
##
## Test of Moderators (coefficient 2):
## QM(df = 1) = 4.4693, p-val = 0.0345
##
## Model Results:
##
##           estimate      se    zval    pval   ci.lb   ci.ub
## intrcpt     0.1431  0.0341  4.1933  <.0001  0.0762  0.2100  ***
## sqrt(vi)    0.6293  0.2977  2.1141  0.0345  0.0459  1.2127    *
##
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

4. Three-level model

```r
# Three-level meta-analysis ------------------------------------------------
meta1_multi1 <- rma.mv(yi = yi,
```

```r
                       V = vi,
                       random = list(~1 | study_id/es_id),
                       data = df3,
                       slab = es_id)
summary(meta1_multi1, digits =3)
```

```
##
## Multivariate Meta-Analysis Model (k = 273; method: REML)
##
##    logLik  Deviance       AIC       BIC      AICc
##    83.431  -166.861  -160.861  -150.044  -160.772
##
## Variance Components:
##
##             estim   sqrt  nlvls  fixed          factor
## sigma^2.1  0.015  0.124    129     no        study_id
## sigma^2.2  0.004  0.064    273     no  study_id/es_id
##
## Test for Heterogeneity:
## Q(df = 272) = 8958.240, p-val < .001
##
## Model Results:
##
## estimate     se    zval    pval   ci.lb   ci.ub
##    0.091  0.013  6.842  <.001  0.065  0.117  ***
##
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```r
round(transf.ztor(meta1_multi1$b), 2)
```

```
##         [,1]
## intrcpt 0.09
```

```r
round(transf.ztor(meta1_multi1$ci.lb), 2)
```

```
## [1] 0.06
```

```r
round(transf.ztor(meta1_multi1$ci.ub), 2)
```

```
## [1] 0.12
```

```r
# Transform from z to r
predict(meta1_multi1, digits=2, transf=transf.ztor)
```

```
##
##  pred ci.lb ci.ub pi.lb pi.ub
##  0.09  0.06  0.12 -0.18  0.35
```

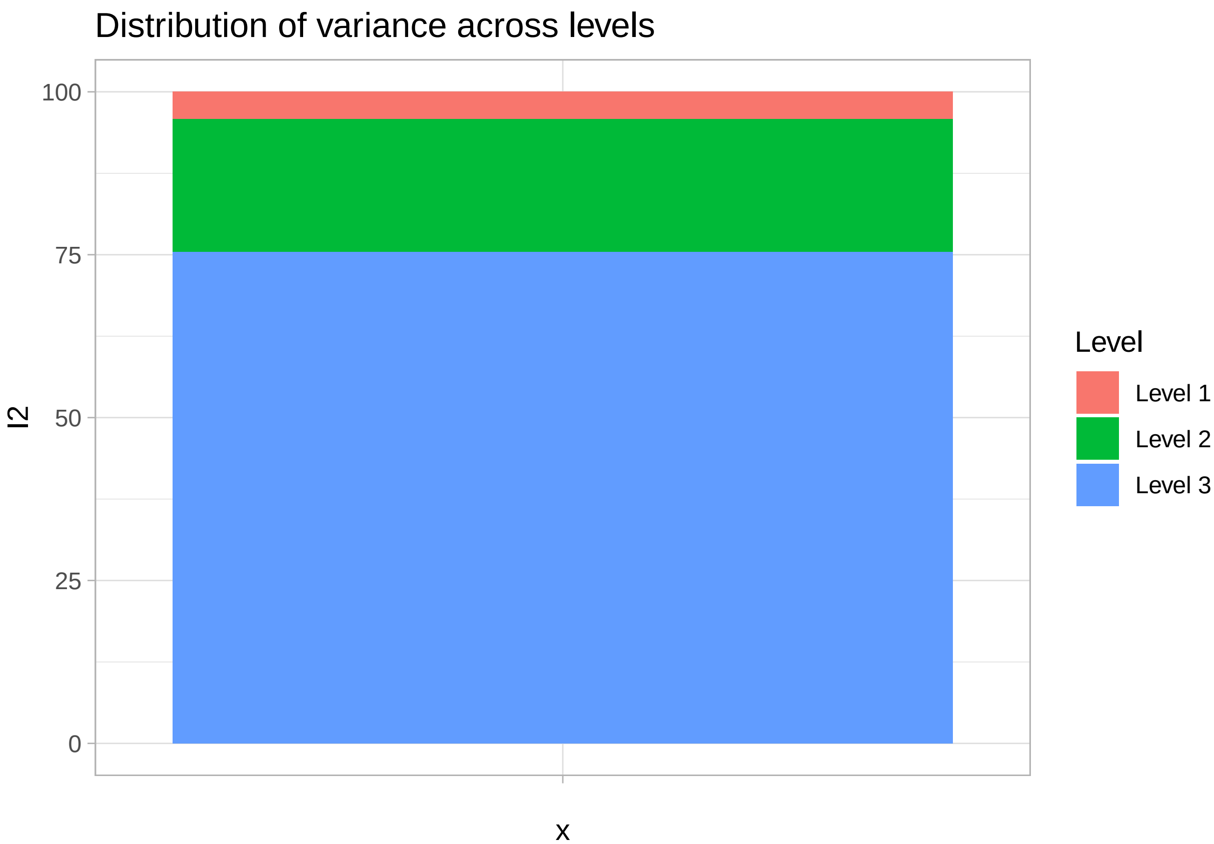
```r
# Confidence intervals
confint.rma.mv(meta1_multi1)
```

```
##
##            estimate  ci.lb  ci.ub
## sigma^2.1    0.0153 0.0103 0.0222
## sigma.1      0.1238 0.1013 0.1489
##
##            estimate  ci.lb  ci.ub
```

```
## sigma^2.2   0.0041 0.0022 0.0073
## sigma.2     0.0644 0.0473 0.0856
```

```r
# * I^2: Distribution of variance at different levels ---------------------
# See function description under 'Load packages' at the top
multilevel_i2(tau2_level2 = meta1_multi1$sigma2[2],
              tau2_level3 = meta1_multi1$sigma2[1],
              vect_var = df3$vi)
```

```
##          I2   Level
## I2_1   4.17 Level 1
## I2_2  20.40 Level 2
## I2_3  75.43 Level 3
```



4.1 Subgroup analysis

```
# * Subgroup analysis -----------------------------------------------------
# Fit 3-level model with developmental_stage as moderator
meta1_multi1_develop1 <- rma.mv(yi = yi,
                                V = vi,
                                random = list(~1 | study_id/es_id),
                                data = df3_develop,
                                slab = es_id,
                                mods = ~ development_stage -1)

summary(meta1_multi1_develop1, digits =3)
```

```
##
## Multivariate Meta-Analysis Model (k = 265; method: REML)
##
##   logLik  Deviance       AIC       BIC      AICc
##   93.340  -186.680  -176.680  -158.839  -176.446
##
## Variance Components:
##
##             estim   sqrt  nlvls  fixed          factor
## sigma^2.1  0.011  0.103    123     no        study_id
## sigma^2.2  0.004  0.063    265     no  study_id/es_id
##
## Test for Residual Heterogeneity:
## QE(df = 262) = 5395.403, p-val < .001
##
## Test of Moderators (coefficients 1:3):
## QM(df = 3) = 100.545, p-val < .001
##
## Model Results:
##
##                                estimate     se   zval   pval   ci.lb  ci.ub
## development_stageAdolescents     0.146  0.017  8.444  <.001   0.112  0.180  ***
## development_stageAdults          0.006  0.018  0.316  0.752  -0.030  0.042
## development_stageChildren        0.195  0.035  5.627  <.001   0.127  0.262  ***
##
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
# Transform the estimates of the differences from z to r
estimate_m <- round(transf.ztor(meta1_multi1_develop1$b),2)
se_m <- round(transf.ztor(meta1_multi1_develop1$se),2)
cilb_m <- round(transf.ztor(meta1_multi1_develop1$ci.lb),2)
ciup_m <- round(transf.ztor(meta1_multi1_develop1$ci.ub),2)

(group_multi <- data.frame(cbind(estimate_m, se_m, cilb_m, ciup_m)))
```

```
##                                V1 se_m cilb_m ciup_m
## development_stageAdolescents 0.15 0.02   0.11   0.18
## development_stageAdults      0.01 0.02  -0.03   0.04
## development_stageChildren    0.19 0.03   0.13   0.26
```

```r
# Multiple comparisons
multcomp_multi1_develop1 <- glht(meta1_multi1_develop1,
                                 linfct=contrMat(c("Adolescents"=1,"Adults"=1,"Children"=1),
                                                 type="Tukey"),test=adjusted("bonferroni"))

summary(multcomp_multi1_develop1)
```

```
##
##   Simultaneous Tests for General Linear Hypotheses
##
## Multiple Comparisons of Means: Tukey Contrasts
##
##
## Fit: rma.mv(yi = yi, V = vi, mods = ~development_stage - 1, random = list(~1 |
##     study_id/es_id), data = df3_develop, slab = es_id)
##
## Linear Hypotheses:
##                              Estimate Std. Error z value Pr(>|z|)
## Adults - Adolescents == 0   -0.14067    0.02523  -5.575   <1e-04 ***
## Children - Adolescents == 0  0.04808    0.03825   1.257    0.413
## Children - Adults == 0       0.18875    0.03913   4.824   <1e-04 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
## (Adjusted p values reported -- single-step method)
```

```r
# Note that the estimate of the differences in the output are Fisher z
# So I need to transform them
estimate <- round(transf.ztor(c(-0.14067, 0.04808, 0.18875)),2)
stand_er <- round(transf.ztor(c(0.02523, 0.03825, 0.03913)),2)
(groups <- data.frame(cbind(estimate, stand_er)))
```

```
##   estimate stand_er
## 1    -0.14     0.03
## 2     0.05     0.04
## 3     0.19     0.04
```

4.2 Publication bias analysis

```r
# * Egger's regression test: multilevel ----------------------------------
# Adolescents
rma.mv(yi = yi,
       V = vi,
       random = list(~1 | study_id/es_id),
       data = df3_develop,
       slab = es_id,
       subset = (development_stage=="Adolescents"),
       mods = ~ sqrt(vi))
```

```
##
## Multivariate Meta-Analysis Model (k = 126; method: REML)
##
## Variance Components:
##
##             estim    sqrt  nlvls  fixed          factor
## sigma^2.1  0.0146  0.1208     55     no        study_id
## sigma^2.2  0.0053  0.0730    126     no  study_id/es_id
##
## Test for Residual Heterogeneity:
## QE(df = 124) = 3987.3836, p-val < .0001
##
## Test of Moderators (coefficient 2):
## QM(df = 1) = 0.3638, p-val = 0.5464
##
## Model Results:
##
##           estimate      se     zval    pval    ci.lb   ci.ub
## intrcpt     0.1566  0.0280   5.5993  <.0001   0.1018  0.2114  ***
## sqrt(vi)   -0.1632  0.2706  -0.6031  0.5464  -0.6937  0.3672
##
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```r
# Adults
rma.mv(yi = yi,
       V = vi,
       random = list(~1 | study_id/es_id),
       data = df3_develop,
       slab = es_id,
       subset = (development_stage=="Adults"),
       mods = sqrt(vi))
```

```
##
## Multivariate Meta-Analysis Model (k = 89; method: REML)
##
## Variance Components:
##
##             estim    sqrt  nlvls  fixed          factor
## sigma^2.1  0.0100  0.0999     55     no        study_id
## sigma^2.2  0.0007  0.0272     89     no  study_id/es_id
##
## Test for Residual Heterogeneity:
```

```
## QE(df = 87) = 363.0890, p-val < .0001
##
## Test of Moderators (coefficient 2):
## QM(df = 1) = 2.7223, p-val = 0.0990
##
## Model Results:
##
##          estimate      se     zval    pval    ci.lb   ci.ub
## intrcpt    0.0629  0.0385   1.6325  0.1026  -0.0126  0.1384
## mods      -0.8006  0.4852  -1.6499  0.0990  -1.7516  0.1504  .
##
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
# Children
rma.mv(yi = yi,
       V = vi,
       random = list(~1 | study_id/es_id),
       data = df3_develop,
       slab = es_id,
       subset = (development_stage=="Children"),
       mods = sqrt(vi))
```

```
##
## Multivariate Meta-Analysis Model (k = 50; method: REML)
##
## Variance Components:
##
##             estim    sqrt  nlvls  fixed          factor
## sigma^2.1  0.0014  0.0376     14     no        study_id
## sigma^2.2  0.0083  0.0914     50     no  study_id/es_id
##
## Test for Residual Heterogeneity:
## QE(df = 48) = 129.5107, p-val < .0001
##
## Test of Moderators (coefficient 2):
## QM(df = 1) = 3.7842, p-val = 0.0517
##
## Model Results:
##
##          estimate      se    zval    pval    ci.lb   ci.ub
## intrcpt    0.1465  0.0370  3.9632  <.0001   0.0740  0.2189  ***
## mods       0.6507  0.3345  1.9453  0.0517  -0.0049  1.3064    .
##
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```