Study 1

This file reproduces the preprocessing and analysis steps of Study 1. The data are automatically imported from Github and necessary packages will be downloaded and installed if they are not yet available.

Create directory to save plots:

```
if (!dir.exists('final_plots')) {dir.create('final_plots')}
```

```
set.seed(42)
```

```
sessionInfo()
```

```
## R version 4.0.3 (2020-10-10)
## Platform: x86_64-apple-darwin17.0 (64-bit)
## Running under: macOS Big Sur 10.16
##
## Matrix products: default
## BLAS:   /Library/Frameworks/R.framework/Versions/4.0/Resources/lib/libRblas.dylib
## LAPACK: /Library/Frameworks/R.framework/Versions/4.0/Resources/lib/libRlapack.dylib
##
## locale:
## [1] en_US.UTF-8/en_US.UTF-8/en_US.UTF-8/C/en_US.UTF-8/en_US.UTF-8
##
## attached base packages:
## [1] stats     graphics  grDevices utils     datasets  methods   base
##
## other attached packages:
##  [1] psych_2.0.9            emmeans_1.5.3          brms_2.14.4
##  [4] Rcpp_1.0.5             BayesFactor_0.9.12-4.2 coda_0.19-4
##  [7] afex_0.28-0            lme4_1.1-26            Matrix_1.2-18
## [10] jmv_1.2.23             readbulk_1.1.3         forcats_0.5.0
## [13] stringr_1.4.0          dplyr_1.0.2            purrr_0.3.4
## [16] readr_1.4.0            tidyr_1.1.2            tibble_3.0.4
## [19] ggplot2_3.3.2          tidyverse_1.3.0        pacman_0.5.1
##
## loaded via a namespace (and not attached):
##   [1] readxl_1.3.1         backports_1.2.1      plyr_1.8.6
##   [4] igraph_1.2.6         splines_4.0.3        crosstalk_1.1.0.1
##   [7] TH.data_1.0-10       inline_0.3.17        rstantools_2.1.1
##  [10] digest_0.6.27        htmltools_0.5.0      rsconnect_0.8.16
##  [13] lmerTest_3.1-3       fansi_0.4.1          magrittr_2.0.1
##  [16] openxlsx_4.2.3       modelr_0.1.8         RcppParallel_5.0.2
##  [19] matrixStats_0.57.0   xts_0.12.1           sandwich_3.0-0
##  [22] prettyunits_1.1.1    colorspace_2.0-0     rvest_0.3.6
##  [25] haven_2.3.1          xfun_0.19            callr_3.5.1
##  [28] crayon_1.3.4         jsonlite_1.7.2       survival_3.2-7
```

```
##  [31] zoo_1.8-8            glue_1.4.2           gtable_0.3.0
##  [34] MatrixModels_0.4-1   V8_3.4.0             pkgbuild_1.1.0
##  [37] car_3.0-10           rstan_2.21.3         abind_1.4-5
##  [40] scales_1.1.1         mvtnorm_1.1-1        DBI_1.1.0
##  [43] miniUI_0.1.1.1       xtable_1.8-4         tmvnsim_1.0-2
##  [46] foreign_0.8-80       StanHeaders_2.21.0-6 stats4_4.0.3
##  [49] DT_0.16              htmlwidgets_1.5.3    httr_1.4.2
##  [52] threejs_0.3.3        ellipsis_0.3.1       pkgconfig_2.0.3
##  [55] loo_2.4.1            dbplyr_2.0.0         tidyselect_1.1.0
##  [58] rlang_0.4.9          reshape2_1.4.4       later_1.1.0.1
##  [61] munsell_0.5.0        cellranger_1.1.0     tools_4.0.3
##  [64] cli_2.2.0            jmvcore_1.2.23       generics_0.1.0
##  [67] broom_0.7.2          ggridges_0.5.2       evaluate_0.14
##  [70] fastmap_1.0.1        yaml_2.2.1           processx_3.4.5
##  [73] knitr_1.30           fs_1.5.0             zip_2.1.1
##  [76] pbapply_1.4-3        nlme_3.1-149         mime_0.9
##  [79] projpred_2.0.2       xml2_1.3.2           shinythemes_1.1.2
##  [82] compiler_4.0.3       bayesplot_1.7.2      rstudioapi_0.13
##  [85] curl_4.3             gamm4_0.2-6          reprex_0.3.0
##  [88] statmod_1.4.35       stringi_1.5.3        ps_1.5.0
##  [91] Brobdingnag_1.2-6    lattice_0.20-41      nloptr_1.2.2.2
##  [94] markdown_1.1         shinyjs_2.0.0        vctrs_0.3.5
##  [97] pillar_1.4.7         lifecycle_0.2.0      bridgesampling_1.0-0
## [100] estimability_1.3     data.table_1.13.4    httpuv_1.5.4
## [103] R6_2.5.0             promises_1.1.1       gridExtra_2.3
## [106] rio_0.5.16           codetools_0.2-16     boot_1.3-25
## [109] colourpicker_1.1.0   MASS_7.3-53          gtools_3.8.2
## [112] assertthat_0.2.1     withr_2.3.0          mnormt_2.0.2
## [115] shinystan_2.5.0      multcomp_1.4-15      mgcv_1.8-33
## [118] parallel_4.0.3       hms_0.5.3            grid_4.0.3
## [121] minqa_1.2.4          rmarkdown_2.6        carData_3.0-4
## [124] numDeriv_2016.8-1.1  shiny_1.5.0          lubridate_1.7.9.2
## [127] base64enc_0.1-3      dygraphs_1.1.1.6
```

Import data

```
github_link = 'https://raw.githubusercontent.com/mertensu/thinking-in-ratios/master/'
file_name = 'data_total_study1.csv'
df = read.csv(paste0(github_link, file_name))
```

Preprocessing

```
# replace zero ratings with 0.001
df[df$brightness_rating==0,'brightness_rating'] = 0.001

# make rating comparable across conditions
df[, "brightness_rating"] = ifelse(df$condition == "reversal",
                                   10 * (10 / df$brightness_rating),
                                   df$brightness_rating
)
```

```
# compute log rating
df$log_brightness_rating = log(df$brightness_rating)
```

Demographics

```
psych::describe(df$age)
```

```
##    vars    n  mean   sd median trimmed  mad min max range skew kurtosis   se
## X1    1 1600 25.15 9.56     23   23.12 4.45  19  64    45  3.3     10.7 0.24
```

```
df %>% distinct(File, .keep_all = T) %>% group_by(gender) %>% summarise(
  N = n(),
  Min =
    min(age),
  Max =
    max(age),
  Mean =
    mean(age),
  Sd =
    sd(age)
)
```

```
## `summarise()` ungrouping output (override with `.groups` argument)
```

```
## # A tibble: 2 x 6
##   gender     N   Min   Max  Mean    Sd
##   <chr>  <int> <int> <int> <dbl> <dbl>
## 1 m          4    20    64  34.8 20.0
## 2 w         16    19    30  22.8  3.30
```

```
df %>% distinct(File, .keep_all = T) %>% count(student)
```

```
##   student  n
## 1       0  4
## 2       1 16
```

```
df %>% distinct(File, .keep_all = T) %>% filter(student == 1) %>% count(psycho)
```

```
##   psycho  n
## 1      0 12
## 2      1  4
```

Analysis

ANOVA I (within 2 (method) x 8(luminance))

```
#
df$cd_factor = factor(df$cd, levels = c(1, 1.8, 3.2, 5.7, 17.9, 32.0, 57.2, 100.0))
(fit = aov_ez(
  dv = 'log_brightness_rating',
  within = c('condition', 'cd_factor'),
  id = 'File',
  data = df
))
```

frequentist fit

```
## Anova Table (Type 3 tests)
##
## Response: log_brightness_rating
##                Effect          df  MSE         F  ges p.value
## 1           condition       1, 19 0.26 50.41 *** .090   <.001
## 2           cd_factor 1.36, 25.75 3.15 69.00 *** .692   <.001
## 3 condition:cd_factor 1.47, 28.02 1.35 13.39 *** .168   <.001
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '+' 0.1 ' ' 1
##
## Sphericity correction method: GG
```

```
df_sub = df %>% select(log_brightness_rating, condition, cd_factor, File)
df_sub$condition = factor(df_sub$condition)
df_sub$File = factor(df_sub$File)
bfs = anovaBF(
  log_brightness_rating ~ condition * cd_factor + File,
  whichRandom = 'File',
  whichModels = 'top',
  data = df_sub
)


# BF cd_stepwise_distance
bf_1 = lmBF(log_brightness_rating ~ condition + File,
            whichRandom = 'File',
            data = df_sub)
bf_2 = lmBF(
  log_brightness_rating ~ cd_factor + condition + File,
  whichRandom = 'File',
  data = df_sub
)
(bf_cd_factor = bf_2 / bf_1)
```

bayesian fit

```
## Bayes factor analysis
```

```
## --------------
## [1] cd_factor + condition + File : 7.084325e+297 ±3.18%
##
## Against denominator:
##   log_brightness_rating ~ condition + File
## ---
## Bayes factor type: BFlinearModel, JZS
```

```
print(paste0('logBF ', bf_cd_factor@bayesFactor$bf))
```

```
## [1] "logBF 685.825657255936"
```

```
# BF condition
bf_1 = lmBF(log_brightness_rating ~ cd_factor + File,
            whichRandom = 'File',
            data = df_sub)
bf_2 = lmBF(
  log_brightness_rating ~ cd_factor + condition + File,
  whichRandom = 'File',
  data = df_sub
)
(bf_condition = bf_2 / bf_1)
```

```
## Bayes factor analysis
## --------------
## [1] cd_factor + condition + File : 6.854014e+19 ±3.91%
##
## Against denominator:
##   log_brightness_rating ~ cd_factor + File
## ---
## Bayes factor type: BFlinearModel, JZS
```

```
print(paste0('logBF ', bf_condition@bayesFactor$bf))
```

```
## [1] "logBF 45.673951230993"
```

```
# BF interaction
bf_1 = lmBF(
  log_brightness_rating ~ cd_factor + condition + File,
  whichRandom = 'File',
  data = df_sub
)
bf_2 = lmBF(
  log_brightness_rating ~ cd_factor * condition + File,
  whichRandom = 'File',
  data = df_sub
)
(bf_interaction = bf_2 / bf_1)
```

```
## Bayes factor analysis
## --------------
```

```
## [1] cd_factor * condition + File : 2.931312e+40 ±2.42%
##
## Against denominator:
##   log_brightness_rating ~ cd_factor + condition + File
## ---
## Bayes factor type: BFlinearModel, JZS
```

```
print(paste0('logBF ', bf_interaction@bayesFactor$bf))
```

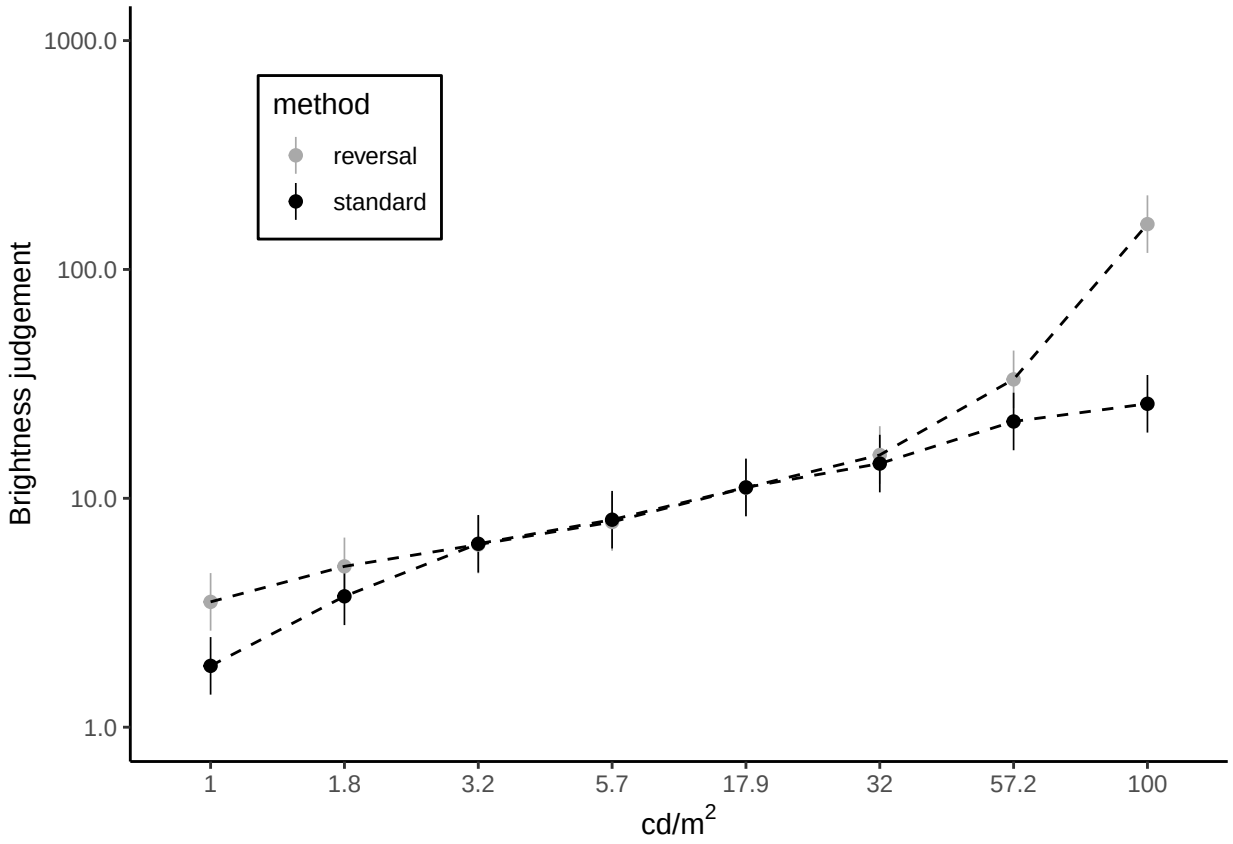
```
## [1] "logBF 93.1788538774165"
```

Figure 1

```
scaleFUN <- function(x)
  sprintf("%.1f", x)

grid = data.frame(emmeans(fit,  ~ cd_factor + condition))

ggplot(grid, aes(
  x = cd_factor,
  y = exp(emmean),
  group = condition
)) +
  geom_pointrange(aes(
    ymin = exp(lower.CL),
    ymax = exp(upper.CL),
    color = condition
  ), size =
    0.3) +
  scale_y_continuous(
    trans = 'log2',
    breaks = c(1.0, 10.0, 100.0, 1000.0),
    limits = c(1.0, 1000.0),
    labels = scaleFUN
  ) +
  geom_line(linetype = 'dashed') +
  labs(y = 'Brightness judgement') +
  xlab(expression(paste("cd/", m ^ 2, sep = ""))) +
  scale_color_manual(
    values = c("darkgrey", "black"),
    name = "method",
    labels = c("reversal", "standard")
  ) +
  scale_x_discrete(labels = substring(grid$cd_factor, 2)) +
  theme_classic() +
  theme(
    legend.position = c(0.2, 0.8),
    legend.background = element_rect(color = "black")
  )
```




```
ggsave(
  paste0("final_plots/study1_figure1.png"),
  dpi = 600,
  height = 4,
  width = 5,
  units = "in"
)
```