## Multilevel Meta-Analysis (Pearson r) Tutorial

Hu, M., Koh, P.S., Soh, X.C., Hartanto, A., Majeed, N.M.

### Introduction

The following script is designed to perform a multilevel meta-analysis using the metafor, lmerTest and psych packages in R. Specifically, this tutorial utilises Pearson's r and Fisher's Z as the effect size measures, to demonstrate how to convert between the two measures.

The analysis is based on data from Lua et al. (2023) and focuses on the overall relationship between the need for cognition and well-being. The original paper can be found here: https://doi.org/10.1007/s11031-023-10047-w.

The script includes steps for data preparation, effect size calculation, overall effect size computation, forest plot generation, tests for publication bias, and moderation analysis.

The script is structured to be run in RStudio, and it includes comments to guide users through each step of the process.

## Setting Up

This section sets up the working environment, installs necessary packages, loads the required libraries, and reads in the data.

If the metafor, lmerTest and psych and packages are not already installed, use the install.packages() function to install it.

#### Explanation of the Code

- The setwd() function sets the working directory to the location of the script, ensuring that all file paths are relative to the script's location.
- The library() function loads the metafor, lmerTest and psych packages.
- The options() function is used to adjust the display settings, specifically to disable scientific notation and set the number of digits displayed.
- The read.csv() function reads in the data from a CSV file named "NFCWB.csv", which contains the data drawn from Lua et al.(2023).

```
### Set Up ------
# R version 4.5.0

# Set working directory to that of script's current location
setwd(dirname(rstudioapi::getActiveDocumentContext()$path))

# Load packages
library(metafor) # version 4.8-0
```

## Loading required package: Matrix

```
## Loading required package: metadat
## Loading required package: numDeriv
##
## Loading the 'metafor' package (version 4.8-0). For an
## introduction to the package please type: help(metafor)
library(lmerTest) # version 3.1-3
## Loading required package: lme4
##
## Attaching package: 'lmerTest'
## The following object is masked from 'package:lme4':
##
##
       lmer
## The following object is masked from 'package:stats':
##
##
       step
library(psych)
                  # version 2.5.3
# Display settings (to disable scientific notation)
options(scipen = 9999, digits = 4)
# Read in data drawn from Lua et al. (2023)
mlmmeta_raw = read.csv("NFCWB.csv")
```

## Prepare Data

This section prepares the data for analysis by computing effect sizes for each study and organizing the data frame.

For more information on the escalc() function, refer to ?escalc in R.

- The corr\_nfcwb variable has to be reversed for studies with negative well-being, ensuring that the correlation reflects that the lower the correlation, the lower the well-being. The ifelse() function is used to reverse the correlation for studies with negative well-being.
- The measure argument specifies the type of effect size to be calculated, in this case, "ZCOR" (Fisher's Z). ZCOR is used to calculate the effect size from the raw correlation coefficients instead of Pearson's r as Fisher's Z normalises the distribution of the effect sizes. Thus, Fisher's Z would be less affected by the sampling distribution skew.
- The ri variable corr\_nfcwb is the column containing the raw correlation coefficients.
- The ni variable sample\_size is the column containing the sample sizes for each study.
- Afterwards, the escalc() function computes the effect sizes (yi) and their corresponding sampling variances (vi) for each study.
- The publication type is categorised into "Published" and "Unpublished" based on the type of publication (e.g., journal article, conference paper, thesis/dissertation).

• The mlmmeta data frame is then sorted by the type of publication (published vs unpublished) to facilitate clearer visualization in the forest plot. Do note that the comma before the closing square bracket is required, as it indicates that we are keeping the columns while reordering the rows.

```
### Prepare Data -----
# Clean data file (reverse correlation for negative well-being)
mlmmeta_raw$corr_nfcwb = with(mlmmeta_raw,
ifelse(wellbeing_category == "Negative well-being", -corr_nfcwb, corr_nfcwb))
# Compute effect sizes for each study
mlmmeta = escalc(
  # Type of effect size measure
  measure = "ZCOR",
  # Column for raw correlation coefficients
  ri = corr_nfcwb,
  # Column for sample sizes
  ni = sample_size,
  # Specify data.frame that the information will be extracted from
  data = mlmmeta raw
  )
# Categorise publication type into "published" and "unpublished"
# Published: Journal articles
# Unpublished: Conference, Panel Data, Thesis/dissertation, Unpublished data
mlmmeta$publication_type = ifelse(
  mlmmeta$publication_type == "Journal article",
  "Published",
  "Unpublished")
# Order the data frame based on publication type and effect sizes (yi)
mlmmeta = mlmmeta[order(mlmmeta$publication_type, mlmmeta$yi), ]
```

## Computing the Overall Effect Size

This section estimates the overall effect size using the rma.mv() function from the metafor package.

#### Explanation of the Multilevel Meta-Analysis Code

- The rma.mv() function is used to compute the overall effect size, accounting for the nested structure of the data.
- The random argument specifies the random effects structure, where ~ 1 | sample\_id/meta\_id, indicates that random effects are nested within the sample and meta ID.
- The yi and vi arguments specify the effect size estimates and their corresponding sampling variances, respectively.
- The data argument specifies the data frame containing the effect size estimates and variances.
- The summary() function is used to display the results of the meta-analysis, including the overall effect size estimate and its confidence interval.

• The fisherz2r() function is used to convert the effect size estimates from Fisher's Z to Pearson's r.

```
### Compute Overall Effect Size -----
# Effect size estimates
mlmmetaresults = rma.mv(
  # Effect size estimates
 yi = yi,
  # Sampling variances
 V = vi,
  # Include random effects for grouping variable (i.e., sample)
  random = ~ 1 | sample_id/meta_id,
  # Specify where to get the data from
  data = mlmmeta
# summary function used to provide detailed results of the meta-analysis
summary(mlmmetaresults)
##
## Multivariate Meta-Analysis Model (k = 108; method: REML)
##
##
     logLik Deviance
                           AIC
                                     BIC
##
   40.9843
            -81.9687 -75.9687 -67.9502 -75.7357
##
## Variance Components:
##
                        sqrt nlvls fixed
                                                       factor
##
               estim
## sigma^2.1 0.0076 0.0873
                                 52
                                       no
                                                    sample_id
## sigma^2.2 0.0156 0.1250
                                108
                                       no
                                           sample_id/meta_id
##
## Test for Heterogeneity:
## Q(df = 107) = 1573.7169, p-val < .0001
##
## Model Results:
##
## estimate
                se
                      zval
                              pval
                                      ci.lb
                                             ci.ub
     0.1977 0.0200 9.8908 <.0001 0.1585
##
                                            0.2369
##
## ---
## Signif. codes: 0 '***' 0.001 '**' 0.05 '.' 0.1 ' ' 1
# Convert from Fisher's Z to Pearson's r
mlmmetaresults$b |> fisherz2r()
##
             [,1]
## intrcpt 0.1952
```

## Forest Plot

This section generates a forest plot to visually represent the effect sizes and confidence intervals for each study included in the meta-analysis.

The forest plot is created using the forest() function from the metafor package.

The plot includes the following features:

- Arrangement of studies by effect sizes
- Sample size information for need for cognition and well-being group
- Custom headers for the plot
- Custom labels for the studies

Saving the forest plot as a PDF file allows for easy sharing and presentation, and allows adjustment to the plot's dimensions.

- The cairo\_pdf() function starts the graphics device driver to create PDF files, and the file argument specifies the name of the file. Specifically, the cairo\_pdf function is used for font compatibility and in this case, it is for the author's names.
- The width and height arguments adjust the dimensions of the PDF file.
- The forest() function is used to create the forest plot, and the tradmetaresults object contains the results of the meta-analysis.
- The order argument specifies the arrangement of studies, with "obs" indicating that the studies should be arranged by effect sizes. To organise by column, replace "obs" with the specific column in the data frame.
- The ylim argument sets the y-axis limits for the plot.
- The ilab argument is used to add extra columns of information to the forest plot beyond just the effect sizes. Here, we are adding sample size data for cognition and well-being group into the forest plot.
- The ilab.xpos argument specifies where the sample size columns appear horizontally on the plot. The negative values position the columns on the left side of the plot, just after the study names.
- The slab argument is used to label each effect size with its respective study.
- The paste() function creates the label by combining the author and year columns. The sep argument specifies the separator between author and the year label, which is set to "," in this case. Hence, the label will be in the format "Author(s), Year" (e.g., "Smith et al., Study 1").
- The xlim argument sets the x-axis limits for the plot.
- The alim argument sets the confidence interval limits, and the steps argument determines the number of intervals in the x-axis.
- The efac argument controls the size of the diamond shapes that represent the effect sizes in the plot.
- The header argument is set to FALSE to allow for manual specification of headers.
- The xlab argument specifies the confidence interval label for the funnel plot, in this case, "Fisher's Z"
- The text() function is used to manually include text within the plot, such as the "Author(s) Year" header and specific sample size column headers.
- The x and y arguments in the text() function adjust the position of the headers, with the x argument specifying the horizontal arrangement of the columns and the y argument specifying the vertical arrangement of the columns.
- The font argument adjusts the font size.
- The dev.off() function is used to close the graphics device and finalize the plot as a saved file.

```
### Forest Plot -----
# Start creating the forest plot itself
```

```
# Specify dataset
forest(
  mlmmetaresults,
  # Arrangement of studies
  order = "obs",
  # Add y-axis limits
  ylim = c(-3, 111),
  # Add sample size information for need for cognition and well-being group
  ilab = sample_size,
  ilab.xpos = -3,
  # Label studies on the forest plot
  slab = paste(author, year, sep = ", "),
  # Add x-axis limits
  xlim = c(-5, 3),
  # Add confidence interval limits
  # Adjust intervals based on the number of steps
  alim = c(-1.5, 1.5),
  steps = 7,
  # Change size of effect size polygons
  efac = 0.3,
  # Show (TRUE) or hide (FALSE) default headers
  # Hide when we want to manually specify our own headers
 header = FALSE,
  # Add label for confidence interval, in this case, "Fisher's Z"
  xlab = "Fisher's Z"
)
# For the following lines of code,
# Use text function to manually include text within the plot
# Add "Author(s) Year" header
text(x = -4.6, y = 110, "Author(s) Year", font = 2)
# Add "Sample Size" header
text(x = -3, y = 110, "Sample Size", font = 2)
# Add "r [95% CI]" header
text(x = 2.7, y = 110, "Z [95\% CI]", font = 2)
```

1.00   1.00		Sample Size		Z [95% C
The man and ma	Roiser et al., 2009		<b></b>	-0.44 [-0.81, -0.0
			<del></del> +	-0.13 [-0.33, 0.0
Amount   A				
The Assembly				-0.05 [-0.19, 0.0
Section 2020 20 20 1 1 1 2 1 0 0 0 0 0 0 0 0 0	Allan & Shearer, 2012		<b>⊢</b> •-1	-0.02 [-0.13, 0.0
Section   1997	lapier & Jost, 2008		The state of the s	0.00 [-0.06, 0.0
Date of Sheet, 2022   316   1			⊢ <del>≡</del> ⊣	0.00 [-0.12, 0.1
Service A. 2007 19 10 10 10 10 10 10 10 10 10 10 10 10 10			* 1 *	
and as Downey. 2020 3 18				
The section of the common and section of the	-			
ye 2012				
Amount				0.05 [-0.06, 0.1
serry 2070 60		282	+=-	0.06 [-0.06, 0.1
	Bye, 2012	275	+•	0.06 [-0.06, 0.1
Toggreen   150			<b>⊢</b> •−−1	0.07 [-0.19, 0.3
The second and a 1972 200   1				
Total Content of Con				
March and A. 2001   12   12   13   13   13   13   13   1				
Part   Color				
Inches 2012   163   143   143   143   144   169   160			· - '	
Martin   1997   1998   1999	ficeli, 2012	163		0.09 [-0.06, 0.2
A	artanto, 2021b	253	H=-1	0.09 [-0.03, 0.2
year, 2009  year, 2012  year,	ISS Dataset, 2008	6802	H	0.09 [ 0.07, 0.1
ye   2012   275	rohaska et al., 2017	192	<del>  ■  </del>	0.10 [-0.04, 0.2
ya. 2012		207	<b>⊢</b>	0.10 [-0.04, 0.2
			<b>⊢</b> =-1	0.10 [-0.02, 0.2
100   101				0.11 [-0.01, 0.2
				0.12 [ 0.05, 0.1
and part of a 1,000 99				
\$\$\text{\$\tex{\$\text{\$\text{\$\text{\$\text{\$\text{\$\text{\$\text{\$\text{\$\text{\$			<u></u>	
my 2001   260   141				0.13 [-0.07, 0.3
uniforer aft 2,000  20,2010  20,2010  20,2010  201  201				
March & September   2017   2018   March   March   March   2018				0.14 [-0.00, 0.2
20.2010   10.00   1			, - ·	0.14 [ 0.11, 0.1
1,2010			1 22	0.14 [ 0.06, 0.2
				0.14 [ 0.05, 0.2
		261		0.14 [ 0.02, 0.2
	artanto, 2021a			0.14 [ 0.02, 0.2
xx 2018				0.14 [ 0.02, 0.2
may 2021				
amp 2001 263				
married   201   203			The state of the s	
mass & Strock. 2019 188				
			· · · · · · · · · · · · · · · · · · ·	
read 2003  96  Internot, 20201  496  Internot, 20201  496  Internot, 20201  497  Internot, 20201  197  Internot, 20201  197  Internot, 20201  197  Internot, 20201  197  Internot, 20201  Interno			, - ·	
1-1			<b>↓</b>	
# Purple 2009   351				
Image: 2021   253   253   254   2	ye & Pushkar, 2009	351	<b>⊢=</b> +	0.19 [ 0.09, 0.3
evenes et al. 1995  discharmacinan, 2016  973  iiii	erstorf et al., 2009	784	<del>     </del>	0.20 [ 0.13, 0.2
ezides et al. 2001	artanto, 2021b	253	<b>⊢=</b> ⊢	0.20 [ 0.08, 0.3
international 2016   973   154		306	<del>  = 1</del>	0.21 [ 0.10, 0.3
raham. 2010 154			<b>⊢•</b> ⊣	0.21 [ 0.03, 0.4
attention, 2021b 223				
seinzehanna King, 2016  hayer et al., 2019  ha				
abbalder & Greiemeyer, 2016 392    He   0.23 [0.13, 0.0]   Common   192   193   193   194				
Payer et al. 2019   182				
Image: Application   Company   Co				0.23 [ 0.09, 0.3
entrame & Diochaluser, 2012   150	namo.lu, 2003		<b>⊢</b> ■→	0.23 [ 0.12, 0.3
eldom et al. 2020 415 415 416 416, 2021s 416 417, 2021s 417, 417, 418, 418, 418, 418, 418, 418, 418, 418	keuchi et al., 2019	1116	i≡i	0.23 [ 0.18, 0.2
Tarlon, 2021s   281	ertrams & Dickhäuser, 2012	150	<b>⊢</b> •	0.24 [ 0.08, 0.4
Image: part	eidorn et al., 2020	415	⊢ <del>∎</del> ⊣	0.24 [ 0.15, 0.3
Image: part			⊢ <del>≡</del> ⊣	0.24 [ 0.12, 0.3
### 0.28   0.00			1 7 7	0.24 [ 0.12, 0.3
Per   0.28   0.02			H=H	
ree, 2003 96				
Image: 2021a   251			H=H  -	
bin & Guadagno, 2019         310         Image: 2018   14,0         10,2         20,1 (2,1)         20,2 (2,0)         20,2 (2,0)         20,2 (2,0)         20,2 (2,0)         20,2 (2,0)         20,2 (2,0)         20,2 (2,0)         20,2 (2,0)         20,2 (2,0)         20,2 (2,0)         20,2 (2,0)         20,2 (2,0)         20,2 (2,0)         20,2 (2,0)         20,2 (2,0)         20,2 (2,0)         20,3 (2,0)         2				
## 0.28   0.28			The state of the s	
wman, 2012 6615  ## 0.28 [0.27, 0.28]  ## 0.28 [0.27, 0.38]  ## 0.31 [0.28, 0.38]  ## 0.31 [0.28, 0.38]  ## 0.31 [0.28, 0.38]  ## 0.31 [0.28, 0.38]  ## 0.31 [0.28, 0.38]  ## 0.31 [0.28, 0.38]  ## 0.31 [0.28, 0.38]  ## 0.31 [0.28, 0.38]  ## 0.31 [0.28, 0.38]  ## 0.31 [0.28, 0.38]  ## 0.31 [0.28, 0.38]  ## 0.38 [0.28, 0.38]  ## 0			1 1 1	
## 0.28   0.21			' <u>-</u> '	0.29 [ 0.27, 0.3
ratino, 2021b  ete., 2003  g6  ete., 2003  g7  ete., 2003  g7  ete., 2003  g8  ete., 2003			; <del>.</del>	0.29 [ 0.21, 0.3
me. 2003 96				0.31 [ 0.19, 0.4
Image: 2021a   261   Image: 2021   Image: 2021   Image: 2022   Image:			•	0.34 [ 0.32, 0.3
uche et al., 2017         202           i & Morrore, 2001         85           i den et al., 2019         210           i en, 2003         96           i en, 2003         96           i en, 2003         96           i en, 2001         188           i en, 2001         188           i en, 2001         253           i en, 2001         38 (10.25, 0.0           i en, 2001         112           i en, 2002         253           i en, 2003         11           i en, 2003         11           i en, 2003			<b>⊢</b>	0.34 [ 0.14, 0.5
ria Merore. 2001 85  mer. 2003 96  mer. 2004 188  mer. 2005 188  mer. 2005 188  mer. 2005 188  mer. 2005 188  mer. 2006 198  mer. 2007 188  mer. 2007 188  mer. 2008 188  mer. 2008 198  mer. 2008 198  mer. 2008 198  mer. 2008 198  mer. 2009				0.34 [ 0.22, 0.4
Celebrate   1,2019   210			. <del></del> -	
me. 2003 96			<del>  -  </del>	
asia & Strobel, 2019  asia & Strobel, 2019  180  I = I			· · · · · · · · · · · · · · · · · · ·	
ratino, 2021b 253			1 7 7	0.35 [ 0.21, 0.5
He   0.37   0.24, 0.2016   He   0.37   0.24, 0.2016   He   0.37   0.24, 0.2016   He   0.38   0.25, 0.2016   He   0.38   0.27, 0.2016   He   0.38   0.27, 0.2016   He   0.38   0.27, 0.2016   He   0.48   0.27, 0.2016   He   0.58   0.28, 0.2016   He   0.58   0.28, 0.2016   He   0.58   0.28, 0.2016   He   0.58   0.24, 0.2016   He   0.24   0.24   He   0.24				0.35 [ 0.23, 0.4
ratino, 2021a 253			1 1 1	0.37 [ 0.24, 0.4
Trainbo, 2021b   253	rtanto, 2021a	261	<b>⊢=</b> +	0.38 [ 0.25, 0.5
2xide xet al., 2001     112       4xid 2, 2001     125       4xid 1, 2020     253       4xid 1, 2020     261       4xid 2, 2020     261       4xid 2, 2020     212       4xid 2, 2020     223       4xid 2, 2020     223       4xid 2, 2020     225				0.38 [ 0.25, 0.5
ratino, 2021b 253  ■			the state of the s	0.39 [ 0.37, 0.4
wman, 2012  ## 0.42 (0.40, 0.40)  ## 10.42 (0.40, 0.40)  ## 10.45 (0.33, 0.45)  ## 1 0.45 (0.33, 0.45)  ## 1 0.45 (0.33, 0.45)  ## 1 0.45 (0.33, 0.45)  ## 1 0.45 (0.33, 0.45)  ## 1 0.45 (0.33, 0.45)  ## 1 0.45 (0.33, 0.45)  ## 1 0.45 (0.33, 0.45)  ## 1 0.45 (0.33, 0.45)  ## 1 0.45 (0.33, 0.45)  ## 1 0.45 (0.33, 0.45)  ## 1 0.45 (0.33, 0.45)  ## 1 0.45 (0.34, 0.45				
ratino, 2021a 261				
ramon, 2021a				
urin et al., 2020 212				
e, 2018 601 F=1 0.51 (0.43, 0. 1				0.45 [ 0.33, 0.5
ration, 2021b 253				0.51 [ 0.43, 0.5
me, 2003 96				0.51 [ 0.39, 0.6
nny & Banks, 2015 60			· - ·	0.52 [ 0.32, 0.7
rtanto, 2021a 261			· · · ·	0.55 [ 0.29, 0.8
hama-Suruse.2016 194 1— 0.58 (0.43, 0.45) 1.54 1— 0.58 (0.42, 0.45) 1.554 1.57 1.594 1.57 1.57 1.57 1.57 1.57 1.57 1.57 1.57	nny & Banks, 2015			0.55 [ 0.43, 0.6
ulitho & Wooley; 2004 157			⊢•	0.58 [ 0.43, 0.7
ree, 2003 96 — 0.73 (0.52, 0.	irtanto, 2021a ilama-Younes, 2016	154	The state of the s	0.58 [ 0.42, 0.7
	artanto, 2021a alama-Younes, 2016 raham, 2010			0.73 ( 0.57. 0.8
	artanto, 2021a alama-Younes, 2016 raham, 2010 outinho & Woolery, 2004	157	i ⊢•	
andom-Effects Model   • 0.20 [ 0.16, 0.	artanto, 2021a alama-Younes, 2016 raham, 2010 outinho & Woolery, 2004	157		0.73 [ 0.52, 0.9

### Optional: Saving the Forest Plot as a Separate File

#### Explanation of the Code

- To save the forest plot as a PDF file, the plotting code can be enclosed within pdf() and dev.off() functions:
- The pdf() function starts the graphics device driver to create PDF files, and the file argument specifies the name of the file.
- The width and height arguments adjust the dimensions of the PDF file.
- Following the pdf() function, the same code used to create the forest plot of moderators is repeated to generate the plot within the PDF file. The graphical output will be directed to the specified PDF file instead of the RStudio plotting window.
- The dev.off() function is used to close the graphics device and finalise the plot as a saved file.

```
### Forest Plot -----
# Save the forest plot as a PDF file
# Name the pdf file of the forest plot
cairo_pdf(file = "NFCWBforestplot.pdf", width = 14, height = 35)
# Same forest plot code as above
forest(
  mlmmetaresults,
  order = "obs",
  ylim = c(-3, 111),
  ilab = sample_size,
  ilab.xpos = -3,
  slab = paste(author, year, sep = ", "),
  xlim = c(-5, 3),
  alim = c(-1.5, 1.5),
  steps = 7,
  efac = 0.3,
 header = FALSE,
  xlab = "Fisher's Z"
)
text(x = -4.6, y = 110, "Author(s) Year", font = 2)
text(x = -3, y = 110, "Sample Size", font = 2)
text(x = 2.7, y = 110, "Z [95\% CI]", font = 2)
# Close the forest plot and finalise it as a saved file
dev.off()
```

#### ## pdf ## 2

#### Tests for Publication Bias

This section performs tests for publication bias, including a funnel plot and Egger's test.

For multilevel meta-analysis, we do not recommend conducting a rank correlation test as it is prone to Type 1 error.

Researchers may refer to this article by Fernández-Castilla et al. (2019) on a detailed discussion of the limitations of rank correlation tests in multilevel meta-analysis, as well as an overview on other publication bias tests: https://doi.org/10.1080/00220973.2019.1582470:

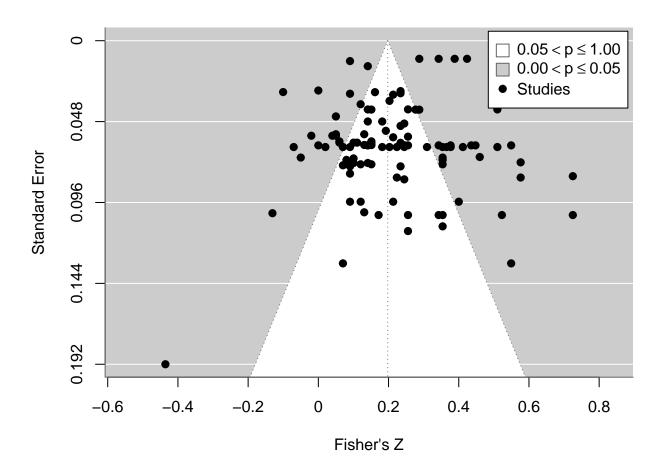
#### Funnel Plot

The funnel plot visually represents the distribution of effect sizes and their standard errors, allowing for the identification of potential publication bias. Saving the funnel plot as a PDF file allows for easy sharing and presentation, and allows adjustment to the plot's dimensions.

- The pdf() function starts the graphics device driver to create PDF files, and the file argument specifies the name of the file.
- The width and height arguments adjust the dimensions of the PDF file.
- The par() function is used to adjust the margins of the funnel plot, with the mar argument specifying the bottom, left, top, and right margins.
- The funnel() function is used to create the funnel plot, and the tradmetaresults object contains the results of the meta-analysis.
- The legend argument specifies whether to include a legend in the plot. TRUE indicates that a legend should be included, FALSE indicates that it should not.
- The xlab argument specifies the confidence interval label for the funnel plot, in this case, "Fisher's Z".
- The dev.off() function is used to close the graphics device and finalize the plot as a saved file.

```
### Tests for Publication Bias -----
# Funnel Plot #

# Adjust margins of the funnel plot
# Set the bottom, left, top, and right margins
par(mar = c(4, 4, 0.3, 1))
# Create the funnel plot
funnel(mlmmetaresults, legend = TRUE, xlab = "Fisher's Z")
```



## Optional: Saving the Funnel Plot as a Separate File

- To save the funnel plot as a PDF file, the plotting code can be enclosed within pdf() and dev.off() functions:
- The pdf() function starts the graphics device driver to create PDF files, and the file function specifies the name of the file.
- The width and height arguments adjust the dimensions of the PDF file.
- Following the pdf() function, the same code used to create the funnel plot is repeated to generate the plot within the PDF file. The graphical output will be directed to the specified PDF file instead of the RStudio plotting window.
- The dev.off() function is used to close the graphics device and finalize the plot as a saved file.

```
### Tests for Publication Bias -----
# Funnel Plot #

# Save the funnel plot as a PDF file
# Name the pdf file of the funnel plot
# Adjust the width and height of the pdf file
pdf(file = "NFCWBfunnelplot.pdf", width = 8, height = 5)
# Same funnel plot code as above
par(mar = c(4, 4, 0.3, 1))
```

```
funnel(mlmmetaresults, legend = TRUE, xlab = "Fisher's Z")
# Close the funnel plot and finalise it as a saved file
dev.off()
## pdf
## 2
```

### Egger's Test

The Egger's test is a statistical test that quantifies the degree of asymmetry in the funnel plot, providing a more formal assessment of publication bias.

- The lmer() function is used to fit a linear mixed-effects model, where the effect size weighted by the standard error is predicted by the intercept and the inverse of the corrected standard error. metafor::rma.mv does not have a weights argument, and metafor::regtest does not support rma.mv objects. For three (or more) level meta-analysis, use lmerTest::lmer instead.
- The I(yi / vi) expression indicates that the effect size (yi) is divided by the standard error (vi), which is used to weight the effect sizes in the model.
- The I(1 / vi) expression indicates that the inverse of the standard error is included in the model as a predictor.
- The 1 | sample\_id expression indicates that random intercepts are included for each lab, accounting for the nested structure of the data.
- The data argument specifies the dataset to be used for the analysis.
- The summary() function provides the results of the Egger's test, including the slope estimate and its significance.

```
### Tests for Publication Bias ------

# Eggers' Test #
lmer(
    # g weighted by SE is predicted by intercept and inverse SE
    # with random intercept by sample
    I(yi / vi) ~ 1 + I(1 / vi) + (1 | sample_id),
    data = mlmmeta
) |>
    # Estimate of interest is the intercept
    summary(correlation = TRUE)
```

```
## Warning: Some predictor variables are on very different scales: consider
## rescaling
## Warning: Some predictor variables are on very different scales: consider
## rescaling

## Linear mixed model fit by REML. t-tests use Satterthwaite's method [
## lmerModLmerTest]
## Formula: I(yi/vi) ~ 1 + I(1/vi) + (1 | sample_id)

## Data: mlmmeta

##
## REML criterion at convergence: 1427

##
## Scaled residuals:
```

```
##
             1Q Median
                           3Q
     Min
                                 Max
## -4.537 -0.103 0.022 0.110
                              5.077
##
## Random effects:
##
   Groups
             Name
                         Variance Std.Dev.
                                  205
   sample id (Intercept) 42221
##
   Residual
                         14832
                                  122
## Number of obs: 108, groups: sample_id, 52
##
## Fixed effects:
              Estimate Std. Error
                                       df t value
                                                             Pr(>|t|)
## (Intercept) -41.0231
                          35.3050
                                  50.5712
                                            -1.16
                                                                 0.25
## I(1/vi)
                0.2564
                           0.0202
                                  45.8603
                                            ## ---
## Signif. codes: 0 '***' 0.001 '**' 0.05 '.' 0.1 ' ' 1
##
## Correlation of Fixed Effects:
##
          (Intr)
## I(1/vi) -0.420
## fit warnings:
## Some predictor variables are on very different scales: consider rescaling
```

## **Moderation Analysis**

This section performs moderation analysis to explore the influence of categorical moderators on the effect sizes.

### Explanation of the Code

- The rma.mv() function is used to compute the multilevel meta-analysis with moderators.
- The yi and vi arguments specify the effect size estimates and their corresponding sampling variances, respectively.
- The random argument specifies the random effects structure, where ~ 1 | sample\_id/meta\_id indicates that random intercepts are included for both the lab and individual studies, accounting for the nested structure of the data.
- The subset argument is used to specify the subset of data for each moderator analysis.
- The data argument specifies the data frame containing the effect size estimates and variances.

Note that if convergence issues arise, the control function can be used to address it. Researchers may also refer more to the metafor package documentation for more information on how to address convergence issues.

```
### Moderation Analysis ------

# Categorical Variable (i.e., publication type)
rma.mv(
    yi = yi,
    V = vi,
    random = ~ 1 | sample_id/meta_id,
    # Specify categorical moderator (i.e., Published articles)
    subset = (publication_type == "Published"),
    data = mlmmeta,
    # To address convergence issues (if it exists)
```

```
control = list(rel.tol=1e-8)
##
## Multivariate Meta-Analysis Model (k = 54; method: REML)
## Variance Components:
##
##
                                                     factor
              estim
                       sqrt nlvls fixed
## sigma^2.1 0.0158 0.1257
                               37
                                                  sample id
                                    no
                               54
## sigma^2.2 0.0103 0.1016
                                     no sample id/meta id
##
## Test for Heterogeneity:
## Q(df = 53) = 1058.6768, p-val < .0001
## Model Results:
##
## estimate
              se
                    zval
                             pval
                                   ci.lb ci.ub
   0.1915  0.0275  6.9686  <.0001  0.1376  0.2453  ***
##
## Signif. codes: 0 '***' 0.001 '**' 0.05 '.' 0.1 ' ' 1
rma.mv(
 yi = yi,
 V = vi,
 random = ~ 1 | sample_id/meta_id,
  # Specify categorical moderator (i.e., Unpublished articles)
 subset = (publication_type == "Unpublished"),
 data = mlmmeta,
  # To address convergence issues (if it exists)
  control = list(rel.tol=1e-8)
)
## Multivariate Meta-Analysis Model (k = 54; method: REML)
## Variance Components:
##
                       sqrt nlvls fixed
##
                                                     factor
              estim
## sigma^2.1 0.0040 0.0633
                               15
                                      no
                                                  sample_id
## sigma^2.2 0.0170 0.1304
                               54
                                      no sample_id/meta_id
##
## Test for Heterogeneity:
## Q(df = 53) = 351.3640, p-val < .0001
##
## Model Results:
##
## estimate
              se
                    zval
                             pval
                                   ci.lb
                                           ci.ub
   0.2126 0.0289 7.3678 <.0001 0.1561 0.2692 ***
## ---
## Signif. codes: 0 '***' 0.001 '**' 0.05 '.' 0.1 ' ' 1
```

## Forest Plot of Moderators

This section generates a forest plot that includes moderators to visually represent the effect sizes and confidence intervals for each study included in the meta-analysis.

The plot is saved as a PDF file for easy sharing and presentation.

The forest plot includes the following features:

- Arrangement of studies by effect sizes and types of moderators
- Sample size information for need for cognition and well-being group
- Custom headers for the plot
- Custom labels for the studies
- Summary effect sizes for each moderator

- The cairo\_pdf() function starts the graphics device driver to create PDF files, and the file argument specifies the name of the file. Specifically, the cairo\_pdf function is used for font compatibility and in this case, it is for the author's names.
- The width and height arguments adjust the dimensions of the PDF file.
- The forest() function is used to create the forest plot, and the mlmmetaresults object contains the results of the meta-analysis.
- The rows argument specifies the arrangement of studies by publication type, and in ascending order of effect sizes per publication type.
- The ylim argument sets the y-axis limits for the plot.
- The ilab argument is used to add extra columns of information to the forest plot beyond just the effect sizes. Here, we are adding sample size data for cognition and well-being group into the forest plot.
- The ilab.xpos argument specifies where the sample size columns appear horizontally on the plot. The negative values position the columns on the left side of the plot, just after the study names.
- The slab argument is used to label each effect size with its respective study.
- The paste() function creates the label by combining the author and year columns. The sep argument specifies the separator between author and the year label, which is set to "," in this case. Hence, the label will be in the format "Author(s), Year" (e.g., "Smith et al., Study 1").
- The xlim argument sets the x-axis limits for the plot.
- The alim argument sets the confidence interval limits, and the steps argument determines the number
  of intervals in the x-axis.
- The efac argument controls the size of the diamond shapes that represent the effect sizes in the plot.
- The header argument is set to FALSE to allow for manual specification of headers.
- The xlab argument specifies the label for the confidence interval, in this case, "Hedge's g".
- The text() function is used to manually include text within the plot, such as the "Author(s) Year" header and specific sample size column headers.
- The x and y arguments in the text() function adjust the position of the headers, with the x argument specifying the horizontal arrangement of the columns and the y argument specifying the vertical arrangement of the columns.
- The font argument adjusts the font size.

- The post argument specifies the position of the text relative to the specified coordinates
- The rma.mv() function is used to perform moderation analysis for each publication type, with the subset argument specifying the subset of data for each category.
- The rest.j, res.t, and res.c variables store the results of the moderation analysis for journal articles, thesis/dissertations, and conference papers, respectively.
- The subset argument is used to specify the subset of data for categorical moderators, allowing for separate analyses for each category.
- The addpoly() function is used to add summary effect sizes for each of the moderators, with the row argument specifying the position of the summary in the plot.
- The dev.off() function is used to close the graphics device and finalize the plot as a saved file.

```
### Forest Plot of Moderators -----
# Start creating the forest plot itself
# Specify dataset
forest(
 mlmmetaresults,
  # Manually arrange effect sizes by publication type
  # - Unpublished: Rows 108 to 51
  # - Published: Rows 50 to 48
  # The arrangement must consider spacing and must end at row 2
  rows = c(112:40, 36:2),
  # Add y-axis limits
 ylim = c(-3, 116),
  # Add sample size information for need for cognition and well-being group
  # Values indicate the x-axis position of the sample size columns
  ilab = sample_size,
  ilab.xpos = -4.2,
  # Label studies on the forest plot
  slab = paste(author, year, sep = ", "),
  # Add x-axis limits
  xlim = c(-7, 4),
  # Add confidence interval limits
  # Adjust intervals based on the number of steps
  alim = c(-1.5, 1.5),
  steps = 7,
  # Change size of effect size polygons
  efac = 0.3,
  # Remove headers (if any), for manual input
  header = FALSE,
  # Add label for confidence interval, in this case, "Fisher's Z"
  xlab = "Fisher's Z"
)
```

```
# For the following lines of code,
# Use text function to manually include text within the plot
# Add text labels for moderator (type of publication)
# Labels for different publication types (Moderator Analysis)
\# - "Unpublished" (Unpublished data, Panel Data, Thesis/Dissertations) at y = 37
\# - "Published" (Journal Articles, Conference) at y = 113
text(
 x = -7,
 y = c(37, 113),
 pos = 4,
 c("Unpublished", "Published"),
 font = 2
# Moderation analysis
res.p = rma.mv(
 уi,
  vi,
 random = ~ 1 | sample_id/meta_id,
 subset = (publication_type == "Published"),
 data = mlmmeta,
 # To address convergence issues (if it exists)
  control = list(rel.tol=1e-8)
)
res.u = rma.mv(
  yi,
  vi,
  random = ~ 1 | sample_id/meta_id,
 subset = (publication_type == "Unpublished"),
 data = mlmmeta,
 # To address convergence issues (if it exists)
  control = list(rel.tol=1e-8)
# Add summary effect sizes for each of the moderators
addpoly(res.u, row = 1) # summary effect for "Unpublished" group
addpoly(res.p, row = 39) # summary effect for "Published" group
# Add"Author(s) Year" header
text(x = -6.4, y = 115, "Author(s) Year", font = 2)
# Add "Sample Size" header
text(x = -4.0, y = 115, "Sample Size", font = 2)
# Add "r [95% CI]" header
text(x = 3.6, y = 115, "Z [95\% CI]", font = 2)
```

Oakberg et al., 2008  Missioner A., 2009  Missioner A., 2009  Missioner A., 2019  Missioner A., 2012  Napier B., 2019  Missioner B., 2017  Napier B., 2018  S.,	30 98 98 98 99 98 99 98 99 99 99 99 99 99		-0.44 [-0.81, -00.13 [-0.33, -00.10] -0.16, -00.05 [-0.19, -00.05 [-0.19, -00.05 [-0.19, -00.05 [-0.09, -00.05 [-0.09, -00.05 [-0.09, -00.05 [-0.09, -00.09] [-0.09] [-0.0
Osberg et al., 2008  Malonery & Restand, 2019  Malonery & Restand, 2011  Malonery & Restand, 2011  Malonery & Restand, 2011  Malonery & Malonery, 2010  Strobel et al., 2019  Malonery & Malonery, 2020  Strobel et al., 2017  Malonery & Malonery, 2020  Malonery, 2021  Malonery, 2020  Malonery, 2020  Malonery, 2020  Malonery, 2020  Malone	98 1075 1075 1075 1076 1076 1076 1076 1076 1076 1076 1076		-0.13 [-0.33, 0] -0.10 [-0.16, -0] -0.05 [-0.19, 0] -0.05 [-0.19, 0] -0.05 [-0.19, 0] -0.05 [-0.05, 0] -0.05 [-0.05, 0] -0.05 [-0.05, 0] -0.05 [-0.05, 0] -0.05 [-0.05, 0] -0.05 [-0.05, 0] -0.05 [-0.05, 0] -0.05 [-0.05, 0] -0.05 [-0.05, 0] -0.05 [-0.05, 0] -0.05 [-0.05, 0] -0.05 [-0.05, 0] -0.05 [-0.05, 0] -0.05 [-0.05, 0] -0.05 [-0.05, 0] -0.05 [-0.05, 0] -0.05 [-0.05, 0] -0.05 [-0.05, 0] -0.05 [-0.05, 0] -0.11 [-0.05, 0] -0.14 [-0.05, 0] -0.14 [-0.05, 0] -0.15 [-0.07, 0] -0.15
**Stude et al. 2,020	210 316 1142 316 316 320 3316 496 496 496 192 202 202 112 112 1008 192 207 173 199 9 9 191 192 192 193 195 195 195 195 195 195 195 195 195 195		-0.10 [-0.16, -0.0] -0.05 [-0.19, 0] -0.02 [-0.13, 0] -0.02 [-0.13, 0] -0.04 [-0.05, 0] -0.05 [-0.06, 0] -0.05 [-0.06, 0] -0.05 [-0.06, 0] -0.05 [-0.06, 0] -0.06 [-0.06, 0] -0.06 [-0.06, 0] -0.06 [-0.06, 0] -0.06 [-0.06, 0] -0.07 [-0.06, 0] -0.
Name A. Shearer. 2012	316 1142 316 320 336 496 496 282 202 202 112 1000 112 99 91 122 207 703 112 99 91 92 92 93 95 96 96 97 97 97 97 97 97 97 97 97 97 97 97 97		-0.02 (-0.13, 0 0.00) (-0.00)
Impure S. Jout. 2008   1	1142 316 320 3316 496 496 496 497 1182 117 1182 117 119 99 191 192 192 193 194 195 195 195 195 195 195 195 195 195 195		0.00 (-0.06, 0 0.04 (-0.07, 0 0.05 (-0.06, 0 0.05 (-0.08, 0 0.06 (-0.08, 0 0.06 (-0.08, 0 0.09 (-0.08, 0 0.09 (-0.08, 0 0.09 (-0.08, 0 0.10 (-0.04, 0 0.10 (-0.04, 0 0.12 (-0.07, 0 0.14 (-0.00, 0 0.14 (-0.00, 0 0.14 (-0.00, 0 0.14 (-0.00, 0 0.15 (0.01, 0
Iana S. Shearer, 2012   Iana S. Shearer, 2012   Iana S. Shearer, 2012   Iana S. Shearer, 2013   Iana S. Shearer, 2014   Iana S. Shearer, 2017   Iana S. Shearer, 2017   Iana S. Shearer, 2017   Iana S. Shearer, 2019   Iana S. Shearer, 2012   Iana S. Shearer, 2014   Iana S. Shearer, 2015   Iana S. Shearer, 2015   Iana S. Shearer, 2015   Iana S. Shearer, 2017   Iana S. Shearer, 2019   Iana S	316 320 316 486 486 282 202 202 112 1008 192 207 703 112 99 91 122 282 354 601 282 361 361	me	0.04 [-0.07, 0 0.05 [-0.08, 0 0.05 [-0.08, 0 0.06 [-0.04, 0 0.06 [-0.05, 0 0.09 [-0.06, 0 0.09 [-0.10, 0 0.09 [-0.10, 0 0.01 [-0.04, 0 0.10 [-0.04, 0 0.11 [-0.04, 0 0.12 [-0.05, 0 0.14 [-0.01, 0 0.14 [-0.01, 0 0.14 [-0.01, 0 0.15 [-0.01, 0
enning & Vorderer. 2001 an & Shewer. 2012 entille et al. 2019 entille et al. 2019 entille et al. 2019 entille et al. 2019 irobel et al. 2017 robel et al. 2017 irobel et al. 2018 irobel et al. 2017 irobel et al. 2018 irobel et al. 2018 irobel et al. 2018 irobel et al. 2018 irobel et al. 2020 irobel et al. 2019 irobel et al. 2012 irobel et al. 2012 irobel et al. 2012 irobel et al. 2010 irobel	320 320 336 496 496 496 496 496 496 496 496 496 49		0.05 [-0.06, 0 0.05 [-0.04, 0 0.06 [-0.04, 0 0.06 [-0.08, 0 0.09 [-0.08, 0 0.09 [-0.08, 0 0.09 [-0.08, 0 0.10 [-0.04, 0 0.10 [-0.04, 0 0.12 [-0.07, 0 0.14 [-0.00, 0 0.14 [-0.00, 0 0.14 [-0.00, 0 0.15 [-0.07, 0 0.14 [-0.00, 0 0.15 [-0.07, 0
Isan & Shearer, 2012  Isan & Shearer, 2012  Isan & Shearer, 2019  Isan & Shearer, 2019  Isan & Shearer, 2019  Isan & Shearer, 2020  Isan & Shearer, 2021  Isan Martino, 2021  Isan M	316 486 282 282 2002 112 1008 192 207 703 1112 99 91 192 282 589 601 381 381 381 381 381 381	##	0.05 [-0.05, 0] 0.05 [-0.04, 0] 0.06 [-0.05, 0] 0.09 [-0.05, 0] 0.09 [-0.10, 0] 0.09 [-0.10, 0] 0.09 [-0.11, 0] 0.09 [-0.11, 0] 0.10 [-0.04, 0] 0.11 [-0.04, 0] 0.12 [-0.05, 0] 0.14 [-0.01, 0] 0.14 [-0.01, 0] 0.14 [-0.01, 0] 0.14 [0.05, 0] 0.15 [0.07, 0] 0.15 [0.07, 0] 0.15 [0.03, 0] 0.15 [0.03, 0] 0.15 [0.03, 0]
entitle et al., 2019  rinche et al., 2019  richel et al., 2017  richel et al., 2017  richel et al., 2017  richel et al., 2001  richel et al., 2000  richel et al., 2001  richel e	496 496 282 202 202 182 112 1008 182 192 207 703 3 193 207 703 3 193 207 703 3 193 2		0.05 [-0.04, 0 0.06 [-0.08, 0 0.09 [-0.08, 0 0.09 [-0.08, 0 0.09 [-0.10, 0 0.10 [-0.04, 0 0.10 [-0.04, 0 0.12 [-0.07, 0 0.14 [-0.00, 0 0.14 [-0.00, 0 0.14 [0.06, 0 0.15 [0.03, 0 0.15 [0.03, 0 0.15 [0.03, 0 0.15 [0.03, 0 0.16 [0.03, 0
simaze & Levine, 2020 simode et al., 2017 support et al., 2019 support et al., 2019 support et al., 2019 subdeberdon et al., 2019 subdeberdon et al., 2019 subdeberdon et al., 2019 subdeberdon et al., 2017 support et al., 2017 subdeberdon et al., 2017 subdeberdon et al., 2017 subdeberdon et al., 2018 subdeberdon et al., 2018 subdeberdon et al., 2008 subdeberdon et al., 2008 subdeberdon et al., 2009 subdeberdon et al., 2019 subdeberdon et al.,	282 2 202 182 182 192 207 192 207 703 192 207 703 192 207 703 192 207 703 195 195 195 195 195 195 195 195 195 195	Mark     M	0.06 [-0.06, 0 0.08 [-0.08, 0 0.08 [-0.10, 0 0.09 [-0.10, 0 0.09 [0.03, 0 0.10 [-0.04, 0 0.12 [0.05, 0 0.12 [0.05, 0 0.14 [0.01, 0 0.14 [0.01, 0 0.15 [0.07, 0 0.15 [0.07, 0 0.15 [0.07, 0 0.15 [0.07, 0 0.15 [0.07, 0
robel et al. 2017	202   202   152	       	0.08 [-0.08, 0   0.08]   0.08
sayer et al., 2019  sachek et al., 2001  schebenerko et al., 2019  schebenerko et al., 2019  schebenerko et al., 2017  syevc, 2008  savenzo et al., 2019  sariok et al., 2001  sariok et al., 2008  sariok et al., 2008  sariok et al., 2008  savenzo et al., 2009  savenzo et al., 2019  save	182 182 1008 1008 1008 1008 1008 1008 10	 	0.09 (-0.06, 0 0.09 (-0.10, 0 0.09 (-0.03, 0 0.10 (-0.04, 0 0.12 (-0.05, 0 0.12 (-0.07, 0 0.13 (-0.07, 0 0.14 (-0.10, 0 0.14 (0.05, 0 0.15 (0.03, 0 0.15 (0.03, 0 0.16 (0.03, 0
acide et al., 2001  Inchaste et al., 2001  Inchaste et al., 2017  Inchaste et al., 2017  Inchaste et al., 2017  Inchaste et al., 2017  Inchaste et al., 2008  Zeride et al., 2001  Inchaste et al., 2008  Zeride et al., 2001  Inchaste et al., 2008  Zeride et al., 2008  Zeride et al., 2001  Inchaste et al., 2008  Zeride et al., 2008  Inchaste et al., 2001  Inchaste et al., 2001  Inchaste et al., 2001  Inchaste et al., 2002  Inchaste et al., 2002  Inchaste et al., 2002  Inchaste et al., 2003  Inchaste et al., 2003  Inchaste et al., 2004  Inchaste et al., 2005  Inchaste et al., 2006  Inchaste et al., 2007  Inchaste et al., 2007  Inchaste et al., 2008  Inchaste et al., 2009  Inchaste et	112 112 112 112 112 112 112 112 112 112		0.09 [-0.10, 0 0.09] [0.03, 0 0.10 [-0.04, 0 0.10 [-0.04, 0 0.12 [-0.05, 0 0.12 [-0.07, 0 0.14 [-0.00, 0 0.14 [-0.10, 0 0.15 [0.05, 0 0.15 [0.07, 0 0.16 [0.07, 0 0.16 [0.07, 0
histophemic et al., 2019  histophemic et al., 2019  weer, 2008  2 weeze & Carone & C	1008 1192 207 703 1112 99 1152 4354 601 282 569 1070 7764 306		0.09 [ 0.03, 0   0.03, 0   0.01   0.04, 0   0.01   0.04, 0   0.12   0.05, 0   0.12   0.05, 0   0.13   0.07, 0   0.14   0.00, 0   0.14   0.00, 0   0.14   0.01, 0   0.15   0.03, 0   0.15   0.03, 0   0.15   0.07, 0   0.16   0.07, 0   0.16   0.07, 0   0.16   0.07, 0   0.16   0.07, 0   0.16   0.07, 0   0.16   0.07, 0   0.16   0.07, 0   0.0
wyer, 2008  average Scanner Sc	207 703 1112 99 91 192 4354 601 282 569 1070 356 7784 306	4	0.10 [-0.04, 0, 0.10 [-0.04, 0, 0.10 [-0.04, 0, 0.12 [-0.05, 0, 0.12 [-0.07, 0, 0.13 [-0.07, 0, 0.14 [-0.10, 0, 0, 0.14 [0.01, 0, 0, 0, 15 [0.03, 0, 0.15 [0.03, 0, 0, 0.16 [0.10, 0, 0, 0, 0.16 [0.10, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0
awazos & Campbell, 2008 7 aciente et al., 2001 1 aberg et al., 2008 1 aberg et al., 2008 1 aciente et al., 2009 1 aciente et al., 2020 1 aciente et al., 2009 7 aciente et al., 2009 7 aciente et al., 2009 3 aciente et al., 2009 1 aciente et al., 2000 1 aciente et al., 2001 1 aciente et al., 2000 2	703 1112 99 1912 14354 4564 4564 4564 4564 4564 4564 4567 4567	Re	0.12 [-0.05, 0. 0.12 [-0.07, 0. 0.13 [-0.07, 0. 0.14 [-0.00, 0. 0.14 [0.11, 0. 0.14 [0.06, 0. 0.15 [0.07, 0. 0.16 [0.10, 0. 0.16 [0.10, 0. 0.16 [0.10, 0.
actiek et al. 2001 abeing et al. 2008 authier et al. 2002 the, 2018 be, 2019	112 99 99 192 1932 1934 1954 1955 1956 1956 1956 1956 1956 1956 1956	    	0.12 [-0.07, 0. 0.13 [-0.07, 0. 0.14 [-0.00, 0. 0.14 [-0.06, 0. 0.15 [0.03, 0. 0.15 [0.07, 0. 0.15 [0.07, 0. 0.16 [0.10, 0.
aberg et al., 2008 auchier et al., 2008 auchier et al., 2005 auchier è Siedelecki, 2021 4, be, 2016 5,	99 192 192 1334 1354 1361 1375 1375 1375 1375 1375 1375 1375 137	      10   10   10   10   10	0.13 [-0.07, 0.014 [-0.00, 0.014 [-0.00, 0.014 [0.01, 0.014 [0.06, 0.015 [0.03, 0.07, 0.016 [0.10, 0.016 [0.10, 0.07]]
auther et al. 2006 1 auther et al. 2006 2 auther set al. 2007 2 auther set al. 2009 3 auther set al. 2001 3 au	192 4354 601 282 599 1070 351 784 4	   H   H      H   H 	0.14 [-0.00, 0. 0.14 [ 0.11, 0. 0.14 [ 0.06, 0. 0.15 [ 0.03, 0. 0.15 [ 0.07, 0. 0.16 [ 0.10, 0.
adani & Siedlecki, 2021 4  w. 2018 6  innaze & Levine, 2020 2  w. 2018 6  intel et al., 2020 1  intel et al., 2030 7  intel et al., 2031 7  intel et al.,	4354 601 282 599 1070 351 784 306	)9  00   00   00   00   -01	0.14[0.11, 0. 0.14[0.06, 0. 0.15[0.03, 0. 0.15[0.07, 0. 0.16[0.10, 0.
xx. 2018	601 282 599 1070 351 784 306	0      0   0  	0.14 [ 0.06, 0. 0.15 [ 0.03, 0. 0.15 [ 0.07, 0. 0.16 [ 0.10, 0.
armaze & Levine, 2020 2. 2. 2. 2. 2. 2. 2. 2. 2. 2. 2. 2.	282 599 1070 351 784 306 112	<del>     </del>	0.15 [ 0.03, 0. 0.15 [ 0.07, 0. 0.16 [ 0.10, 0.
se, 2018 5  was 2 humber 1 and 2020 1  se & Pushkar, 2009 3  seasof et al., 2009 3  sevenes et al., 1995 3  selected at al., 2009 1  sincherhan & King, 2016	599 1070 351 784 306 112	<del>                                    </del>	0.15 [ 0.07, 0. 0.16 [ 0.10, 0.
Intel et al., 2020  a. & Pushkar, 2009  brestoff et al., 2009  crestoff et al., 2019  crestoff et al., 2019  crestoff et al., 2019  crestoff et al., 2019  crestoff et al., 2001  crestoff et al., 2002  crestoff et al., 2001  crestoff et al., 2002  crest	1070 351 784 306 112	<b> - </b>   <del>- </del>	0.16 [ 0.10, 0.
	351 784 306 112	<del>I=I</del>	
enstorf et al., 2009  revene et al., 1905  aziek et al., 2001  initzeirana & King, 2016  initzeirana & Lickina  initzeiran	784 306 112		0.401000.0
sevene et al. 1,995  32 celek et al., 2001  intezienna et King, 2016  1 shizkaria et al., 2019  sayyer et al., 2019  skeuchi et al., 2019  skeuchi et al., 2019  skeuchi et al., 2019  skeuchi et al., 2010  skeuchi et al., 2017  skeuchi et al., 2017  skeuchi et al., 2017  skeuchi et al., 2019  skeuchi et al., 2010  skeuchi et al.,	306 112	; I=1	0.19 [ 0.09, 0.
zelek et al. 2001 interzelma & King, 2016 abbisdari & Greitemeyer, 2016 subyer et al. 2019 amoutu, 2003 amoutu, 2003 amoutu, 2003 december et al. 2019 amoutu, 2003 december et al. 2000 december et al. 2001 december et al. 2017 december et al. 2019 december et a	112	F■H	0.20 [ 0.13,  0. 0.21 [ 0.10,  0.
intizetima & Kinig, 2016 biblicatin & Cortellemyer, 2016 3 spyer et al., 2019 super et al., 2019 tecerist et al., 2019 tecerist et al., 2010 tecerist et al., 2011 tecerist et a		<del>                                    </del>	0.21 [ 0.10, 0.
abbisdin & Greitemeyer, 2016 3 3 saysper et al., 2019 3 3 amol.u. 2003 2 4 secuh et al., 2019 1 5 secuh et al., 2019 1 6 secuh et al., 2019 1 6 secuh et al., 2019 1 7 secuh et al., 2019 1 7 secuh et al., 2017 1 7 secuh et al., 2019 1 7 secuh et al., 20	1020	<del></del>	0.23 [ 0.17, 0.
supper et al., 2019 supper et al., 2019 steach et al., 2019 steach et al., 2019 steach et al., 2010 steach et al., 2020 steach et al., 2021 steach et al., 2021 steach et al., 2017 steach et al., 2019 steach et al., 2019 steach et al., 2019 steach et al., 2021 steach et al., 2020 steach	392		0.23 [ 0.17, 0.
amo bil., 2003  amo bil., 2003  tritamis & Dicishaluser, 2012  tritamis, 2015  tritamis, 2017  tritamis, 2018	182	T=1	0.23 [ 0.09, 0.
Newbill et al., 2019   1   1   1   1   1   1   1   1   1	274	F=-	0.23 [ 0.12, 0
ritrams & Diskhauser, 2012 abdome et al., 2002 gloy et al., 1986 e., 2018 e., 2019 e., 2018 e., 2019 e	274 1116		0.23 [ 0.12, 0
eisdom et al., 2020 4 eisdom et al., 2020 5 et al., 2086 8 e. 2018 1 e. 2019	150	F=1	0.24 [ 0.08, 0.
suby et al. 1986 s. 2019 s. 20	415	<del>  I</del>	0.24 [ 0.15, 0
se, 2018 6 se, 2018 7 se, 2017 7 se, 2018 7 se, 2018 7 se, 2018 7 se, 2018 8 se, 2018 9	81	<del>  • •  </del>	0.26 [ 0.03, 0
se, 2018 5 wman, 2012 8 se, 2018 5 second 1, 2017 6 second 1, 2017 6 second 1, 2019 6 s	602	· 🛏 '	0.26 [ 0.18, 0
wwman, 2012 8 8 8 2018 1 8 1 8 1 8 1 8 1 8 1 8 1 8 1 8 1 8	598	   <del> </del>	0.28 [ 0.20, 0
e. 2018 5  www.nam., 2012 8  sobel et al., 2017 7  2 18, Monroe, 2001  dehn et al., 2019 9  www.nam., 2012 8  zelek et al., 2019 9  www.nam., 2012 8  zelek et al., 2001  www.nam., 2016 6  zelek et al., 2000  www.nam., 2016 1  zelek et al., 2000  www.nam., 2016 1  zelek et al., 2000  www.nam., 2016 1  zelek et al., 2012 9  zelek, 2012 9  zelek, 2012 1  zelek, 2012 2  zel	8615		0.29 [ 0.27, 0
robel et al. 2017 2 ai & Monroe, 2001 3 aich et al. 2019 2 aich et al. 2019 2 aich et al. 2019 3 aich et al. 2019 3 aich et al. 2001 3 aich et al. 2001 3 aich et al. 2001 3 aich et al. 2000 2 aich et al. 2000 3 aich et al.	597	i i	0.29 [ 0.21, 0
ari & Moncoe, 2001 adden et al., 2019 2 serversan, 2012 8 serversan, 2016 8 serversan, 2016 9 serversan, 2017 9 serversa	8615		0.34 [ 0.32, 0
schen et al., 2019  zelde et al., 2019  zelde et al., 2001  strin et al., 2001  strin et al., 2002  see, 2019  servi & Banks, 2015  servi & Banks, 2015  servi & Banks, 2016  servi & Banks, 2016  servi & Banks, 2016  servi & Banks, 2016  servi & Strin et al., 2020  servi & Strin et al., 2020  servi & Strin et al., 2021  servi & Strin et	202	⊦ <del>=</del> ⊣	0.35 [ 0.22, 0
weman, 2012 8 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2	85	⊢•−1	0.35 [ 0.14, 0
zzlek et al. 2001  strine et al. 2001  strine et al. 2020  z strine et al. 2020  strine et al. 2021  strine al. 2021  strine al. 2021  z strane, 2021	210	<del>  =  </del>	0.35 [ 0.22, 0
wman, 2012 strint et al., 2020 se, 2018 se, 2018 se, 2018 se, 2018 se, 2018 se, 2018 se, 2016 se, 2016 se, 2016 se, 2016 se, 2016 se, 2016 se, 2012 seep; 2007 stration, 2021b seep; 2007 stration, 2021b seep; 2007 stration, 2021b seep; 2007 stration, 2021b seep; 2012 seep; 2007 stration, 2021b seep; 2007	8615		0.39 [ 0.37, 0
urin et al. 2020 2016 2021	112	H=-1	0.40 [ 0.21, 0
e, 2018 enny & Banks, 2015 internal Noveley, 2016 internal Noveley, 2016 internal Noveley, 2004 internal Noveley, 2004 internal, 2021b 2 internal, 2021b 2 e, 2012 enery, 2007 internal, 2021b 2 enery, 2007 internal, 2021b 2 enery, 2021	8615		0.42 [ 0.40, 0
nony & Banks, 2015  alama-Younes, 2016  suthin & Wooley, 2004  stranto, 2021b	212	<del>    </del>	0.46 [ 0.32, 0.
latina- Younes, 2016  suithin & Wooley, 2004  stranto, 2021 b  stranto, 2021 b  suithin & Wooley, 2004  stranto, 2021 b  suithin & Wooley, 2004  suithin & Wooley, 2004  suithin & Wooley, 2007  stranton, 2021 b  suithin & 2021 b	601	H	0.51 [ 0.43, 0.
usinho & Wooley, 2004  1 trainio, 2021b  1 trainio, 2021a  1 trainio, 2021a  1 trainio, 2021b  2 trainio, 2021b  1 trainio, 2021b  2 trainio, 2021b	60	1	0.55 [ 0.29, 0
artanto, 2021b  2	194	⊢ <del>≡</del> ⊢	0.58 [ 0.43, 0
artanto, 2021a  artanto, 2021b  artanto, 2021b  artanto, 2021b  artanto, 2021  artanto, 2021b  ag. 2021  ag. 2021  artanto, 2021b  artanto, 2021b  artanto, 2021b  artanto, 2021b	157	j. +	0.73 [ 0.57, 0
artanto, 2021b  2e, 2012  2g, 2012  2g 2g  weery, 2007  artanto, 2021b  2g 2021  1g 2021  1g artanto, 2021b  2g artanto, 2021b  2g 2021  2g 2	253 261	H <b>=</b> H H <del>=H</del>	-0.07 [-0.19, 0 0.00 [-0.12, 0
ve, 2012 3 ve, 2012 2 vee, 2012 2 veery, 2007 1 vertanto, 2021b 2 vertanto, 2021 1 toeli, 2012 1 vertanto, 2021b 2 vertanto, 2021b 2	253	F <del></del>	0.02 [-0.10, 0
ye, 2012 2  wery, 2007 1  artanto, 2021b 2  pog, 2021 1  iceli, 2012 1  artanto, 2021b 2	253 326	- I	0.05 [-0.06, 0
owery, 2007 artanto, 2021b ong, 2021 ficeli, 2012 artanto, 2021b 2	275		0.06 [-0.06, 0
artanto, 2021b 2 ong, 2021 1 iceli, 2012 1 artanto, 2021b 2	60		0.07 [-0.19, 0.
ong, 2021 1 iceli, 2012 1 artanto, 2021b 2	253	'	0.07 [-0.05, 0
iceli, 2012 1 artanto, 2021b 2	185	I <del></del> 1	0.07 [-0.08, 0
	163	H■H	0.09 [-0.06, 0
	253	É≡⊣	0.09 [-0.03, 0.
SS Dataset, 2008 6	6802	H	0.09 [ 0.07, 0.
	275	<del>(=</del> 1	0.10 [-0.02, 0
	275	∳ <del>=</del> 1	0.11 [-0.01, 0
	188	<del>(=</del> -1	0.12 [-0.02, 0
	326	<del>) = 1</del>	0.13 [ 0.02, 0
	263	<del>}=</del> +	0.13 [ 0.01, 0
	436	H <del>el</del>	0.14 [ 0.05, 0
	261	<del>) = 1</del>	0.14 [ 0.02, 0
	261	<del>) -  </del>	0.14 [ 0.02, 0
andom-Effects Model		•	0.19 [ 0.14, 0
bit-bd			
npublished artanto, 2021a 2	261	<b>\_</b> .	0.14 [ 0.02. 0
	261 275	} <del>=</del> 1	0.14 [ 0.02, 0 0.15 [ 0.03, 0
	263	<del>} = 1</del> <del>} = 1</del>	0.15 [ 0.03, 0
	263 263		0.15 [ 0.03, 0
	188		0.15 [ 0.01, 0
	96		0.17 [-0.03, 0
	436	iei,	0.18 [ 0.09, 0
	253		0.18 [ 0.06, 0
rtanto, 2021b 2	253	H <del>≡</del> H	0.20 [ 0.08, 0
bramaniam, 2016	973	H	0.21 [ 0.15, 0
aham, 2010 1	154	⊢ <del>=</del> ⊣	0.22 [ 0.06, 0
	253	ŀ₩	0.22 [ 0.10, 0
	261	н	0.24 [ 0.12, 0
	261	ŀ≕	0.24 [ 0.12, 0
	253	H <del>e</del> H.	0.24 [ 0.12, 0
	96	<del>   </del>	0.26 [ 0.05, 0
	261	<b>!=</b> -1	0.26 [ 0.13, 0
	310	Hed Les	0.26 [ 0.14, 0
	253 96	+ <b>=</b> -	0.31 [ 0.19, 0 0.34 [ 0.14, 0
	96 261		0.34 [ 0.14, 0
	261 96	F■+	0.34 [ 0.22, 0
	188	<del></del>	0.35 [ 0.21, 0
	253	<del> </del>	0.35 [ 0.23, 0
	253	FB-1	0.37 [ 0.24, 0
-	263 261	F=1	0.37 [ 0.24, 0
	253	F=1	0.38 [ 0.25, 0
	253	F=1	0.36 [ 0.25, 0
	263 261	<del>       </del>	0.44 [ 0.29, 0
	261		0.44 [ 0.31, 0
	253	F=-1	0.51 [ 0.39, 0
	253 96	FET	0.52 [ 0.32, 0
	261	T=1	0.55 [ 0.43, 0
	154	F	0.58 [ 0.42, 0
	96		0.73 [ 0.52, 0
andom-Effects Model		<b>♦</b> ' - '	0.21 [ 0.16, 0
		<b>~</b>	
indom-Effects Model		•	0.20 [ 0.16, 0

## Optional: Saving the Forest Plot of Moderators as a Separate File

- To save the forest plot of moderators as a PDF file, the plotting code can be enclosed within pdf() and dev.off() functions:
- The pdf() function starts the graphics device driver to create PDF files, and the file argument specifies the name of the file.
- The width and height arguments adjust the dimensions of the PDF file.
- Following the pdf() function, the same code used to create the forest plot of moderators is repeated to generate the plot within the PDF file. The graphical output will be directed to the specified PDF file instead of the RStudio plotting window.
- The dev.off() function is used to close the graphics device and finalise the plot as a saved file.

```
### Forest Plot of Moderators -----
# Save the forest plot as a PDF file
# Name the pdf file of the forest plot
# cairo_pdf function used for font compatibility
# Adjust the width and height of the pdf file
cairo_pdf(file = "NFCWBforestplotwithmod.pdf", width = 13, height = 35)
# Same forest plot code as above
forest(
  mlmmetaresults,
 rows = c(112:40, 36:2),
  ylim = c(-3, 116),
  ilab = sample_size,
  ilab.xpos = -4.2,
  slab = paste(author, year, sep = ", "),
  xlim = c(-7, 4),
  alim = c(-1.5, 1.5),
  steps = 7,
  efac = 0.3,
  header = FALSE,
  xlab = "Fisher's Z"
text(
  x = -7,
 y = c(37, 113),
  pos = 4,
  c("Unpublished", "Published"),
  font = 2
)
res.p = rma.mv(
  yi,
  νi,
  random = ~ 1 | sample_id/meta_id,
  subset = (publication_type == "Published"),
  data = mlmmeta,
  control = list(rel.tol=1e-8)
```

```
)
res.u = rma.mv(
    yi,
    vi,
    random = ~ 1 | sample_id/meta_id,
    subset = (publication_type == "Unpublished"),
    data = mlmmeta,
    control = list(rel.tol=1e-8)
)

addpoly(res.u, row = 1)
    addpoly(res.p, row = 39)

text(x = -6.4, y = 115, "Author(s) Year", font = 2)

text(x = -4.0, y = 115, "Sample Size", font = 2)

text(x = 3.6, y = 115, "Z [95% CI]", font = 2)

# Close the forest plot and finalise it as a saved file
dev.off()
## pdf
```

# END OF CODE

## 2