A meta-analysis of mental rotation ability in the first years of life

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Commit 1d82f49

```r
gender %>%
  mutate(
    experiment = str_c(year, article, group, seq = ", "),
    # Convert mean sample age from days to months and center
    age_months = age_mean / 30.417,
    age_months_c = age_months - mean(age_months, na.rm = TRUE),
    # Add d_z from paired t test of condition means (Rosenthal, 1991)
    d_s_t = t * sqrt(1 / female_n + 1 / male_n),
    # Add d_z from ANOVA F value via conversion to a t value
    d_s_f = sqrt(as.numeric(f)) * sqrt(1 / female_n + 1 / male_n),
    # Add d_z from mean and standard deviation of the difference
    d_s_diff = (mean_diff_males_mean - mean_diff_females_mean) / sqrt(((male_n - 1) * (mean_diff_males_s
    # Add d_av from mean difference and standard devations (assumes r = 0.5)
    # (Cumming, 2012)
    # Add d from one-sample t test of novelty preference scores
    d_s_nov_pref = (novelty_pref_males_mean - novelty_pref_females_mean) / sqrt(((male_n - 1) * (novelty

    # Choose one type of outcome variable for each experiment
    di = case_when(
      # 1. If d was reported directed
      !is.na(d) ~ d,
      # 2. If a paired sample t test was reported
      !is.na(d_s_t) ~ d_s_t,
      # 3. If ANOVA was reported
      !is.na(d_s_f) ~ d_s_f,
      # 4. If the difference between means and its SD were reported
      !is.na(d_s_diff) ~ d_s_diff,
      # 6. If a novelty preference score and its SD were reported
      !is.na(d_s_nov_pref) ~ d_s_nov_pref
    ),
    # Keep track which type of outcome measure was chosen for each article
    di_type = case_when(
      # 1. If d was reported directly
      !is.na(d) ~ "d",
      # 2. If a paired sample t test was reported
      !is.na(d_s_t) ~ "d_s_t",
      # 3. If ANOVA was reported
      !is.na(d_s_f) ~ "d_s_f",
      # 4. If the difference between means and its SD were reported
      !is.na(d_s_diff) ~ "d_s_diff",
      # 6. If a novelty preference score and its SD were reported
      !is.na(d_s_nov_pref) ~ "d_s_nov_pref"
```

```r
    ) %>%
      factor(levels = c("d", "d_s_t", "d_s_f", "d_s_diff", "d_s_nov_pref")),
    # As per Lankens et. al. 2013, the formula for Hedge's is as follows, is this even correct? Can we
    # g = d_i * (1 - (3 / (4 * (female_n + male_n) - 9))),
    # Apply small sample correction using Hedges' exact method
    # See http://dx.doi.org/10.20982/tqmp.14.4.p242
    df = (male_n + female_n - 2),
    j = exp(lgamma(df / 2) - log(sqrt(df / 2)) - lgamma((df - 1) / 2)),
    gi = di * j,
    # Compute empirical correlation based on sd_z and condition SDs
    d_s = case_when(
      !is.na(d_s_t) ~ d_s_t,
      !is.na(d_s_f) ~ d_s_f,
      !is.na(d_s_diff) ~ d_s_diff,
      !is.na(d_s_nov_pref) ~ d_s_nov_pref
    ),
    # harmonic mean od the sample sizes has to be taken hear
    n_h = (female_n * male_n) / (female_n + male_n),
    sei = sqrt((df * 2 * (1 + (gi^2 * n_h * 0.5))) / ((df - 2) * n_h) - (gi^2 / j^2))
  ) -> dat
```

```r
dat %>%
  select(
    article,
    group,
    experiment,
    gi,
    di,
    di_type,
    d,
    d_s_t,
    d_s_f,
    d_s_diff,
    sei
  ) %>%
  print(n = Inf)
```

```
## # A tibble: 44 x 11
##    article      group experiment       gi      di di_type     d    d_s_t   d_s_f
##    <chr>        <chr> <chr>         <dbl>   <dbl> <fct>   <dbl>    <dbl>   <dbl>
##  1 Antrilli & ~ All   "2016Antr~  0        0      d_s_f   NA    NA         0
##  2 Christodoul~ All   "2016Chri~  0        0      d_s_f   NA    NA         0
##  3 Constantine~ All   "2016Cons~  0.631    0.64   d        0.64  0.643   NA
##  4 Erdmann 2015 5 mo. "2015Erdm~  0.00996  0.01   d        0.01  0.0693   0
##  5 Erdmann 2015 9 mo. "2015Erdm~  0.0299   0.03   d        0.03  0.0262   0.0345
##  6 Erdmann et ~ 5 mo. "2018Erdm~  0.0498   0.05   d        0.05  0.00416  0.0519
##  7 Erdmann et ~ 9 mo. "2018Erdm~  0.0154   0.0154 d_s_f   NA    NA         0.0154
##  8 Erdmann et ~ All   "2019Erdm~  0.0498   0.05   d        0.05  0.0510   NA
##  9 Frick & Möh~ All   "2013Fric~  0.472    0.482  d_s_f   NA    NA         0.482
## 10 Frick & Wan~ Exp.~ "2014Fric~  0        0      d_s_f   NA    NA         0
## 11 Frick & Wan~ Exp.~ "2014Fric~  0        0      d_s_f   NA    NA         0
## 12 Frick & Wan~ Exp.~ "2014Fric~  0        0      d_s_f   NA    NA         0
## 13 Gerhard & S~ All   "2018Gerh~  0        0      d_s_f   NA    NA         0
## 14 Gerhard-Sam~ All   "2021Gerh~  0        0      d_s_f   NA    NA         0
```

```
## 15 Hespos & Ro~ Exp.~ "1997Hesp~  0        0      d_s_f   NA    NA        0
## 16 Hespos & Ro~ Exp.~ "1997Hesp~  0        0      d_s_f   NA    NA        0
## 17 Hespos & Ro~ Exp.~ "1997Hesp~  0        0      d_s_f   NA    NA        0
## 18 Hespos & Ro~ Exp.~ "1997Hesp~  0        0      d_s_f   NA    NA        0
## 19 Hespos & Ro~ Exp.~ "1997Hesp~  0        0      d_s_f   NA    NA        0
## 20 Hespos & Ro~ Exp.~ "1997Hesp~  0        0      d_s_f   NA    NA        0
## 21 Kaaz & Heil~ Exp.~ "2020Kaaz~ -0.149   -0.15   d       -0.15 -0.153   NA
## 22 Kaaz & Heil~ Exp.~ "2020Kaaz~  0.0992   0.1    d        0.1   0.0980  NA
## 23 Kaaz & Heil~ Exp.~ "2020Kaaz~  0.109    0.11   d        0.11  0.108   NA
## 24 Kaaz & Heil~ Exp.~ "2020Kaaz~  0.0199   0.02   d        0.02  0.0177  NA
## 25 Kaaz & Heil~ Exp.~ "2020Kaaz~  0.446    0.45   d        0.45  0.449   NA
## 26 Kelch et al~ Exp.~ "2021Kelc~  0.425    0.440  d_s_f   NA    NA        0.440
## 27 Kelch et al~ Exp.~ "2021Kelc~ NA       NA      <NA>    NA    NA       NA
## 28 Kelch et al~ Craw~ "2021Kelc~  0.520    0.539  d_s_f   NA    NA        0.539
## 29 Lauer et al~ All   "2015Laue~  0.537    0.545  d_s_f   NA    NA        0.545
## 30 Lauer & Lou~ All   "2016Laue~ NA       NA      <NA>    NA    NA       NA
## 31 Möhring & F~ All   "2013Möhr~ NA       NA      <NA>    NA    NA       NA
## 32 Moore & Joh~ All   "2008Moor~  0.647    0.66   d        0.66  0.655   NA
## 33 Moore & Joh~ All   "2011Moor~  0.797    0.813  d_s_f   NA    NA        0.813
## 34 Quinn & Lib~ All   "2008Quin~  1.28     1.32   d_s_t   NA     1.32    NA
## 35 Quinn & Lib~ Exp.~ "2014Quin~  1.21     1.23   d_s_f   NA    NA        1.23
## 36 Quinn & Lib~ Exp.~ "2014Quin~  1.48     1.54   d_s_no~ NA    NA       NA
## 37 Quinn & Lib~ Exp.~ "2014Quin~  0.918    0.951  d_s_no~ NA    NA       NA
## 38 Rochat & He~ Exp.~ "1996Roch~  0        0      d_s_f   NA    NA        0
## 39 Rochat & He~ Exp.~ "1996Roch~  0        0      d_s_f   NA    NA        0
## 40 Schwarzer e~ All   "2013Schw~  0        0      d_s_f   NA    NA        0
## 41 Schwarzer e~ All   "2013Schw~ NA       NA      <NA>    NA    NA       NA
## 42 Slone et al~ All   "2018Slon~  0        0      d_s_f   NA    NA        0
## 43 Slone et al~ Mitt~ "2018Slon~  0        0      d_s_f   NA    NA        0
## 44 Slone et al~ Mitt~ "2018Slon~  0        0      d_s_f   NA    NA        0
## # ... with 2 more variables: d_s_diff <dbl>, sei <dbl>
```

```
dat$sei
```

```
##  [1] 0.5185630 0.4174236 0.3979975 0.1970758 0.2195507 0.1970907 0.2195461
##  [8] 0.1970907 0.4629853 0.5621141 0.5695794 0.5621141 0.3299480 0.4574746
## [15] 0.8976553 0.6592727 0.6995670 0.7319251 0.6741999 0.7032108 0.2920061
## [22] 0.2918894 0.2919090 0.1672546 0.2936809 0.6292969        NA 0.6715999
## [29] 0.3888732        NA        NA 0.4660499 0.4694193 0.6410455 0.4377461
## [36] 0.6529254 0.6241374 0.5560256 0.7032108 0.4188805        NA 0.3203616
## [43] 0.4594683 0.4594683
```

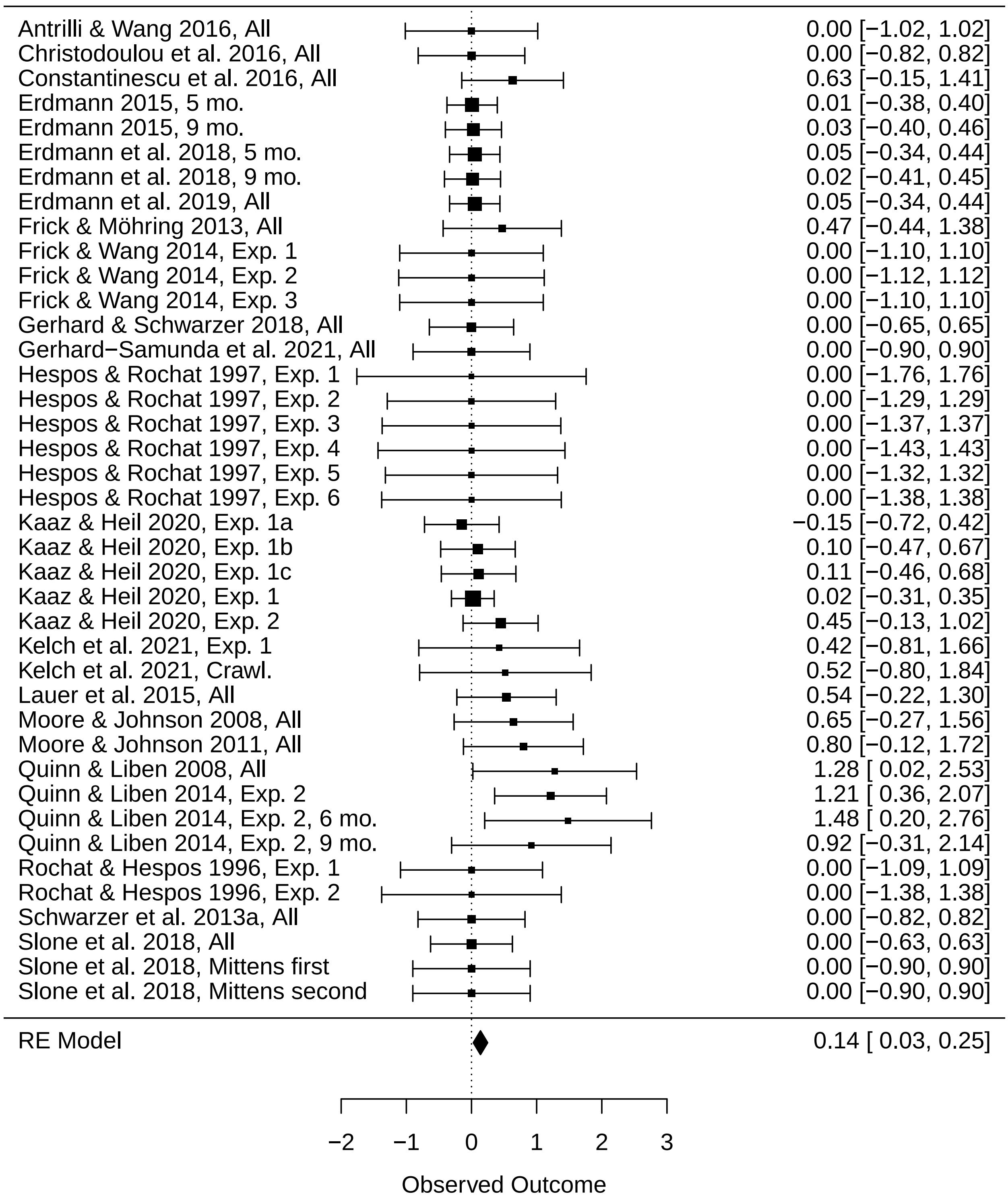
```
dat %>%
  mutate(
    ni = sample_size,
    vi = sei^2
  ) %>%
  filter(!is.na(gi)) %>%
  select(
    article, group, experiment, gi, ni, vi, sei, age_months_c, female_n, sample_size
  ) -> dat_r

# Three-level model
res_ml <- rma.mv(
  gi, vi,
```

```r
  random = ~ 1 | article / experiment,
  data = dat_r,
  slab = paste(article, group, sep = ", ")
)
print(res_ml)
```

```
##
## Multivariate Meta-Analysis Model (k = 40; method: REML)
##
## Variance Components:
##
##             estim    sqrt  nlvls  fixed              factor
## sigma^2.1  0.0000  0.0000     21     no             article
## sigma^2.2  0.0000  0.0000     40     no  article/experiment
##
## Test for Heterogeneity:
## Q(df = 39) = 27.1835, p-val = 0.9230
##
## Model Results:
##
## estimate      se    zval    pval   ci.lb   ci.ub
##   0.1381  0.0559  2.4697  0.0135  0.0285  0.2476  *
##
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```r
# jpeg("forest_between_three_level.jpg")
forest(res_ml)
```


Antrilli & Wang 2016, All 0.00 [−1.02, 1.02]
Christodoulou et al. 2016, All 0.00 [−0.82, 0.82]
Constantinescu et al. 2016, All 0.63 [−0.15, 1.41]
Erdmann 2015, 5 mo. 0.01 [−0.38, 0.40]
Erdmann 2015, 9 mo. 0.03 [−0.40, 0.46]
Erdmann et al. 2018, 5 mo. 0.05 [−0.34, 0.44]
Erdmann et al. 2018, 9 mo. 0.02 [−0.41, 0.45]
Erdmann et al. 2019, All 0.05 [−0.34, 0.44]
Frick & Möhring 2013, All 0.47 [−0.44, 1.38]
Frick & Wang 2014, Exp. 1 0.00 [−1.10, 1.10]
Frick & Wang 2014, Exp. 2 0.00 [−1.12, 1.12]
Frick & Wang 2014, Exp. 3 0.00 [−1.10, 1.10]
Gerhard & Schwarzer 2018, All 0.00 [−0.65, 0.65]
Gerhard−Samunda et al. 2021, All 0.00 [−0.90, 0.90]
Hespos & Rochat 1997, Exp. 1 0.00 [−1.76, 1.76]
Hespos & Rochat 1997, Exp. 2 0.00 [−1.29, 1.29]
Hespos & Rochat 1997, Exp. 3 0.00 [−1.37, 1.37]
Hespos & Rochat 1997, Exp. 4 0.00 [−1.43, 1.43]
Hespos & Rochat 1997, Exp. 5 0.00 [−1.32, 1.32]
Hespos & Rochat 1997, Exp. 6 0.00 [−1.38, 1.38]
Kaaz & Heil 2020, Exp. 1a −0.15 [−0.72, 0.42]
Kaaz & Heil 2020, Exp. 1b 0.10 [−0.47, 0.67]
Kaaz & Heil 2020, Exp. 1c 0.11 [−0.46, 0.68]
Kaaz & Heil 2020, Exp. 1 0.02 [−0.31, 0.35]
Kaaz & Heil 2020, Exp. 2 0.45 [−0.13, 1.02]
Kelch et al. 2021, Exp. 1 0.42 [−0.81, 1.66]
Kelch et al. 2021, Crawl. 0.52 [−0.80, 1.84]
Lauer et al. 2015, All 0.54 [−0.22, 1.30]
Moore & Johnson 2008, All 0.65 [−0.27, 1.56]
Moore & Johnson 2011, All 0.80 [−0.12, 1.72]
Quinn & Liben 2008, All 1.28 [0.02, 2.53]
Quinn & Liben 2014, Exp. 2 1.21 [0.36, 2.07]
Quinn & Liben 2014, Exp. 2, 6 mo. 1.48 [0.20, 2.76]
Quinn & Liben 2014, Exp. 2, 9 mo. 0.92 [−0.31, 2.14]
Rochat & Hespos 1996, Exp. 1 0.00 [−1.09, 1.09]
Rochat & Hespos 1996, Exp. 2 0.00 [−1.38, 1.38]
Schwarzer et al. 2013a, All 0.00 [−0.82, 0.82]
Slone et al. 2018, All 0.00 [−0.63, 0.63]
Slone et al. 2018, Mittens first 0.00 [−0.90, 0.90]
Slone et al. 2018, Mittens second 0.00 [−0.90, 0.90]
RE Model 0.14 [0.03, 0.25]
−2 −1 0 1 2 3
Observed Outcome

```
# dev.off()
```