Experiment 2

General preparations

Load libraries

```
library(mousetrap)
library(ggplot2)
library(dplyr)
library(tidyr)
library(afex)
library(MBESS)
library(ordinal)
```

Custom ggplot2 theme

```
theme_set(theme_classic()+
  theme(
    axis.line = element_line(colour = "black"),
    axis.ticks = element_line(colour = "black"),
    axis.text = element_text(colour = "black"),
    panel.border = element_rect(colour = "black", fill=NA)
  ))
```

Custom functions

```
# Function to compute confidence interval for partial eta-squared
get_partial_etas <- function(anova_table, conf.level=.90){
  partial_etas <- sapply(row.names(anova_table),function(i){
    F <- anova_table[i,"F"]
    df1 <- anova_table[i,"num Df"]
    df2 <- anova_table[i,"den Df"]
    ci <- conf.limits.ncf(F.value=F,conf.level=conf.level,df.1=df1,df.2=df2)
    return(
      c(pes=((F*df1)/(F*df1+df2)),
        lower=ci$Lower.Limit/(ci$Lower.Limit+df1+df2+1),
        upper=ci$Upper.Limit/(ci$Upper.Limit+df1+df2+1)))
  })
  return(t(partial_etas))
}
```

Data import

```
raw_data <- read.csv("../data/exp2.csv")
raw_data$Typicality <- factor(raw_data$Condition,levels=c("Typical","Atypical"))
raw_data$group <- factor(raw_data$group,levels=c("default","slow"))
```

Correctness

Percent of correct trials per condition

```
with(raw_data,table(group, correct)/c(table(group)))
```

```
##          correct
## group              0          1
##   default 0.06512043 0.93487957
##   slow    0.05530776 0.94469224
```

Chi-squared test

```
chisq.test(with(raw_data,table(group, correct)),correct = FALSE)
```

```
##
##  Pearson's Chi-squared test
##
## data:  with(raw_data, table(group, correct))
## X-squared = 0.95372, df = 1, p-value = 0.3288
```

Generalized linear mixed model

```
contrasts(raw_data$group) <- c(0.5,-0.5)
summary(glmer(correct~(1|subject_nr)+group,family="binomial",data=raw_data))
```

```
## Generalized linear mixed model fit by maximum likelihood (Laplace
##   Approximation) [glmerMod]
##  Family: binomial  ( logit )
## Formula: correct ~ (1 | subject_nr) + group
##    Data: raw_data
##
##      AIC      BIC   logLik deviance df.resid
##   1008.6   1025.8   -501.3   1002.6     2239
##
## Scaled residuals:
##     Min      1Q  Median      3Q     Max
## -4.5190  0.1804  0.2213  0.2337  0.5278
##
## Random effects:
##  Groups     Name        Variance Std.Dev.
##  subject_nr (Intercept) 0.573    0.757
## Number of obs: 2242, groups:  subject_nr, 118
##
## Fixed effects:
##             Estimate Std. Error z value Pr(>|z|)
## (Intercept)   2.9990     0.1401  21.409   <2e-16 ***
## group1       -0.1648     0.2358  -0.699    0.485
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
```

```
## Correlation of Fixed Effects:
##        (Intr)
## group1 -0.031
```

Exclude incorrect trials

```
raw_data <- subset(raw_data, correct==1)
```

Trajectory preprocessing

```
mt_data <- mt_import_mousetrap(raw_data)
mt_data <- mt_remap_symmetric(mt_data)

# Start position descriptives (xpos)
mean(mt_data$trajectories[,1,"xpos"])
```

```
## [1] -0.2477456
```

```
sd(mt_data$trajectories[,1,"xpos"])
```

```
## [1] 45.62261
```

```
# Start position descriptives (ypos)
mean(mt_data$trajectories[,1,"ypos"])+1050/2
```

```
## [1] 103.6232
```

```
sd(mt_data$trajectories[,1,"ypos"])
```

```
## [1] 32.45008
```

```
mt_data <- mt_align_start(mt_data, start=c(0,0))
mt_data <- mt_derivatives(mt_data)
mt_data <- mt_measures(mt_data)
mt_data <- mt_time_normalize(mt_data)
```

Manipulation check: maximum velocity and acceleration

Aggregate data per participant and condition

```
agg_vel_acc <- mt_aggregate_per_subject(mt_data, use_variables=c("vel_max","acc_max"),
  use2_variables="group", subject_id="subject_nr")
```

Descriptives

```
mean_vel_acc <- agg_vel_acc %>%
  group_by(group) %>%
  summarize(
    N = n(),
```

```
    M_vel = mean(vel_max),
    SD_vel = sd(vel_max),
    M_acc = mean(acc_max),
    SD_acc = sd(acc_max)
    ) %>%
  as.data.frame()

print(mean_vel_acc, digits=2)
```

```
##     group  N M_vel SD_vel M_acc SD_acc
## 1 default 59  10.0    2.2  0.54  0.119
## 2    slow 59   4.3    1.1  0.22  0.056
```

Compare maximum velocity

```
# Between groups t-test
vel_t <- t.test(vel_max~group, data=agg_vel_acc, paired=FALSE,var.equal=TRUE)
vel_t
```

```
##
##  Two Sample t-test
##
## data:  vel_max by group
## t = 18.086, df = 116, p-value < 2.2e-16
## alternative hypothesis: true difference in means is not equal to 0
## 95 percent confidence interval:
##  5.117120 6.375717
## sample estimates:
## mean in group default    mean in group slow
##             10.004925              4.258506
```

```
# Cohen's d including 95 % CI
ci.smd(ncp = vel_t$statistic[[1]],n.1 = mean_vel_acc$N[1],n.2 = mean_vel_acc$N[2], conf.level = .95)
```

```
## $Lower.Conf.Limit.smd
## [1] 2.766925
##
## $smd
## [1] 3.329905
##
## $Upper.Conf.Limit.smd
## [1] 3.886533
```

Compare maximum acceleration

```
# Between groups t-test
acc_t <- t.test(acc_max~group, data=agg_vel_acc, paired=FALSE,var.equal=TRUE)
acc_t
```

```
##
##  Two Sample t-test
##
```

```
## data:  acc_max by group
## t = 18.667, df = 116, p-value < 2.2e-16
## alternative hypothesis: true difference in means is not equal to 0
## 95 percent confidence interval:
##  0.2854992 0.3532744
## sample estimates:
## mean in group default    mean in group slow
##             0.5420214             0.2226346
```

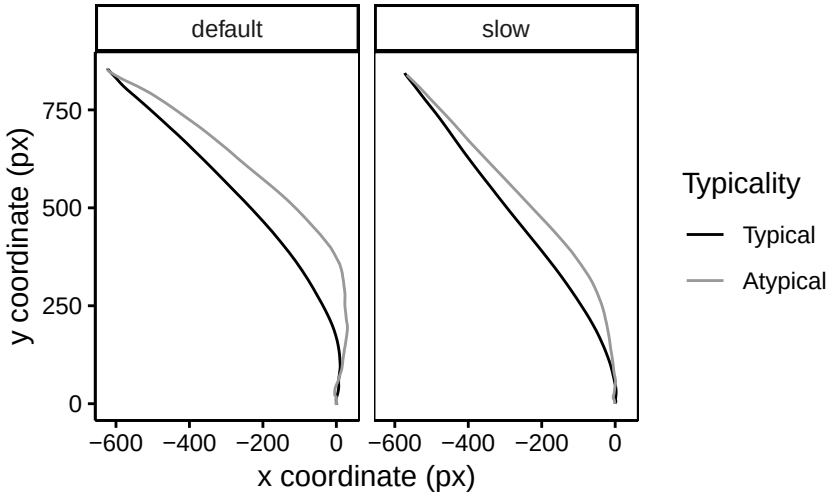
```
# Cohen's d including 95 % CI
ci.smd(ncp = acc_t$statistic[[1]],n.1 = mean_vel_acc$N[1],n.2 = mean_vel_acc$N[2], conf.level = .95)
```

```
## $Lower.Conf.Limit.smd
## [1] 2.86335
##
## $smd
## [1] 3.436905
##
## $Upper.Conf.Limit.smd
## [1] 4.00412
```

Aggregate trajectory curvature

Average time-normalized tajectories

```
mt_plot_aggregate(mt_data, use = "tn_trajectories", facet_col = "group",
  x = "xpos", y = "ypos", color = "Typicality", subject_id = "subject_nr")+
  xlab("x coordinate (px)") + ylab("y coordinate (px)")+
  scale_color_manual(values = c("black","grey60"))
```



Comparison of MAD aggregated per participant

Aggregate data per participant and condition

```
agg_mad <- mt_aggregate_per_subject(mt_data, subject_id = "subject_nr",
  use_variables = "MAD", use2_variables = c("Typicality","group"))
```

Descriptives and paired t-tests

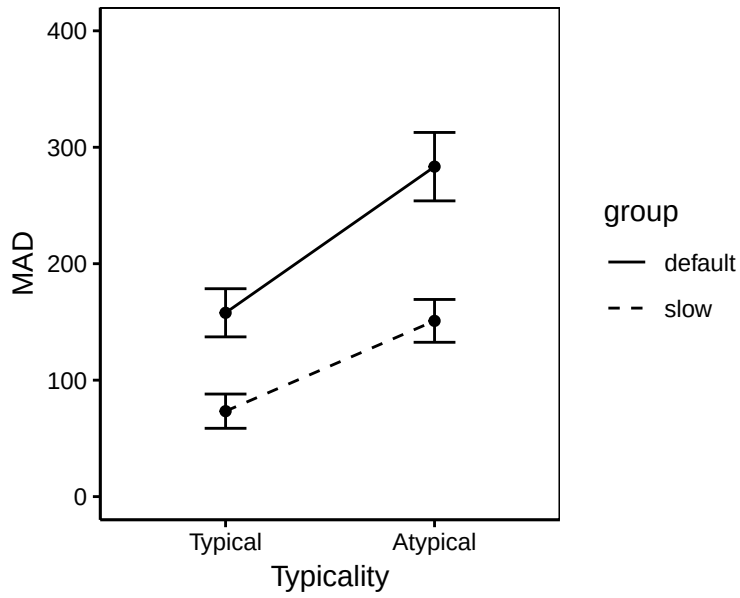
```
mad_table <- agg_mad %>%
  group_by(group) %>%
  select(MAD,group,Typicality) %>%
  summarize(
    N =  length(MAD[Typicality=="Typical"]),
    M_t = mean(MAD[Typicality=="Typical"]),
    SD_t = sd(MAD[Typicality=="Typical"]),
    M_a = mean(MAD[Typicality=="Atypical"]),
    SD_a = sd(MAD[Typicality=="Atypical"]),
    t = t.test(MAD[Typicality=="Atypical"],MAD[Typicality=="Typical"],paired=TRUE)$statistic,
    p = t.test(MAD[Typicality=="Atypical"],MAD[Typicality=="Typical"],paired=TRUE)$p.value,
    d = (M_a-M_t)/sd(MAD[Typicality=="Atypical"]-MAD[Typicality=="Typical"])
    )

mad_table %>%
  as.data.frame() %>%
  print(digits=3)
```

```
##     group  N   M_t SD_t M_a SD_a    t        p     d
## 1 default 59 157.8  159 283  226 5.49 9.32e-07 0.715
## 2    slow 59  73.4  113 151  141 4.52 3.05e-05 0.589
```

Figure

```
ggplot(agg_mad,aes(x=Typicality,y=MAD,linetype=group,group=group))+
  geom_line(stat="summary",fun.y="mean")+
  geom_point(stat="summary",fun.y="mean")+
  geom_errorbar(stat="summary",fun.data="mean_se",width=.2,linetype=1)+
  scale_linetype_manual(values=c(1,2))+
  coord_cartesian(ylim=c(0,400))
```



ANOVA

```
anova_mad <- aov_ez(data=agg_mad, dv = "MAD", between = "group", within = "Typicality",
                    id = "subject_nr")
```

```
## Contrasts set to contr.sum for the following variables: group
```

```
nice(anova_mad,es = c("pes","ges"))
```

```
## Anova Table (Type 3 tests)
##
## Response: MAD
##              Effect     df      MSE         F  ges pes p.value
## 1             group 1, 116 42401.22 16.37 ***  .10 .12  <.0001
## 2       Typicality 1, 116 12045.29 50.49 ***  .09 .30  <.0001
## 3 group:Typicality 1, 116 12045.29    2.82 + .005 .02     .10
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '+' 0.1 ' ' 1
```

```
# 90 % confidence interval for partial eta-squared
round(get_partial_etas(anova_mad$anova_table, conf.level=.90),2)
```

```
##                   pes lower upper
## group            0.12  0.04  0.22
## Typicality       0.30  0.19  0.40
## group:Typicality 0.02    NA  0.09
```

Distribution of trajectory shapes

Bimodality coefficient

```
# Standardize MAD per participant
mt_data <- mt_standardize(mt_data, use_variables = "MAD", within = "subject_nr")

# Calculate bimodality coefficient
mt_check_bimodality(mt_data, use_variables = "z_MAD",
  grouping_variables = c("group","Typicality"), methods = "BC")
```

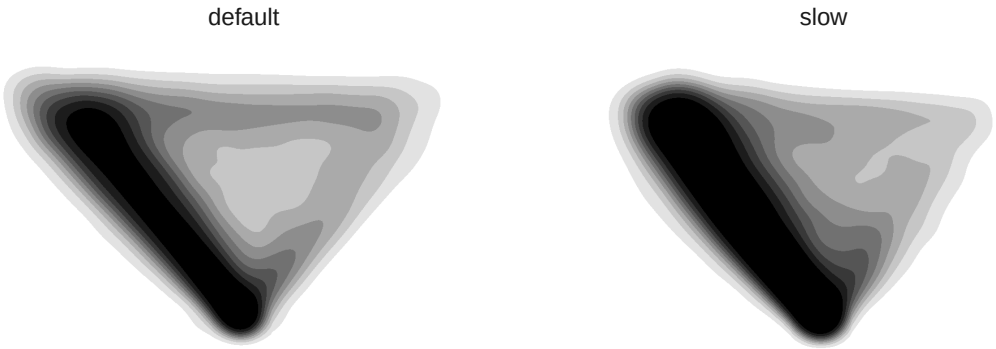
```
## $BC
##     group Typicality     z_MAD
## 1 default    Typical 0.5582705
## 2 default   Atypical 0.5762162
## 3    slow    Typical 0.5727287
## 4    slow   Atypical 0.5926053
```

Smoothed heatmaps

```
heatmap_smoothed <- mt_heatmap_ggplot(mt_data,
  xres = 1000,
  smooth_radius = 20,
  n_shades = 10,
  mean_image = 0.2,
  colors=c("white","black"),
  facet_col="group")
```

```
## spatializing trajectories
## calculate image
## smooth image
## enhance image by 4.8
## spatializing trajectories
## calculate image
## smooth image
## enhance image by 9.1
```

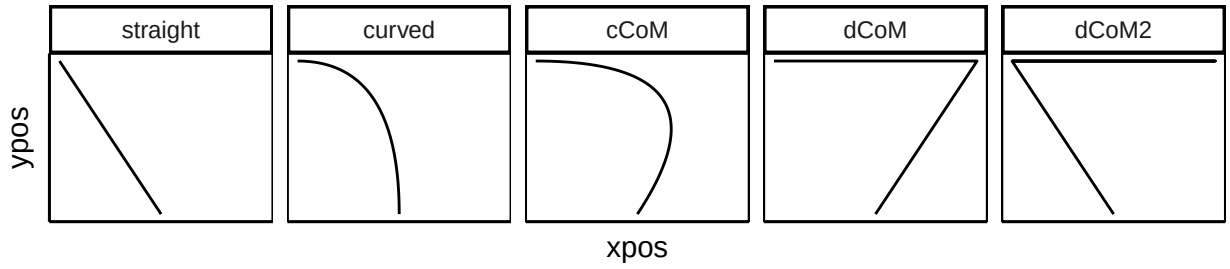
```
heatmap_smoothed+
  theme(strip.background = element_rect(colour = NA))
```



Prototype classification

Plot prototypes

```
mt_plot(mt_prototypes,facet_col="mt_id",only_ggplot = TRUE)+
  geom_path()+
  facet_grid(cols = vars(factor(mt_id,levels=rownames(mt_prototypes))))+
  theme(axis.text=ggplot2::element_blank(),axis.ticks=ggplot2::element_blank())
```



Map trajectories onto prototypes

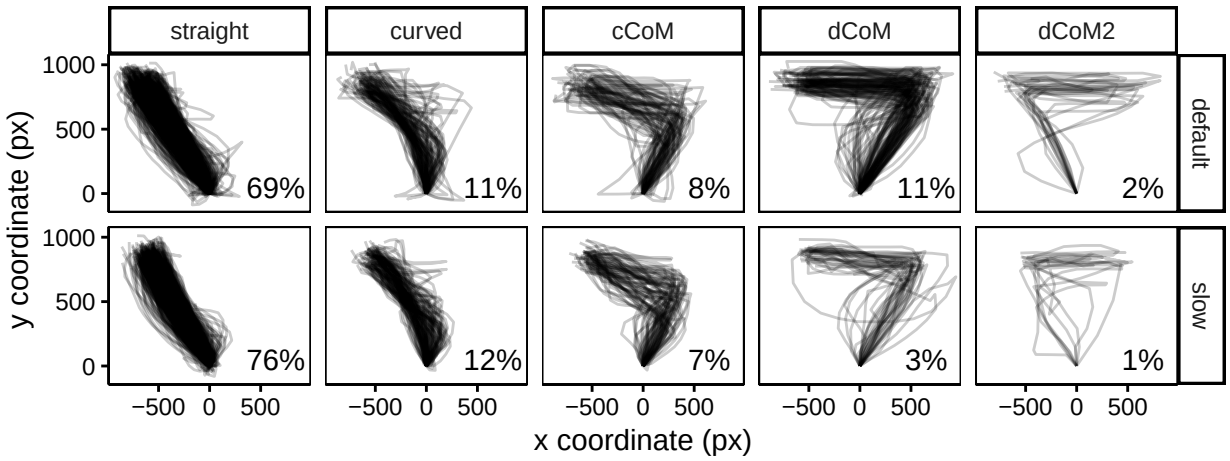
```
mt_data <- mt_spatialize(mt_data)
mt_data <- mt_map(mt_data,prototypes = mt_prototypes,
  save_as = "measures", grouping_variables = "group")
mt_data$data$prototype_label <- mt_data$measures$prototype_label
```

Classified trajectories per group

Relative frequencies

```
prototype_percentages <- mt_data$data %>%
  group_by(group,prototype_label) %>%
  summarise(n=n()) %>%
  mutate(Percent=paste(round(100*n/sum(n)),"%",sep=""))

mt_plot(mt_data, use = "sp_trajectories",
  x = "xpos", y = "ypos", facet_col = "prototype_label", facet_row="group",alpha=.2)+
  xlab("x coordinate (px)") + ylab("y coordinate (px)")+
  geom_text(data=prototype_percentages,aes(label=Percent),x=650,y=50)+
  scale_y_continuous(breaks=c(0,500,1000))+
  coord_cartesian(xlim=c(-900,900))
```



Chi-squared test

```
chisq.test(with(mt_data$data,table(group, prototype_label)))
```

```
##
##  Pearson's Chi-squared test
##
## data:  with(mt_data$data, table(group, prototype_label))
## X-squared = 49.656, df = 4, p-value = 4.261e-10
```

Classified trajectories per group X typicality condition

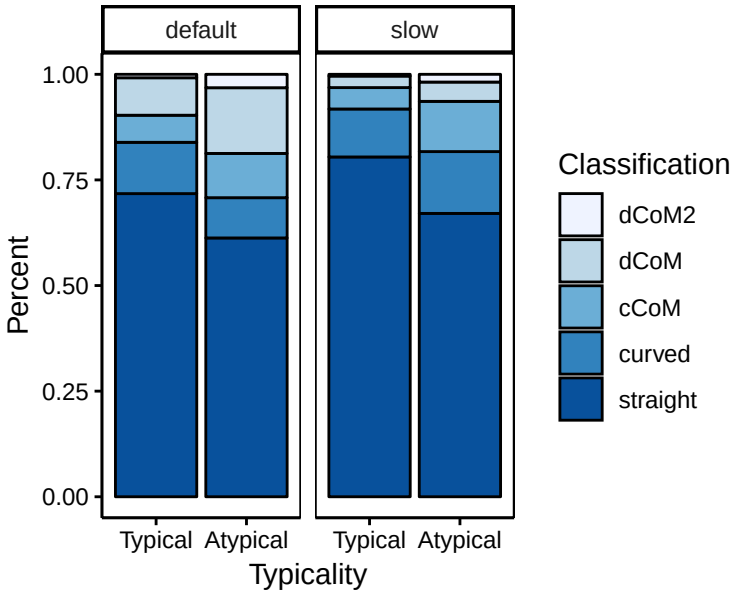
Relative frequencies

```
rel_freq_agg <- mt_data$data %>%
  group_by(group,Typicality,prototype_label) %>%
  summarise(n=n()) %>%
  mutate(Percent=n/sum(n))

spread(rel_freq_agg[,-4],"prototype_label","Percent",fill = 0) %>%
  as.data.frame()%>%
  print(digits=2)
```

```
##     group Typicality straight curved  cCoM  dCoM  dCoM2
## 1 default    Typical     0.72  0.121 0.064 0.089 0.0082
## 2 default   Atypical     0.61  0.095 0.105 0.156 0.0317
## 3    slow    Typical     0.80  0.114 0.051 0.027 0.0041
## 4    slow   Atypical     0.67  0.146 0.119 0.046 0.0183
```

```
ggplot(rel_freq_agg,aes(x=Typicality,y=Percent,fill=forcats::fct_rev(prototype_label)))+
  geom_bar(stat="identity",color="black")+
  scale_fill_brewer(type="seq",name="Classification")+
  facet_grid(.~group)
```



Ordinal mixed regression

```
contrasts(mt_data$data$Typicality) <- c(-0.5,0.5)
contrasts(mt_data$data$group) <- c(0.5,-0.5)
summary(clmm(prototype_label~Typicality*group+(1|subject_nr),data=mt_data$data))
```

```
## Cumulative Link Mixed Model fitted with the Laplace approximation
##
## formula: prototype_label ~ Typicality * group + (1 | subject_nr)
## data:    mt_data$data
##
##  link  threshold nobs logLik   AIC     niter     max.grad cond.H
##  logit flexible  2107 -1818.10 3652.20 584(2340) 1.43e-03 6.8e+01
##
## Random effects:
##  Groups     Name        Variance Std.Dev.
##  subject_nr (Intercept) 1.021    1.01
## Number of groups:  subject_nr 118
##
## Coefficients:
##                     Estimate Std. Error z value Pr(>|z|)
## Typicality1          0.77413    0.10859   7.129 1.01e-12 ***
## group1               0.61284    0.21926   2.795  0.00519 **
## Typicality1:group1 -0.05205    0.21571  -0.241  0.80932
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Threshold coefficients:
##                 Estimate Std. Error z value
## straight|curved   1.0353     0.1121   9.237
## curved|cCoM       1.8798     0.1193  15.752
## cCoM|dCoM         2.6979     0.1320  20.439
## dCoM|dCoM2        4.8252     0.2297  21.004
```