

Semantic Networks Analysis

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Reading the Data

```
library(dplyr)
sem = read.csv("NetworksE1_FINAL.csv", header = TRUE, sep = ",")
sem$mean_len = as.double(as.character(sem$mean_len))
sem$mean_logf = as.double(as.character(sem$mean_logf))
sem$mean_ldtz = as.double(as.character(sem$mean_ldtz))
sem$mean_nmgz = as.double(as.character(sem$mean_nmgz))
sem$undirected = as.double(as.character(sem$undirected))
sem$directed = as.double(as.character(sem$directed))
sem$logp = as.double(as.character(sem$logp))

sem$mean_len = round(sem$mean_len, 2)
sem$mean_logf = round(sem$mean_logf, 2)
sem$mean_ldtz = round(sem$mean_ldtz, 2)
sem$mean_nmgz = round(sem$mean_nmgz, 2)

itemlist = read.csv("KenettCompleteItemList.csv", header = TRUE, sep = ",")
colnames(itemlist) = c("prime_word", "target_word", "ItemNo", "List", "proc")
itemlist$prime_word = paste(itemlist$prime_word, "")
itemlist$target_word = paste(itemlist$target_word, "")
sem$prime_word = as.character(sem$prime_word)
sem$target_word = as.character(sem$target_word)
sem$proc = as.character(sem$proc)
itemlist$proc = as.character(itemlist$proc)

## Problem in ITEM NAIVE-INTEREST due to coding issues
## So we replae this item by simple text

sem$prime_word = ifelse(sem$prime_word == "NAÃ\u008fVE ", "NA\xecVE ",
                        sem$prime_word)
sem$target_word = ifelse(sem$target_word == "NAÃ\u008fVE ", "NA\xecVE ",
                        sem$target_word)

sem = inner_join(sem, itemlist, by = c("prime_word",
                                       "target_word", "proc"))

sem = sem[order(sem$subject),]

kenettproc= group_by(sem, ItemNo) %>%
  summarise(items = n())
kenettitems = group_by(sem, ItemNo, pathlength) %>%
  summarise(n = n())
kenettitems_n = group_by(kenettitems, pathlength) %>%
  summarise(n = n())
```

```
sem_directed = sem #>% filter(directed > 5)
directeditems = group_by(sem_directed, ItemNo, directed) %>%
  summarise(n = n())
directeditems_n = group_by(directeditems, directed) %>%
  summarise(n = n())

subject_count = group_by(sem, subject) %>%
  summarise(n = n())
```

PL Distribution

```
item_dist = group_by(sem, proc, ItemNo) %>%
  summarise_at(vars(pathlength, undirected, directed), mean)
## count distribution of items
library(dplyr)
undirected_items = group_by(item_dist, proc, pathlength, undirected) %>%
  summarize(undirecteditems = n())
undirected_items$undirectedpercent = undirected_items$undirecteditems/40

undirected_rmisc = Rmisc::summarySE(undirected_items,
                                     measurevar = "undirectedpercent",
                                     groupvars = c("pathlength", "undirected"))
undirected_rmisc$pathlengthfac = ordered(as.factor(as.character(undirected_rmisc$pathlength)),
                                          levels = c("1", "2", "3", "4", "6", "15"))

undirected_rmisc$UndirectedPaths = ordered(as.factor(as.character(undirected_rmisc$undirected)),
                                           levels = c("1", "2", "3", "4"))

## undirected plot

library(ggplot2)

## Warning: package 'ggplot2' was built under R version 3.4.4
library(ggthemes)

## Warning: package 'ggthemes' was built under R version 3.4.4

u_plot = undirected_rmisc %>%
  ggplot(aes(x = pathlengthfac, y = undirectedpercent,
            fill = UndirectedPaths, group = UndirectedPaths)) +
  geom_bar(stat = "identity", position = "dodge", width = 0.7, color = "black") +
  geom_errorbar(aes(ymin=undirectedpercent - ci, ymax=undirectedpercent + ci),
               width=.2, color = "gray26",
               position = position_dodge(0.7)) +
  theme_few() +
  scale_fill_colorblind() +
  xlab("") + ylab("Proportion of Items") +
  ggtitle("Items at Different Undirected SDN Path Lengths") +
  theme(axis.text = element_text(size = rel(1)),
        axis.title = element_text(face = "bold", size = rel(1)),
        legend.title = element_text(face = "bold", size = rel(1)),
        plot.title = element_text(hjust = .5),
        strip.text.x = element_text(face = "bold", size = rel(1.4)))
```

```

directed_items = group_by(item_dist, proc, pathlength, directed) %>%
  summarize(directeditems = n())
directed_items$directedpercent = directed_items$directeditems/40
directed_items$directedcollapsed = ifelse(( directed_items$directed == "6" |
  directed_items$directed == "7" |
  directed_items$directed == "8" ), "Higher PLs",
  ifelse(directed_items$directed == "Inf", "No Path",
    directed_items$directed))

directed_rmisc = Rmisc::summarySE(directed_items,
  measurevar = "directedpercent",
  groupvars = c("pathlength", "directedcollapsed"))

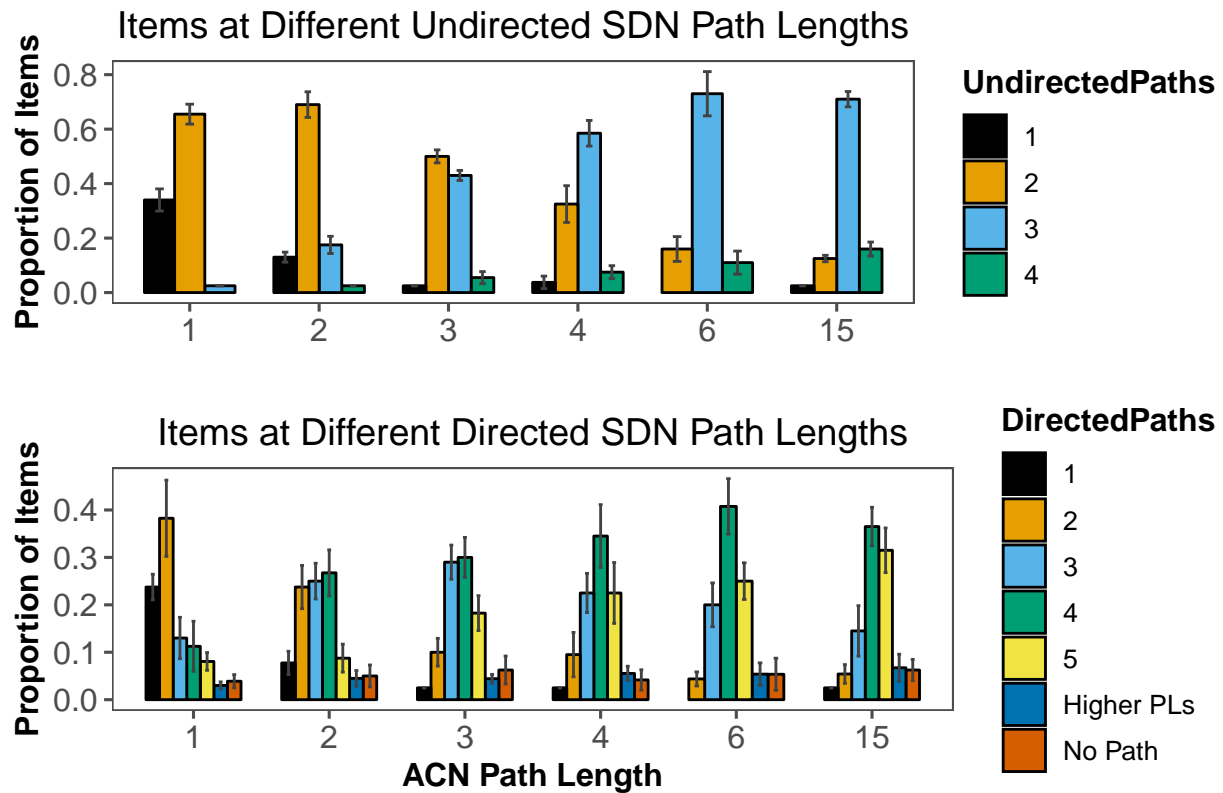
directed_rmisc$pathlengthfac = ordered(as.factor(as.character(directed_rmisc$pathlength)),
  levels = c("1", "2", "3", "4", "6", "15"))

directed_rmisc$DirectedPaths = ordered(as.factor(as.character(directed_rmisc$directedcollapsed)),
  levels = c("1", "2", "3", "4", "5", "Higher PLs",
    "No Path"))

d_plot = directed_rmisc %>%
  ggplot(aes(x = pathlengthfac, y = directedpercent,
    fill = DirectedPaths, group = DirectedPaths))+
  geom_bar(stat = "identity", position = "dodge", width = 0.7, color= "black")+
  geom_errorbar(aes(ymin=directedpercent - ci, ymax=directedpercent + ci),
    width=.2, color = "gray26",
    position = position_dodge(0.7))+
  theme_few()+
  scale_fill_colorblind()+
  xlab("ACN Path Length") + ylab("Proportion of Items") +
  ggtitle("Items at Different Directed SDN Path Lengths") +
  theme(axis.text = element_text(size = rel(1)),
    axis.title = element_text(face = "bold", size = rel(1)),
    legend.title = element_text(face = "bold", size = rel(1)),
    plot.title = element_text(hjust = .5),
    strip.text.x = element_text(face = "bold", size = rel(1.4)))

library(grid)
gridExtra::grid.arrange(u_plot, d_plot, nrow = 2, ncol = 1,
  top=textGrob("",
    gp=gpar(fontsize=16)))

```



Related-Unrelated Decisions

```
library(dplyr)

sem_decision = group_by(sem, Population, subject, pathlength, Type ) %>%
  summarize(Trials = n())

sem_subjctrows = group_by(sem_decision, Population, subject) %>%
  summarise(numrows = n())
rows = which(sem_subjctrows$numrows < 12)

subjects = sem_subjctrows[rows,]

# With N = 80, there are 12 rows missing!

sem_decision[949,] = c("Mturk", "42406", 15, "Related", 0)
sem_decision[950,] = c("Mturk", "61558", 15, "Related", 0)
sem_decision[951,] = c("Mturk", "27113", 15, "Related", 0)
sem_decision[952,] = c("Mturk", "34686", 6, "Related", 0)
sem_decision[953,] = c("Mturk", "81385", 6, "Related", 0)
sem_decision[954,] = c("Mturk", "35312", 3, "Related", 0)
sem_decision[955,] = c("Mturk", "65089", 1, "Unrelated", 0)
sem_decision[956,] = c("Mturk", "65448", 4, "Related", 0)
sem_decision[957,] = c("Mturk", "65448", 15, "Related", 0)
sem_decision[958,] = c("Mturk", "84694", 6, "Related", 0)
```

```
sem_decision[959,] = c("WU", "7416", 15, "Related", 0)
sem_decision[960,] = c("WU", "79426", 15, "Related", 0)
```

```
sem_decision$Trials = as.numeric(as.character(sem_decision$Trials))
```

```
sem_decision_agg = group_by(sem_decision, pathlength, Type ) %>%
  summarise_at(vars(Trials), mean)
```

Plotting Proportions

```
sem_decision$Trials = as.numeric(as.character(sem_decision$Trials))
sem_decision_agg$Trials = as.numeric(as.character(sem_decision_agg$Trials))

sem_decision$proportion = sem_decision$Trials/40

sem_decision_agg$proportion = sem_decision_agg$Trials/(40)

sem_decision$pathlengthfac = ordered(as.factor(as.character(sem_decision$pathlength)),
                                     levels = c("1", "2", "3", "4", "6", "15"))

sem_decision_agg$pathlengthfac = ordered(as.factor(as.character(sem_decision_agg$pathlength)),
                                         levels = c("1", "2", "3", "4", "6", "15"))

library(ggplot2)
library(ggthemes)

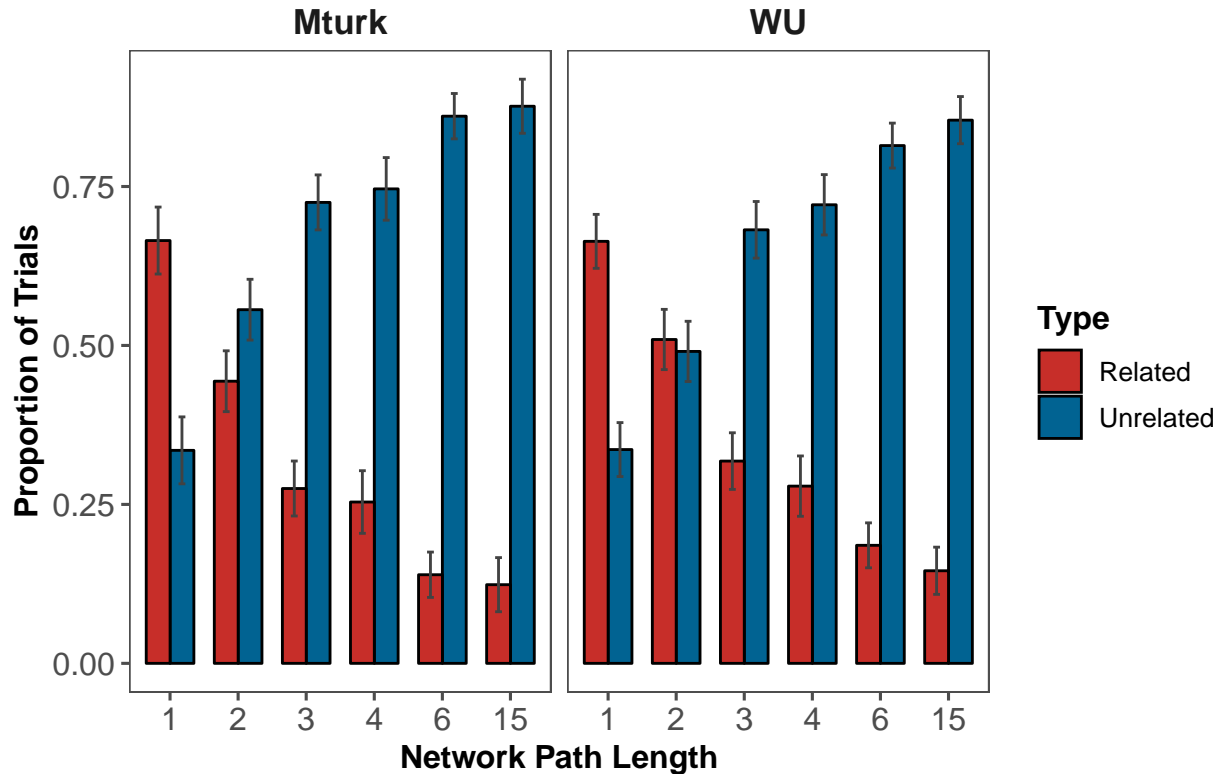
sem_decision_agg = sem_decision_agg[order(sem_decision_agg$pathlength,
                                          sem_decision_agg$Type),]

proportion_sem = Rmisc::summarySE(sem_decision,
                                  measurevar = "proportion",
                                  groupvars = c("pathlengthfac", "Type",
                                                "Population"))

proportion_sem %>% mutate(WordPair = factor(Type,
                                             levels = unique(Type),
                                             labels = c("Related", "Unrelated")))%>%
  ggplot(aes(x = pathlengthfac, y = proportion,
            fill = Type, group = Type))+
  geom_bar(stat = "identity", position = "dodge", width = 0.7, color= "black")+
  geom_errorbar(aes(ymin=proportion - ci, ymax=proportion + ci),
              width=.2, color = "gray26",
              position = position_dodge(0.7))+
  theme_few()+
  scale_fill_wsj()+
  facet_wrap(~Population)+
  xlab("Network Path Length") + ylab("Proportion of Trials") +
  ggtitle("Kenett Network Relatedness Judgments") +
  theme(axis.text = element_text(size = rel(1)),
```

```
axis.title = element_text(face = "bold", size = rel(1)),
legend.title = element_text(face = "bold", size = rel(1)),
plot.title = element_text(hjust = .5),
strip.text.x = element_text(face = "bold", size = rel(1.4)))
```

Kenett Network Relatedness Judgments



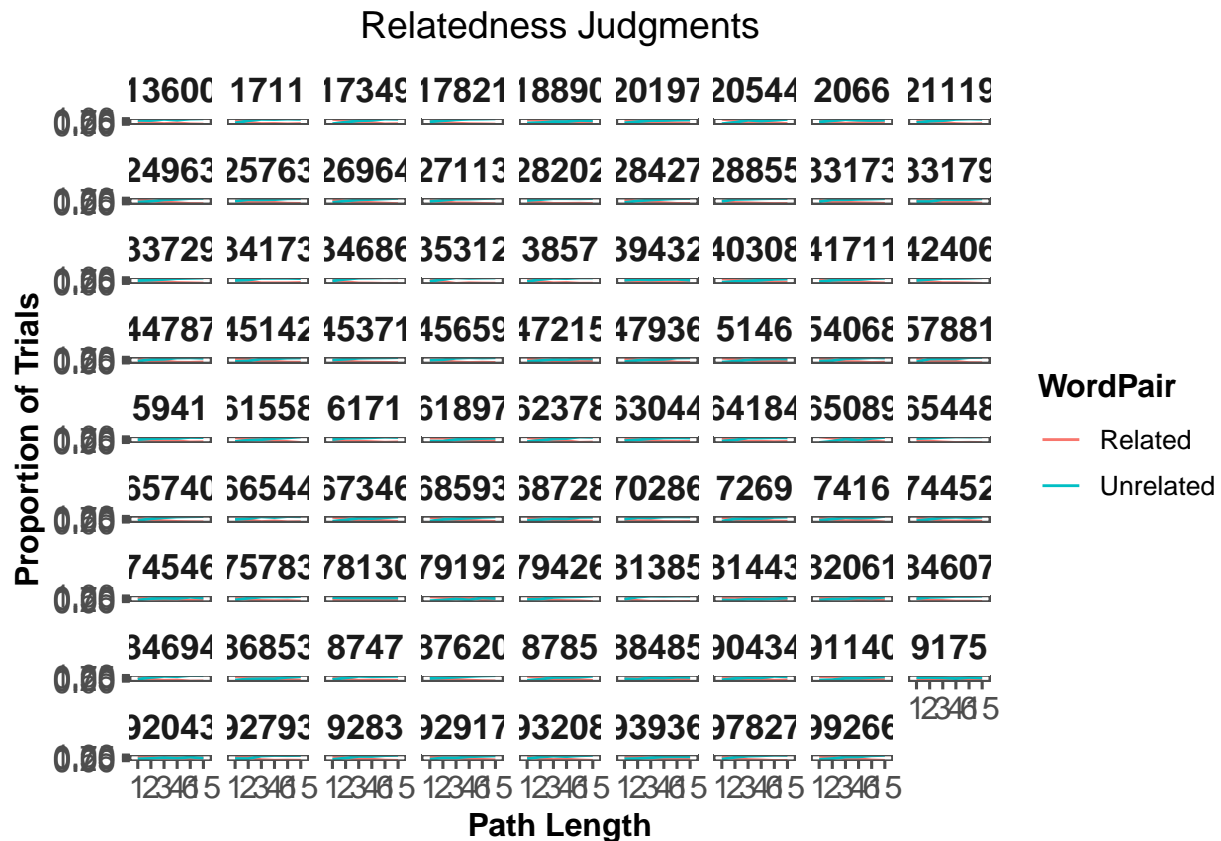
Subject-Wise

```
sem_decision$subject = as.factor(as.character(sem_decision$subject))

sem_decision = sem_decision[order(sem_decision$subject,
                                  sem_decision$pathlength,
                                  sem_decision$Type),]

sem_decision %>% mutate(WordPair = factor(Type,
                                           levels = unique(Type),
                                           labels = c("Related", "Unrelated")))%>%
  ggplot(aes(x = pathlengthfac, y = proportion,
             color = WordPair, group = WordPair))+
  geom_line()+
  # geom_bar(stat = "identity", position = "dodge", width = 0.7, color= "black")+
  # geom_errorbar(aes(ymin=Trials - ci, ymax=Trials + ci),
  #              width=.2, color = "gray26",
  #              position = position_dodge(0.7))+
  theme_few()+
```

```
scale_fill_solarized()+
  facet_wrap(~subject)+
  xlab("Path Length") + ylab("Proportion of Trials") +
  ggtitle("Relatedness Judgments") +
  theme(axis.text = element_text(size = rel(1)),
        axis.title = element_text(face = "bold", size = rel(1)),
        legend.title = element_text(face = "bold", size = rel(1)),
        plot.title = element_text(hjust = .5),
        strip.text.x = element_text(face = "bold", size = rel(1.4)))
```



Line Plot Subject-Wise

```
sem_decision$subject = as.factor(as.character(sem_decision$subject))

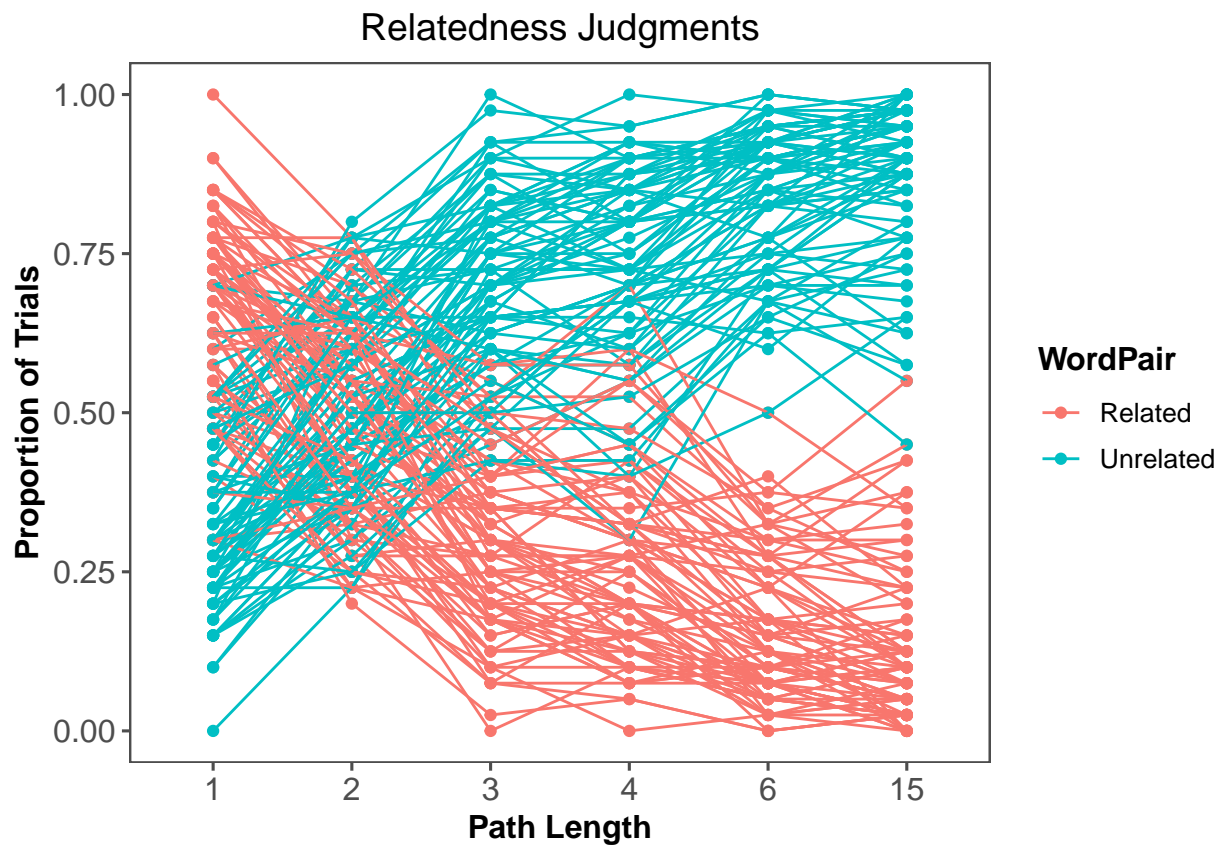
sem_decision = sem_decision[order(sem_decision$subject,
                                  sem_decision$pathlength,
                                  sem_decision$Type),]

sem_decision %>% mutate(WordPair = factor(Type,
                                           levels = unique(Type),
                                           labels = c("Related", "Unrelated")))%>%
  ggplot(aes(x = pathlengthfac, y = proportion,
             color = WordPair, group=interaction(WordPair, subject))) +
  geom_point()+
```

```

geom_line() +
theme_few()+
scale_fill_solarized()+
# facet_wrap(~subject)+
  xlab("Path Length") + ylab("Proportion of Trials") +
  ggtitle("Relatedness Judgments") +
  theme(axis.text = element_text(size = rel(1)),
        axis.title = element_text(face = "bold", size = rel(1)),
        legend.title = element_text(face = "bold", size = rel(1)),
        plot.title = element_text(hjust = .5),
        strip.text.x = element_text(face = "bold", size = rel(1.4)))

```



Proc Plot

```

sem_proc = group_by(sem, proc, pathlength, Type ) %>%
  summarize(Trials = n())

sem_proc$prop = sem_proc$Trials/320

sem_proc$pathlengthfac = ordered(as.factor(as.character(sem_proc$pathlength)),
                                levels = c("1", "2", "3", "4", "6", "15"))

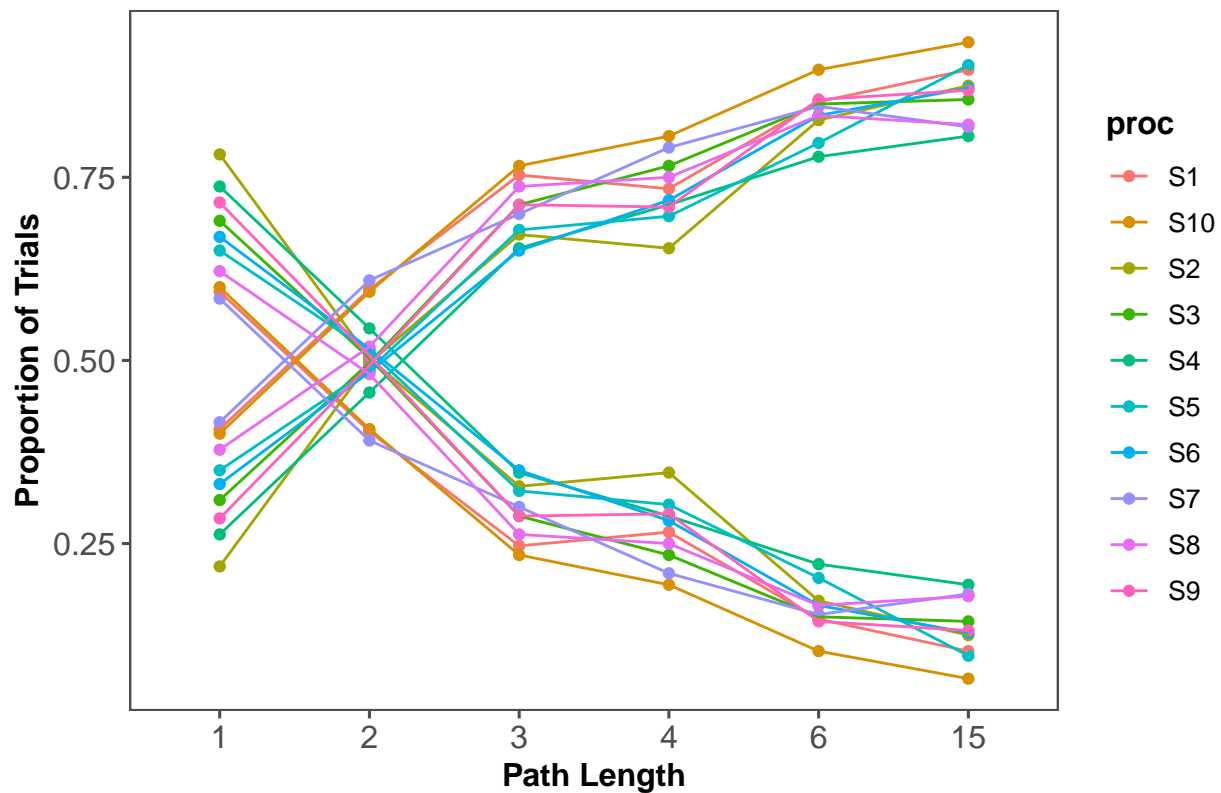
library(ggplot2)
library(ggthemes)

```



```
sem_proc %>% mutate(WordPair = factor(Type,
                                     levels = unique(Type),
                                     labels = c("Related", "Unrelated")))%>%
  ggplot(aes(x = pathlengthfac, y = prop,
            color = proc, group=interaction(WordPair, proc))) +
  geom_point()+
  geom_line() +
  theme_few()+
  scale_fill_solarized()+
  # facet_wrap(~subject)+
  xlab("Path Length") + ylab("Proportion of Trials") +
  ggtitle("Relatedness Judgments") +
  theme(axis.text = element_text(size = rel(1)),
        axis.title = element_text(face = "bold", size = rel(1)),
        legend.title = element_text(face = "bold", size = rel(1)),
        plot.title = element_text(hjust = .5),
        strip.text.x = element_text(face = "bold", size = rel(1.4)))
```

Relatedness Judgments



ANOVA

```
relunrel_aov = aov(data = sem_decision,
                  proportion ~ Population*pathlengthfac*Type +
                    Error(subject/(pathlengthfac*Type)))
summary(relunrel_aov)
```

```

##
## Error: subject
##           Df      Sum Sq   Mean Sq F value Pr(>F)
## Population 1 2.000e-32 1.630e-32    0.01  0.922
## Residuals 78 1.307e-28 1.676e-30
##
## Error: subject:pathlengthfac
##           Df      Sum Sq   Mean Sq F value Pr(>F)
## pathlengthfac      5 4.600e-29 9.147e-30    0.76  0.579
## Population:pathlengthfac      5 1.600e-29 3.126e-30    0.26  0.935
## Residuals          390 4.694e-27 1.204e-29
##
## Error: subject:Type
##           Df Sum Sq Mean Sq F value Pr(>F)
## Type          1 26.617  26.617 178.491 <2e-16 ***
## Population:Type 1  0.268   0.268   1.799  0.184
## Residuals      78 11.631   0.149
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Error: subject:pathlengthfac:Type
##           Df Sum Sq Mean Sq F value Pr(>F)
## pathlengthfac:Type      5  32.74   6.547 414.124 <2e-16 ***
## Population:pathlengthfac:Type      5   0.11   0.022   1.367  0.236
## Residuals          390   6.17   0.016
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
options(contrasts = c('contr.sum', 'contr.poly'))
library(lsmeans)

## Warning: package 'lsmeans' was built under R version 3.4.4
## The 'lsmeans' package is being deprecated.
## Users are encouraged to switch to 'emmeans'.
## See help('transition') for more information, including how
## to convert 'lsmeans' objects and scripts to work with 'emmeans'.
library(multcomp)

## Loading required package: mvtnorm
## Warning: package 'mvtnorm' was built under R version 3.4.4
## Loading required package: survival
## Warning: package 'survival' was built under R version 3.4.4
## Loading required package: TH.data
## Warning: package 'TH.data' was built under R version 3.4.4
## Loading required package: MASS
## Warning: package 'MASS' was built under R version 3.4.4
##
## 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
sem_lsm = lsmeans::lsmeans(relunrel_aov, c("pathlengthfac", "Type"))

## Warning in lsm.basis.aovlist(object, trms, xlev, grid, ...): Some predictors are correlated with the
## May help to re-fit with different contrasts, e.g. 'contr.sum'
## NOTE: Results may be misleading due to involvement in interactions

prime_effect = cld(sem_lsm, alpha = 0.05,
                    adjust = "tukey", details = TRUE, by = "pathlengthfac")
library(knitr)
kable(subset(prime_effect$comparisons, prime_effect$comparisons$p.value < 0.05))
```

	contrast	pathlengthfac	estimate	SE	df	t.ratio	p.value
1	Related - Unrelated	1	0.328750	0.0308335	172.8965	10.66210	0
3	Related - Unrelated	3	0.406875	0.0308335	172.8965	13.19586	0
4	Related - Unrelated	4	0.467500	0.0308335	172.8965	15.16207	0
5	Related - Unrelated	6	0.675000	0.0308335	172.8965	21.89176	0
6	Related - Unrelated	15	0.730625	0.0308335	172.8965	23.69580	0

Kenett proportions

```
proportion_sem_compare = Rmisc::summarySE(sem_decision,
                                           measurevar = "proportion",
                                           groupvars = c("pathlengthfac", "Type"))
proportion_sem_compare = proportion_sem_compare[, -c(3,6,7)]

kenett_prop = matrix(NA, nrow = 12, ncol = 4)
kenett_prop = as.data.frame(kenett_prop)
colnames(kenett_prop) = c("pathlengthfac", "Type",
                          "proportion", "sd")
kenett_prop$pathlengthfac = c(1,1,2, 2,3,3, 4, 4, 6, 6, 15, 15)
kenett_prop$Type = c("Related", "Unrelated",
                    "Related", "Unrelated",
                    "Related", "Unrelated",
                    "Related", "Unrelated",
                    "Related", "Unrelated",
                    "Related", "Unrelated")
kenett_prop$proportion = c(0.91, 0.09,
                          0.69, 0.31,
                          0.64, 0.36,
                          0.14, 0.86,
                          0.05, 0.95,
                          0.03, 0.97)
```

```

kenett_prop$sd = c(0.08, 0.08,
                  0.14, 0.14,
                  0.14, 0.14,
                  0.10, 0.10,
                  0.06, 0.06,
                  0.05, 0.05)
kenett_prop$Network = "Kenett et al., 2017"
proportion_sem_compare$Network = "Experiment 1"

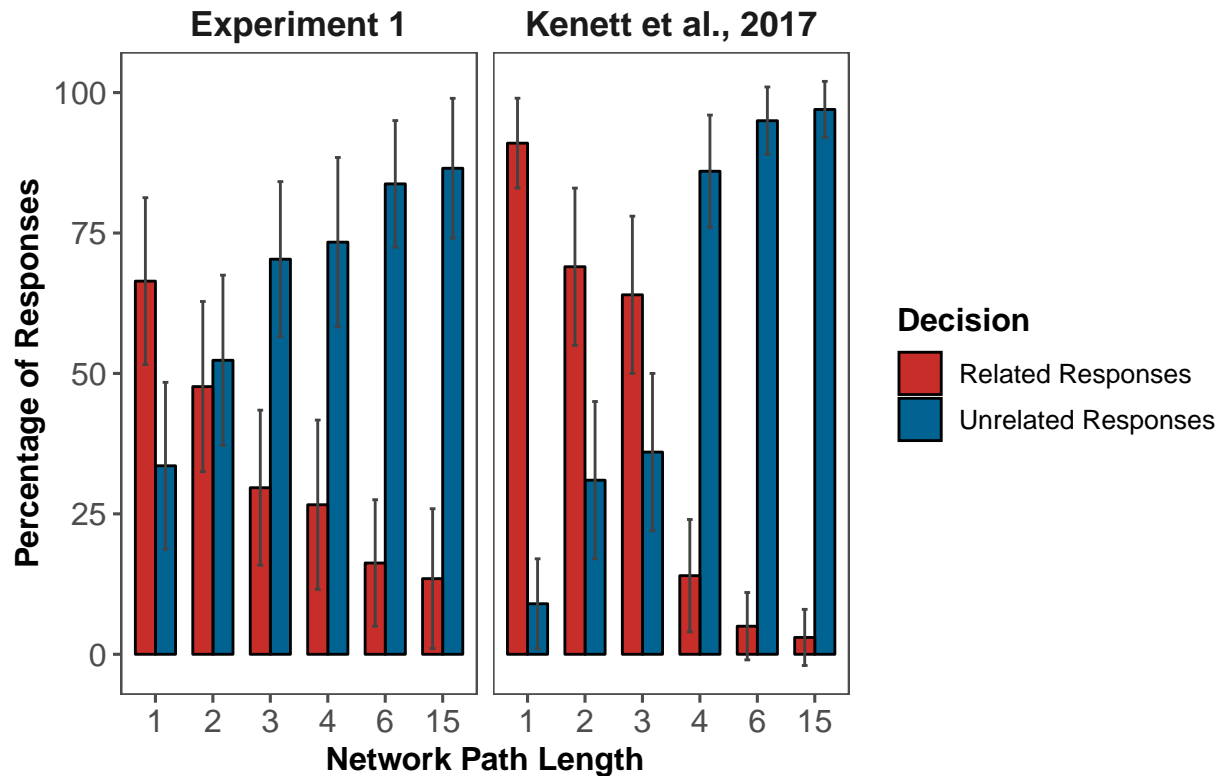
proportion_sem_combined = rbind(proportion_sem_compare, kenett_prop)

proportion_sem_combined$percentage = proportion_sem_combined$proportion*100
proportion_sem_combined$sd100 = proportion_sem_combined$sd*100

proportion_sem_combined$Decision = ifelse(proportion_sem_combined$Type == "Related",
                                           "Related Responses", "Unrelated Responses")

proportion_sem_combined %>% mutate(WordPair = factor(Decision,
                                                    levels = unique(Decision),
                                                    labels = c("Related", "Unrelated")))%>%
  ggplot(aes(x = pathlengthfac, y = percentage,
            fill = Decision, group = Decision))+
  geom_bar(stat = "identity", position = "dodge", width = 0.7, color= "black")+
  geom_errorbar(aes(ymin=percentage - sd100, ymax=percentage + sd100),
              width=.2, color = "gray26",
              position = position_dodge(0.7))+
  theme_few()+
  scale_fill_wsj()+
  facet_wrap(~Network)+
  xlab("Network Path Length") + ylab("Percentage of Responses") +
  ggtitle("") +
  theme(axis.text = element_text(size = rel(1)),
        axis.title = element_text(face = "bold", size = rel(1)),
        legend.title = element_text(face = "bold", size = rel(1)),
        plot.title = element_text(hjust = .5),
        strip.text.x = element_text(face = "bold", size = rel(1.4)))

```



Raw Reaction Time

```
sem_rt = group_by(sem, Population, subject, pathlength ) %>%
  summarise_at(vars(rt), mean)

sem_rt_agg = group_by(sem, Population, pathlength ) %>%
  summarise_at(vars(rt), mean)

sem_agg_rmisc = Rmisc::summarySE(sem_rt,
  measurevar = "rt",
  groupvars = c("pathlength", "Population" ))
```

ANOVA

```
sem_rt$pathlengthfac = ordered(as.factor(as.character(sem_rt$pathlength)),
  levels = c("1", "2", "3", "4", "6", "15"))
sem_rt$subject = as.factor(sem_rt$subject)
rt_aov = aov(data = sem_rt, rt ~ Population*pathlengthfac +
  Error(subject/(pathlengthfac)))
summary(rt_aov)
```

```
##
## Error: subject
##          Df    Sum Sq Mean Sq F value Pr(>F)
## Population 1    876980   876980   2.915 0.0917 .
```

```
## Residuals 78 23462774 300805
## ---
## Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Error: subject:pathlengthfac
##
##          Df Sum Sq Mean Sq F value Pr(>F)
## pathlengthfac      5 190645    38129   6.173 1.6e-05 ***
## Population:pathlengthfac  5  33192     6638   1.075  0.374
## Residuals      390 2408860     6177
## ---
## Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

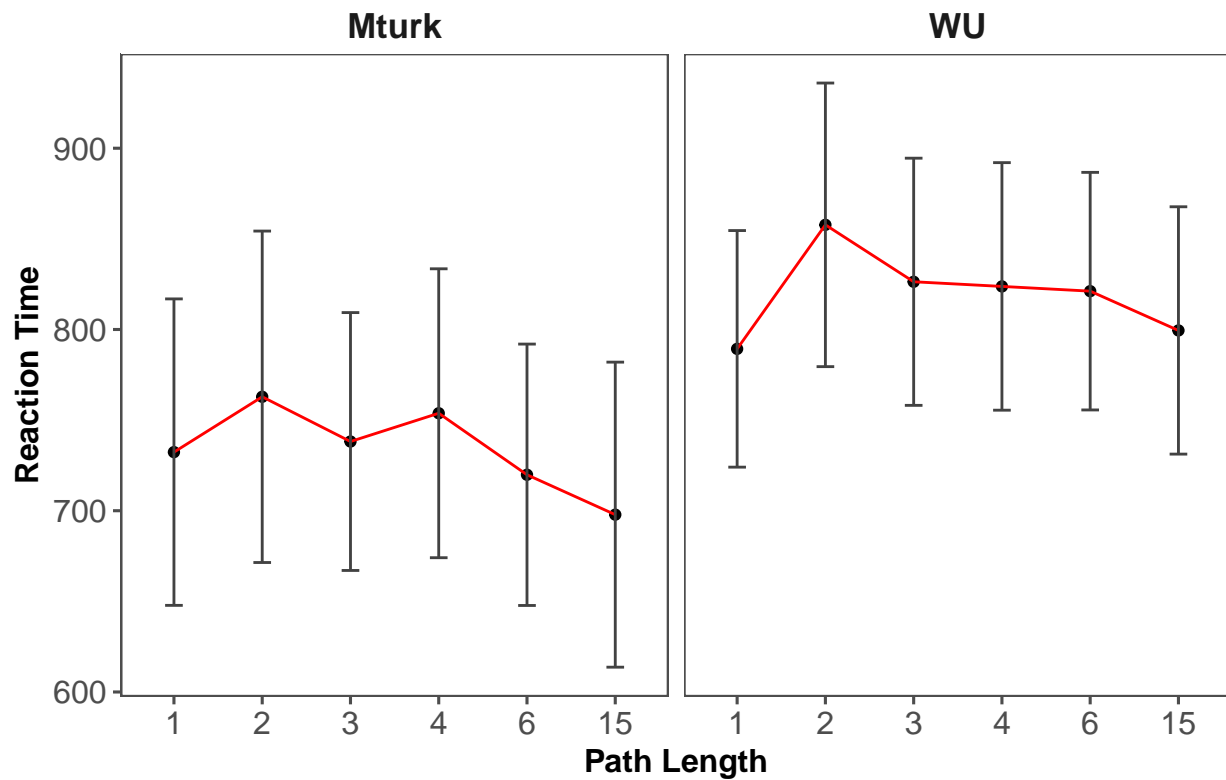
Plotting RTs

```
sem_agg_rmisc$pathlengthfac = ordered(as.factor(as.character(sem_agg_rmisc$pathlength))),

library(ggplot2)
library(ggthemes)

sem_agg_rmisc %>%
  ggplot(aes(x = pathlengthfac, y = rt, group = 1))+
  geom_point()+
  geom_line(color = "red")+
  geom_errorbar(aes(ymin=rt - ci, ymax=rt + ci),
                width=.2, color = "gray26",
                position = position_dodge(0.7))+
  theme_few()+
  facet_wrap(~Population) +
  # scale_x_continuous(breaks = c(1,2,3,4,5,6,10,15,20))+
  xlab("Path Length") + ylab("Reaction Time") +
  ggtitle("RT for Relatedness Judgments") +
  theme(axis.text = element_text(size = rel(1)),
        axis.title = element_text(face = "bold", size = rel(1)),
        legend.title = element_text(face = "bold", size = rel(1)),
        plot.title = element_text(hjust = .5),
        strip.text.x = element_text(face = "bold", size = rel(1.4)))
```

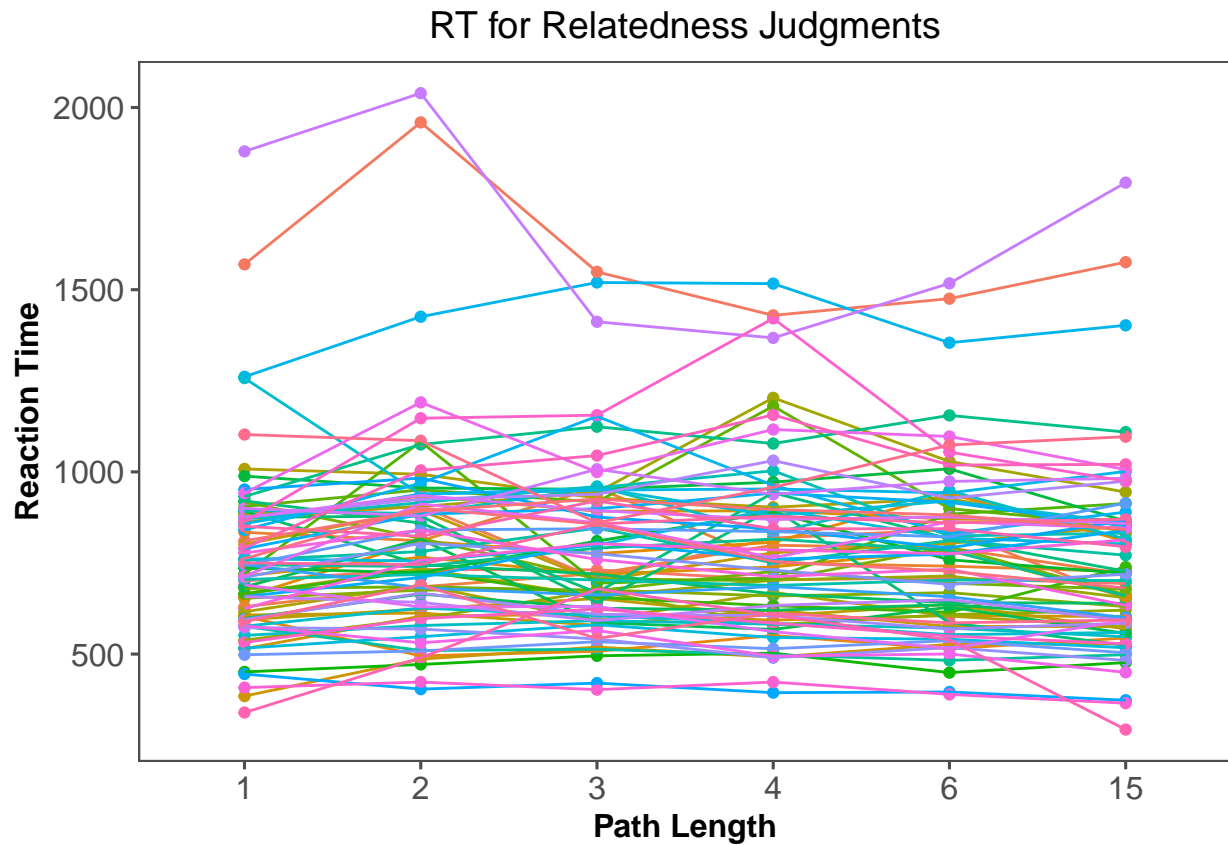
RT for Relatedness Judgments



Subject-Wise

```
library(ggplot2)
library(ggthemes)

sem_rt %>%
  ggplot(aes(x = pathlengthfac, y = rt,
             group = subject, color = subject))+
  geom_point()+
  geom_line()+
  #geom_errorbar(aes(ymin=Trials - ci, ymax=Trials + ci),
  #              width=.2, color = "gray26",
  #              position = position_dodge(0.7))+
  theme_few()+
  guides(color = FALSE)+
  # scale_x_continuous(breaks = c(1,2,3,4,6,15))+
  xlab("Path Length") + ylab("Reaction Time") +
  ggtitle("RT for Relatedness Judgments") +
  theme(axis.text = element_text(size = rel(1)),
        axis.title = element_text(face = "bold", size = rel(1)),
        legend.title = element_blank(),
        plot.title = element_text(hjust = .5),
        strip.text.x = element_text(face = "bold", size = rel(1.4)))
```

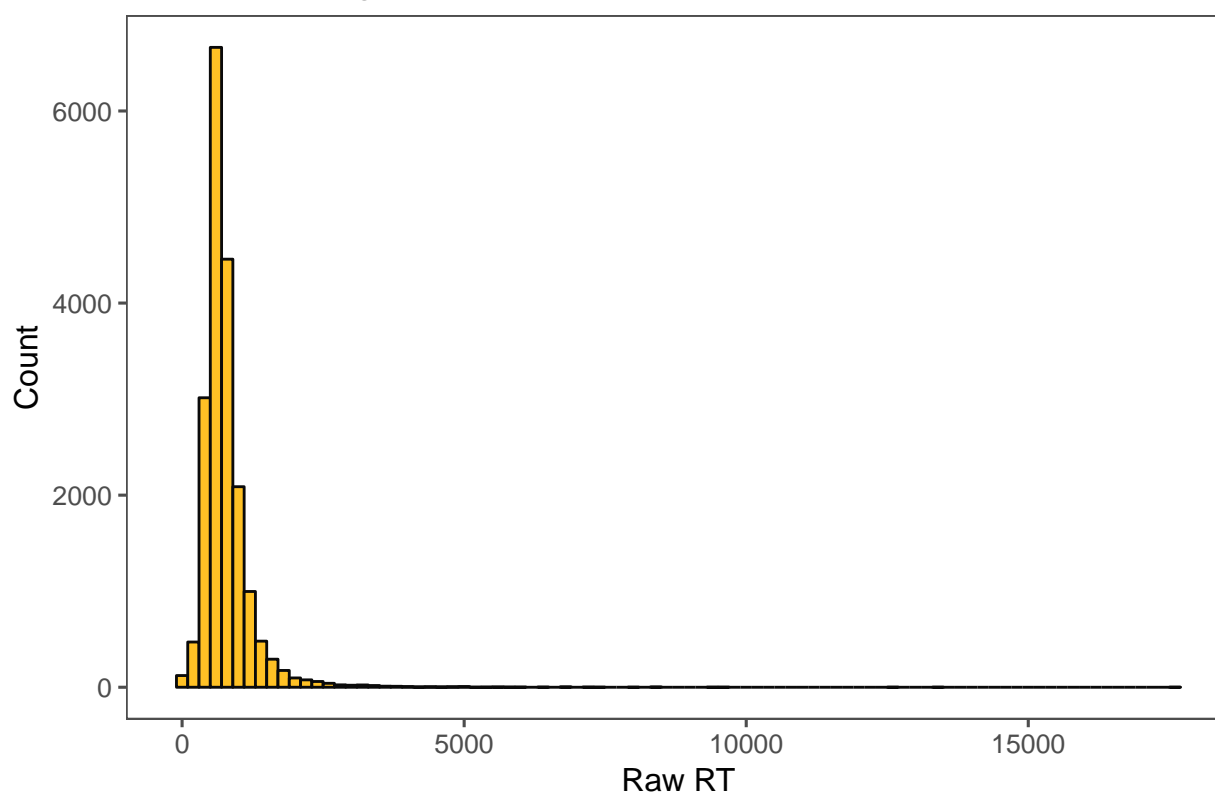


z-scored Reaction Time

Histogram of RT

```
library(ggplot2)
library(ggthemes)
ggplot(sem, aes(x = rt))+
  geom_histogram(binwidth = 200, color = "gray4", fill = "goldenrod1")+
  theme_few()+
  #facet_wrap(~subject)+
  xlab("Raw RT") + ylab("Count") +
  ggtitle("Raw RT Histogram for All Trials")
```

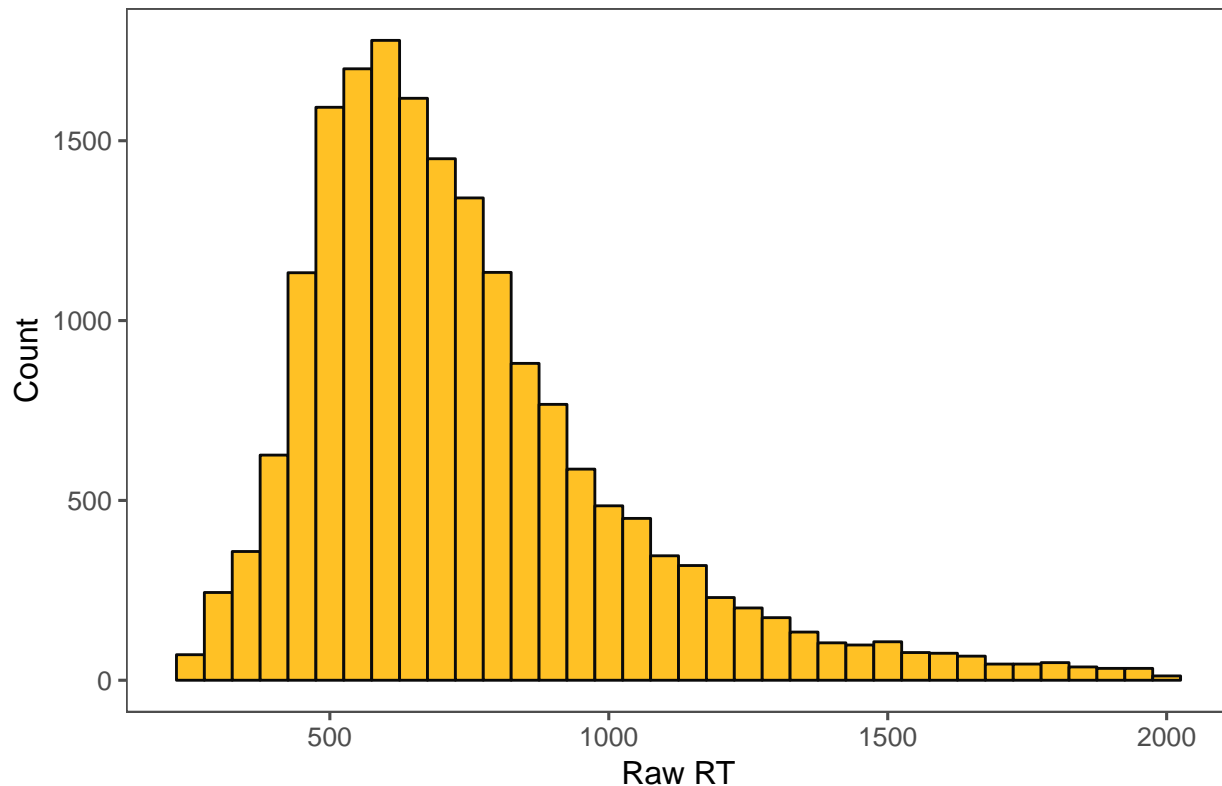

Raw RT Histogram for All Trials



First Trim

```
library(dplyr)
sem_firsttrim = sem %>% filter( rt > 250 & rt < 2000)
ggplot(sem_firsttrim, aes(x = rt))+
  geom_histogram(binwidth = 50, color = "gray4", fill = "goldenrod1")+
  theme_few()+
  #facet_wrap(~subject)+
  xlab("Raw RT") + ylab("Count") +
  ggtitle("Raw RT Histogram for Trials Above 250 ms and below 2000 ms")
```

Raw RT Histogram for Trials Above 250 ms and below 2000 ms



Raw RT aggregates After Trimming

```
sem_rt_firsttrim = group_by(sem_firsttrim, subject, pathlength ) %>%
  summarise_at(vars(rt), mean)

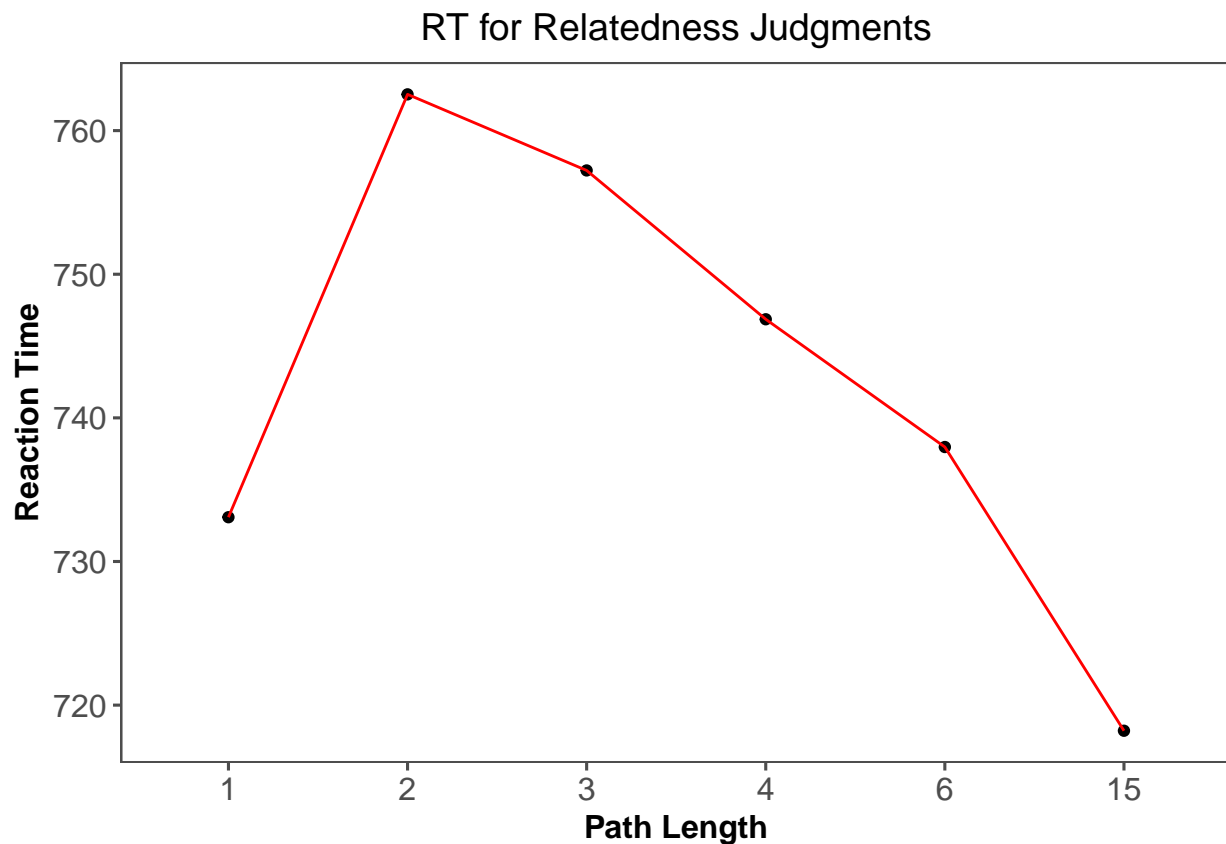
sem_rt_agg_firsttrim = group_by(sem_firsttrim, pathlength ) %>%
  summarise_at(vars(rt), mean)

sem_rt_agg_firsttrim$pathlengthfac = ordered(as.factor(as.character(sem_rt_agg_firsttrim$pathlength))),

library(ggplot2)
library(ggthemes)

sem_rt_agg_firsttrim %>%
  ggplot(aes(x = pathlengthfac, y = rt, group = 1))+
  geom_point()+
  geom_line(color = "red")+
  #geom_errorbar(aes(ymin=Trials - ci, ymax=Trials + ci),
  #              width=.2, color = "gray26",
  #              position = position_dodge(0.7))+
  theme_few()+
  #scale_x_continuous(breaks = c(1,2,3,4,6,15))+
  xlab("Path Length") + ylab("Reaction Time") +
  ggtitle("RT for Relatedness Judgments") +
  theme(axis.text = element_text(size = rel(1)),
```

```
axis.title = element_text(face = "bold", size = rel(1)),
legend.title = element_text(face = "bold", size = rel(1)),
plot.title = element_text(hjust = .5),
strip.text.x = element_text(face = "bold", size = rel(1.4)))
```



Subject Raw RT again

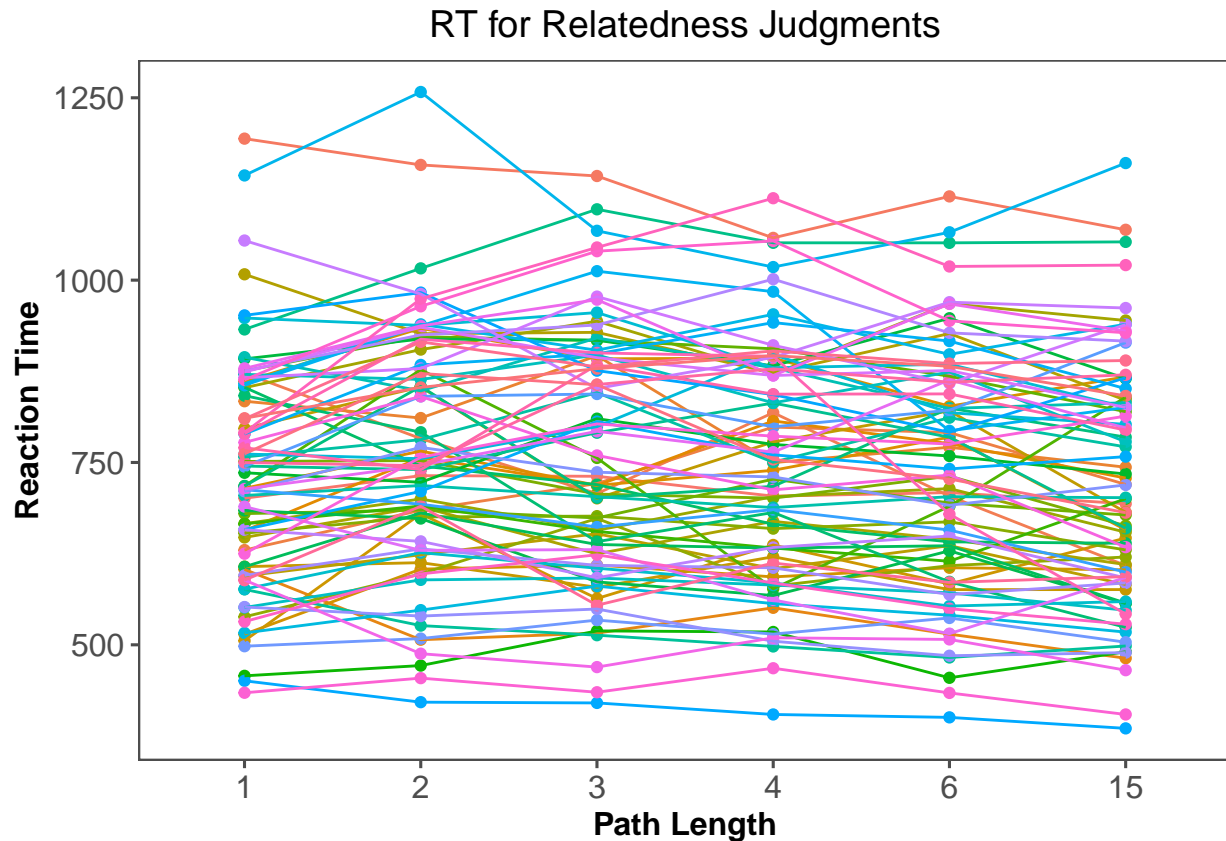
```
library(ggplot2)
library(ggthemes)

sem_rt_firsttrim$pathlengthfac = ordered(as.factor(as.character(sem_rt_firsttrim$pathlength)),
                                          levels = c("1", "2", "3", "4", "6", "15"))
sem_rt_firsttrim$subject = as.factor(sem_rt_firsttrim$subject)
sem_rt_firsttrim %>%
  ggplot(aes(x = pathlengthfac, y = rt,
             group = subject, color = subject))+
  geom_point()+
  geom_line()+
  #geom_errorbar(aes(ymin=Trials - ci, ymax=Trials + ci),
  #              width=.2, color = "gray26",
  #              position = position_dodge(0.7))+
  theme_few()+
  guides(color = FALSE)+
  # scale_x_continuous(breaks = c(1,2,3,4,5,6,10,15,20))+
  xlab("Path Length") + ylab("Reaction Time") +
```

```

ggtitle("RT for Relatedness Judgments") +
# facet_wrap(~subject)+
theme(axis.text = element_text(size = rel(1)),
      axis.title = element_text(face = "bold", size = rel(1)),
      legend.title = element_text(face = "bold", size = rel(1)),
      plot.title = element_text(hjust = .5),
      strip.text.x = element_text(face = "bold", size = rel(1.4)))

```



Making the z-scores

```

## aggregate per subject all IVs and DVs
meanRT = group_by(sem_firsttrim, subject) %>%
  summarise_at(vars(rt), mean)
colnames(meanRT) = c("subject", "MeanRT")

sdRT = group_by(sem_firsttrim, subject) %>%
  summarise_at(vars(rt), sd)
colnames(sdRT) = c("subject", "sdRT")

RT_agg = merge(meanRT, sdRT, by = "subject")

## merge aggregate info with long data
sem_z = merge(sem_firsttrim, RT_agg, by = "subject", all.x = T)

## person and grand-mean centered scores using original and aggregate

```

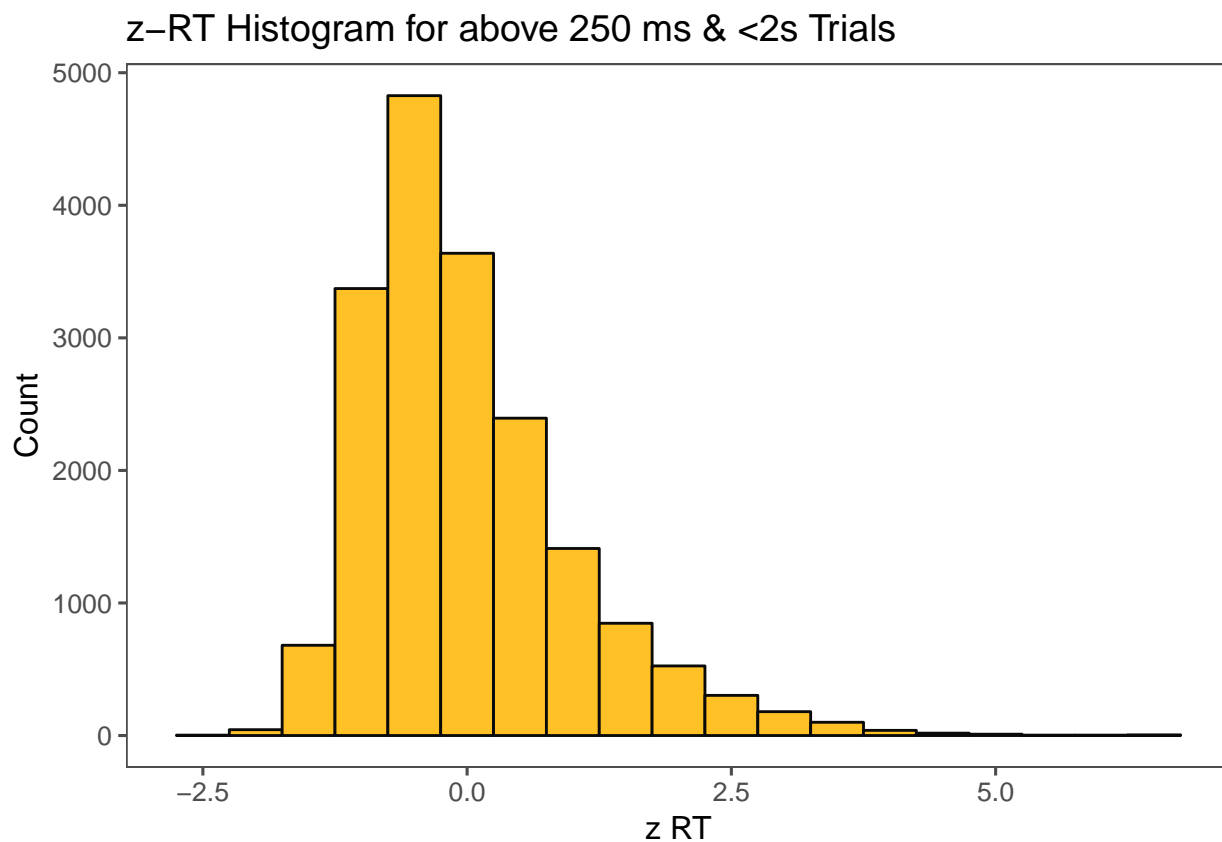
```
library(dplyr)
sem_z = sem_z %>% mutate(zRT = (rt - MeanRT)/sdRT)

## checking: subject level means should be zero

sub_pic = group_by(sem_z, subject) %>%
  summarise_at(vars(zRT), mean)
```

z-RT Distribution

```
ggplot(sem_z, aes(x = zRT)) +
  geom_histogram(binwidth = 0.5, color = "gray4", fill = "goldenrod1") +
  theme_few() +
  xlab("z RT") + ylab("Count") +
  ggtitle("z-RT Histogram for above 250 ms & <2s Trials")
```

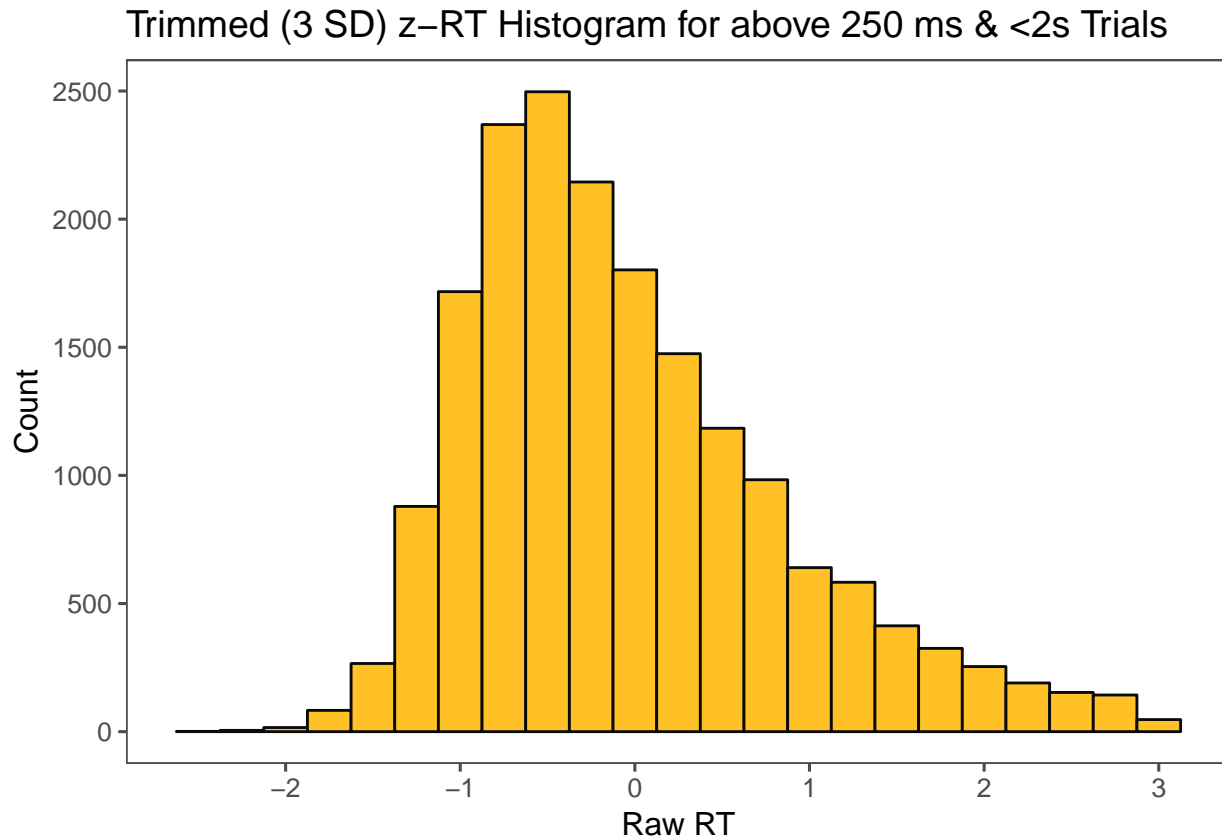


Trimming z-RT

```
sem_z_trimmed = subset(sem_z, sem_z$zRT < 3 & sem_z$zRT > -3)

ggplot(sem_z_trimmed, aes(x = zRT)) +
  geom_histogram(binwidth = 0.25, color = "gray4", fill = "goldenrod1") +
  theme_few() +
```

```
xlab("Raw RT") + ylab("Count") +
ggtitle("Trimmed (3 SD) z-RT Histogram for above 250 ms & <2s Trials")
```



Repeating z-scoring

```
library(dplyr)

## aggregate per subject all IVs and DVs
meanRT_trim = group_by(sem_z_trimmed, subject) %>%
  summarise_at(vars(rt), mean)
colnames(meanRT_trim) = c("subject", "MeanRT_trim")

sdRT_trim = group_by(sem_z_trimmed, subject) %>%
  summarise_at(vars(rt), sd)
colnames(sdRT_trim) = c("subject", "sdRT_trim")

RT_agg_trim = merge(meanRT_trim, sdRT_trim, by = "subject")

## merge aggregate info with long data
new_sem_z = merge(sem_z_trimmed, RT_agg_trim, by = "subject", all.x = T)

## person and grand-mean centered scores using original and aggregate
library(dplyr)
new_sem_z = new_sem_z %>% mutate(zRT_trim = (rt - MeanRT_trim)/sdRT_trim)
```

```
## checking: subject level means should be zero

sub_pic = group_by(new_sem_z, subject) %>%
  summarise_at(vars(zRT_trim), mean)

# % trials removed
(nrow(sem) - nrow(sem_z_trimmed))/nrow(sem)

## [1] 0.05364583

#write.csv(new_pic_z, file="final_pic_z.csv")
```

Aggregating zRT

```
z_sem_rt = group_by(new_sem_z, subject, pathlength ) %>%
  summarise_at(vars(zRT_trim, rt), mean)

z_sem_rt_rel = group_by(new_sem_z, subject, pathlength, Type ) %>%
  summarise_at(vars(zRT_trim, rt), mean)

z_sem_rt_rel_trials = group_by(z_sem_rt_rel, subject) %>%
  summarise(numtrials = n())

x = which(z_sem_rt_rel_trials$numtrials != 12)

missingtrial_subjects = z_sem_rt_rel_trials[x,][,1]

z_sem_rt_agg = group_by(new_sem_z, pathlength ) %>%
  summarise_at(vars(zRT_trim), mean)

z_rmisc = Rmisc::summarySE(new_sem_z,
  measurevar = "zRT_trim",
  groupvars = c("pathlength"))

z_sem_rt_rel_agg = group_by(new_sem_z, pathlength, Type ) %>%
  summarise_at(vars(zRT_trim), mean)

z_sem_rt_rel_agg_rmisc = Rmisc::summarySE(new_sem_z,
  measurevar = "zRT_trim",
  groupvars = c("pathlength", "Type"))
```

1- way collapsed ANOVA (collapsed)

```
z_sem_rt$pathlengthfac = ordered(as.factor(as.character(z_sem_rt$pathlength)),
  levels = c("1", "2", "3", "4", "6", "15"))
z_sem_rt$subject = as.factor(z_sem_rt$subject)

z_rt_aov = aov(data = z_sem_rt, zRT_trim ~ pathlengthfac +
  Error(subject/(pathlengthfac)))
summary(z_rt_aov)
```

```
##
## Error: subject
##           Df Sum Sq Mean Sq F value Pr(>F)
## Residuals 79 0.00641 8.114e-05
##
## Error: subject:pathlengthfac
##           Df Sum Sq Mean Sq F value Pr(>F)
## pathlengthfac 5 2.638 0.5276 13.45 3.99e-12 ***
## Residuals    395 15.494 0.0392
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
options(contrasts = c('contr.sum', 'contr.poly'))
library(lsmeans)
library(multcomp)
sem_lsm = lsmeans::lsmeans(z_rt_aov, c("pathlengthfac"))
prime_effect = cld(sem_lsm, alpha = 0.05,
                    adjust = "tukey", details = TRUE)
library(knitr)
kable(subset(prime_effect$comparisons, prime_effect$comparisons$p.value < 0.1 ))
```

	contrast	estimate	SE	df	t.ratio	p.value
2	6 - 15	0.0894452	0.0313149	395	2.856311	0.0510422
4	4 - 15	0.1430209	0.0313149	395	4.567179	0.0000963
5	4 - 1	0.0850114	0.0313149	395	2.714725	0.0745850
7	3 - 15	0.1814771	0.0313149	395	5.795227	0.0000002
8	3 - 1	0.1234677	0.0313149	395	3.942774	0.0013288
9	3 - 6	0.0920319	0.0313149	395	2.938916	0.0404645
11	2 - 15	0.2181746	0.0313149	395	6.967114	0.0000000
12	2 - 1	0.1601652	0.0313149	395	5.114661	0.0000073
13	2 - 6	0.1287295	0.0313149	395	4.110803	0.0006793

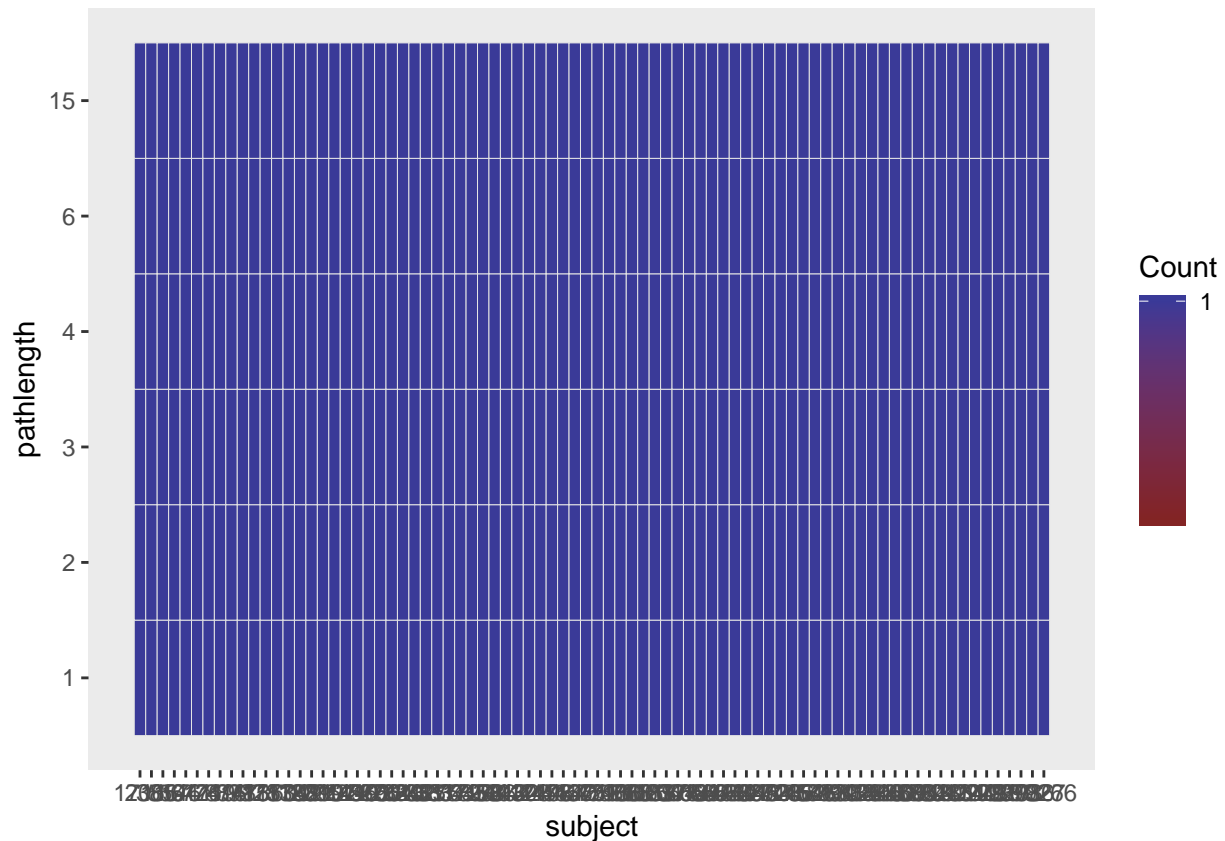
1-way successful ANOVA

subject

```
## z_sem_rt_rel contains the type x path data
## for kenett (using our outlier procedure) we need to extract only successful trials from this

z_sem_success = z_sem_rt_rel %>%
  filter((pathlength == "1" & Type == "Related") |
         (pathlength == "2" & Type == "Unrelated") |
         (pathlength == "3" & Type == "Unrelated") |
         (pathlength == "4" & Type == "Unrelated") |
         (pathlength == "6" & Type == "Unrelated") |
         (pathlength == "15" & Type == "Unrelated") )

ez::ezDesign(z_sem_success, subject, pathlength) ## complete data
```

```

z_sem_success$pathlengthfac = ordered(as.factor(as.character(z_sem_success$pathlength)),
                                       levels = c("1", "2", "3", "4", "6", "15"))

z_sem_success$subject = as.factor(z_sem_success$subject)

success_aov = aov(data = z_sem_success,
                  zRT_trim ~ pathlengthfac +
                      Error(subject/pathlengthfac))
summary(success_aov)

##
## Error: subject
##           Df Sum Sq Mean Sq F value Pr(>F)
## Residuals  79   3.483   0.04409
##
## Error: subject:pathlengthfac
##           Df Sum Sq Mean Sq F value    Pr(>F)
## pathlengthfac   5   2.701   0.5402    7.42 1.15e-06 ***
## Residuals      395  28.758   0.0728
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

options(contrasts = c('contr.sum', 'contr.poly'))
library(lsmeans)
library(multcomp)
sem_lsm = lsmeans::lsmeans(success_aov, c("pathlengthfac"))
prime_effect = cld(sem_lsm, alpha = 0.05,
                   adjust = "tukey", details = TRUE)

```

```
library(knitr)
kable(subset(prime_effect$comparisons,prime_effect$comparisons$p.value < 0.1 ))
```

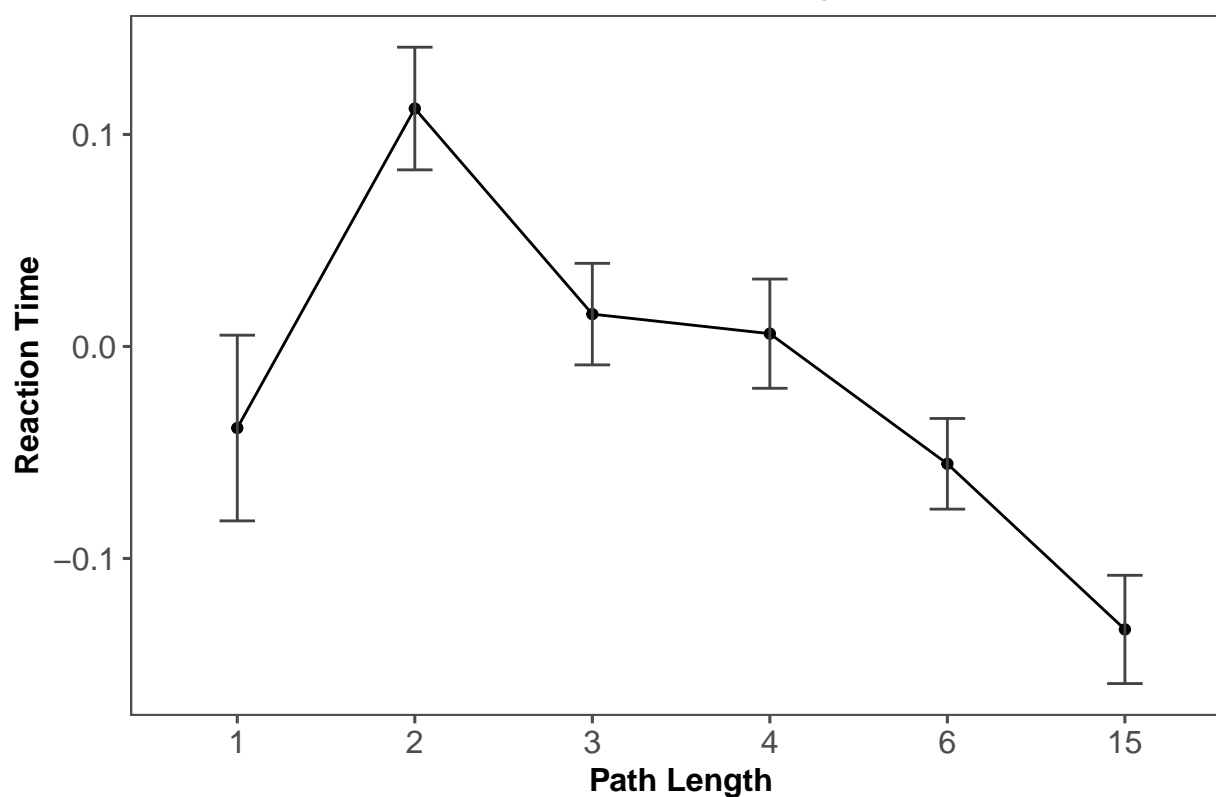
	contrast	estimate	SE	df	t.ratio	p.value
4	4 - 15	0.1395206	0.0426631	395	3.270285	0.0147443
7	3 - 15	0.1487363	0.0426631	395	3.486297	0.0071584
11	2 - 15	0.2457212	0.0426631	395	5.759570	0.0000003
12	2 - 6	0.1675878	0.0426631	395	3.928166	0.0014069
13	2 - 1	0.1507180	0.0426631	395	3.532746	0.0060893

```
## plot

success_rmisc = Rmisc::summarySE(z_sem_success,
                                measurevar = "zRT_trim",
                                groupvars = "pathlengthfac")

success_rmisc %>%
  ggplot(aes(x = pathlengthfac, y = zRT_trim))+
  geom_point()+
  geom_line(group = 1)+
  geom_errorbar(aes(ymin=zRT_trim - se, ymax=zRT_trim + se),
                width=.2, color = "gray26",
                position = position_dodge(0.7))+
  theme_few()+
  guides(color = FALSE)+
# scale_x_continuous(breaks = c(1,2,3,4,5,6,10,15,20))+
  xlab("Path Length") + ylab("Reaction Time") +
  ggtitle("RT for Relatedness Judgments") +
# facet_wrap(~subject)+
  theme(axis.text = element_text(size = rel(1)),
        axis.title = element_text(face = "bold", size = rel(1)),
        legend.title = element_text(face = "bold", size = rel(1)),
        plot.title = element_text(hjust = .5),
        strip.text.x = element_text(face = "bold", size = rel(1.4)))
```

RT for Relatedness Judgments



item

```
z_sem_rt_rel_item = group_by(new_sem_z, ItemNo, pathlength, Type ) %>%
  summarise_at(vars(zRT_trim, rt), mean)

z_sem_success_item = z_sem_rt_rel_item %>%
  filter((pathlength == "1" & Type == "Related") |
         (pathlength == "2" & Type == "Unrelated") |
         (pathlength == "3" & Type == "Unrelated") |
         (pathlength == "4" & Type == "Unrelated") |
         (pathlength == "6" & Type == "Unrelated") |
         (pathlength == "15" & Type == "Unrelated") )

z_sem_success_item$pathlengthfac = ordered(as.factor(as.character(z_sem_success_item$pathlength)),
                                           levels = c("1", "2", "3", "4", "6", "15"))

z_sem_success_item$ItemNo = as.factor(z_sem_success_item$ItemNo)

success_aov_item = aov(data = z_sem_success_item,
                       zRT_trim ~ pathlengthfac)
summary(success_aov_item)
```

```
##              Df Sum Sq Mean Sq F value    Pr(>F)
## pathlengthfac  5   5.69   1.1389    7.399 7.62e-07 ***
## Residuals    1189 183.01   0.1539
```

```
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

options(contrasts = c('contr.sum', 'contr.poly'))
library(lsmmeans)
library(multcomp)
sem_lsm = lsmeans::lsmeans(success_aov_item, c("pathlengthfac"))
prime_effect = cld(sem_lsm, alpha = 0.05,
                    adjust = "tukey", details = TRUE)
library(knitr)
kable(subset(prime_effect$comparisons, prime_effect$comparisons$p.value < 0.1 ))
```

	contrast	estimate	SE	df	t.ratio	p.value
2	1 - 15	0.1217910	0.0392819	1189	3.100434	0.0241854
4	4 - 15	0.1362988	0.0392819	1189	3.469760	0.0071242
7	3 - 15	0.1626394	0.0392327	1189	4.145510	0.0005184
11	2 - 15	0.2259796	0.0393817	1189	5.738181	0.0000002
12	2 - 6	0.1369199	0.0393817	1189	3.476736	0.0069513
13	2 - 1	0.1041886	0.0394308	1189	2.642314	0.0881132

2-way ANOVA

```
# need to exclude missing trial subjects from z_sem_rt_rel

z_sem_rt_rel_final = z_sem_rt_rel %>%
  filter(!subject %in% missingtrial_subjects$subject)

z_sem_rt_rel_final$subject = as.factor(z_sem_rt_rel_final$subject)
z_sem_rt_rel_final$pathlength = as.factor(z_sem_rt_rel_final$pathlength)

z_rt_rel_aov = aov(data = z_sem_rt_rel_final, zRT_trim ~ pathlength*Type +
                    Error(subject/(pathlength*Type)))
summary(z_rt_rel_aov)

##
## Error: subject
##              Df Sum Sq Mean Sq F value Pr(>F)
## Residuals  67   8.745   0.1305
##
## Error: subject:pathlength
##              Df Sum Sq Mean Sq F value    Pr(>F)
## pathlength    5    4.17   0.8338    6.322 1.26e-05 ***
## Residuals  335   44.18   0.1319
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Error: subject:Type
##              Df Sum Sq Mean Sq F value    Pr(>F)
## Type          1    6.74    6.741   13.99 0.000384 ***
## Residuals  67   32.29    0.482
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
##
## Error: subject:pathlength:Type
##           Df Sum Sq Mean Sq F value    Pr(>F)
## pathlength:Type    5    6.23   1.2465     9.33 2.46e-08 ***
## Residuals       335   44.76   0.1336
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
options(contrasts = c('contr.sum', 'contr.poly'))
library(lsmmeans)
library(multcomp)
sem_lsm = lsmmeans::lsmmeans(z_rt_rel_aov, c("pathlength", "Type"))
prime_effect = cld(sem_lsm, alpha = 0.05,
                    adjust = "tukey", details = TRUE)
library(knitr)
kable(subset(prime_effect$comparisons, prime_effect$comparisons$p.value < 0.8 ))
```

	contrast	estimate	SE	df	t.ratio	p.value
4	3,Unrelated - 15,Unrelated	0.1296819	0.0624830	669.9720	2.075476	0.6405786
7	1,Unrelated - 15,Unrelated	0.1316442	0.0624830	669.9720	2.106881	0.6180271
11	4,Unrelated - 15,Unrelated	0.1485018	0.0624830	669.9720	2.376676	0.4234530
16	2,Unrelated - 15,Unrelated	0.2315651	0.0624830	669.9720	3.706053	0.0121472
17	2,Unrelated - 1,Related	0.2060603	0.0749106	316.0235	2.750750	0.2068934
18	2,Unrelated - 6,Unrelated	0.1453127	0.0624830	669.9720	2.325637	0.4592713
22	2,Related - 15,Unrelated	0.2639082	0.0749106	316.0235	3.522976	0.0242743
23	2,Related - 1,Related	0.2384033	0.0624830	669.9720	3.815493	0.0081454
24	2,Related - 6,Unrelated	0.1776558	0.0749106	316.0235	2.371571	0.4285795
29	4,Related - 15,Unrelated	0.3115565	0.0749106	316.0235	4.159046	0.0023949
30	4,Related - 1,Related	0.2860517	0.0624830	669.9720	4.578075	0.0003469
31	4,Related - 6,Unrelated	0.2253041	0.0749106	316.0235	3.007641	0.1111871
32	4,Related - 3,Unrelated	0.1818747	0.0749106	316.0235	2.427890	0.3904181
33	4,Related - 1,Unrelated	0.1799124	0.0749106	316.0235	2.401695	0.4079954
34	4,Related - 4,Unrelated	0.1630548	0.0750789	275.5725	2.171778	0.5715306
37	15,Related - 15,Unrelated	0.3240048	0.0750789	275.5725	4.315523	0.0013183
38	15,Related - 1,Related	0.2984999	0.0624830	669.9720	4.777302	0.0001377
39	15,Related - 6,Unrelated	0.2377524	0.0749106	316.0235	3.173816	0.0707316
40	15,Related - 3,Unrelated	0.1943229	0.0749106	316.0235	2.594066	0.2875465
41	15,Related - 1,Unrelated	0.1923607	0.0749106	316.0235	2.567871	0.3026559
42	15,Related - 4,Unrelated	0.1755030	0.0749106	316.0235	2.342834	0.4485436
46	3,Related - 15,Unrelated	0.4041316	0.0749106	316.0235	5.394854	0.0000087
47	3,Related - 1,Related	0.3786267	0.0624830	669.9720	6.059679	0.0000001
48	3,Related - 6,Unrelated	0.3178791	0.0749106	316.0235	4.243448	0.0017055
49	3,Related - 3,Unrelated	0.2744497	0.0750789	275.5725	3.655482	0.0158384
50	3,Related - 1,Unrelated	0.2724874	0.0749106	316.0235	3.637503	0.0165404
51	3,Related - 4,Unrelated	0.2556298	0.0749106	316.0235	3.412466	0.0346259
52	3,Related - 2,Unrelated	0.1725664	0.0749106	316.0235	2.303633	0.4762125
53	3,Related - 2,Related	0.1402234	0.0624830	669.9720	2.244186	0.5179498
56	6,Related - 15,Unrelated	0.4892099	0.0749106	316.0235	6.530586	0.0000000
57	6,Related - 1,Related	0.4637050	0.0624830	669.9720	7.421304	0.0000000
58	6,Related - 6,Unrelated	0.4029575	0.0750789	275.5725	5.367119	0.0000109
59	6,Related - 3,Unrelated	0.3595280	0.0749106	316.0235	4.799430	0.0001540
60	6,Related - 1,Unrelated	0.3575658	0.0749106	316.0235	4.773235	0.0001735
61	6,Related - 4,Unrelated	0.3407081	0.0749106	316.0235	4.548198	0.0004728
62	6,Related - 2,Unrelated	0.2576448	0.0749106	316.0235	3.439365	0.0318021

	contrast	estimate	SE	df	t.ratio	p.value
63	6,Related - 2,Related	0.2253017	0.0624830	669.9720	3.605811	0.0172958
64	6,Related - 4,Related	0.1776534	0.0624830	669.9720	2.843229	0.1645287
65	6,Related - 15,Related	0.1652051	0.0624830	669.9720	2.644003	0.2573966

Specific t-tests

```

z_1 = z_sem_rt %>% filter(pathlength == "1")
colnames(z_1) = c("subject", "pathlength1", "zRT_1", "RawRT_1", "pathlengthfac1")
z_2 = z_sem_rt %>% filter(pathlength == "2")
colnames(z_2) = c("subject", "pathlength2", "zRT_2", "RawRT_2", "pathlengthfac2")
z_3 = z_sem_rt %>% filter(pathlength == "3")
colnames(z_3) = c("subject", "pathlength3", "zRT_3", "RawRT_3", "pathlengthfac3")
z_4 = z_sem_rt %>% filter(pathlength == "4")
colnames(z_4) = c("subject", "pathlength4", "zRT_4", "RawRT_4", "pathlengthfac4")
z_6 = z_sem_rt %>% filter(pathlength == "6")
colnames(z_6) = c("subject", "pathlength6", "zRT_6", "RawRT_6", "pathlengthfac6")
z_15 = z_sem_rt %>% filter(pathlength == "15")
colnames(z_15) = c("subject", "pathlength15", "zRT_15", "RawRT_15", "pathlengthfac15")

```

```

z_all = Reduce(function(x, y) merge(x, y, all=TRUE, by = "subject"),
               list(z_1, z_2, z_3, z_4, z_6, z_15))
z_all = z_all[,-c(2,5,6,9,10,13,14,17,18,21,22,25)]

```

```

t.test(z_all$zRT_1, z_all$zRT_2, paired = TRUE)

```

```

##
## Paired t-test
##
## data:  z_all$zRT_1 and z_all$zRT_2
## t = -5.8642, df = 79, p-value = 9.999e-08
## alternative hypothesis: true difference in means is not equal to 0
## 95 percent confidence interval:
##  -0.2145288 -0.1058016
## sample estimates:
## mean of the differences
##          -0.1601652

```

```

t.test(z_all$zRT_2, z_all$zRT_3, paired = TRUE)

```

```

##
## Paired t-test
##
## data:  z_all$zRT_2 and z_all$zRT_3
## t = 1.3017, df = 79, p-value = 0.1968
## alternative hypothesis: true difference in means is not equal to 0
## 95 percent confidence interval:
##  -0.01941843  0.09281353
## sample estimates:
## mean of the differences
##          0.03669755

```

```

t.test(z_all$zRT_3, z_all$zRT_4, paired = TRUE)

##
## Paired t-test
##
## data: z_all$zRT_3 and z_all$zRT_4
## t = 1.465, df = 79, p-value = 0.1469
## alternative hypothesis: true difference in means is not equal to 0
## 95 percent confidence interval:
## -0.01379417 0.09070664
## sample estimates:
## mean of the differences
## 0.03845624

t.test(z_all$zRT_4, z_all$zRT_6, paired = TRUE)

##
## Paired t-test
##
## data: z_all$zRT_4 and z_all$zRT_6
## t = 2.2224, df = 79, p-value = 0.02912
## alternative hypothesis: true difference in means is not equal to 0
## 95 percent confidence interval:
## 0.005591437 0.101559973
## sample estimates:
## mean of the differences
## 0.0535757

t.test(z_all$zRT_6, z_all$zRT_15, paired = TRUE)

##
## Paired t-test
##
## data: z_all$zRT_6 and z_all$zRT_15
## t = 3.4899, df = 79, p-value = 0.0007933
## alternative hypothesis: true difference in means is not equal to 0
## 95 percent confidence interval:
## 0.03843111 0.14045921
## sample estimates:
## mean of the differences
## 0.08944516

```

Plotting RTs: collapsed

```

z_rmisc$pathlengthfac = ordered(as.factor(as.character(z_rmisc$pathlength))),

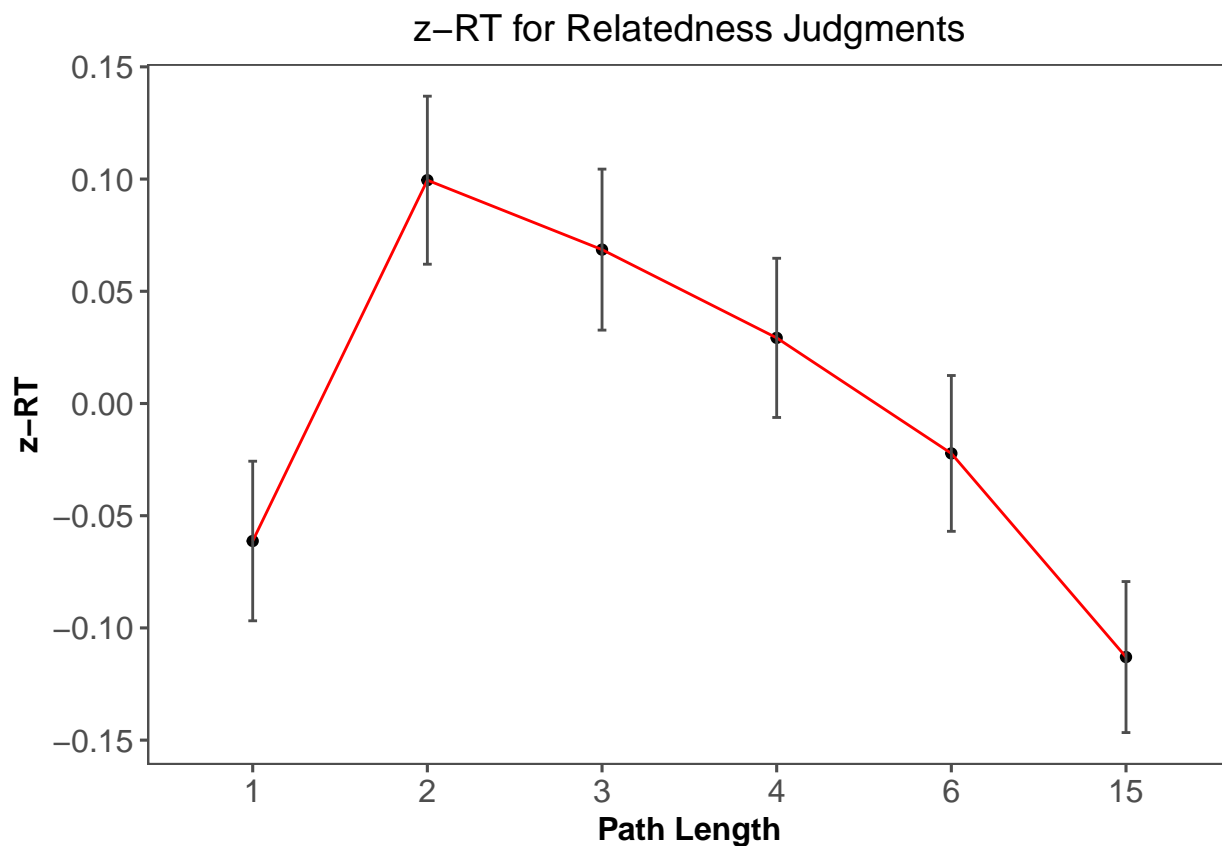
z_rmisc$zRT_trim = as.numeric(z_rmisc$zRT_trim)

library(ggplot2)
library(ggthemes)

z_rmisc %>%
  ggplot(aes(x = pathlengthfac, y = zRT_trim, group = 1))+
  geom_point()+

```

```
# geom_smooth(method = "loess")+
geom_line(color = "red")+
  geom_errorbar(aes(ymin=zRT_trim - ci, ymax=zRT_trim + ci),
    width=.05, color = "gray30",
    position = position_dodge(0.7))+
theme_few()+
#scale_x_continuous(breaks = c(1,2,3,4,5,6,10,15,20))+
  xlab("Path Length") + ylab("z-RT") +
ggtitle("z-RT for Relatedness Judgments") +
  theme(axis.text = element_text(size = rel(1)),
    axis.title = element_text(face = "bold", size = rel(1)),
    legend.title = element_text(face = "bold", size = rel(1)),
    plot.title = element_text(hjust = .5),
    strip.text.x = element_text(face = "bold", size = rel(1.4)))
```



```
z_rmisc_kenett = z_rmisc
z_rmisc_kenett$Network = "Association Correlation"
```

Plotting RTs: Rel-Unrel

```
z_sem_rt_rel_agg_rmisc$pathlengthfac = ordered(as.factor(as.character(z_sem_rt_rel_agg_rmisc$pathlengthh
z_sem_rt_rel_agg_rmisc$zRT_trim = as.numeric(z_sem_rt_rel_agg_rmisc$zRT_trim)
library(ggplot2)
```



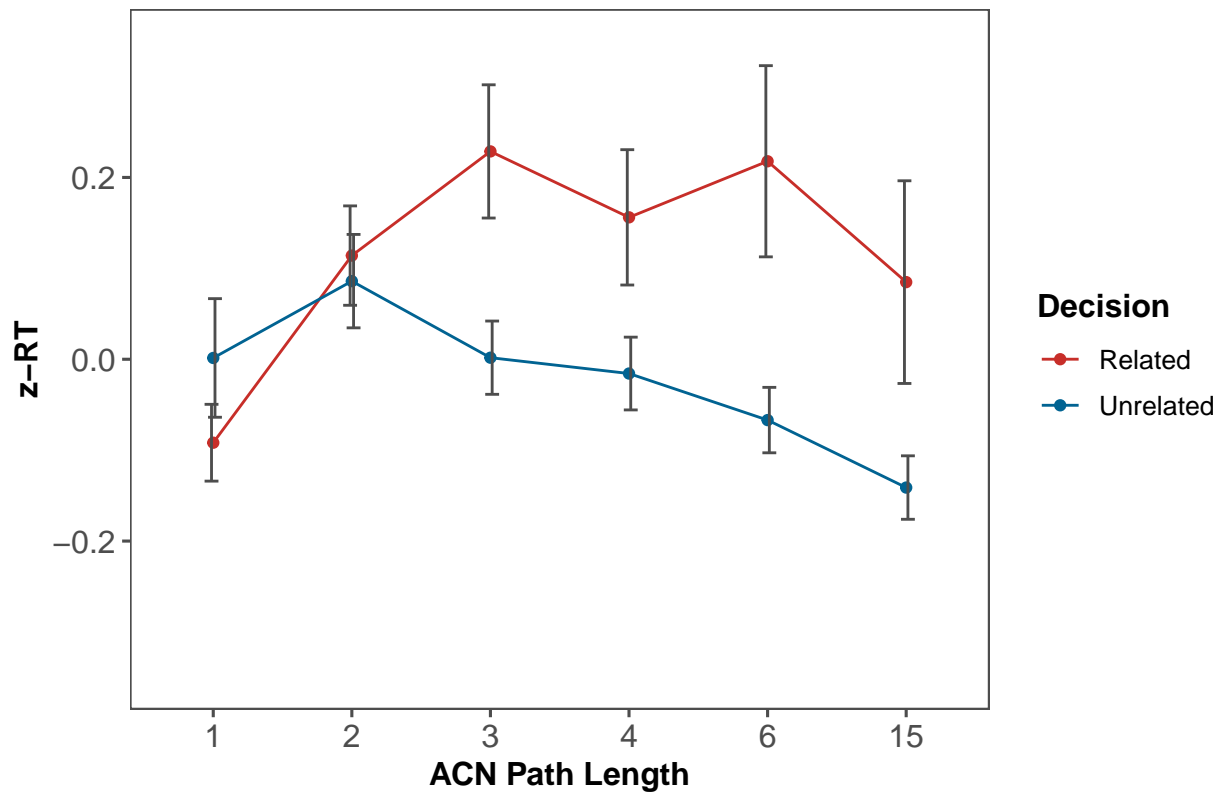
```

library(ggthemes)

z_sem_rt_rel_agg_rmisc %>%
  mutate(Decision = factor(Type,
    levels = unique(Type),
    labels = c("Related", "Unrelated"))) %>%
  ggplot(aes(x = pathlengthfac, y = zRT_trim, group = Decision, color = Decision))+
  geom_point()+
  # geom_smooth(method = "loess")+
  geom_line()+
  geom_errorbar(aes(ymin=zRT_trim - ci, ymax=zRT_trim + ci),
    width=.2, color = "gray30",
    position = position_dodge(0.05))+
  ylim(-0.35, 0.35)+
  theme_few()+
  scale_color_wsj()+ #scale_x_continuous(breaks = c(1,2,3,4,5,6,10,15,20))+
  xlab("ACN Path Length") + ylab("z-RT") +
  ggtitle("Association Correlation Network: All Lists") +
  theme(axis.text = element_text(size = rel(1)),
    axis.title = element_text(face = "bold", size = rel(1)),
    legend.title = element_text(face = "bold", size = rel(1)),
    plot.title = element_text(hjust = .5),
    strip.text.x = element_text(face = "bold", size = rel(1.4)))

```

Association Correlation Network: All Lists

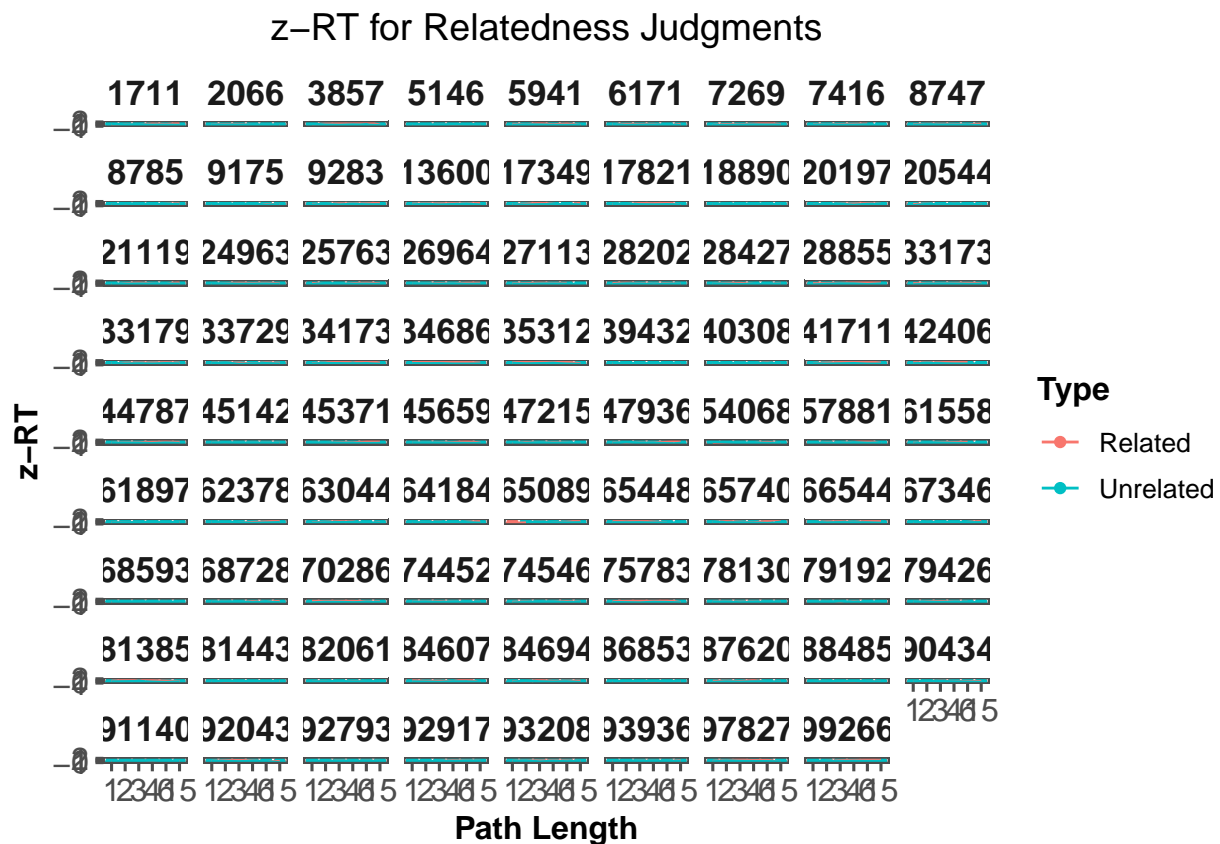


Plotting RTs: Subject Wise Rel-Unrel

```
z_sem_rt_rel$pathlengthfac = ordered(as.factor(as.character(z_sem_rt_rel$pathlength))),
z_sem_rt_rel$zRT_trim = as.numeric(z_sem_rt_rel$zRT_trim)

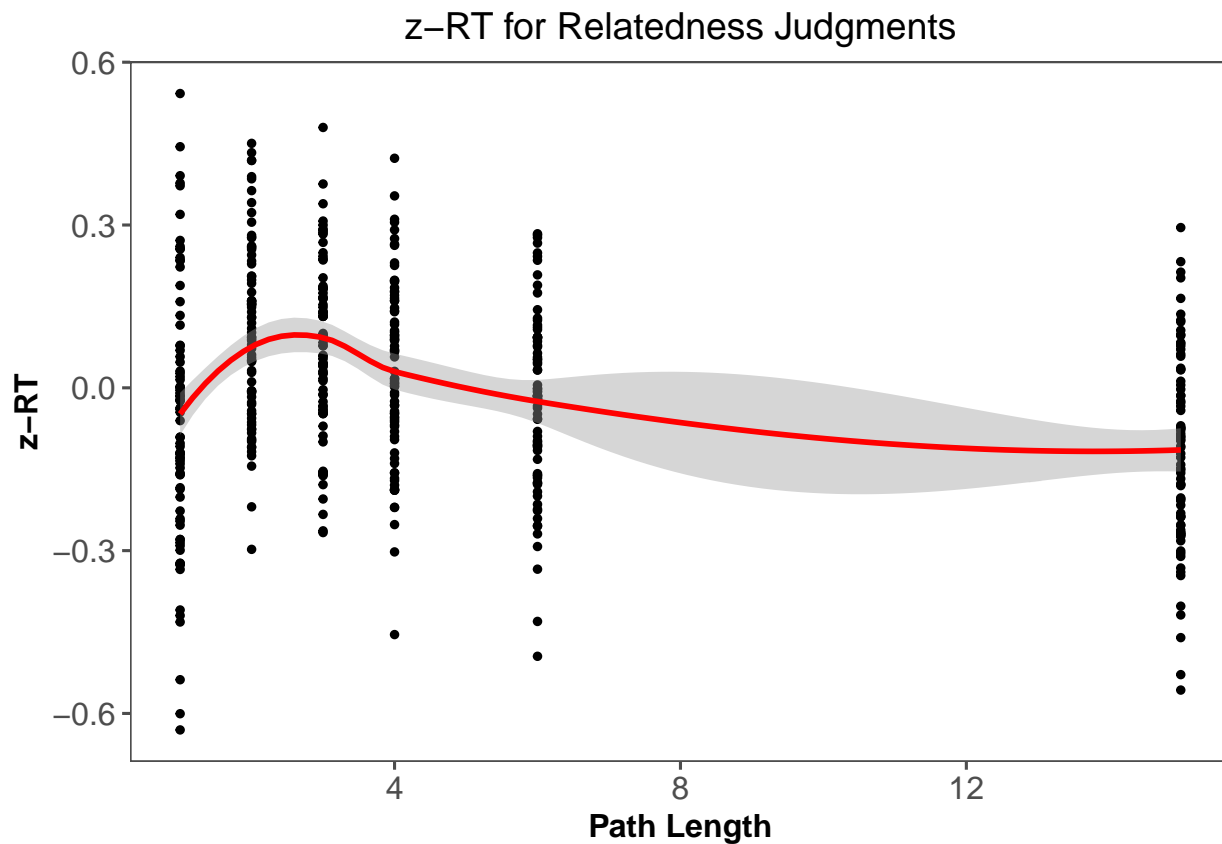
library(ggplot2)
library(ggthemes)

z_sem_rt_rel %>%
  ggplot(aes(x = pathlengthfac, y = zRT_trim, color = Type, group=interaction(Type, subject))) +
  geom_point()+
  # geom_smooth(method = "loess")+
  geom_line()+
  theme_few()+
  facet_wrap(~subject)+
  #scale_x_continuous(breaks = c(1,2,3,4,5,6,10,15,20))+
  xlab("Path Length") + ylab("z-RT") +
  ggtitle("z-RT for Relatedness Judgments") +
  theme(axis.text = element_text(size = rel(1)),
        axis.title = element_text(face = "bold", size = rel(1)),
        legend.title = element_text(face = "bold", size = rel(1)),
        plot.title = element_text(hjust = .5),
        strip.text.x = element_text(face = "bold", size = rel(1.4)))
```



Quadratic Trend

```
z_sem_rt %>%
  ggplot(aes(x = pathlength, y = zRT_trim))+
  geom_point(color = "black", size = 1)+
  geom_smooth(method = "loess", color = "red")+
  #geom_errorbar(aes(ymin=Trials - ci, ymax=Trials + ci),
  #              width=.2, color = "gray26",
  #              position = position_dodge(0.7))+
  theme_few()+
  # scale_x_continuous(breaks = c(1,2,3,4,5,6,10,15,20))+
  xlab("Path Length") + ylab("z-RT") +
  ggtitle("z-RT for Relatedness Judgments") +
  # facet_wrap(~subject)+
  theme(axis.text = element_text(size = rel(1)),
        axis.title = element_text(face = "bold", size = rel(1)),
        legend.title = element_text(face = "bold", size = rel(1)),
        plot.title = element_text(hjust = .5),
        strip.text.x = element_text(face = "bold", size = rel(1.4)))
```



List 1 only

```
new_sem_z_l1 = new_sem_z %>% filter(proc %in% c("S1", "S2"))
list1_z = Rmisc::summarySE(new_sem_z_l1,
                           measurevar = "zRT_trim",
```

```

groupvars = c("pathlength", "Type"))

list1_z$pathlengthfac = ordered(as.factor(as.character(list1_z$pathlength)),

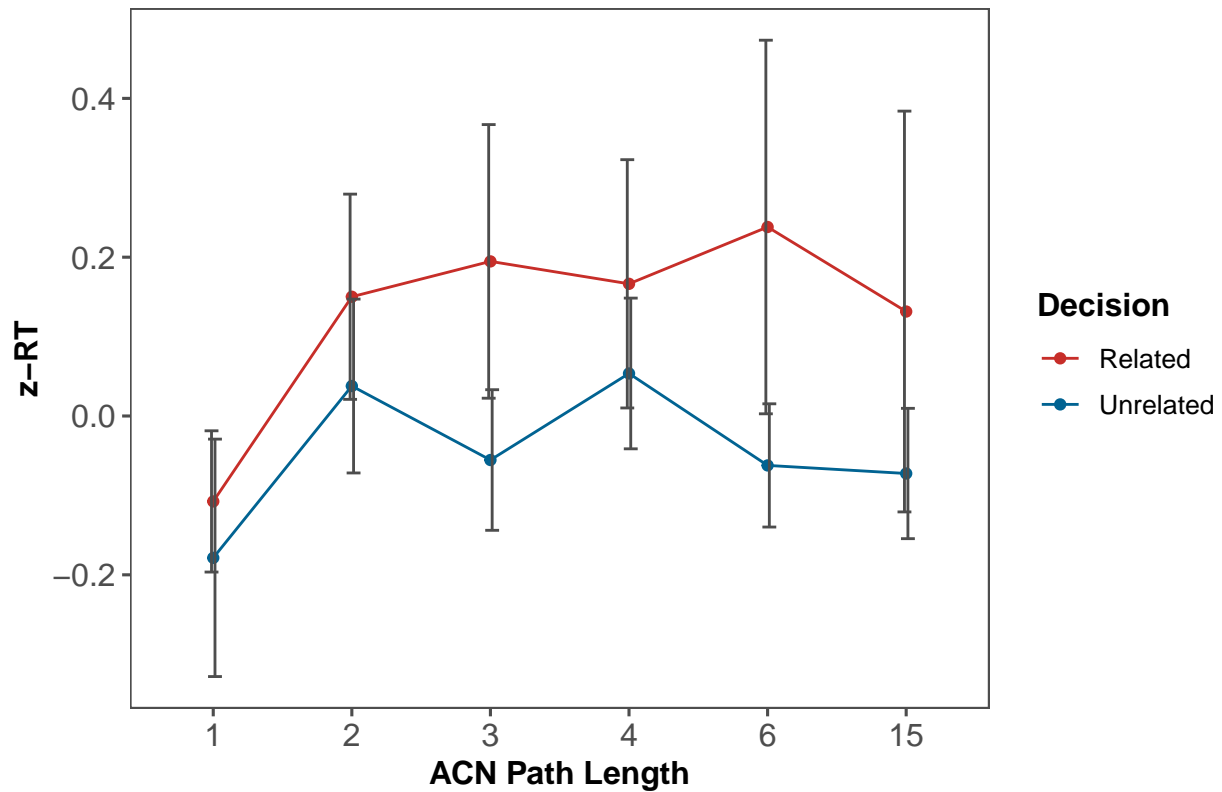
list1_z$zRT_trim = as.numeric(list1_z$zRT_trim)

library(ggplot2)
library(ggthemes)

list1_z %>%
  mutate(Decision = factor(Type,
    levels = unique(Type),
    labels = c("Related", "Unrelated"))) %>%
  ggplot(aes(x = pathlengthfac, y = zRT_trim, group = Decision, color = Decision))+
  geom_point()+
  # geom_smooth(method = "loess")+
  geom_line()+
  geom_errorbar(aes(ymin=zRT_trim - ci, ymax=zRT_trim + ci),
    width=.2, color = "gray30",
    position = position_dodge(0.05))+
  theme_few()+
  scale_color_wsj()+ #scale_x_continuous(breaks = c(1,2,3,4,5,6,10,15,20))+
  xlab("ACN Path Length") + ylab("z-RT") +
  ggtitle("Association Correlation Network for List 1") +
  theme(axis.text = element_text(size = rel(1)),
    axis.title = element_text(face = "bold", size = rel(1)),
    legend.title = element_text(face = "bold", size = rel(1)),
    plot.title = element_text(hjust = .5),
    strip.text.x = element_text(face = "bold", size = rel(1.4)))

```

Association Correlation Network for List 1

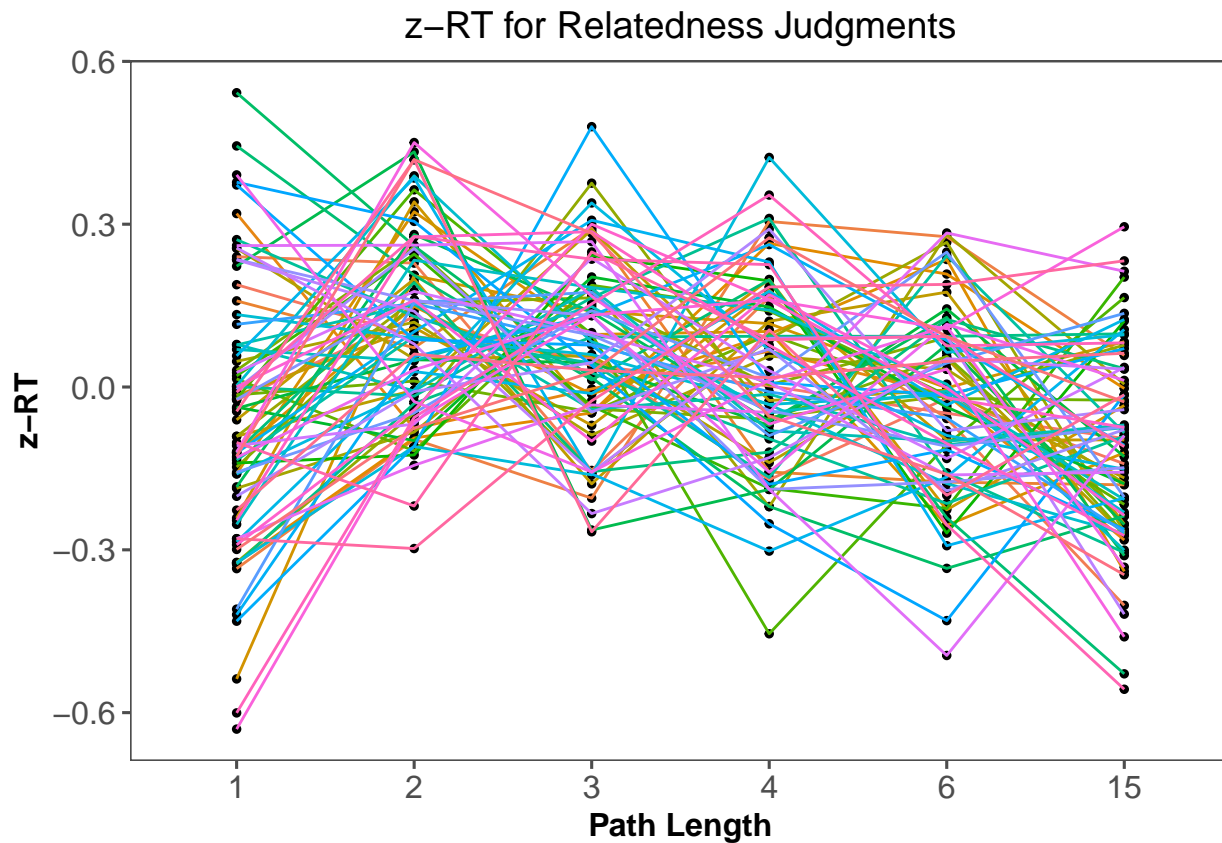


Subject-Wise

```
library(ggplot2)
library(ggthemes)

z_sem_rt %>%
  ggplot(aes(x = pathlengthfac, y = zRT_trim,
             color = subject, group = subject))+
  geom_point(color = "black", size = 1)+
  geom_line()+
  #geom_errorbar(aes(ymin=Trials - ci, ymax=Trials + ci),
  #              width=.2, color = "gray26",
  #              position = position_dodge(0.7))+
  theme_few()+
  guides(color = FALSE)+
  # scale_x_continuous(breaks = c(1,2,3,4,5,6,10,15,20))+
  xlab("Path Length") + ylab("z-RT") +
  ggtitle("z-RT for Relatedness Judgments") +
  # facet_wrap(~subject)+
  theme(axis.text = element_text(size = rel(1)),
        axis.title = element_text(face = "bold", size = rel(1)),
        legend.title = element_text(face = "bold", size = rel(1)),
        plot.title = element_text(hjust = .5),
```

```
strip.text.x = element_text(face = "bold", size = rel(1.4)))
```



Regressions

```
library(lme4)
```

```
## Warning: package 'lme4' was built under R version 3.4.4
```

```
## Loading required package: Matrix
```

```
## Warning: package 'Matrix' was built under R version 3.4.4
```

```
sem$pathlengthfac = ordered(as.factor(as.character(sem$pathlength)),
                             levels = c("1", "2", "3", "4", "6", "15"))
```

```
new_sem_z$pathlengthfac = ordered(as.factor(as.character(new_sem_z$pathlength)),
                                   levels = c("1", "2", "3", "4", "6", "15"))
```

```
m0 = lmer(data = new_sem_z, rt ~ 1 + (1|subject) + (1|trial_index) +
           (1|ItemNo))
```

```
summary(m0)
```

```
## Linear mixed model fit by REML ['lmerMod']
```

```
## Formula: rt ~ 1 + (1 | subject) + (1 | trial_index) + (1 | ItemNo)
```

```
## Data: new_sem_z
```

```
##
```

```

## REML criterion at convergence: 249131.9
##
## Scaled residuals:
##      Min       1Q   Median       3Q      Max
## -3.2009 -0.6212 -0.1612  0.4479  5.3272
##
## Random effects:
##      Groups      Name      Variance Std.Dev.
## ItemNo      (Intercept)  1522.3   39.02
## trial_index (Intercept)   208.9   14.45
## subject     (Intercept) 23823.6  154.35
## Residual                50252.2  224.17
## Number of obs: 18170, groups: ItemNo, 1200; trial_index, 240; subject, 80
##
## Fixed effects:
##              Estimate Std. Error t value
## (Intercept)    734.2      17.4    42.19

```

```

reghelper::ICC(m0)

## [1] 0.3371028

contrasts(sem$pathlengthfac) = contr.treatment(6, base = 1)

contrasts(new_sem_z$pathlengthfac) = contr.treatment(6, base = 2)

m1_fixed = lmer(data = new_sem_z, zRT_trim ~ pathlengthfac +
  (1|subject) + (1|ItemNo) + (1|trial_index))
summary(m1_fixed)

```

```

## Linear mixed model fit by REML ['lmerMod']
## Formula: zRT_trim ~ pathlengthfac + (1 | subject) + (1 | ItemNo) + (1 |
##      trial_index)
##      Data: new_sem_z
##
## REML criterion at convergence: 51296.7
##
## Scaled residuals:
##      Min       1Q   Median       3Q      Max
## -2.5782 -0.7127 -0.1964  0.5389  3.9565
##
## Random effects:
##      Groups      Name      Variance Std.Dev.
## ItemNo      (Intercept)  0.033695  0.18356
## trial_index (Intercept)  0.004246  0.06516
## subject     (Intercept)  0.000000  0.00000
## Residual                0.952788  0.97611
## Number of obs: 18170, groups: ItemNo, 1200; trial_index, 240; subject, 80
##
## Fixed effects:
##              Estimate Std. Error t value
## (Intercept)    0.09995    0.02245   4.451
## pathlengthfac1 -0.16082    0.03115  -5.162
## pathlengthfac3 -0.03054    0.03115  -0.980

```

```
## pathlengthfac4 -0.07032    0.03117 -2.256
## pathlengthfac5 -0.12080    0.03116 -3.876
## pathlengthfac6 -0.21266    0.03115 -6.827
##
## Correlation of Fixed Effects:
##          (Intr) pthln1 pthln3 pthln4 pthln5
## pthlngthfc1 -0.696
## pthlngthfc3 -0.696  0.502
## pthlngthfc4 -0.695  0.501  0.501
## pthlngthfc5 -0.695  0.501  0.501  0.501
## pthlngthfc6 -0.696  0.501  0.502  0.501  0.501

# m1_random = lmer(data = sem, rt ~ pathlengthfac +
#                  (pathlengthfac/subject) + (pathlengthfac/ItemNo) +
#                  (pathlengthfac/trial_index))
# summary(m1_random)
```

ELP Model

```
## Adding ELP covariates

# elp_model = lmer(data = new_sem_z, rt ~ mean_len + mean_logf +
#                  mean_ldtz +
#                  (1|subject) + (1|trial_index) + (1|ItemNo))
# fit_from_elp = broom::augment(elp_model, new_sem_z)
#
# contrasts(fit_from_elp$pathlengthfac) = contr.treatment(6, base = 2)
#
# m1_fixed_elp = lmer(data = fit_from_elp, .resid ~ pathlengthfac +
#                  (1|subject) + (1|trial_index) + (1|ItemNo))
# summary(m1_fixed_elp)
#

new_sem_z$proc = as.factor(new_sem_z$proc)
m1_all_elp = lmer(data = new_sem_z, rt ~ pathlengthfac*proc +
                  mean_len + mean_logf + mean_ldtz +
                  (1|subject) + (1|trial_index) + (1|ItemNo))
summary(m1_all_elp)

## Linear mixed model fit by REML ['lmerMod']
## Formula: rt ~ pathlengthfac * proc + mean_len + mean_logf + mean_ldtz +
##          (1 | subject) + (1 | trial_index) + (1 | ItemNo)
## Data: new_sem_z
##
## REML criterion at convergence: 248410
##
## Scaled residuals:
##      Min       1Q   Median       3Q      Max
## -3.1592 -0.6203 -0.1572  0.4477  5.4469
##
## Random effects:
## Groups      Name                Variance Std.Dev.
## ItemNo      (Intercept)    1198.1     34.61
```



```

## trial_index (Intercept)    207.6   14.41
## subject      (Intercept) 23254.9 152.50
## Residual                50203.8 224.06
## Number of obs: 18162, groups: ItemNo, 1200; trial_index, 240; subject, 80
##
## Fixed effects:
##
##              Estimate Std. Error t value
## (Intercept)    706.7591    24.4483  28.908
## pathlengthfac1   -32.6908     6.7431  -4.848
## pathlengthfac3    -5.1147     6.7445  -0.758
## pathlengthfac4   -13.7654     6.7499  -2.039
## pathlengthfac5   -22.6871     6.7469  -3.363
## pathlengthfac6   -40.5047     6.7476  -6.003
## proc1           -44.7690    52.8619  -0.847
## proc2           -45.5878    52.7815  -0.864
## proc3           -25.8878    52.7858  -0.490
## proc4            50.5891    52.7971   0.958
## proc5            65.2477    52.8180   1.235
## proc6            23.4277    52.8153   0.444
## proc7           -78.3525    52.7989  -1.484
## proc8           -18.8166    52.9990  -0.355
## proc9           -51.4922    52.8665  -0.974
## mean_len         4.8116     1.5162   3.173
## mean_logf        3.0312     1.7587   1.724
## mean_ldtz        18.7877    14.4139   1.303
## pathlengthfac1:proc1  16.4357    18.8101   0.874
## pathlengthfac3:proc1 -33.8760    18.7755  -1.804
## pathlengthfac4:proc1  -9.0144    18.8321  -0.479
## pathlengthfac5:proc1  -8.2269    18.7515  -0.439
## pathlengthfac6:proc1   0.4162    18.8472   0.022
## pathlengthfac1:proc2  37.9366    18.4842   2.052
## pathlengthfac3:proc2 -16.7295    18.4297  -0.908
## pathlengthfac4:proc2 -17.8836    18.4988  -0.967
## pathlengthfac5:proc2  -3.4032    18.4235  -0.185
## pathlengthfac6:proc2 -26.2259    18.4266  -1.423
## pathlengthfac1:proc3 -18.9460    18.4217  -1.028
## pathlengthfac3:proc3  14.7091    18.4644   0.797
## pathlengthfac4:proc3  44.8086    18.5167   2.420
## pathlengthfac5:proc3  25.1015    18.4986   1.357
## pathlengthfac6:proc3  36.1060    18.5473   1.947
## pathlengthfac1:proc4 -14.1014    18.6395  -0.757
## pathlengthfac3:proc4 -27.0719    18.5273  -1.461
## pathlengthfac4:proc4   0.6228    18.5887   0.034
## pathlengthfac5:proc4   2.9664    18.5766   0.160
## pathlengthfac6:proc4 -12.1401    18.5512  -0.654
## pathlengthfac1:proc5 -36.8314    18.5696  -1.983
## pathlengthfac3:proc5  22.3383    18.5475   1.204
## pathlengthfac4:proc5  20.9809    18.5669   1.130
## pathlengthfac5:proc5   5.3939    18.5302   0.291
## pathlengthfac6:proc5  -9.5056    18.5100  -0.514
## pathlengthfac1:proc6  11.9360    18.5403   0.644
## pathlengthfac3:proc6  29.7448    18.5304   1.605
## pathlengthfac4:proc6  31.2214    18.5176   1.686
## pathlengthfac5:proc6  34.1753    18.5337   1.844

```

```
## pathlengthfac6:proc6 33.0137 18.4793 1.787
## pathlengthfac1:proc7 16.1100 18.4799 0.872
## pathlengthfac3:proc7 -4.8085 18.4744 -0.260
## pathlengthfac4:proc7 8.3258 18.4829 0.450
## pathlengthfac5:proc7 -6.4620 18.5241 -0.349
## pathlengthfac6:proc7 -2.3131 18.4833 -0.125
## pathlengthfac1:proc8 11.9844 19.4028 0.618
## pathlengthfac3:proc8 -3.2440 19.2991 -0.168
## pathlengthfac4:proc8 -31.6267 19.4064 -1.630
## pathlengthfac5:proc8 -8.6523 19.3317 -0.448
## pathlengthfac6:proc8 6.1347 19.3991 0.316
## pathlengthfac1:proc9 -8.3706 18.7963 -0.445
## pathlengthfac3:proc9 33.4509 18.8900 1.771
## pathlengthfac4:proc9 0.2983 18.7473 0.016
## pathlengthfac5:proc9 -6.3321 18.9255 -0.335
## pathlengthfac6:proc9 8.6125 18.7925 0.458

##
## Correlation matrix not shown by default, as p = 63 > 12.
## Use print(x, correlation=TRUE) or
##     vcov(x)           if you need it

car::Anova(m1_all_elp)

## Analysis of Deviance Table (Type II Wald chisquare tests)
##
## Response: rt
##
##           Chisq Df Pr(>Chisq)
## pathlengthfac 55.3429 5 1.11e-10 ***
## proc          10.9748 9 0.277440
## mean_len      10.0707 1 0.001506 **
## mean_logf      2.9706 1 0.084790 .
## mean_ldtz      1.6990 1 0.192423
## pathlengthfac:proc 78.7641 45 0.001373 **
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

Plot from ELP Model

```
# fixed.frame <-
#   data.frame(expand.grid( pathlengthfac = c("1", "2", "3",
#                                             "4", "6", "15"))) %>%
#   mutate(pred = predict(m1_all_elp, newdata = ., re.form = NA))
#
#
# fixed.frame %>%
#   mutate(Pathlength = factor(pathlengthfac,
#                               levels = unique(pathlengthfac),
#                               labels = c("1", "2", "3",
#                                           "4", "6", "15"))) %>%
#   ggplot(aes(x = Pathlength, y = pred, group = 1)) +
#   geom_point() +
#   geom_line(color = "green") +
#   theme_few()
```

```
# xlab("Path Length") + ylab("RT residuals ") +
# ggtitle("z-RT for Relatedness Judgments") +
# theme(axis.text = element_text(size = rel(1)),
#       axis.title = element_text(face = "bold", size = rel(1)),
#       legend.title = element_text(face = "bold", size = rel(1)),
#       plot.title = element_text(hjust = .5),
#       strip.text.x = element_text(face = "bold", size = rel(1.4)))
```

Concreteness Norms

```
elpnorms = read.csv("ELP_norms 2.csv", header = TRUE, sep = ",")
elpnorms = elpnorms[,c(1,2)]
colnames(elpnorms) = c("prime_word", "prime_concreteness")
elpnorms$prime_word = toupper(elpnorms$prime_word)
elpnorms$prime_word = paste(elpnorms$prime_word, "")

elpnorms$prime_word = as.character(elpnorms$prime_word)

sem$prime_word = as.character(sem$prime_word)
merged_sem_prime = inner_join(sem, elpnorms, by = "prime_word")
merged_sem_prime = merged_sem_prime[,c(4,7,16,44)]

colnames(elpnorms) = c("target_word", "target_concreteness")
sem$target_word = as.character(sem$target_word)
merged_sem_target = inner_join(sem, elpnorms, by = "target_word")
merged_sem_target = merged_sem_target[,c(4,7, 17,44)]

merged_concretness = full_join(merged_sem_prime, merged_sem_target,
                               by = c("trial_index", "subject"))
merged_concretness$mean_conc = (merged_concretness$prime_concreteness +
                               merged_concretness$target_concreteness) / 2

### NOW WE HAVE CONCRETENESS NORMS FOR ALL ITEMS IN THE DATASET
### NEED TO COMBINE THIS WITH ACTUAL SEM DATA

new_sem_z$prime_word = as.character(new_sem_z$prime_word)
new_sem_z$target_word = as.character(new_sem_z$target_word)
final_sem = inner_join(new_sem_z, merged_concretness,
                       by = c("trial_index", "subject",
                              "prime_word", "target_word"))

count_n = group_by(final_sem, subject, prime_word, target_word) %>%
  summarize(n = n())
x = which(count_n$n != 1)

#View(count_n[x,])
```

Concreteness Model

```
final_sem$pathlengthfac = ordered(as.factor(as.character(final_sem$pathlength)),
                                  levels = c("1", "2", "3", "4", "6", "15"))

# elp_model = lmer(data = final_sem, zRT_trim ~ mean_len + mean_logf +
#                 mean_ldtz + mean_conc +
#                 (1|subject) + (1|trial_index) + (1|ItemNo))
# fit_from_elp = broom::augment(elp_model, final_sem)
#
# contrasts(fit_from_elp$pathlengthfac) = contr.treatment(6, base = 2)
#
# m1_fixed_elp = lmer(data = fit_from_elp, .resid ~ pathlengthfac +
#                 (1|subject) + (1|trial_index) + (1|ItemNo))
# summary(m1_fixed_elp)

m1_all_elp = lme4::lmer(data = final_sem, zRT_trim ~ pathlengthfac +
                      mean_len + mean_logf + mean_ldtz + mean_conc +
                      (1|subject) + (1|trial_index) + (1|ItemNo))
summary(m1_all_elp)

## Linear mixed model fit by REML ['lmerMod']
## Formula: zRT_trim ~ pathlengthfac + mean_len + mean_logf + mean_ldtz +
##          mean_conc + (1 | subject) + (1 | trial_index) + (1 | ItemNo)
## Data: final_sem
##
## REML criterion at convergence: 46175.9
##
## Scaled residuals:
##      Min       1Q   Median       3Q      Max
## -2.5474 -0.7096 -0.1953  0.5381  4.0062
##
## Random effects:
##   Groups       Name             Variance Std.Dev.
##   ItemNo      (Intercept)  0.028862  0.16989
##   trial_index (Intercept)  0.003494  0.05911
##   subject     (Intercept)  0.000000  0.00000
##   Residual                    0.949326  0.97433
## Number of obs: 16390, groups:  ItemNo, 1083; trial_index, 240; subject, 80
##
## Fixed effects:
##              Estimate Std. Error t value
## (Intercept)    0.228025   0.108655   2.099
## pathlengthfac.L -0.084375   0.022548  -3.742
## pathlengthfac.Q -0.147674   0.022486  -6.568
## pathlengthfac.C  0.059418   0.022650   2.623
## pathlengthfac^4 -0.050604   0.022699  -2.229
## pathlengthfac^5  0.012222   0.022585   0.541
## mean_len        0.015521   0.007386   2.101
## mean_logf       -0.009404   0.008818  -1.066
## mean_ldtz        0.004286   0.069186   0.062
## mean_conc       -0.065622   0.011872  -5.528
##
```

```

## Correlation of Fixed Effects:
##          (Intr) pthl.L pthl.Q pthl.C pthl^4 pthl^5 men_ln mn_lgf mn_ldt
## pthlngthf.L -0.050
## pthlngthf.Q  0.048 -0.003
## pthlngthf.C  0.008 -0.016 -0.006
## pthlngthf^4 -0.014 -0.003  0.001  0.004
## pthlngthf^5 -0.001 -0.009  0.005  0.009 -0.005
## mean_len    -0.603  0.061 -0.023 -0.004 -0.002 -0.016
## mean_logf    -0.665  0.028 -0.011 -0.025  0.016 -0.001 -0.009
## mean_ldtz     0.010 -0.006  0.020 -0.029 -0.006  0.020 -0.361  0.550
## mean_conc    -0.685  0.009 -0.064  0.006  0.001  0.035  0.240  0.311  0.110

# m1_all_elp_random = lme4::lmer(data = final_sem, zRT_trim ~ pathlengthfac +
#                               mean_len + mean_logf + mean_ldtz + mean_conc +
#                               (pathlengthfac/subject) +
#                               + (1|trial_index) + (pathlengthfac|ItemNo),
#                               control=lmerControl(optimizer="bobyqa",
#                               optCtrl=list(maxfun=100000)))
# summary(m1_all_elp_random)
#
## centering so that contrasts are easier
final_sem$mean_len_c = scale(final_sem$mean_len,
                             center = TRUE, scale = FALSE)
final_sem$mean_logf_c = scale(final_sem$mean_logf,
                              center = TRUE, scale = FALSE)
final_sem$mean_ldtz_c = scale(final_sem$mean_ldtz,
                              center = TRUE, scale = FALSE)
final_sem$mean_conc_c = scale(final_sem$mean_conc,
                              center = TRUE, scale = FALSE)

final_sem$mean_len_c = as.numeric(final_sem$mean_len_c)
final_sem$mean_logf_c = as.numeric(final_sem$mean_logf_c)
final_sem$mean_ldtz_c = as.numeric(final_sem$mean_ldtz_c)
final_sem$mean_conc_c = as.numeric(final_sem$mean_conc_c)

contrasts(final_sem$pathlengthfac) = contr.treatment(6, base = 2)

m1_all_elp_type = lme4::lmer(data = final_sem,
                             zRT_trim ~ pathlengthfac*Type +
                             mean_len_c + mean_logf_c + mean_ldtz_c + mean_conc_c +
                             (1|subject) + (1|trial_index) +
                             + (1|target_word))
summary(m1_all_elp_type)

## Linear mixed model fit by REML ['lmerMod']
## Formula: zRT_trim ~ pathlengthfac * Type + mean_len_c + mean_logf_c +
##          mean_ldtz_c + mean_conc_c + (1 | subject) + (1 | trial_index) +
##          +(1 | target_word)
## Data: final_sem
##
## REML criterion at convergence: 46174.3
##
## Scaled residuals:
##      Min       1Q   Median       3Q      Max
## -2.5546 -0.7093 -0.1896  0.5454  4.1265

```

```

##
## Random effects:
##   Groups      Name      Variance Std.Dev.
## target_word (Intercept) 0.022157 0.14885
## trial_index (Intercept) 0.003409 0.05839
## subject      (Intercept) 0.000000 0.00000
## Residual                0.951645 0.97552
## Number of obs: 16390, groups:
## target_word, 1741; trial_index, 240; subject, 80
##
## Fixed effects:
##               Estimate Std. Error t value
## (Intercept)      0.106342   0.020915   5.084
## pathlengthfac1   -0.155943   0.029663  -5.257
## pathlengthfac3   -0.001245   0.030117  -0.041
## pathlengthfac4   -0.054133   0.030385  -1.782
## pathlengthfac5   -0.040004   0.034418  -1.162
## pathlengthfac6   -0.161663   0.036015  -4.489
## Type1            0.007245   0.019402   0.373
## mean_len_c       0.013069   0.006831   1.913
## mean_logf_c     -0.010149   0.008144  -1.246
## mean_ldtz_c      0.018507   0.063637   0.291
## mean_conc_c     -0.065844   0.010913  -6.033
## pathlengthfac1:Type1 -0.053266   0.028118  -1.894
## pathlengthfac3:Type1 0.097122   0.028618   3.394
## pathlengthfac4:Type1 0.062309   0.028883   2.157
## pathlengthfac5:Type1 0.119272   0.033162   3.597
## pathlengthfac6:Type1 0.083182   0.034701   2.397
##
## Correlation matrix not shown by default, as p = 16 > 12.
## Use print(x, correlation=TRUE) or
##      vcov(x)          if you need it

m1_all_elp_type_withoutinteraction = lme4::lmer(data = final_sem,
      zRT_trim ~ pathlengthfac + Type +
      mean_len_c + mean_logf_c + mean_ldtz_c + mean_conc_c +
      (1|subject) + (1|trial_index) +
      + (1|target_word))
summary(m1_all_elp_type_withoutinteraction)

## Linear mixed model fit by REML ['lmerMod']
## Formula: zRT_trim ~ pathlengthfac + Type + mean_len_c + mean_logf_c +
##      mean_ldtz_c + mean_conc_c + (1 | subject) + (1 | trial_index) +
##      +(1 | target_word)
##      Data: final_sem
##
## REML criterion at convergence: 46191.6
##
## Scaled residuals:
##      Min      1Q  Median      3Q      Max
## -2.5618 -0.7090 -0.1932  0.5447  4.1057
##
## Random effects:
##   Groups      Name      Variance Std.Dev.

```

```

## target_word (Intercept) 0.025209 0.15877
## trial_index (Intercept) 0.003479 0.05898
## subject (Intercept) 0.000000 0.00000
## Residual 0.951457 0.97543
## Number of obs: 16390, groups:
## target_word, 1741; trial_index, 240; subject, 80
##
## Fixed effects:
## Estimate Std. Error t value
## (Intercept) 0.107360 0.021119 5.083
## pathlengthfac1 -0.190650 0.029233 -6.522
## pathlengthfac3 -0.025557 0.029323 -0.872
## pathlengthfac4 -0.065592 0.029221 -2.245
## pathlengthfac5 -0.094950 0.029806 -3.186
## pathlengthfac6 -0.195359 0.029682 -6.582
## Type1 0.047946 0.009162 5.233
## mean_len_c 0.013158 0.006893 1.909
## mean_logf_c -0.009735 0.008226 -1.183
## mean_ldtz_c 0.017601 0.064275 0.274
## mean_conc_c -0.064744 0.011032 -5.869
##
## Correlation of Fixed Effects:
## (Intr) pthln1 pthln3 pthln4 pthln5 pthln6 Type1 mn_ln_ mn_lg_
## pthlngthfc1 -0.694
## pthlngthfc3 -0.688 0.484
## pthlngthfc4 -0.689 0.484 0.517
## pthlngthfc5 -0.675 0.464 0.512 0.517
## pthlngthfc6 -0.680 0.466 0.517 0.525 0.529
## Type1 0.014 -0.122 0.116 0.138 0.201 0.220
## mean_len_c -0.023 -0.008 0.019 0.018 0.027 0.021 -0.054
## mean_logf_c -0.035 0.016 0.022 0.038 0.031 0.024 -0.011 -0.005
## mean_ldtz_c -0.011 0.015 -0.011 0.017 0.017 0.009 0.038 -0.364 0.547
## mean_conc_c 0.015 -0.048 -0.002 0.032 -0.008 -0.016 0.040 0.239 0.314
## mn_ld_
## pthlngthfc1
## pthlngthfc3
## pthlngthfc4
## pthlngthfc5
## pthlngthfc6
## Type1
## mean_len_c
## mean_logf_c
## mean_ldtz_c
## mean_conc_c 0.111
anova(m1_all_elp_type_withoutinteraction, m1_all_elp_type)

## refitting model(s) with ML (instead of REML)

## Data: final_sem
## Models:
## m1_all_elp_type_withoutinteraction: zRT_trim ~ pathlengthfac + Type + mean_len_c + mean_logf_c +
## m1_all_elp_type_withoutinteraction: mean_ldtz_c + mean_conc_c + (1 | subject) + (1 | trial_index)
## m1_all_elp_type_withoutinteraction: +(1 | target_word)
## m1_all_elp_type: zRT_trim ~ pathlengthfac * Type + mean_len_c + mean_logf_c +

```

```
## m1_all_elp_type:      mean_ldtz_c + mean_conc_c + (1 | subject) + (1 | trial_index) +
## m1_all_elp_type:      +(1 | target_word)
##                      Df    AIC    BIC logLik deviance  Chisq
## m1_all_elp_type_withoutinteraction 15 46151 46267 -23061    46121
## m1_all_elp_type          20 46117 46271 -23038    46077 44.325
##                      Chi Df Pr(>Chisq)
## m1_all_elp_type_withoutinteraction
## m1_all_elp_type          5  1.99e-08 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

Contrast Codes with Covariates

```
groups <- read.table('groups.csv',
                     sep=',',header=TRUE,stringsAsFactors=FALSE)
groups
```

```
##      Group Type pathlength Type1 pathlength1 pathlength3 pathlength4
## 1      1    U        1      0          1          0          0
## 2      2    R        1      1          1          0          0
## 3      3    U        2      0          0          0          0
## 4      4    R        2      1          0          0          0
## 5      5    U        3      0          0          1          0
## 6      6    R        3      1          0          1          0
## 7      7    U        4      0          0          0          1
## 8      8    R        4      1          0          0          1
## 9      9    U        6      0          0          0          0
## 10     10   R        6      1          0          0          0
## 11     11   U       15      0          0          0          0
## 12     12   R       15      1          0          0          0
##      pathlength5 pathlength6
## 1              0          0
## 2              0          0
## 3              0          0
## 4              0          0
## 5              0          0
## 6              0          0
## 7              0          0
## 8              0          0
## 9              1          0
## 10             1          0
## 11             0          1
## 12             0          1
```

```
dummy_codes <- as.matrix(groups[,4:9])
dummy_codes
```

```
##      Type1 pathlength1 pathlength3 pathlength4 pathlength5 pathlength6
## [1,]      0          1          0          0          0          0
## [2,]      1          1          0          0          0          0
## [3,]      0          0          0          0          0          0
## [4,]      1          0          0          0          0          0
## [5,]      0          0          1          0          0          0
## [6,]      1          0          1          0          0          0
```



```
## [7,] 0 0 0 1 0 0
## [8,] 1 0 0 1 0 0
## [9,] 0 0 0 0 1 0
## [10,] 1 0 0 0 1 0
## [11,] 0 0 0 0 0 1
## [12,] 1 0 0 0 0 1
```

```
fixed_effects <- matrix(fixef(m1_all_elp_type))
fixed_effects
```

```
## [1,]
## [1,] 0.106342132
## [2,] -0.155942649
## [3,] -0.001244544
## [4,] -0.054133074
## [5,] -0.040004039
## [6,] -0.161663447
## [7,] 0.007245169
## [8,] 0.013069359
## [9,] -0.010149494
## [10,] 0.018507043
## [11,] -0.065844017
## [12,] -0.053265599
## [13,] 0.097121931
## [14,] 0.062309309
## [15,] 0.119271651
## [16,] 0.083181774
```

```
means_matrix <- matrix(rep(0,192),ncol=16,nrow=12)
means_matrix[,1] <- 1
means_matrix[,2:6] <- dummy_codes[,2:6]
means_matrix[,7] <- dummy_codes[,1]
means_matrix[,8:11] <- 0
means_matrix[,12:16] <- dummy_codes[,1]*dummy_codes[,2:6]
means_matrix
```

```
## [,1] [,2] [,3] [,4] [,5] [,6] [,7] [,8] [,9] [,10] [,11] [,12] [,13]
## [1,] 1 1 0 0 0 0 0 0 0 0 0 0 0
## [2,] 1 1 0 0 0 0 0 1 0 0 0 0 1
## [3,] 1 0 0 0 0 0 0 0 0 0 0 0 0
## [4,] 1 0 0 0 0 0 0 1 0 0 0 0 0
## [5,] 1 0 1 0 0 0 0 0 0 0 0 0 0
## [6,] 1 0 1 0 0 0 0 1 0 0 0 0 1
## [7,] 1 0 0 1 0 0 0 0 0 0 0 0 0
## [8,] 1 0 0 1 0 0 0 1 0 0 0 0 0
## [9,] 1 0 0 0 1 0 0 0 0 0 0 0 0
## [10,] 1 0 0 0 1 0 1 0 0 0 0 0 0
## [11,] 1 0 0 0 0 1 0 0 0 0 0 0 0
## [12,] 1 0 0 0 0 1 1 0 0 0 0 0 0
## [,14] [,15] [,16]
## [1,] 0 0 0
## [2,] 0 0 0
## [3,] 0 0 0
## [4,] 0 0 0
## [5,] 0 0 0
```

```
## [6,] 0 0 0
## [7,] 0 0 0
## [8,] 1 0 0
## [9,] 0 0 0
## [10,] 0 1 0
## [11,] 0 0 0
## [12,] 0 0 1
```

```
means <- means_matrix %*% fixed_effects
print(cbind(means,groups[,2:3]))
```

```
##           means Type pathlength
## 1 -0.04960052    U           1
## 2 -0.09562095    R           1
## 3  0.10634213    U           2
## 4  0.11358730    R           2
## 5  0.10509759    U           3
## 6  0.20946469    R           3
## 7  0.05220906    U           4
## 8  0.12176354    R           4
## 9  0.06633809    U           6
## 10 0.19285491    R           6
## 11 -0.05532132    U          15
## 12 0.03510563    R          15
```

```
contrast_matrix <- matrix(c(
  0,1,-1,0,0,0,0,0,0,0,0,0,
  0,0,1,0,-1,0,0,0,0,0,0,0,
  0,0,1,0,0,0,-1,0,0,0,0,0,
  0,0,1,0,0,0,-1,0,0,0,0,0,
  0,0,0,0,0,0,1,0,-1,0,0,0,
  0,0,0,0,0,0,0,1,0,-1,0), nrow=5,ncol=12,byrow=TRUE)
row.names(contrast_matrix) <- c("path 1, related vs. path 2, unrelated",
                                "path 2, unrelated vs. path 3, unrelated",
                                "path 2, unrelated vs. path 4, unrelated",
                                "path 4, unrelated vs. path 6, unrelated",
                                "path 6, unrelated vs. path 15, unrelated")
```

```
matrix_for_glht <-contrast_matrix %*% means_matrix
matrix_for_glht
```

```
##           [,1] [,2] [,3] [,4] [,5] [,6]
## path 1, related vs. path 2, unrelated      0      1      0      0      0      0
## path 2, unrelated vs. path 3, unrelated      0      0     -1      0      0      0
## path 2, unrelated vs. path 4, unrelated      0      0      0     -1      0      0
## path 4, unrelated vs. path 6, unrelated      0      0      0      1     -1      0
## path 6, unrelated vs. path 15, unrelated      0      0      0      0      1     -1
##           [,7] [,8] [,9] [,10] [,11] [,12]
## path 1, related vs. path 2, unrelated      1      0      0      0      0      1
## path 2, unrelated vs. path 3, unrelated      0      0      0      0      0      0
## path 2, unrelated vs. path 4, unrelated      0      0      0      0      0      0
## path 4, unrelated vs. path 6, unrelated      0      0      0      0      0      0
## path 6, unrelated vs. path 15, unrelated      0      0      0      0      0      0
##           [,13] [,14] [,15] [,16]
## path 1, related vs. path 2, unrelated      0      0      0      0
## path 2, unrelated vs. path 3, unrelated      0      0      0      0
```

```

## path 2, unrelated vs. path 4, unrelated      0      0      0      0
## path 4, unrelated vs. path 6, unrelated      0      0      0      0
## path 6, unrelated vs. path 15, unrelated     0      0      0      0

matrix_for_glht <-contrast_matrix %*% means_matrix
matrix_for_glht

##              [,1] [,2] [,3] [,4] [,5] [,6]
## path 1, related vs. path 2, unrelated      0      1      0      0      0      0
## path 2, unrelated vs. path 3, unrelated      0      0     -1      0      0      0
## path 2, unrelated vs. path 4, unrelated      0      0      0     -1      0      0
## path 4, unrelated vs. path 6, unrelated      0      0      0      1     -1      0
## path 6, unrelated vs. path 15, unrelated     0      0      0      0      1     -1
##              [,7] [,8] [,9] [,10] [,11] [,12]
## path 1, related vs. path 2, unrelated      1      0      0      0      0      1
## path 2, unrelated vs. path 3, unrelated      0      0      0      0      0      0
## path 2, unrelated vs. path 4, unrelated      0      0      0      0      0      0
## path 4, unrelated vs. path 6, unrelated      0      0      0      0      0      0
## path 6, unrelated vs. path 15, unrelated     0      0      0      0      0      0
##              [,13] [,14] [,15] [,16]
## path 1, related vs. path 2, unrelated      0      0      0      0
## path 2, unrelated vs. path 3, unrelated      0      0      0      0
## path 2, unrelated vs. path 4, unrelated      0      0      0      0
## path 4, unrelated vs. path 6, unrelated      0      0      0      0
## path 6, unrelated vs. path 15, unrelated     0      0      0      0

glht_sem <- multcomp::glht(m1_all_elp_type,
                           linfct = matrix_for_glht,
                           alternative = "two.sided", rhs = 0)
summary(glht_sem)

##
## Simultaneous Tests for General Linear Hypotheses
##
## Fit: lme4::lmer(formula = zRT_trim ~ pathlengthfac * Type + mean_len_c +
## mean_logf_c + mean_ldtz_c + mean_conc_c + (1 | subject) +
## (1 | trial_index) + +(1 | target_word), data = final_sem)
##
## Linear Hypotheses:
##
##              Estimate Std. Error
## path 1, related vs. path 2, unrelated == 0    -0.201963    0.031584
## path 2, unrelated vs. path 3, unrelated == 0     0.001245    0.030117
## path 2, unrelated vs. path 4, unrelated == 0     0.054133    0.030385
## path 4, unrelated vs. path 6, unrelated == 0    -0.014129    0.035682
## path 6, unrelated vs. path 15, unrelated == 0     0.121659    0.040525
##              z value Pr(>|z|)
## path 1, related vs. path 2, unrelated == 0     -6.395    <0.001 ***
## path 2, unrelated vs. path 3, unrelated == 0      0.041    1.0000
## path 2, unrelated vs. path 4, unrelated == 0      1.782    0.2870
## path 4, unrelated vs. path 6, unrelated == 0     -0.396    0.9949
## path 6, unrelated vs. path 15, unrelated == 0      3.002    0.0128 *
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
## (Adjusted p values reported -- single-step method)

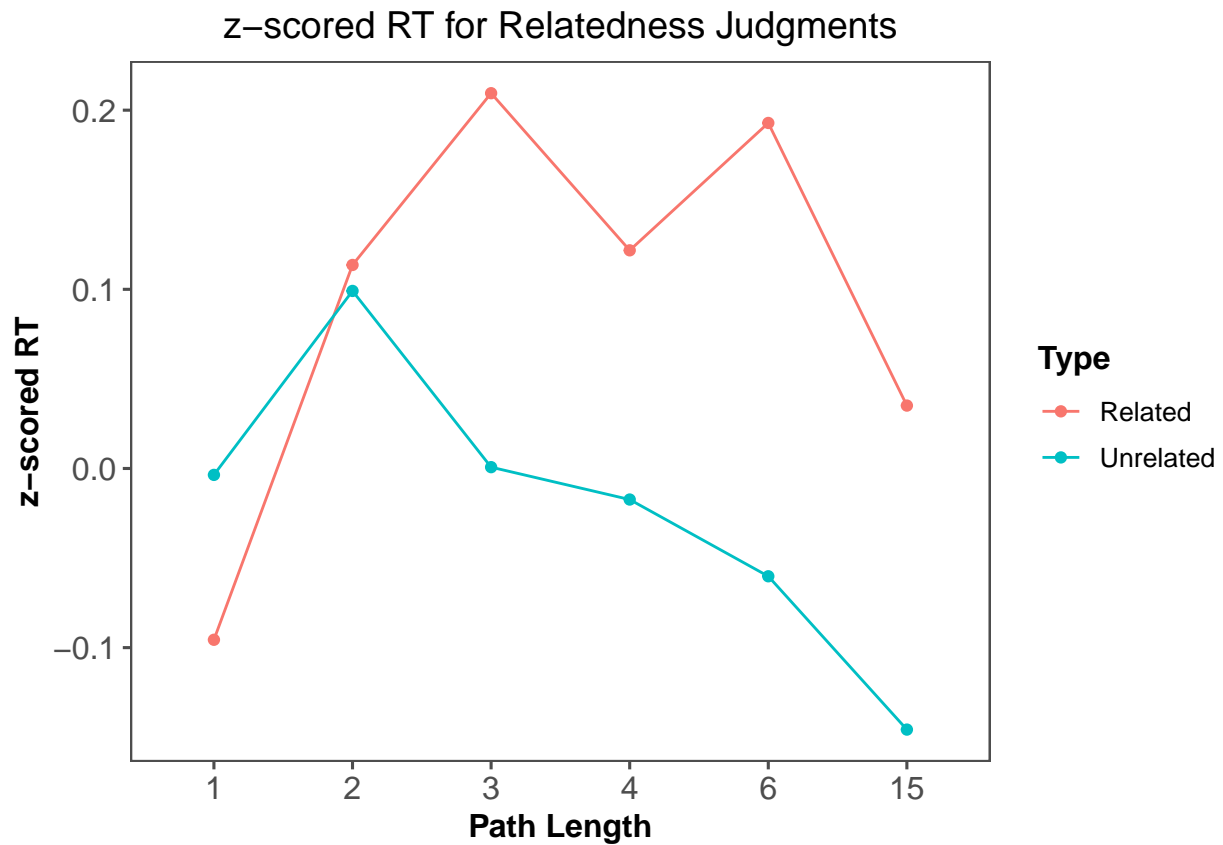
```

Plot

```
mean_length = mean(final_sem$mean_len_c, na.rm = TRUE)
mean_logfreq = mean(final_sem$mean_logf_c, na.rm = TRUE)
mean_lexdec = mean(final_sem$mean_ldtz_c, na.rm = TRUE)
mean_concreteness = mean(final_sem$mean_conc_c, na.rm = TRUE)

fixed.frame <-
  data.frame(expand.grid( pathlengthfac = c("1","2", "3",
                                           "4", "6", "15"),
                        Type= c("Related", "Unrelated"),
                        mean_len_c = mean_length,
                        mean_logf_c = mean_logfreq,
                        mean_ldtz_c = mean_lexdec,
                        mean_conc_c = mean_concreteness)) %>%
  mutate(pred = predict(m1_all_elp_type, newdata = ., re.form = NA))

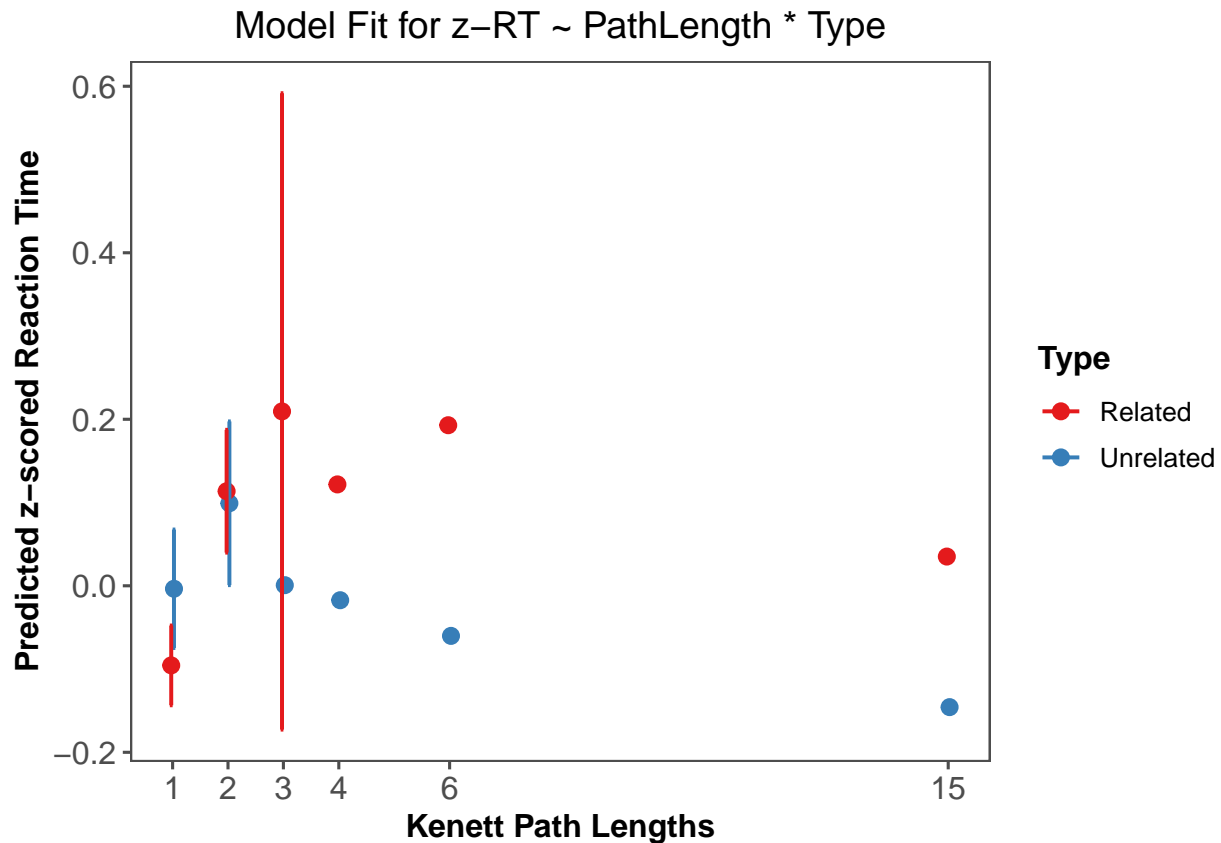
fixed.frame %>%
  mutate(Pathlength = factor(pathlengthfac,
                             levels = unique(pathlengthfac),
                             labels = c("1","2", "3",
                                         "4", "6", "15"))) %>%
ggplot(aes(x = Pathlength, y = pred, group = Type, color = Type))+
  geom_point()+
  geom_line()+
  # geom_smooth(method = "loess")+
  #geom_line(color = "green")+
  theme_few()+
  xlab("Path Length") + ylab("z-scored RT") +
  ggtitle("z-scored RT for Relatedness Judgments") +
  theme(axis.text = element_text(size = rel(1)),
        axis.title = element_text(face = "bold", size = rel(1)),
        legend.title = element_text(face = "bold", size = rel(1)),
        plot.title = element_text(hjust = .5),
        strip.text.x = element_text(face = "bold", size = rel(1.4)))
```



SjPlot Model

```
x = sjPlot::plot_model(m1_all_elp_type, type = "int")
x + theme_few() +
  xlab("Kenett Path Lengths") +
  ylab("Predicted z-scored Reaction Time") +
  ggtitle("Model Fit for z-RT ~ PathLength * Type") +
  theme(axis.text = element_text(size = rel(1)),
        axis.title = element_text(face = "bold", size = rel(1)),
        legend.title = element_text(face = "bold", size = rel(1)),
        plot.title = element_text(hjust = .5),
        strip.text.x = element_text(face = "bold", size = rel(1.4)))
```

```
## Warning: Removed 7 rows containing missing values (geom_errorbar).
```



Quadratic Model

```
## TESTING QUADRATIC TREND
m3_linear = lmer(data = final_sem, zRT_trim ~ pathlength +
                 mean_len + mean_logf + mean_ldtz + mean_conc +
                 (1|subject) + (1|trial_index) +
                 (1|target_word))
summary(m3_linear)

## Linear mixed model fit by REML ['lmerMod']
## Formula:
## zRT_trim ~ pathlength + mean_len + mean_logf + mean_ldtz + mean_conc +
## (1 | subject) + (1 | trial_index) + (1 | target_word)
## Data: final_sem
##
## REML criterion at convergence: 46240.3
##
## Scaled residuals:
##      Min       1Q   Median       3Q      Max
## -2.6177 -0.7124 -0.1957  0.5445  4.0803
##
## Random effects:
## Groups      Name                Variance Std.Dev.
## target_word (Intercept) 0.027446 0.16567
## trial_index (Intercept) 0.003608 0.06007
```

```

## subject      (Intercept) 0.000000 0.00000
## Residual              0.953658 0.97655
## Number of obs: 16390, groups:
## target_word, 1741; trial_index, 240; subject, 80
##
## Fixed effects:
##              Estimate Std. Error t value
## (Intercept)  0.315882   0.102808   3.073
## pathlength  -0.011034   0.001790  -6.164
## mean_len     0.013863   0.006928   2.001
## mean_logf    -0.008944   0.008288  -1.079
## mean_ldtz     0.017111   0.064709   0.264
## mean_conc    -0.071214   0.011092  -6.420
##
## Correlation of Fixed Effects:
##              (Intr) pthlng men_ln mn_lgf mn_ldt
## pathlength  -0.116
## mean_len    -0.603  0.042
## mean_logf   -0.665  0.016 -0.007
## mean_ldtz   0.010 -0.006 -0.362  0.548
## mean_conc   -0.678 -0.012  0.240  0.314  0.111

m3_quad = lmer(data = final_sem, zRT_trim ~ pathlength + I((pathlength)^2) +
              mean_len + mean_logf + mean_ldtz + mean_conc +
              (1|subject) + (1|trial_index) +
              + (1|target_word))
summary(m3_quad)

## Linear mixed model fit by REML ['lmerMod']
## Formula:
## zRT_trim ~ pathlength + I((pathlength)^2) + mean_len + mean_logf +
## mean_ldtz + mean_conc + (1 | subject) + (1 | trial_index) +
## +(1 | target_word)
## Data: final_sem
##
## REML criterion at convergence: 46247.5
##
## Scaled residuals:
##      Min       1Q   Median       3Q      Max
## -2.5911 -0.7117 -0.1948  0.5460  4.0659
##
## Random effects:
## Groups      Name                Variance Std.Dev.
## target_word (Intercept) 2.736e-02 1.654e-01
## trial_index (Intercept) 3.656e-03 6.047e-02
## subject     (Intercept) 6.770e-49 8.228e-25
## Residual                    9.534e-01 9.764e-01
## Number of obs: 16390, groups:
## target_word, 1741; trial_index, 240; subject, 80
##
## Fixed effects:
##              Estimate Std. Error t value
## (Intercept)    0.2524722  0.1059372   2.383
## pathlength      0.0103305  0.0088504   1.167
## I((pathlength)^2) -0.0012753  0.0005174  -2.465

```

```
## mean_len          0.0146950  0.0069336  2.119
## mean_logf        -0.0083107  0.0082892 -1.003
## mean_ldtz         0.0164802  0.0646858  0.255
## mean_conc         -0.0700390  0.0110980 -6.311
##
## Correlation of Fixed Effects:
##          (Intr) pthlng I((^2 men_ln mn_lgf mn_ldt
## pathlength -0.260
## I((pthl)^2)  0.243 -0.979
## mean_len    -0.596  0.056 -0.049
## mean_logf   -0.652  0.034 -0.031 -0.005
## mean_ldtz    0.011 -0.005  0.004 -0.362  0.548
## mean_conc   -0.668  0.040 -0.043  0.242  0.315  0.111
anova(m3_linear, m3_quad)

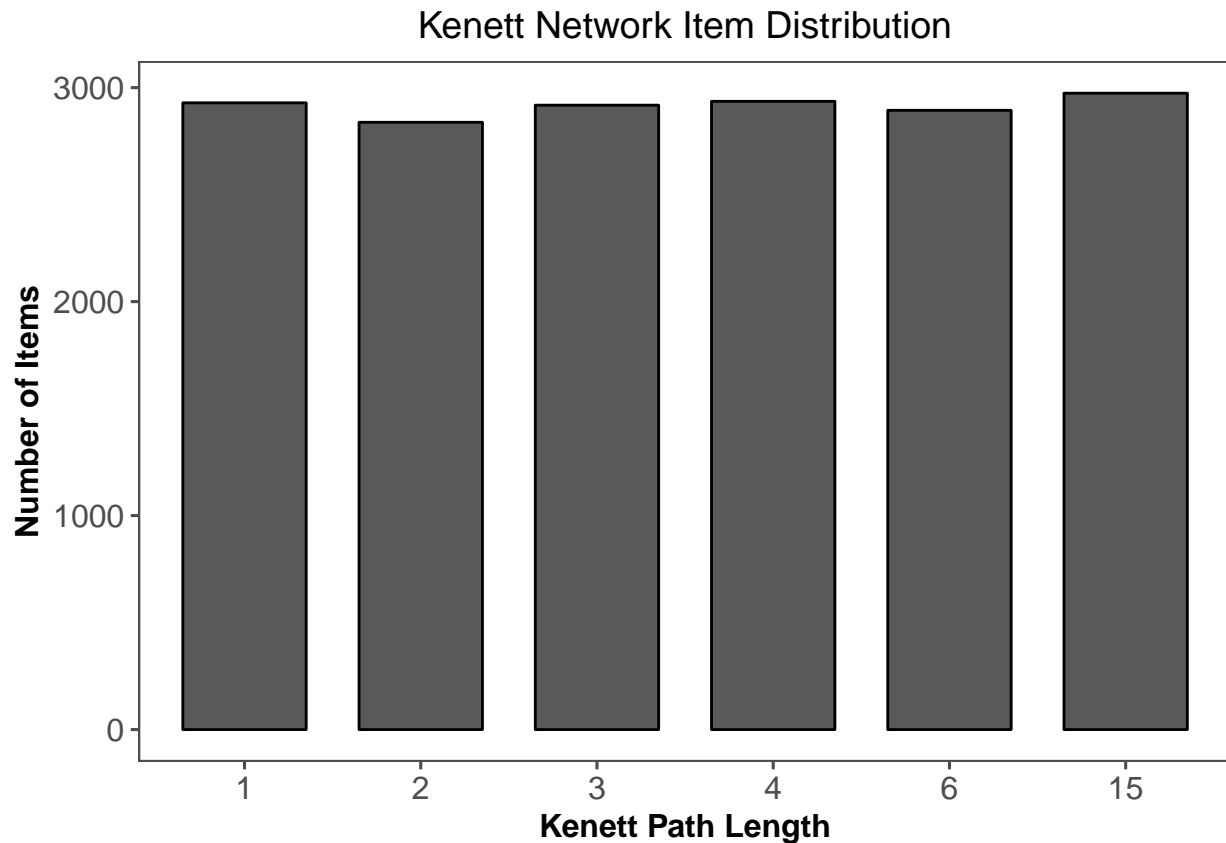
## refitting model(s) with ML (instead of REML)
## Data: final_sem
## Models:
## m3_linear: zRT_trim ~ pathlength + mean_len + mean_logf + mean_ldtz + mean_conc +
## m3_linear:      (1 | subject) + (1 | trial_index) + +(1 | target_word)
## m3_quad: zRT_trim ~ pathlength + I((pathlength)^2) + mean_len + mean_logf +
## m3_quad:      mean_ldtz + mean_conc + (1 | subject) + (1 | trial_index) +
## m3_quad:      +(1 | target_word)
##          Df   AIC   BIC logLik deviance  Chisq Chi Df Pr(>Chisq)
## m3_linear 10 46215 46292 -23097    46195
## m3_quad   11 46211 46295 -23094    46189 6.0783     1  0.01368 *
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

Other Networks

Kenett Path Length

```
items_kenett = group_by(final_sem, pathlength) %>%
  summarise(items = n())

items_kenett$pathlength = as.factor(items_kenett$pathlength)
ggplot(items_kenett, aes(x = pathlength, y = items))+
  geom_bar(stat = "identity", position = "dodge", width = 0.7, color= "black")+
  theme_few()+
  xlab("Kenett Path Length") + ylab("Number of Items") +
  ggtitle("Kenett Network Item Distribution") +
  theme(axis.text = element_text(size = rel(1)),
        axis.title = element_text(face = "bold", size = rel(1)),
        legend.title = element_text(face = "bold", size = rel(1)),
        plot.title = element_text(hjust = .5),
        strip.text.x = element_text(face = "bold", size = rel(1.4)))
```

Undirected

```

items_undirected = group_by(final_sem, undirected) %>%
  summarise(items = n())

items_undirected_subject = group_by(final_sem, subject, undirected) %>%
  summarise(items = n())

undirected_rmisc = Rmisc::summarySE(items_undirected_subject,
  measurevar = "items",
  groupvars = c("undirected"))

final_sem$undirectedfac = ordered(as.factor(as.character(final_sem$undirected)),
  levels = c("1", "2", "3", "4"))
contrasts(final_sem$undirectedfac) = contr.treatment(4, base = 2)

m_undirected = lmer(data = final_sem, zRT_trim ~ undirectedfac +
  mean_len + mean_logf + mean_ldtz + mean_conc +
  (1|subject) + (1|trial_index) +
  + (1|target_word))
summary(m_undirected)

## Linear mixed model fit by REML ['lmerMod']
## Formula: zRT_trim ~ undirectedfac + mean_len + mean_logf + mean_ldtz +

```

```

##      mean_conc + (1 | subject) + (1 | trial_index) + +(1 | target_word)
##      Data: final_sem
##
## REML criterion at convergence: 46172.5
##
## Scaled residuals:
##      Min       1Q   Median       3Q      Max
## -2.6393 -0.7123 -0.1985  0.5466  4.1166
##
## Random effects:
##      Groups          Name          Variance Std.Dev.
## target_word (Intercept) 0.023163 0.1522
## trial_index (Intercept) 0.003434 0.0586
## subject      (Intercept) 0.000000 0.0000
## Residual                0.952962 0.9762
## Number of obs: 16390, groups:
## target_word, 1741; trial_index, 240; subject, 80
##
## Fixed effects:
##              Estimate Std. Error t value
## (Intercept)    0.336313   0.101489   3.314
## undirectedfac1 -0.278769   0.030999  -8.993
## undirectedfac3 -0.094131   0.017983  -5.234
## undirectedfac4 -0.240761   0.035407  -6.800
## mean_len        0.015078   0.006830   2.208
## mean_logf       -0.003982   0.008179  -0.487
## mean_ldtz        0.047707   0.064167   0.743
## mean_conc       -0.080127   0.010950  -7.317
##
## Correlation of Fixed Effects:
##              (Intr) undrc1 undrc3 undrc4 men_ln mn_lgf mn_ldt
## undirctdfc1 -0.050
## undirctdfc3 -0.122  0.302
## undirctdfc4 -0.076  0.150  0.266
## mean_len    -0.600  0.003  0.014  0.016
## mean_logf   -0.660 -0.049  0.008 -0.023 -0.008
## mean_ldtz    0.017  0.009 -0.016 -0.106 -0.363  0.546
## mean_conc   -0.682  0.080  0.037  0.018  0.241  0.310  0.110

m_undirected_type = lmer(data = final_sem, zRT_trim ~ undirectedfac*Type +
                        mean_len_c + mean_logf_c + mean_ldtz_c + mean_conc_c +
                        (1|subject) + (1|trial_index) +
                        + (1|target_word))
summary(m_undirected_type)

## Linear mixed model fit by REML ['lmerMod']
## Formula: zRT_trim ~ undirectedfac * Type + mean_len_c + mean_logf_c +
##      mean_ldtz_c + mean_conc_c + (1 | subject) + (1 | trial_index) +
##      +(1 | target_word)
##      Data: final_sem
##
## REML criterion at convergence: 46109
##
## Scaled residuals:
##      Min       1Q   Median       3Q      Max

```

```

## -2.6960 -0.7115 -0.1921  0.5381  4.1838
##
## Random effects:
##   Groups      Name      Variance Std.Dev.
## target_word (Intercept) 0.020883 0.14451
## trial_index (Intercept) 0.003296 0.05741
## subject      (Intercept) 0.000000 0.00000
## Residual                0.950074 0.97472
## Number of obs: 16390, groups:
## target_word, 1741; trial_index, 240; subject, 80
##
## Fixed effects:
##               Estimate Std. Error t value
## (Intercept)      0.080808  0.013553  5.962
## undirectedfac1    -0.206014  0.035371 -5.824
## undirectedfac3    -0.023988  0.020786 -1.154
## undirectedfac4    -0.172530  0.059740 -2.888
## Type1              0.050177  0.012291  4.082
## mean_len_c         0.011838  0.006793  1.743
## mean_logf_c        -0.005793  0.008106 -0.715
## mean_ldtz_c         0.051060  0.063614  0.803
## mean_conc_c        -0.077908  0.010848 -7.182
## undirectedfac1:Type1 -0.184880  0.033675 -5.490
## undirectedfac3:Type1  0.061184  0.020029  3.055
## undirectedfac4:Type1  0.035122  0.058381  0.602
##
## Correlation of Fixed Effects:
##      (Intr) undrc1 undrc3 undrc4 Type1 mn_ln_ mn_lg_ mn_ld_ mn_cn_
## undirctdfc1 -0.351
## undirctdfc3 -0.588  0.230
## undirctdfc4 -0.207  0.078  0.136
## Type1        0.076 -0.028 -0.049 -0.016
## mean_len_c   -0.012  0.010 -0.004  0.011 -0.068
## mean_logf_c   0.005 -0.051 -0.003 -0.012 -0.006 -0.007
## mean_ldtz_c   0.017 -0.003 -0.006 -0.063  0.007 -0.364  0.545
## mean_conc_c  -0.042  0.066  0.048  0.025 -0.003  0.240  0.309  0.110
## undrctd1:T1 -0.028 -0.450  0.018  0.005 -0.365  0.014  0.019  0.017  0.009
## undrctd3:T1 -0.047  0.022  0.435  0.011 -0.610  0.011 -0.012  0.008  0.026
## undrctd4:T1 -0.017  0.007  0.012  0.794 -0.210  0.014  0.003 -0.002  0.018
##      un1:T1 un3:T1
## undirctdfc1
## undirctdfc3
## undirctdfc4
## Type1
## mean_len_c
## mean_logf_c
## mean_ldtz_c
## mean_conc_c
## undrctd1:T1
## undrctd3:T1  0.223
## undrctd4:T1  0.077  0.130
car::Anova(m_undirected_type)

```

```
## Analysis of Deviance Table (Type II Wald chisquare tests)
```

```

##
## Response: zRT_trim
##               Chisq Df Pr(>Chisq)
## undirectedfac 120.5610 3 < 2.2e-16 ***
## Type          36.6745 1 1.396e-09 ***
## mean_len_c    3.0367 1 0.0814 .
## mean_logf_c   0.5107 1 0.4748
## mean_ldtz_c   0.6442 1 0.4222
## mean_conc_c   51.5786 1 6.879e-13 ***
## undirectedfac:Type 49.6846 3 9.325e-11 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

final_sem_success = final_sem %>%
  filter((undirectedfac == "1" & Type == "Related") |
         (undirectedfac == "2" & Type == "Unrelated") |
         (undirectedfac == "3" & Type == "Unrelated") |
         (undirectedfac == "4" & Type == "Unrelated"))

m_undirected_success = lmer(data = final_sem_success,
                           zRT_trim ~ undirectedfac +
                             mean_len_c + mean_logf_c + mean_ldtz_c + mean_conc_c +
                             (1|subject) + (1|trial_index) +
                             (1|target_word))
summary(m_undirected_type)

## Linear mixed model fit by REML ['lmerMod']
## Formula: zRT_trim ~ undirectedfac * Type + mean_len_c + mean_logf_c +
##          mean_ldtz_c + mean_conc_c + (1 | subject) + (1 | trial_index) +
##          (1 | target_word)
## Data: final_sem
##
## REML criterion at convergence: 46109
##
## Scaled residuals:
##      Min       1Q   Median       3Q      Max
## -2.6960 -0.7115 -0.1921  0.5381  4.1838
##
## Random effects:
##   Groups             Name             Variance Std.Dev.
## target_word (Intercept) 0.020883 0.14451
## trial_index (Intercept) 0.003296 0.05741
## subject      (Intercept) 0.000000 0.00000
## Residual                    0.950074 0.97472
## Number of obs: 16390, groups:
## target_word, 1741; trial_index, 240; subject, 80
##
## Fixed effects:
##              Estimate Std. Error t value
## (Intercept)    0.080808   0.013553   5.962
## undirectedfac1 -0.206014   0.035371  -5.824
## undirectedfac3 -0.023988   0.020786  -1.154
## undirectedfac4 -0.172530   0.059740  -2.888
## Type1          0.050177   0.012291   4.082
## mean_len_c     0.011838   0.006793   1.743

```

```
## mean_logf_c          -0.005793    0.008106   -0.715
## mean_ldtz_c          0.051060    0.063614    0.803
## mean_conc_c          -0.077908    0.010848   -7.182
## undirectedfac1:Type1 -0.184880    0.033675   -5.490
## undirectedfac3:Type1 0.061184    0.020029    3.055
## undirectedfac4:Type1 0.035122    0.058381    0.602
##
## Correlation of Fixed Effects:
##      (Intr) undrc1 undrc3 undrc4 Type1 mn_ln_ mn_lg_ mn_ld_ mn_cn_
## undirctdfc1 -0.351
## undirctdfc3 -0.588  0.230
## undirctdfc4 -0.207  0.078  0.136
## Type1       0.076 -0.028 -0.049 -0.016
## mean_len_c  -0.012  0.010 -0.004  0.011 -0.068
## mean_logf_c  0.005 -0.051 -0.003 -0.012 -0.006 -0.007
## mean_ldtz_c  0.017 -0.003 -0.006 -0.063  0.007 -0.364  0.545
## mean_conc_c -0.042  0.066  0.048  0.025 -0.003  0.240  0.309  0.110
## undrctd1:T1 -0.028 -0.450  0.018  0.005 -0.365  0.014  0.019  0.017  0.009
## undrctd3:T1 -0.047  0.022  0.435  0.011 -0.610  0.011 -0.012  0.008  0.026
## undrctd4:T1 -0.017  0.007  0.012  0.794 -0.210  0.014  0.003 -0.002  0.018
##      un1:T1 un3:T1
## undirctdfc1
## undirctdfc3
## undirctdfc4
## Type1
## mean_len_c
## mean_logf_c
## mean_ldtz_c
## mean_conc_c
## undrctd1:T1
## undrctd3:T1 0.223
## undrctd4:T1 0.077 0.130
```

```
car::Anova(m_undirected_type)
```

```
## Analysis of Deviance Table (Type II Wald chisquare tests)
```

```
##
```

```
## Response: zRT_trim
```

```
##           Chisq Df Pr(>Chisq)
## undirectedfac    120.5610  3 < 2.2e-16 ***
## Type             36.6745  1 1.396e-09 ***
## mean_len_c        3.0367  1   0.0814 .
## mean_logf_c        0.5107  1   0.4748
## mean_ldtz_c        0.6442  1   0.4222
## mean_conc_c       51.5786  1 6.879e-13 ***
## undirectedfac:Type 49.6846  3 9.325e-11 ***
```

```
## ---
```

```
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
m_undirected_linear = lmer(data = final_sem, zRT_trim ~ undirected +
                           mean_len + mean_logf + mean_ldtz + mean_conc +
                           (1|subject) + (1|trial_index) +
                           + (1|target_word))
```

```
final_sem$squadundirected = I(final_sem$undirected ^2)
```

```

m_undirected_quad = lmer(data = final_sem, zRT_trim ~ undirected +
                        quadundirected +
                        mean_len + mean_logf + mean_ldtz + mean_conc +
                        (1|subject) + (1|trial_index) +
                        + (1|target_word))
summary(m_undirected_quad)

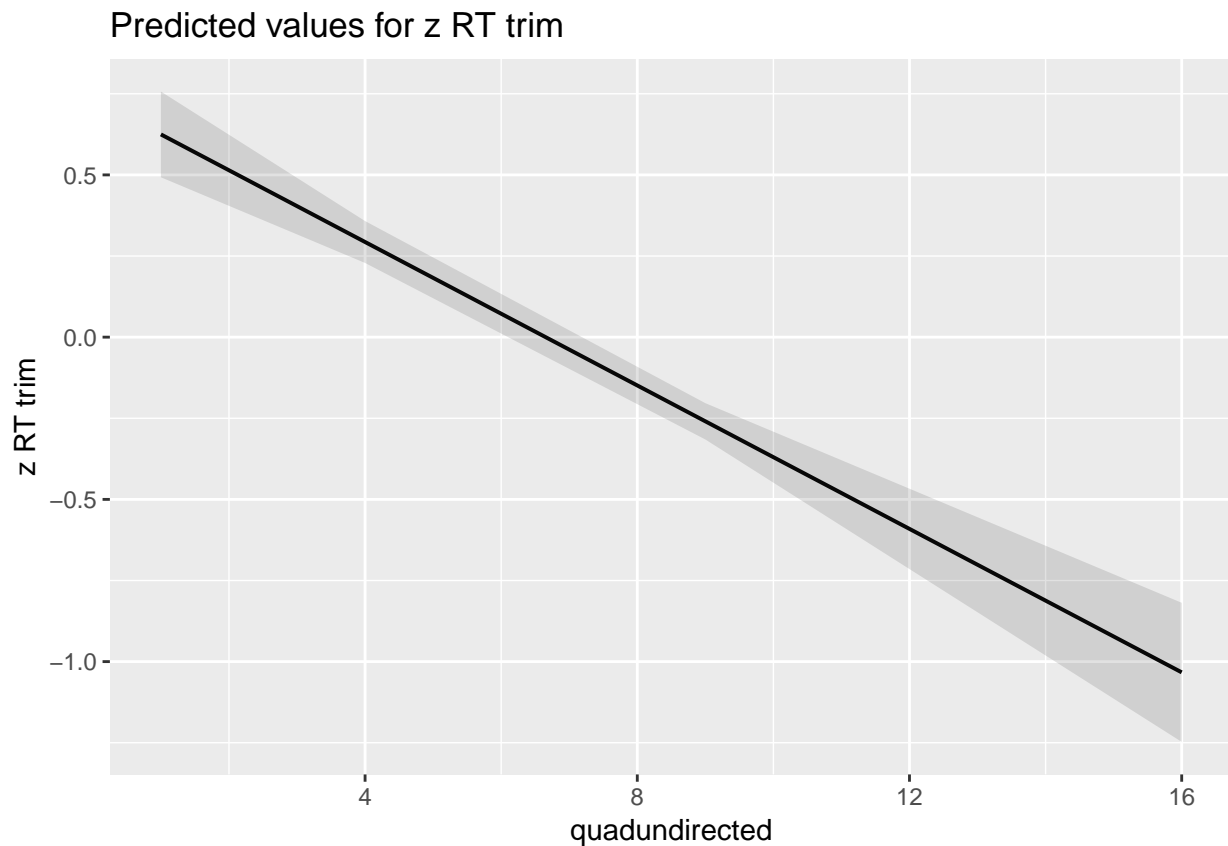
## Linear mixed model fit by REML ['lmerMod']
## Formula: zRT_trim ~ undirected + quadundirected + mean_len + mean_logf +
##      mean_ldtz + mean_conc + (1 | subject) + (1 | trial_index) +
##      +(1 | target_word)
##      Data: final_sem
##
## REML criterion at convergence: 46191.7
##
## Scaled residuals:
##      Min       1Q   Median       3Q      Max
## -2.6081 -0.7142 -0.1969  0.5455  4.0848
##
## Random effects:
##      Groups      Name      Variance Std.Dev.
## target_word (Intercept) 0.024454 0.15638
## trial_index (Intercept) 0.003362 0.05798
## subject      (Intercept) 0.000000 0.00000
## Residual                0.953191 0.97632
## Number of obs: 16390, groups:
## target_word, 1741; trial_index, 240; subject, 80
##
## Fixed effects:
##              Estimate Std. Error t value
## (Intercept)  -0.304249   0.122987  -2.474
## undirected    0.523366   0.058284   8.980
## quadundirected -0.110522   0.011716  -9.433
## mean_len       0.015122   0.006858   2.205
## mean_logf      -0.004177   0.008216  -0.508
## mean_ldtz      0.060984   0.064381   0.947
## mean_conc     -0.077405   0.010987  -7.045
##
## Correlation of Fixed Effects:
##              (Intr) undrct qdndrc men_ln mn_lgf mn_ldt
## undirected  -0.548
## quadundrctd  0.508 -0.981
## mean_len     -0.495 -0.005  0.009
## mean_logf    -0.581  0.057 -0.053 -0.008
## mean_ldtz    -0.005  0.049 -0.065 -0.363  0.546
## mean_conc    -0.528 -0.059  0.057  0.241  0.310  0.108
anova(m_undirected_linear, m_undirected_quad)

## refitting model(s) with ML (instead of REML)
## Data: final_sem
## Models:
## m_undirected_linear: zRT_trim ~ undirected + mean_len + mean_logf + mean_ldtz + mean_conc +
## m_undirected_linear:      (1 | subject) + (1 | trial_index) + +(1 | target_word)

```

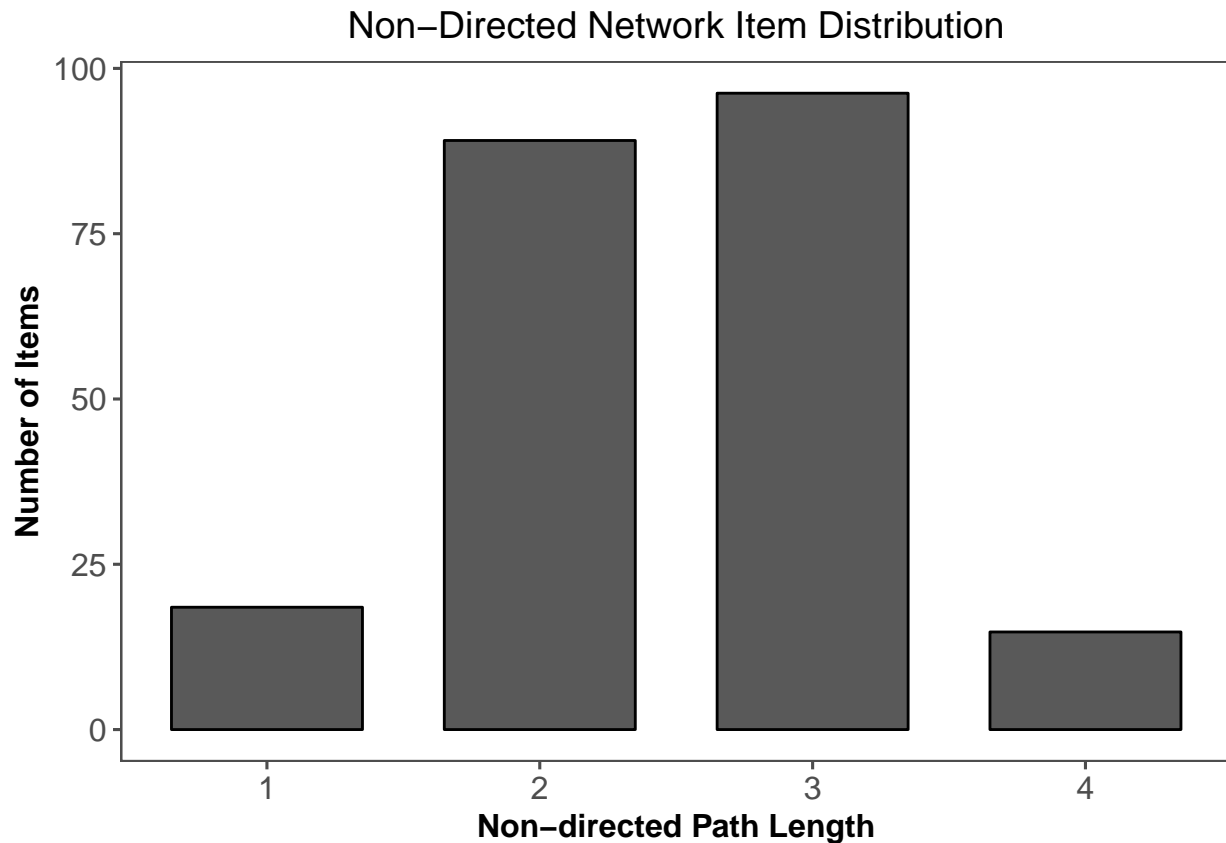
```
## m_undirected_quad: zRT_trim ~ undirected + quadundirected + mean_len + mean_logf +
## m_undirected_quad:      mean_ldtz + mean_conc + (1 | subject) + (1 | trial_index) +
## m_undirected_quad:      +(1 | target_word)
##               Df    AIC    BIC logLik deviance  Chisq Chi Df
## m_undirected_linear 10 46251 46328 -23115    46231
## m_undirected_quad   11 46165 46249 -23071    46143 87.975    1
##               Pr(>Chisq)
## m_undirected_linear
## m_undirected_quad    < 2.2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

sjPlot::plot_model(m_undirected_quad, type = "pred", terms = "quadundirected")
```



Plot Item Distribution

```
ggplot(undirected_rmisc, aes(x = undirected, y = items))+
  geom_bar(stat = "identity", position = "dodge", width = 0.7, color= "black")+
  theme_few()+
  xlab("Non-directed Path Length") + ylab("Number of Items") +
  ggtitle("Non-Directed Network Item Distribution") +
  theme(axis.text = element_text(size = rel(1)),
        axis.title = element_text(face = "bold", size = rel(1)),
        legend.title = element_text(face = "bold", size = rel(1)),
        plot.title = element_text(hjust = .5),
        strip.text.x = element_text(face = "bold", size = rel(1.4)))
```



Plot Undirected

```

z_undirected_rmisc = Rmisc::summarySE(final_sem,
  measurevar = "zRT_trim",
  groupvars = c("undirectedfac", "Type"))

z_undirected_rmisc$undirectedfac = ordered(as.factor(as.character(z_undirected_rmisc$undirectedfac)),

z_undirected_rmisc$zRT_trim = as.numeric(z_undirected_rmisc$zRT_trim)

library(ggplot2)
library(ggthemes)

z_undirected_rmisc %>%
  mutate(Decision = factor(Type,
    levels = unique(Type),
    labels = c("Related", "Unrelated"))) %>%
  ggplot(aes(x = undirectedfac, y = zRT_trim, group = Decision, color = Decision))+
  geom_point()+
  # geom_smooth(method = "loess")+
  geom_line()+
  geom_errorbar(aes(ymin=zRT_trim - ci, ymax=zRT_trim + ci),
    width=.2, color = "gray30",
    position = position_dodge(0.05))+
  theme_few()

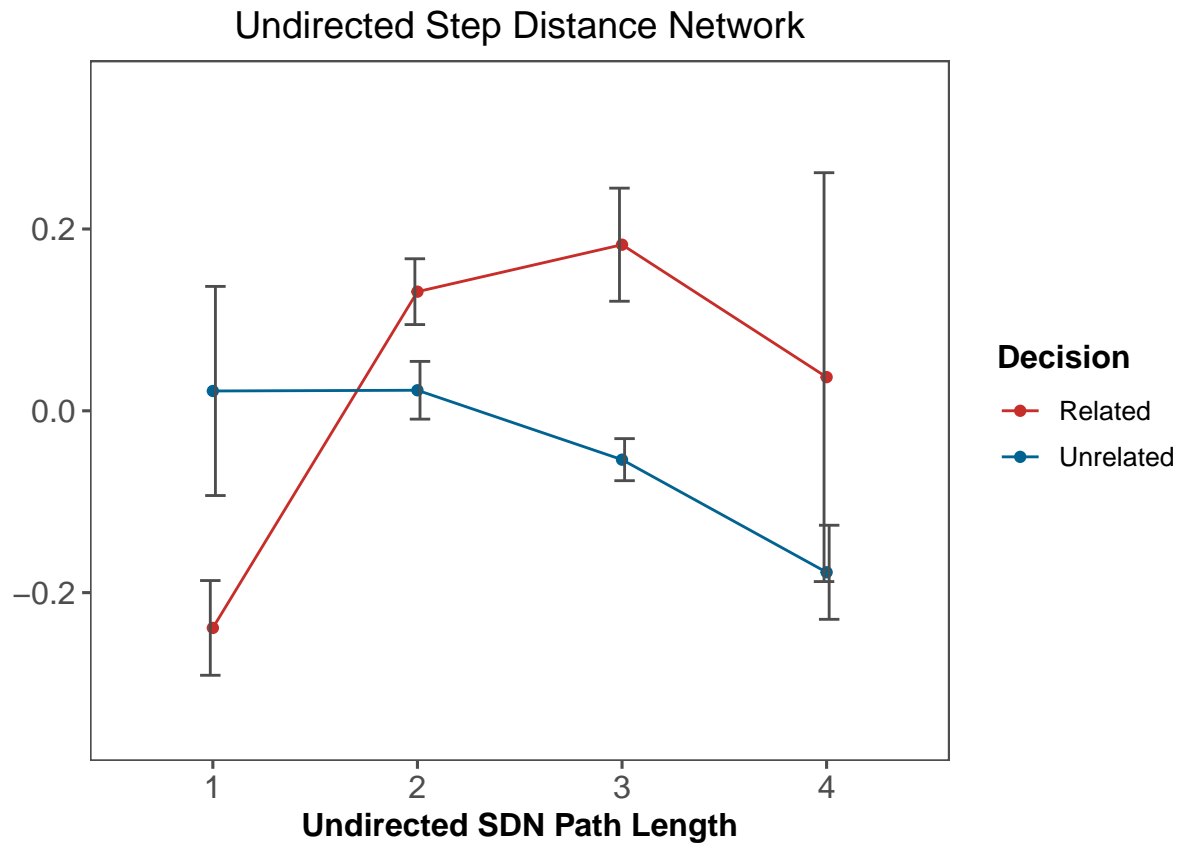
```



```

ylim(-0.35, 0.35)+
scale_color_wsj()+
#scale_x_continuous(breaks = c(1,2,3,4,5,6,10,15,20))+
xlab("Undirected SDN Path Length") + ylab("") +
ggtitle("Undirected Step Distance Network") +
theme(axis.text = element_text(size = rel(1)),
      axis.title = element_text(face = "bold", size = rel(1)),
      legend.title = element_text(face = "bold", size = rel(1)),
      plot.title = element_text(hjust = .5),
      strip.text.x = element_text(face = "bold", size = rel(1.4)))

```



Directed

```

final_sem$newdirected = ifelse(final_sem$directed == "Inf" |
                              final_sem$directed == "NA", NA,
                              final_sem$directed)

final_sem$directedcollapsed = ifelse(( final_sem$newdirected == "6" |
                                       final_sem$newdirected == "7" |
                                       final_sem$newdirected == "8"), "H",
                                       final_sem$newdirected)

items_directed = group_by(final_sem, newdirected) %>%
  summarise(items = n())

```

```

items_directed_subject = group_by(final_sem, subject, newdirected) %>%
  summarise(items = n())

directed_rmisc = Rmisc::summarySE(items_directed_subject,
  measurevar = "items",
  groupvars = c("newdirected"))

final_sem$directedfac =
  ordered(as.factor(as.character(final_sem$newdirected))),
  levels = c("1", "2", "3", "4", "5",
    "6", "7", "8"))
contrasts(final_sem$directedfac) = contr.treatment(8, base = 2)

final_sem$collapsedfac =
  ordered(as.factor(as.character(final_sem$directedcollapsed))),
  levels = c("1", "2", "3", "4", "5", "H"))
contrasts(final_sem$collapsedfac) = contr.treatment(6, base = 2)

m_directed = lme4::lmer(data = final_sem, zRT_trim ~ collapsedfac +
  mean_len + mean_logf + mean_ldtz + mean_conc +
  (1|subject) + (1|trial_index) +
  + (1|target_word))
summary(m_directed)

## Linear mixed model fit by REML ['lmerMod']
## Formula: zRT_trim ~ collapsedfac + mean_len + mean_logf + mean_ldtz +
##      mean_conc + (1 | subject) + (1 | trial_index) + (1 | target_word)
## Data: final_sem
##
## REML criterion at convergence: 44514.3
##
## Scaled residuals:
##      Min       1Q   Median       3Q      Max
## -2.5912 -0.7163 -0.1977  0.5463  4.0248
##
## Random effects:
##   Groups      Name      Variance Std.Dev.
## target_word (Intercept) 0.026530 0.16288
## trial_index (Intercept) 0.003269 0.05717
## subject      (Intercept) 0.000000 0.00000
## Residual                0.953879 0.97667
## Number of obs: 15778, groups:
## target_word, 1673; trial_index, 240; subject, 80
##
## Fixed effects:
##              Estimate Std. Error t value
## (Intercept)   0.311816   0.108500   2.874
## collapsedfac1 -0.214657   0.040746  -5.268
## collapsedfac3  0.048473   0.028336   1.711
## collapsedfac4 -0.025313   0.026417  -0.958
## collapsedfac5 -0.091190   0.029539  -3.087
## collapsedfac6 -0.011259   0.041298  -0.273
## mean_len       0.013623   0.007061   1.929

```

```

## mean_logf      -0.006138   0.008484  -0.724
## mean_ldtz      0.045511   0.066514   0.684
## mean_conc      -0.079788   0.011362  -7.022
##
## Correlation of Fixed Effects:
##      (Intr) cllps1 cllps3 cllps4 cllps5 cllps6 men_ln mn_lgf mn_ldt
## collapstdfc1 -0.115
## collapstdfc3 -0.146  0.402
## collapstdfc4 -0.199  0.432  0.620
## collapstdfc5 -0.197  0.386  0.555  0.607
## collapstdfc6 -0.193  0.280  0.397  0.433  0.403
## mean_len     -0.594  0.011 -0.009  0.007 -0.004  0.018
## mean_logf     -0.660 -0.033 -0.002  0.021  0.034  0.042  0.005
## mean_ldtz      0.031 -0.001 -0.006 -0.019 -0.047 -0.065 -0.366  0.534
## mean_conc     -0.678  0.073 -0.004  0.034  0.035  0.084  0.249  0.322  0.102

m_directed_type = lme4::lmer(data = final_sem, zRT_trim ~ directedfac*Type +
                             mean_len_c + mean_logf_c + mean_ldtz_c + mean_conc_c +
                             (1|subject) + (1|trial_index) +
                             + (1|target_word))
summary(m_directed_type)

## Linear mixed model fit by REML ['lmerMod']
## Formula:
## zRT_trim ~ directedfac * Type + mean_len_c + mean_logf_c + mean_ldtz_c +
##      mean_conc_c + (1 | subject) + (1 | trial_index) + +(1 | target_word)
##      Data: final_sem
##
## REML criterion at convergence: 44442.4
##
## Scaled residuals:
##      Min       1Q   Median       3Q      Max
## -2.5844 -0.7121 -0.1874  0.5423  4.0774
##
## Random effects:
##      Groups      Name      Variance Std.Dev.
## target_word (Intercept) 0.022793 0.15097
## trial_index (Intercept) 0.003194 0.05651
## subject      (Intercept) 0.000000 0.00000
## Residual                0.950535 0.97495
## Number of obs: 15778, groups:
## target_word, 1673; trial_index, 240; subject, 80
##
## Fixed effects:
##              Estimate Std. Error t value
## (Intercept)    0.028435   0.022047  1.290
## directedfac1   -0.119271   0.046273 -2.578
## directedfac3    0.062237   0.028858  2.157
## directedfac4    0.021560   0.027911  0.772
## directedfac5    0.012038   0.032574  0.370
## directedfac6    0.027516   0.048385  0.569
## directedfac7   -0.082577   0.113457 -0.728
## directedfac8    0.316385   0.217767  1.453
## Type1          -0.012283   0.020416 -0.602
## mean_len_c      0.009983   0.006997  1.427

```

```
## mean_logf_c      -0.007765    0.008368   -0.928
## mean_ldtz_c      0.050858    0.065661    0.775
## mean_conc_c      -0.076973    0.011223   -6.858
## directedfac1:Type1 -0.152221    0.044035   -3.457
## directedfac3:Type1 0.058693    0.027394    2.143
## directedfac4:Type1 0.101464    0.026540    3.823
## directedfac5:Type1 0.183593    0.030845    5.952
## directedfac6:Type1 0.067104    0.046052    1.457
## directedfac7:Type1 0.137482    0.108368    1.269
## directedfac8:Type1 0.114581    0.204589    0.560

##
## Correlation matrix not shown by default, as p = 20 > 12.
## Use print(x, correlation=TRUE) or
##      vcov(x)          if you need it
```

Plot directed

```
z_directed_rmisc = Rmisc::summarySE(final_sem,
                                     measurevar = "zRT_trim",
                                     groupvars = c("directedfac", "Type"))

z_directed_rmisc$collapsedfac2 = ordered(as.factor(as.character(z_directed_rmisc$directedfac))),

z_directed_rmisc = z_directed_rmisc %>% filter(collapsedfac2 != "NA")

z_directed_rmisc$zRT_trim = as.numeric(z_directed_rmisc$zRT_trim)

z_directed_rmisc = z_directed_rmisc %>% filter(! collapsedfac2 > 5)

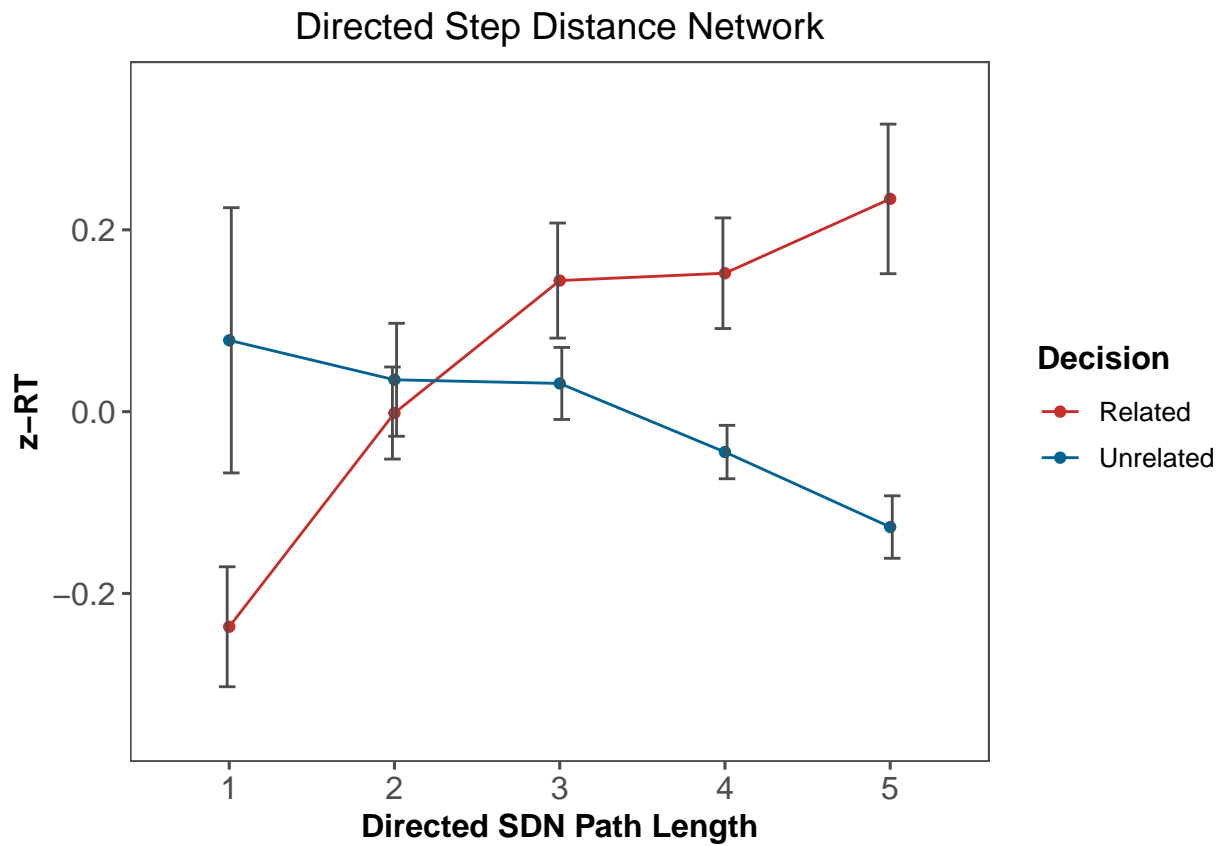
library(ggplot2)
library(ggthemes)

z_directed_rmisc %>%
  mutate(Decision = factor(Type,
                           levels = unique(Type),
                           labels = c("Related", "Unrelated"))) %>%
  ggplot(aes(x = collapsedfac2, y = zRT_trim, group = Decision, color = Decision))+
  geom_point()+
  # geom_smooth(method = "loess")+
  geom_line()+
  geom_errorbar(aes(ymin=zRT_trim - ci, ymax=zRT_trim + ci),
               width=.2, color = "gray30",
               position = position_dodge(0.05))+
  theme_few()+
  ylim(-0.35, 0.35)+
  scale_color_wsj()+
  #scale_x_continuous(breaks = c(1,2,3,4,5,6,10,15,20))+
  xlab("Directed SDN Path Length") + ylab("z-RT") +
  ggtitle("Directed Step Distance Network") +
  theme(axis.text = element_text(size = rel(1)),
        axis.title = element_text(face = "bold", size = rel(1)),
```

```

legend.title = element_text(face = "bold", size = rel(1)),
plot.title = element_text(hjust = .5),
strip.text.x = element_text(face = "bold", size = rel(1.4))

```



Plot collapsed directed

```

z_directed_rmisc = Rmisc::summarySE(final_sem,
  measurevar = "zRT_trim",
  groupvars = c("collapsedfac", "Type"))

z_directed_rmisc$collapsedfac2 = ordered(as.factor(as.character(z_directed_rmisc$collapsedfac)),
  z_directed_rmisc = z_directed_rmisc %>% filter(collapsedfac2 != "NA")

z_directed_rmisc$zRT_trim = as.numeric(z_directed_rmisc$zRT_trim)

library(ggplot2)
library(ggthemes)

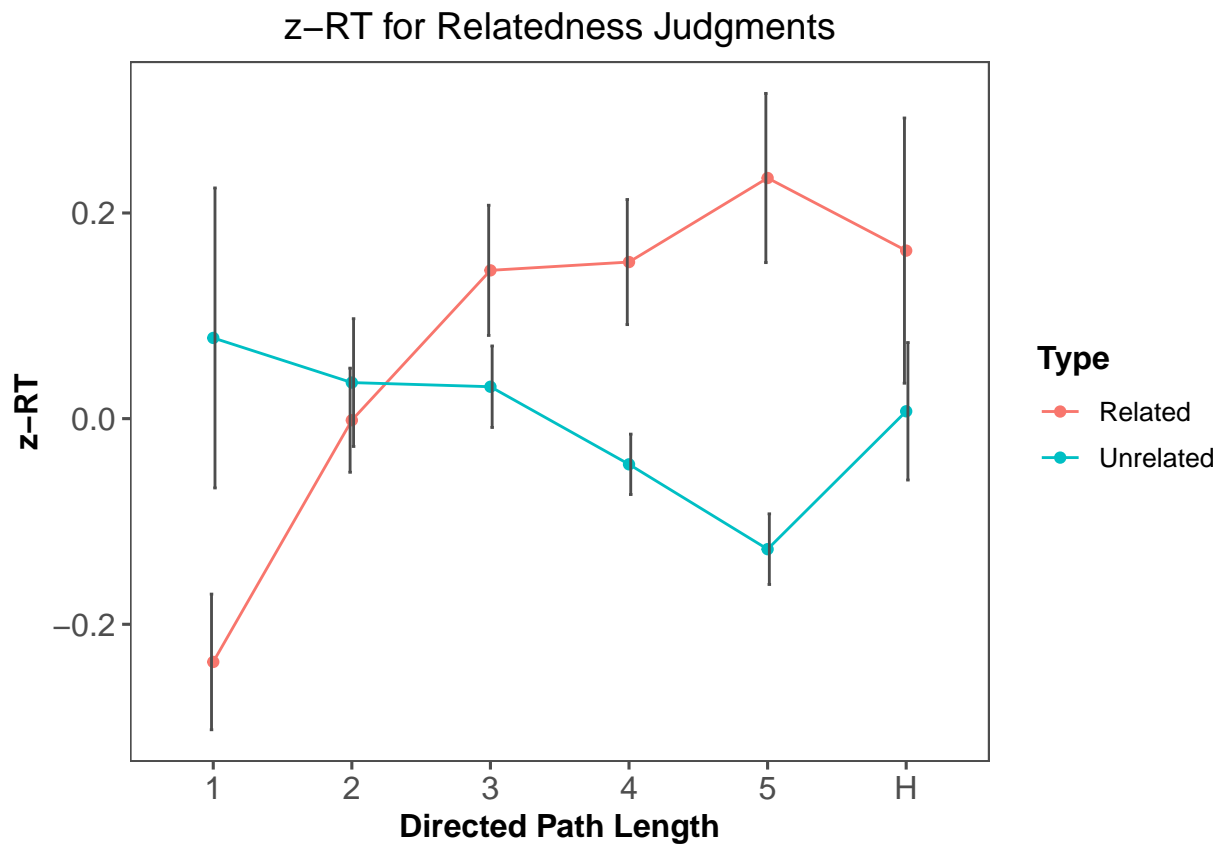
z_directed_rmisc %>%
  ggplot(aes(x = collapsedfac2, y = zRT_trim, group = Type, color = Type))+
  geom_point()+
  # geom_smooth(method = "loess")+
  geom_line()+

```

```

geom_errorbar(aes(ymin=zRT_trim - ci, ymax=zRT_trim + ci),
              width=.05, color = "gray30",
              position = position_dodge(0.05))+
theme_few()+
#scale_x_continuous(breaks = c(1,2,3,4,5,6,10,15,20))+
  xlab("Directed Path Length") + ylab("z-RT") +
ggtitle("z-RT for Relatedness Judgments") +
  theme(axis.text = element_text(size = rel(1)),
        axis.title = element_text(face = "bold", size = rel(1)),
        legend.title = element_text(face = "bold", size = rel(1)),
        plot.title = element_text(hjust = .5),
        strip.text.x = element_text(face = "bold", size = rel(1.4)))

```



Plot Item Distribution

```

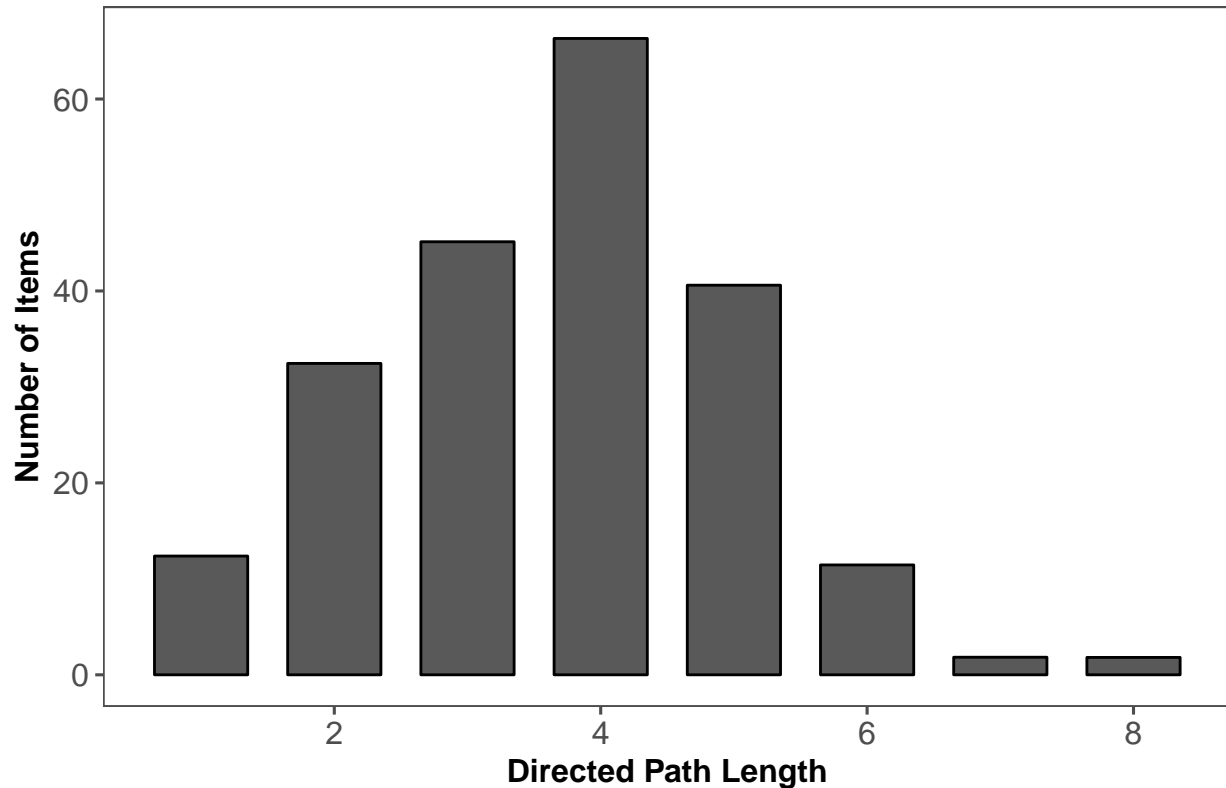
items_directed$newdirected = as.factor(items_directed$newdirected)
ggplot(directed_rmisc, aes(x = newdirected, y = items))+
  geom_bar(stat = "identity", position = "dodge", width = 0.7, color= "black")+
  theme_few()+
  xlab("Directed Path Length") + ylab("Number of Items") +
  ggtitle("Directed Network Item Distribution") +
  theme(axis.text = element_text(size = rel(1)),
        axis.title = element_text(face = "bold", size = rel(1)),
        legend.title = element_text(face = "bold", size = rel(1)),
        plot.title = element_text(hjust = .5),

```

```
strip.text.x = element_text(face = "bold", size = rel(1.4))
```

```
## Warning: Removed 1 rows containing missing values (geom_bar).
```

Directed Network Item Distribution



LSA-Word2vec Simple Models

```
word2vec = read.csv("word2veccosines.csv", header = TRUE, sep = ",")

final_word2vec = merge(final_sem, word2vec,
  by = c( "ItemNo", "proc"))
final_word2vec = final_word2vec %>% arrange(subject, ItemNo)

mean_cosines = group_by(final_word2vec, ItemNo,
  prime_word, target_word) %>%
  summarise_at(vars(undirected, directed, pathlength, word2veccosine,
    LSA), mean)

mean_cosines$newdirected = ifelse(mean_cosines$directed == "Inf" |
  mean_cosines$directed == "NA", NA,
  mean_cosines$directed)

Hmisc::rcorr(as.matrix(mean_cosines[,c(7,8)]))$r
```

```
##           word2veccosine      LSA
## word2veccosine      1.000000 0.596135
```

```
## LSA                                0.596135 1.000000
```

z-scoring measures

```
final_word2vec$zUndirected = as.numeric(scale(final_word2vec$undirected,
                                              center = TRUE, scale = TRUE))

final_word2vec$zword2vec = as.numeric(scale(final_word2vec$word2veccosine,
                                              center = TRUE, scale = TRUE))

final_word2vec$zLSA = as.numeric(scale(final_word2vec$LSA,
                                        center = TRUE, scale = TRUE))

final_word2vec$zDirected = as.numeric(scale(final_word2vec$newdirected,
                                              center = TRUE, scale = TRUE))

final_word2vec$zKenett = as.numeric(scale(final_word2vec$pathlength,
                                           center = TRUE, scale = TRUE))
```

Item Level

```
final_item = group_by(final_word2vec, Item) %>%
  summarize_at(vars(zword2vec, zLSA, zUndirected, zDirected, zKenett,
                    zRT_trim, newdirected, undirected, pathlength,
                    mean_len_c, mean_logf_c, mean_ldtz_c, mean_conc_c), mean)

final_item$directedcollapsed = ifelse((final_item$newdirected == "6" | final_item$newdirected == "7" | f

final_item$directedcollapsed = as.factor(final_item$directedcollapsed)
final_item$undirectedfac = as.factor(final_item$undirected)
final_item$kenettfac = as.factor(final_item$pathlength)

## use same dataset for everyone

x = final_item[which(!is.na(final_item$directedcollapsed) & !is.na(final_item$mean_conc_c)),]
```

Cat-Cont Model

unconditional

```
final_item_unconditional = lm(data = x,
                              zRT_trim ~ 1 +
                                mean_len_c + mean_logf_c +
                                mean_ldtz_c + mean_conc_c)

summary(final_item_unconditional)
```

```
##
## Call:
## lm(formula = zRT_trim ~ 1 + mean_len_c + mean_logf_c + mean_ldtz_c +
```



```
##      mean_conc_c, data = x)
##
## Residuals:
##      Min        1Q      Median        3Q        Max
## -1.03713 -0.29805 -0.02506  0.26839  1.44977
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept)  0.001349   0.008962   0.150   0.8804
## mean_len_c    0.019673   0.007766   2.533   0.0114 *
## mean_logf_c  -0.007934   0.008735  -0.908   0.3638
## mean_ldtz_c   0.021674   0.069529   0.312   0.7553
## mean_conc_c  -0.070640   0.011586  -6.097 1.28e-09 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.4084 on 2073 degrees of freedom
## Multiple R-squared:  0.03052,    Adjusted R-squared:  0.02864
## F-statistic: 16.31 on 4 and 2073 DF,  p-value: 3.658e-13
```

```
car::Anova(final_item_unconditional)
```

```
## Anova Table (Type II tests)
##
## Response: zRT_trim
##              Sum Sq   Df F value    Pr(>F)
## mean_len_c     1.07    1  6.4163   0.01138 *
## mean_logf_c     0.14    1  0.8250   0.36381
## mean_ldtz_c     0.02    1  0.0972   0.75528
## mean_conc_c     6.20    1 37.1759 1.284e-09 ***
## Residuals    345.83 2073
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## r2 = 0.03052
```

word2vec

```
final_item_word2vec = lm(data = x,
                        zRT_trim ~ 1 + zword2vec +
                        mean_len_c + mean_logf_c +
                        mean_ldtz_c + mean_conc_c)
summary(final_item_word2vec)
```

```
##
## Call:
## lm(formula = zRT_trim ~ 1 + zword2vec + mean_len_c + mean_logf_c +
##      mean_ldtz_c + mean_conc_c, data = x)
##
## Residuals:
##      Min        1Q      Median        3Q        Max
## -1.05831 -0.29857 -0.02343  0.26834  1.43200
##
## Coefficients:
```

```
##           Estimate Std. Error t value Pr(>|t|)
## (Intercept)  0.001685   0.008957   0.188   0.8508
## zword2vec    -0.018108   0.008814  -2.055   0.0401 *
## mean_len_c   0.019990   0.007762   2.575   0.0101 *
## mean_logf_c  -0.008855   0.008739  -1.013   0.3111
## mean_ldtz_c  0.019483   0.069483   0.280   0.7792
## mean_conc_c  -0.069826   0.011583  -6.028 1.96e-09 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.4081 on 2072 degrees of freedom
## Multiple R-squared:  0.03249,    Adjusted R-squared:  0.03015
## F-statistic: 13.91 on 5 and 2072 DF,  p-value: 2.123e-13
```

```
anova(final_item_word2vec)
```

```
## Analysis of Variance Table
##
## Response: zRT_trim
##           Df Sum Sq Mean Sq F value    Pr(>F)
## zword2vec    1   0.84   0.8355   5.0160  0.02522 *
## mean_len_c    1   4.52   4.5184  27.1264 2.094e-07 ***
## mean_logf_c    1   0.06   0.0605   0.3633  0.54675
## mean_ldtz_c    1   0.12   0.1213   0.7282  0.39356
## mean_conc_c    1   6.05   6.0528  36.3380 1.959e-09 ***
## Residuals  2072 345.13   0.1666
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
#r2 = 0.03249
# un ique = 14.71%
```

undirected

```
final_item_undirected = lm(data = x,
                           zRT_trim ~ undirectedfac +
                           mean_len_c + mean_logf_c +
                           mean_ldtz_c + mean_conc_c)
summary(final_item_undirected)
```

```
##
## Call:
## lm(formula = zRT_trim ~ undirectedfac + mean_len_c + mean_logf_c +
##     mean_ldtz_c + mean_conc_c, data = x)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -1.11909 -0.29240 -0.02195  0.25660  1.44034
##
## Coefficients:
##           Estimate Std. Error t value Pr(>|t|)
## (Intercept) -0.069956   0.012424  -5.631 2.04e-08 ***
## undirectedfac1 -0.127318   0.024234  -5.254 1.64e-07 ***
## undirectedfac2  0.154474   0.015815   9.767 < 2e-16 ***
```

```
## undirectedfac3  0.056701  0.015538  3.649  0.00027 ***
## mean_len_c     0.018731  0.007587  2.469  0.01364 *
## mean_logf_c    -0.004344  0.008544  -0.508  0.61126
## mean_ldtz_c     0.055904  0.068289  0.819  0.41309
## mean_conc_c    -0.079552  0.011358  -7.004  3.35e-12 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.399 on 2070 degrees of freedom
## Multiple R-squared:  0.07633,    Adjusted R-squared:  0.07321
## F-statistic: 24.44 on 7 and 2070 DF,  p-value: < 2.2e-16

anova(final_item_unconditional,
      final_item_word2vec, final_item_undirected) ## donot differ

## Analysis of Variance Table
##
## Model 1: zRT_trim ~ 1 + mean_len_c + mean_logf_c + mean_ldtz_c + mean_conc_c
## Model 2: zRT_trim ~ 1 + zword2vec + mean_len_c + mean_logf_c + mean_ldtz_c +
##   mean_conc_c
## Model 3: zRT_trim ~ undirectedfac + mean_len_c + mean_logf_c + mean_ldtz_c +
##   mean_conc_c
##   Res.Df    RSS Df Sum of Sq      F Pr(>F)
## 1    2073 345.83
## 2    2072 345.13  1    0.7031  4.4171 0.0357 *
## 3    2070 329.49  2   15.6404 49.1300 <2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
## r2 = 0.07633

# unique - 12.75%
```

LSA

Quintile Figure

```
final_word2vec = final_word2vec %>%
  mutate(LSAquintile = ntile(zLSA, 5))

lsa_quintile_means = Rmisc::summarySE(final_word2vec,
                                       measurevar = "zRT_trim",
                                       groupvars = c("LSAquintile", "Type"))

lsa_quintile_means$reversequintile = 6-lsa_quintile_means$LSAquintile
lsa_quintile_means %>% mutate(Decision = factor(Type,
  levels = unique(Type),
  labels = c("Related", "Unrelated"))) %>%
ggplot(aes(x = reversequintile, y = zRT_trim,
  group = Decision, color = Decision))+
geom_point()+
geom_line()+
ylim(-0.35, 0.35)+
```

```

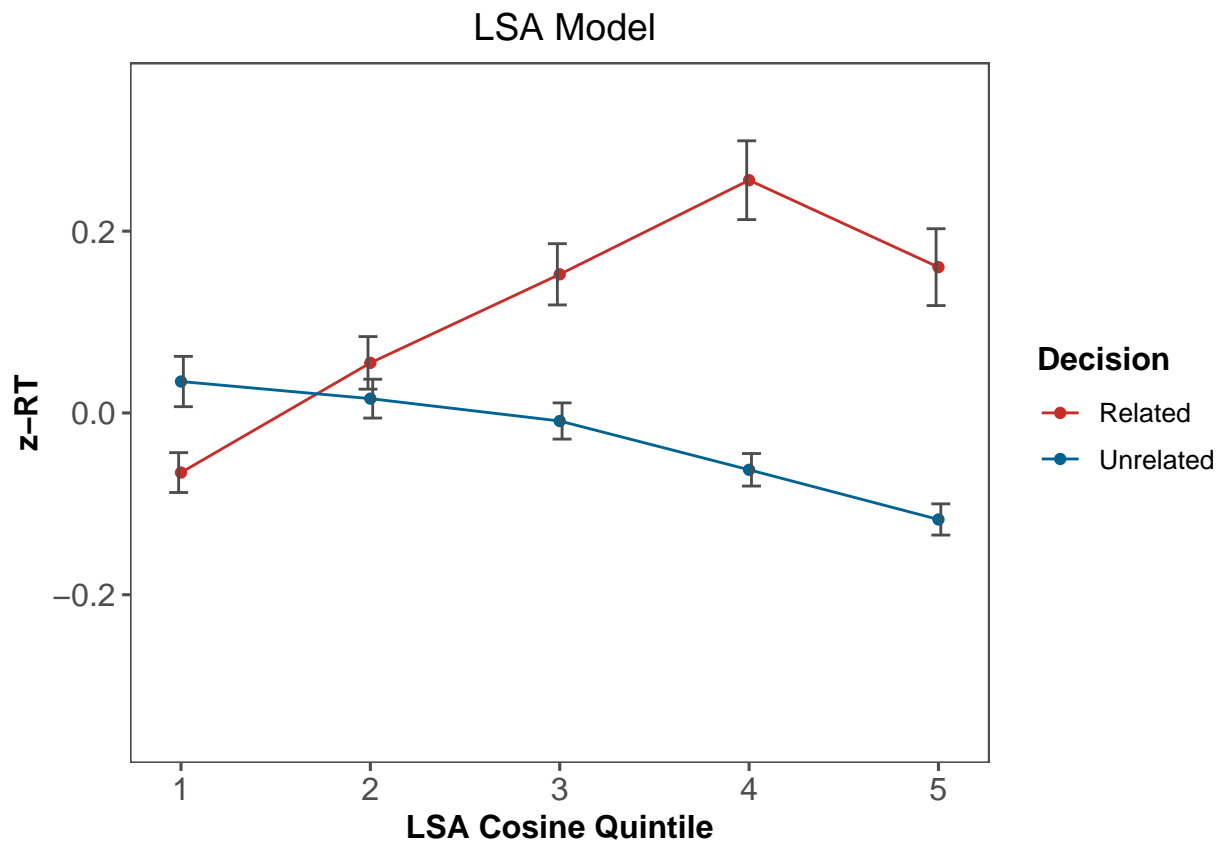
geom_errorbar(aes(ymin=zRT_trim - se, ymax=zRT_trim + se),
              width=.2, color = "gray30",
              position = position_dodge(0.05))+
theme_few()+
scale_color_wsj()+
  xlab("LSA Cosine Quintile") + ylab("z-RT") +
ggtitle(" LSA Model") +
  theme(axis.text = element_text(size = rel(1)),
        axis.title = element_text(face = "bold", size = rel(1)),
        legend.title = element_text(face = "bold", size = rel(1)),
        plot.title = element_text(hjust = .5),
        strip.text.x = element_text(face = "bold", size = rel(1.4)))

```

Warning: Removed 2 rows containing missing values (geom_point).

Warning: Removed 2 rows containing missing values (geom_path).

Warning: Removed 2 rows containing missing values (geom_errorbar).



word2vec

Quintile Figure

```

final_word2vec = final_word2vec %>%
  mutate(word2vecquintile = ntile(zword2vec, 5))

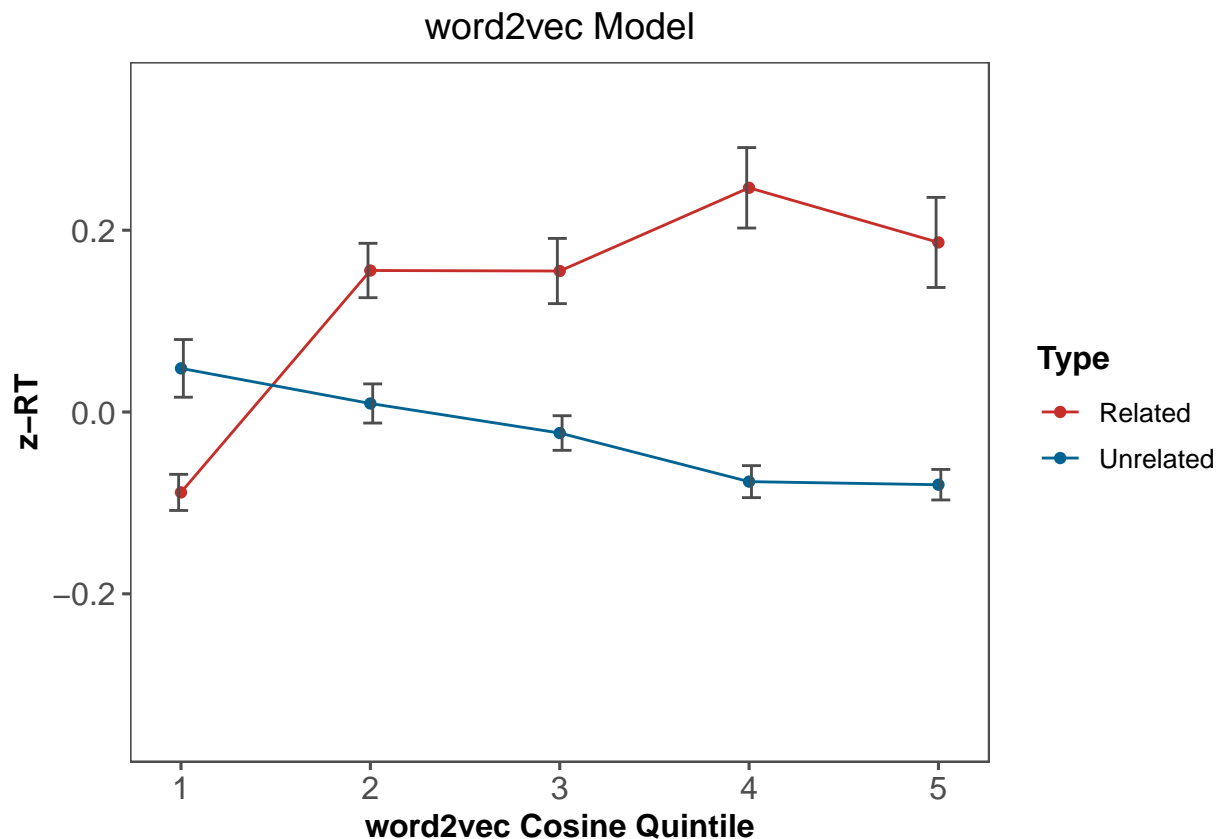
```

```

word2vec_quintile_means = Rmisc::summarySE(final_word2vec,
                                           measurevar = "zRT_trim",
                                           groupvars = c("word2vecquintile", "Type"))

word2vec_quintile_means$reversecosine = 6 - word2vec_quintile_means$word2vecquintile
word2vec_quintile_means %>%mutate(Decision = factor(Type,
  levels = unique(Type),
  labels = c("Related", "Unrelated"))) %>%
ggplot(aes(x = reversecosine, y = zRT_trim,
  group = Type, color = Type))+
geom_point()+
geom_line()+
ylim(-0.35,0.35)+
  geom_errorbar(aes(ymin=zRT_trim - se, ymax=zRT_trim + se),
    width=.2, color = "gray30",
    position = position_dodge(0.05))+
theme_few()+
scale_color_wsj()+
  xlab("word2vec Cosine Quintile") + ylab("z-RT") +
ggtitle("word2vec Model") +
  theme(axis.text = element_text(size = rel(1)),
    axis.title = element_text(face = "bold", size = rel(1)),
    legend.title = element_text(face = "bold", size = rel(1)),
    plot.title = element_text(hjust = .5),
    strip.text.x = element_text(face = "bold", size = rel(1.4)))

```



Model Comparison Approach

Cat Cont

```
final_item_catcont = group_by(final_word2vec, ItemNo, Item) %>%
  summarize_at(vars(word2veccosine, LSA, undirected, newdirected, pathlength,
                    zRT_trim, mean_len_c, mean_logf_c ,mean_ldtz_c, mean_conc_c), mean)

final_item_catcont$LSA2 = final_item_catcont$LSA*final_item_catcont$LSA
final_item_catcont$u2 = final_item_catcont$undirected*final_item_catcont$undirected
final_item_catcont$d2 = final_item_catcont$newdirected*final_item_catcont$newdirected
final_item_catcont$k2 = final_item_catcont$pathlength*final_item_catcont$pathlength

final_item_catcont$word2vec2 = final_item_catcont$word2veccosine*final_item_catcont$word2veccosine

final_item_catcont$undirectedfac = as.factor(final_item_catcont$undirected)
final_item_catcont$kenettfac = as.factor(final_item_catcont$pathlength)
final_item_catcont$directedfac = as.factor(final_item_catcont$newdirected)

final_item_catcont$directedcollapsed = ifelse((final_item_catcont$newdirected == "6" |final_item_catcon

final_item_catcont$directedcollapsed = as.factor(final_item_catcont$directedcollapsed)

## ensure same dataset

x = final_item_catcont[which(!is.na(final_item_catcont$directedcollapsed) & !is.na(final_item_catcont$
```

Cat cont R2

```
final_unconditional_model = lm(data = x,
                               zRT_trim ~ mean_len_c + mean_logf_c + mean_ldtz_c + mean_conc_c)
summary(final_unconditional_model)

##
## Call:
## lm(formula = zRT_trim ~ mean_len_c + mean_logf_c + mean_ldtz_c +
##     mean_conc_c, data = x)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -1.03601 -0.29837 -0.02489  0.26983  1.45360
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept)  0.0007387  0.0090013   0.082   0.9346
## mean_len_c    0.0195338  0.0078109   2.501   0.0125 *
## mean_logf_c  -0.0080274  0.0088013  -0.912   0.3618
## mean_ldtz_c   0.0169568  0.0699064   0.243   0.8084
## mean_conc_c  -0.0691373  0.0116166  -5.952 3.11e-09 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
```

```
## Residual standard error: 0.4086 on 2058 degrees of freedom
## Multiple R-squared:  0.02924,    Adjusted R-squared:  0.02735
## F-statistic: 15.5 on 4 and 2058 DF,  p-value: 1.704e-12
```

```
## R squared = 2.9%

final_model_lsa = lm(data = x,
                     zRT_trim ~ LSA2 + LSA +
                     mean_len_c + mean_logf_c + mean_ldtz_c + mean_conc_c)
summary(final_model_lsa)
```

```
##
## Call:
## lm(formula = zRT_trim ~ LSA2 + LSA + mean_len_c + mean_logf_c +
##      mean_ldtz_c + mean_conc_c, data = x)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -1.05153 -0.29489 -0.02019  0.26307  1.47201
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept) -0.015492   0.015085  -1.027  0.30455
## LSA2         -1.187568   0.261121  -4.548 5.73e-06 ***
## LSA           0.469496   0.150019   3.130  0.00178 **
## mean_len_c    0.020440   0.007771   2.630  0.00859 **
## mean_logf_c  -0.007452   0.008784  -0.848  0.39633
## mean_ldtz_c   0.020814   0.069715   0.299  0.76531
## mean_conc_c  -0.062558   0.011674  -5.359 9.31e-08 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.4061 on 2056 degrees of freedom
## Multiple R-squared:  0.04194,    Adjusted R-squared:  0.03915
## F-statistic: 15 on 6 and 2056 DF,  p-value: < 2.2e-16
```

```
## 0.85%

final_model_word2vec = lm(data = x,
                          zRT_trim ~ word2vec2 + word2veccosine+
                          mean_len_c + mean_logf_c + mean_ldtz_c + mean_conc_c)
summary(final_model_word2vec)
```

```
##
## Call:
## lm(formula = zRT_trim ~ word2vec2 + word2veccosine + mean_len_c +
##      mean_logf_c + mean_ldtz_c + mean_conc_c, data = x)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -1.01400 -0.29738 -0.02651  0.26745  1.48076
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept)  -0.042677   0.016282  -2.621  0.00883 **
```

```
## word2vec2      -1.859935    0.286316   -6.496 1.03e-10 ***
## word2veccosine 0.821874    0.158820    5.175 2.50e-07 ***
## mean_len_c     0.021869    0.007735    2.827 0.00474 **
## mean_logf_c    -0.007486    0.008721   -0.858 0.39079
## mean_ldtz_c     0.009681    0.069173    0.140 0.88870
## mean_conc_c    -0.070664    0.011506   -6.142 9.77e-10 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.4043 on 2056 degrees of freedom
## Multiple R-squared:  0.05076,    Adjusted R-squared:  0.04799
## F-statistic: 18.32 on 6 and 2056 DF,  p-value: < 2.2e-16

## 0.9 %

final_model_undirected = lm(data = x,
                             zRT_trim ~ undirectedfac +
                             mean_len_c + mean_logf_c + mean_ldtz_c + mean_conc_c)
summary(final_model_undirected)

##
## Call:
## lm(formula = zRT_trim ~ undirectedfac + mean_len_c + mean_logf_c +
##     mean_ldtz_c + mean_conc_c, data = x)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -1.11752 -0.29209 -0.02237  0.25873  1.44097
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept)  -0.069836   0.012393  -5.635 1.99e-08 ***
## undirectedfac1 -0.127113   0.024225  -5.247 1.70e-07 ***
## undirectedfac2  0.152965   0.015823   9.667 < 2e-16 ***
## undirectedfac3  0.056965   0.015548   3.664 0.000255 ***
## mean_len_c     0.018609   0.007633   2.438 0.014848 *
## mean_logf_c    -0.004453   0.008611  -0.517 0.605089
## mean_ldtz_c     0.052929   0.068683   0.771 0.441021
## mean_conc_c    -0.078270   0.011393  -6.870 8.49e-12 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.3992 on 2055 degrees of freedom
## Multiple R-squared:  0.07462,    Adjusted R-squared:  0.07147
## F-statistic: 23.67 on 7 and 2055 DF,  p-value: < 2.2e-16

## 7.46%

final_model_directed = lm(data = x,
                           zRT_trim ~ directedcollapsed +
                           mean_len_c + mean_logf_c + mean_ldtz_c + mean_conc_c)
summary(final_model_directed)

##
## Call:
```



```
## lm(formula = zRT_trim ~ directedcollapsed + mean_len_c + mean_logf_c +
##     mean_ldtz_c + mean_conc_c, data = x)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -1.11153 -0.29532 -0.03285  0.26133  1.50279
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept)   -0.018950   0.010706  -1.770   0.0769 .
## directedcollapsed1 -0.161105   0.031268  -5.152 2.82e-07 ***
## directedcollapsed2  0.045061   0.021379   2.108   0.0352 *
## directedcollapsed3  0.097279   0.019031   5.112 3.49e-07 ***
## directedcollapsed4  0.021310   0.016777   1.270   0.2042
## directedcollapsed5 -0.038993   0.019924  -1.957   0.0505 .
## mean_len_c      0.018586   0.007728   2.405   0.0163 *
## mean_logf_c     -0.007167   0.008725  -0.821   0.4115
## mean_ldtz_c      0.030760   0.069406   0.443   0.6577
## mean_conc_c     -0.075750   0.011572  -6.546 7.43e-11 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.4041 on 2053 degrees of freedom
## Multiple R-squared:  0.0529, Adjusted R-squared:  0.04874
## F-statistic: 12.74 on 9 and 2053 DF,  p-value: < 2.2e-16
```

```
## 5.29%
```

```
final_model_kenett = lm(data = x,
                        zRT_trim ~ kenettfac +
                        mean_len_c + mean_logf_c + mean_ldtz_c + mean_conc_c)
summary(final_model_kenett)
```

```
##
## Call:
## lm(formula = zRT_trim ~ kenettfac + mean_len_c + mean_logf_c +
##     mean_ldtz_c + mean_conc_c, data = x)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -1.15111 -0.30004 -0.02397  0.26276  1.38991
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept)  0.001381   0.008855   0.156 0.876120
## kenettfac1  -0.065241   0.019662  -3.318 0.000922 ***
## kenettfac2   0.107337   0.019960   5.378 8.41e-08 ***
## kenettfac3   0.068960   0.019892   3.467 0.000538 ***
## kenettfac4   0.023482   0.019583   1.199 0.230623
## kenettfac5  -0.016479   0.020040  -0.822 0.410988
## mean_len_c   0.018781   0.007701   2.439 0.014816 *
## mean_logf_c  -0.009344   0.008665  -1.078 0.280994
## mean_ldtz_c  0.005937   0.068815   0.086 0.931252
## mean_conc_c  -0.064532   0.011451  -5.635 1.99e-08 ***
## ---
```

```

## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.4019 on 2053 degrees of freedom
## Multiple R-squared:  0.0633, Adjusted R-squared:  0.0592
## F-statistic: 15.42 on 9 and 2053 DF,  p-value: < 2.2e-16

## 6.33%

final_model_combined = lm(data = x,
                           zRT_trim ~ kenettfac +
                           directedcollapsed + undirectedfac +
                           mean_len_c + mean_logf_c + mean_ldtz_c + mean_conc_c )
summary(final_model_combined)

##
## Call:
## lm(formula = zRT_trim ~ kenettfac + directedcollapsed + undirectedfac +
##     mean_len_c + mean_logf_c + mean_ldtz_c + mean_conc_c, data = x)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -1.18162 -0.28288 -0.02718  0.25645  1.45782
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept)   -0.059719   0.013177  -4.532 6.17e-06 ***
## kenettfac1     -0.024471   0.024523  -0.998 0.318450
## kenettfac2      0.092542   0.021161   4.373 1.29e-05 ***
## kenettfac3      0.045189   0.019799   2.282 0.022570 *
## kenettfac4      0.009806   0.019702   0.498 0.618727
## kenettfac5     -0.018016   0.021308  -0.846 0.397912
## directedcollapsed1  0.047850   0.052267   0.916 0.360036
## directedcollapsed2 -0.033038   0.024012  -1.376 0.168996
## directedcollapsed3  0.032358   0.020848   1.552 0.120794
## directedcollapsed4 -0.009192   0.019418  -0.473 0.636016
## directedcollapsed5 -0.050516   0.022504  -2.245 0.024893 *
## undirectedfac1   -0.172237   0.042453  -4.057 5.15e-05 ***
## undirectedfac2     0.130731   0.020092   6.507 9.64e-11 ***
## undirectedfac3     0.073301   0.021023   3.487 0.000499 ***
## mean_len_c        0.017590   0.007578   2.321 0.020378 *
## mean_logf_c       -0.006357   0.008530  -0.745 0.456205
## mean_ldtz_c        0.038972   0.068128   0.572 0.567361
## mean_conc_c       -0.074881   0.011360  -6.592 5.52e-11 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.3945 on 2045 degrees of freedom
## Multiple R-squared:  0.1007, Adjusted R-squared:  0.09327
## F-statistic: 13.48 on 17 and 2045 DF,  p-value: < 2.2e-16

car::Anova(final_model_combined)

## Anova Table (Type II tests)
##
## Response: zRT_trim

```

```

##              Sum Sq   Df F value    Pr(>F)
## kenettfac         6.67    5  8.5671 4.834e-08 ***
## directedcollapsed  1.77    5  2.2790  0.04449 *
## undirectedfac      7.10    3 15.2141 8.592e-10 ***
## mean_len_c         0.84    1  5.3876  0.02038 *
## mean_logf_c         0.09    1  0.5554  0.45620
## mean_ldtz_c         0.05    1  0.3272  0.56736
## mean_conc_c        6.76    1 43.4481 5.523e-11 ***
## Residuals        318.31 2045
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

## cannot use anova because models are non nested
## thus using AIC and BIC with covariates

# > AIC(final_model_undirected)
# [1] 2076.054
# > AIC(final_model_kenett)
# [1] 2105.138
# > AIC(final_model_directed)
# [1] 2127.933
# > AIC(final_model_lsa)
# [1] 2153.458
# > AIC(final_model_word2vec)
# [1] 2151.271

# > stats4::BIC(final_model_kenett)
# [1] 2167.089
# > stats4::BIC(final_model_undirected)
# [1] 2126.741
# > stats4::BIC(final_model_directed)
# [1] 2189.884
# > stats4::BIC(final_model_lsa)
# [1] 2192.881
# > stats4::BIC(final_model_word2vec)
# [1] 2190.694

## without covariates

# > AIC(final_model_undirected)
# [1] 2147.08
# > AIC(final_model_kenett)
# [1] 2152.223
# > AIC(final_model_directed)
# [1] 2190.518
# > AIC(final_model_lsa)
# [1] 2206.424
# > AIC(final_model_word2vec)
# [1] 2205.103
# > stats4::BIC(final_model_undirected)
# [1] 2175.24
# > stats4::BIC(final_model_kenett)
# [1] 2191.646
# > stats4::BIC(final_model_directed)

```

```
# [1] 2229.941
# > stats4::BIC(final_model_lsa)
# [1] 2223.32
# > stats4::BIC(final_model_word2vec)
# [1] 2221.999
```

Combined zRT plot

```
final_word2vec$undirectedfacfinal = as.factor(final_word2vec$zUndirected)
final_word2vec$directedfacfinal = as.factor(final_word2vec$zDirected)
final_word2vec$kenettffacfinal = as.factor(final_word2vec$zKenett)
final_word2vec$LSAfacfinal = as.factor(round(final_word2vec$LSAqintile))
final_word2vec$word2vecfacfinal = as.factor(round(final_word2vec$word2vecqintile))

z_sem_rt_rel_agg_rmisc = Rmisc::summarySE(final_word2vec,
  measurevar = "zRT_trim",
  groupvars = c("pathlength", "Type"))

colnames(z_sem_rt_rel_agg_rmisc) = c("measure", "Type", "N",
  "zRT_trim", "sd", "se", "ci")
z_sem_rt_rel_agg_rmisc$Representation = "ACN"

z_sem_rt_rel_agg_rmisc = z_sem_rt_rel_agg_rmisc %>%
  filter((Type == "Related" & measure == 1) |
    (Type == "Unrelated" & measure != 1))

z_undirected_rmisc = Rmisc::summarySE(final_word2vec,
  measurevar = "zRT_trim",
  groupvars = c("undirectedfac", "Type"))
colnames(z_undirected_rmisc) = c("measure", "Type", "N",
  "zRT_trim", "sd", "se", "ci")
z_undirected_rmisc$Representation = "Undirected SDN"
z_undirected_rmisc = z_undirected_rmisc %>%
  filter((Type == "Related" & measure == 1) |
    (Type == "Unrelated" & measure != 1))

z_directed_rmisc = Rmisc::summarySE(final_word2vec,
  measurevar = "zRT_trim",
  groupvars = c("directedfac", "Type"))
colnames(z_directed_rmisc) = c("measure", "Type", "N",
  "zRT_trim", "sd", "se", "ci")
z_directed_rmisc$Representation = "Directed SDN"
z_directed_rmisc = z_directed_rmisc %>% filter(measure <= 5)
z_directed_rmisc = z_directed_rmisc %>%
  filter((Type == "Related" & measure == 1) |
    (Type == "Unrelated" & measure != 1))

word2vec_cosine_agg = Rmisc::summarySE(final_word2vec,
```

```

        measurevar = "zRT_trim",
        groupvars = c("word2vecfacfinal", "Type"))

colnames(word2vec_cosine_agg) = c("measure", "Type", "N",
                                "zRT_trim", "sd", "se", "ci")

word2vec_cosine_agg$Representation = "word2vec"
word2vec_cosine_agg = word2vec_cosine_agg %>%
  filter((Type == "Related" & measure == 5) |
         (Type == "Unrelated" & measure != 5))

word2vec_cosine_agg = word2vec_cosine_agg[,-c(1)]
x = as.data.frame(matrix(NA, nrow = 5, ncol = 1))
colnames(x) = "measure"
x$measure = c(5,4,3,2,1)
word2vec_cosine_agg = cbind(x, word2vec_cosine_agg)

LSA_cosine_agg = Rmisc::summarySE(final_word2vec,
                                measurevar = "zRT_trim",
                                groupvars = c("LSAfacfinal", "Type"))

colnames(LSA_cosine_agg) = c("measure", "Type", "N",
                             "zRT_trim", "sd", "se", "ci")

LSA_cosine_agg$Representation = "LSA"
LSA_cosine_agg = LSA_cosine_agg %>%
  filter((Type == "Related" & measure == 5) |
         (Type == "Unrelated" & measure != 5))

LSA_cosine_agg = LSA_cosine_agg[,-c(1)]
x = as.data.frame(matrix(NA, nrow = 5, ncol = 1))
colnames(x) = "measure"
x$measure = c(5,4,3,2,1)
LSA_cosine_agg = cbind(x, LSA_cosine_agg)

combined_zrt_plot = rbind(z_sem_rt_rel_agg_rmisc,
                          z_undirected_rmisc,
                          z_directed_rmisc,
                          word2vec_cosine_agg,
                          LSA_cosine_agg)

combined_zrt_plot$measurefac = ordered(as.factor(as.character(combined_zrt_plot$measure)),
                                       levels = c("1", "2", "3", "4", "5", "6",
                                                  "15"))

combined_zrt_plot$Representation = ordered(as.factor(as.character(combined_zrt_plot$Representation)),
                                           levels = c("ACN", "Undirected SDN", "Directed SDN", "LSA", "word2vec"))

combined_zrt_plot1 = combined_zrt_plot %>%

```

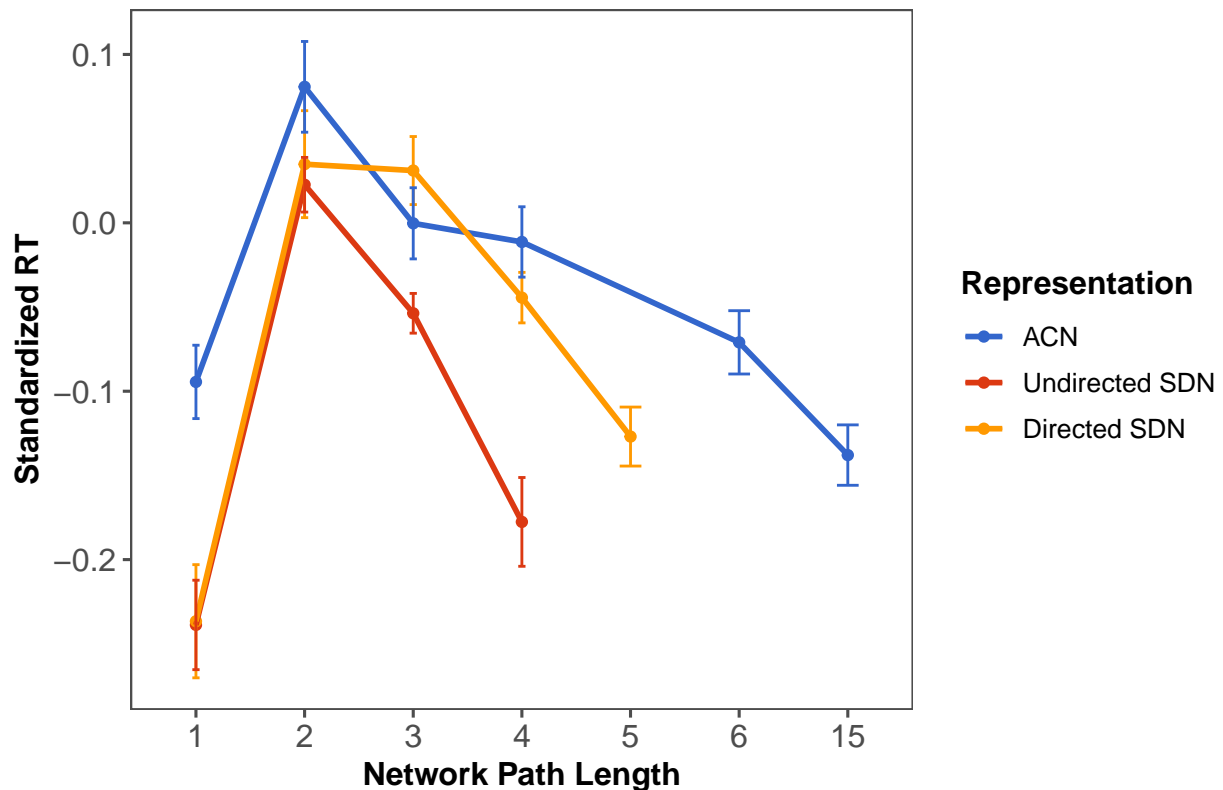
```

filter(!Representation %in% c("word2vec", "LSA"))

combined_zrt_plot1 %>%
  ggplot(aes(x = measurefac, y = zRT_trim,
             group = Representation, color = Representation))+
  geom_point()+
  geom_line(size = 1)+
  geom_errorbar(aes(ymin=zRT_trim - se, ymax=zRT_trim + se),
               width=.2,
               position = position_dodge(0))+
  theme_few()+
  scale_color_gdocs()+
  #scale_x_continuous(breaks = c(1,2,3,4,5,6,10,15,20))+
  xlab("Network Path Length") + ylab("Standardized RT") +
  ggtitle("Experiment 1: Relatedness Judgments") +
  theme(axis.text = element_text(size = rel(1)),
        axis.title = element_text(face = "bold", size = rel(1)),
        legend.title = element_text(face = "bold", size = rel(1)),
        plot.title = element_text(hjust = .5),
        strip.text.x = element_text(face = "bold", size = rel(1.4)))

```

Experiment 1: Relatedness Judgments



z-scores for Path Lengths

```
library(dplyr)
z_pathlength1 = final_sem %>% filter(pathlength == "1")
z_pathlength2 = final_sem %>% filter(pathlength == "2")
z_pathlength3 = final_sem %>% filter(pathlength == "3")
z_pathlength4 = final_sem %>% filter(pathlength == "4")
z_pathlength6 = final_sem %>% filter(pathlength == "6")
z_pathlength15 = final_sem %>% filter(pathlength == "15")
```

Creating separate z-scores

```
sem_firsttrim1 = sem_firsttrim %>% filter(pathlength == "15")

## aggregate per subject all IVs and DVs
meanRT = group_by(sem_firsttrim1, subject) %>%
  summarise_at(vars(rt), mean)
colnames(meanRT) = c("subject", "MeanRT")

sdRT = group_by(sem_firsttrim1, subject) %>%
  summarise_at(vars(rt), sd)
colnames(sdRT) = c("subject", "sdRT")

RT_agg = merge(meanRT, sdRT, by = "subject")

## merge aggregate info with long data
sem_z_1 = merge(sem_firsttrim1, RT_agg, by = "subject", all.x = T)

## person and grand-mean centered scores using original and aggregate
library(dplyr)
sem_z_1 = sem_z_1 %>% mutate(zRT = (rt - MeanRT)/sdRT)

## checking: subject level means should be zero
sub_pic = group_by(sem_z_1, subject) %>%
  summarise_at(vars(zRT), mean)
```

Item Diagnostics

```
item_mean = group_by(new_sem_z, pathlength, proc, ItemNo, Type) %>%
  summarise_at(vars(zRT_trim), mean) %>%
  arrange(ItemNo)

sem$proc = as.factor(sem$proc)

item_rel = group_by(sem, pathlength, ItemNo, Type) %>%
  summarise(Trials = n())

item_rel_proc = group_by(sem, pathlength, proc, ItemNo, Type) %>%
```

```

summarise(Trials = n())

item_rel_rt = group_by(sem, pathlength, ItemNo, Type) %>%
  summarise_at(vars(rt), mean)

item_rel_collapsed = group_by(sem, pathlength, ItemNo) %>%
  summarise_at(vars(rt), mean)

item_rel_wide = tidyr::spread(item_rel, Type, Trials)

item_rel_rt_wide = tidyr::spread(item_rel_rt, Type, rt)

item_sub = group_by(sem, ItemNo, subject) %>%
  summarise(Subjects = n())

item_rel_wide$Related = ifelse(is.na(item_rel_wide$Related), 0, item_rel_wide$Related)

item_rel_wide$Unrelated = ifelse(is.na(item_rel_wide$Unrelated), 0, item_rel_wide$Unrelated)

item_rel_rt_wide$Related = ifelse(is.na(item_rel_rt_wide$Related), 0, item_rel_rt_wide$Related)

item_rel_rt_wide$Unrelated = ifelse(is.na(item_rel_rt_wide$Unrelated), 0, item_rel_rt_wide$Unrelated)

```

Item-Wise Slopes for Path Lengths

Path Length 1

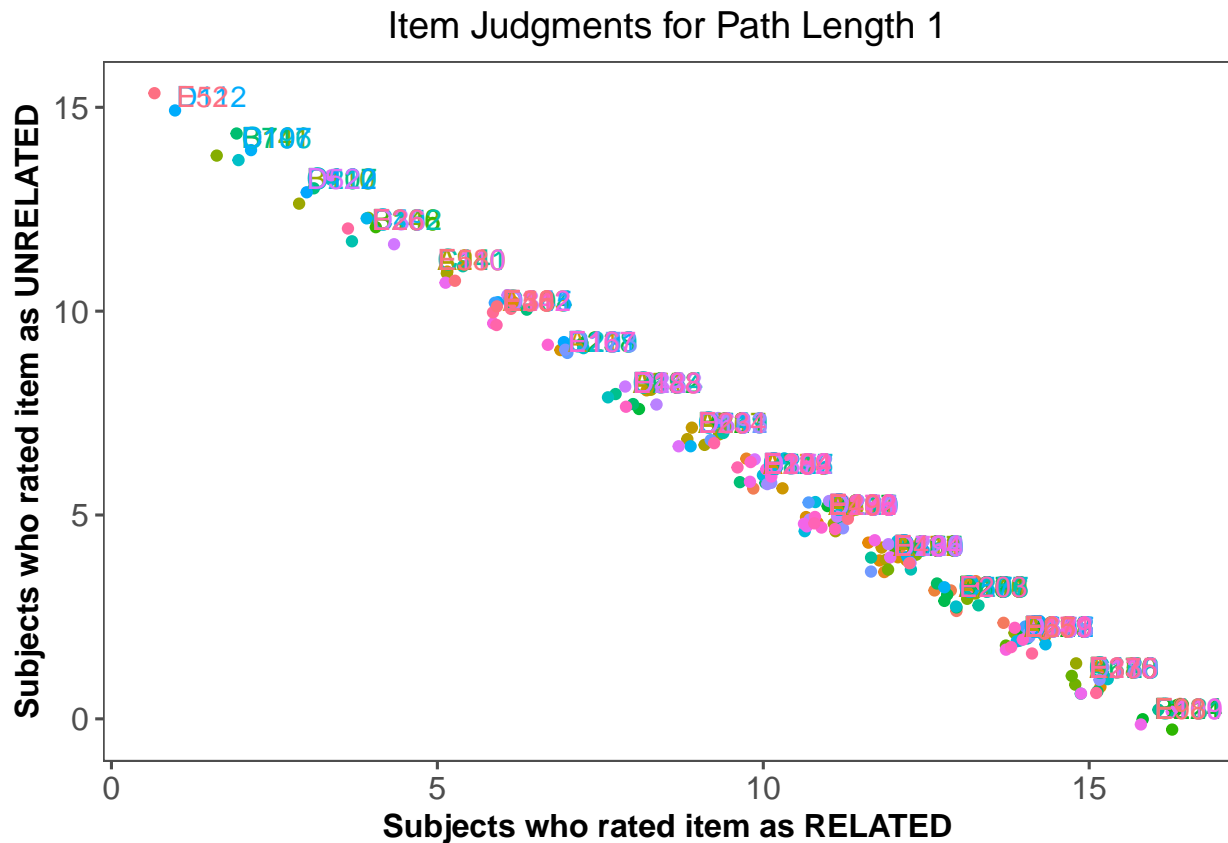
```

p1 = item_rel_wide %>% filter (pathlength == 1)

p1_sample = p1[1:10,]

ggplot(p1, aes(x = Related,
               y = Unrelated, group = ItemNo, color = ItemNo))+
  geom_point(position = "jitter")+
  #geom_line(group=1)+
  geom_text(aes(label=ItemNo),hjust=0, vjust=0) +
  theme_few()+
  guides(color = FALSE)+
  xlab("Subjects who rated item as RELATED") + ylab("Subjects who rated item as UNRELATED") +
  ggtitle("Item Judgments for Path Length 1") +
  theme(axis.text = element_text(size = rel(1)),
        axis.title = element_text(face = "bold", size = rel(1)),
        legend.title = element_text(face = "bold", size = rel(1)),
        plot.title = element_text(hjust = .5),
        strip.text.x = element_text(face = "bold", size = rel(1.4)))

```

Path Length 2

```
p2 = item_rel_wide %>% filter (pathlength == 1)

p2_sample = p2[1:50,]

ggplot(p2, aes(x = Related,
                y = Unrelated, group = ItemNo, color = ItemNo))+
  geom_point(position = "jitter")+
  #geom_line(group=1)+
  geom_text(aes(label=ItemNo),hjust=0, vjust=0) +
  theme_few()+
  guides(color = FALSE)+
  theme_few()+
  guides(color = FALSE)+
  xlab("Subjects who rated item as RELATED") + ylab("Subjects who rated item as UNRELATED") +
  ggtitle("Item Judgments for Path Length 2") +
  theme(axis.text = element_text(size = rel(1)),
        axis.title = element_text(face = "bold", size = rel(1)),
        legend.title = element_text(face = "bold", size = rel(1)),
        plot.title = element_text(hjust = .5),
        strip.text.x = element_text(face = "bold", size = rel(1.4)))
```

Item Judgments for Path Length 2



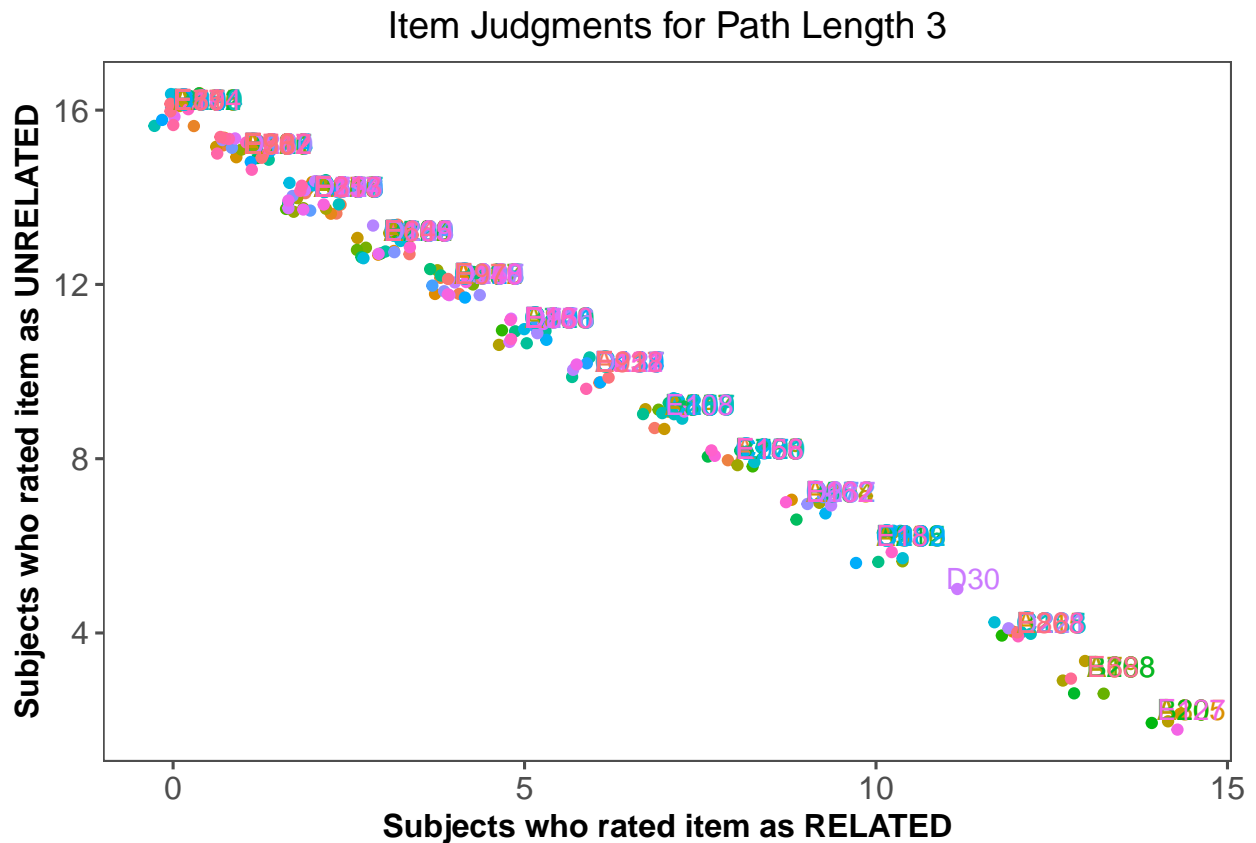
Path Length 3

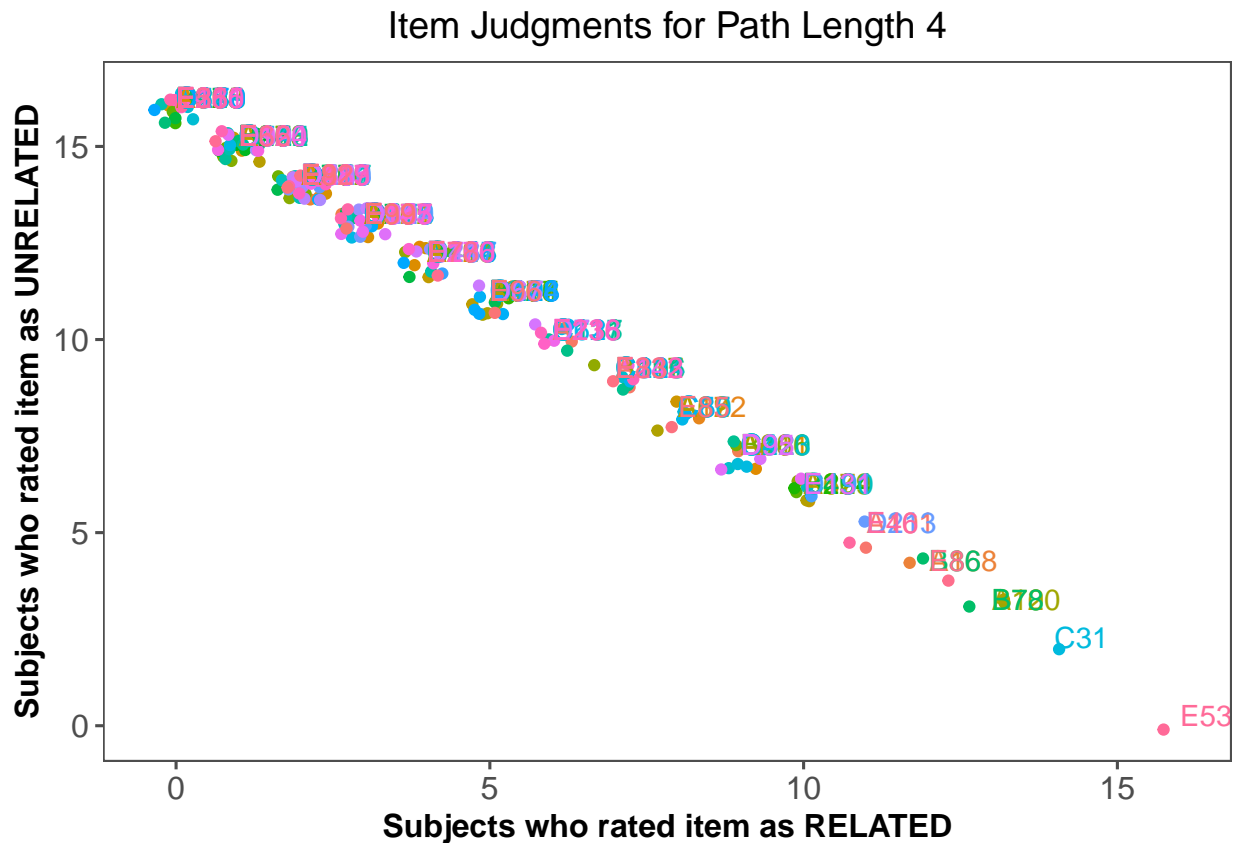
```
p3 = item_rel_wide %>% filter (pathlength == 3)

p3_sample = p3[1:50,]

ggplot(p3, aes(x = Related,
               y = Unrelated, group = ItemNo, color = ItemNo))+
  geom_point(position = "jitter")+
  #geom_line(group=1)+
  geom_text(aes(label=ItemNo),hjust=0, vjust=0) +
  theme_few()+

  guides(color = FALSE)+
  theme_few()+
  theme_few()+
  xlab("Subjects who rated item as RELATED") + ylab("Subjects who rated item as UNRELATED") +
  ggtitle("Item Judgments for Path Length 3") +
  theme(axis.text = element_text(size = rel(1)),
        axis.title = element_text(face = "bold", size = rel(1)),
        legend.title = element_text(face = "bold", size = rel(1)),
        plot.title = element_text(hjust = .5),
        strip.text.x = element_text(face = "bold", size = rel(1.4)))
```





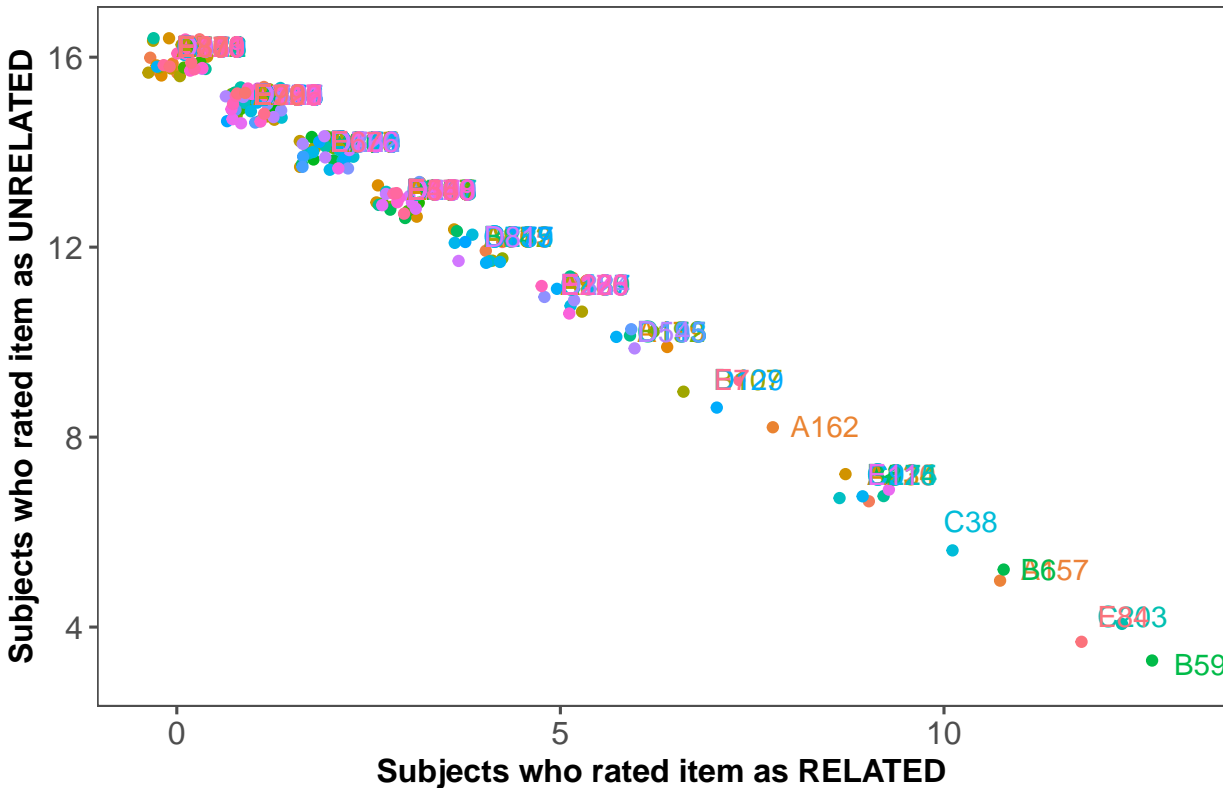
Path Length 6

```
p6 = item_rel_wide %>% filter (pathlength == 6)

p6_sample = p6[1:50,]

ggplot(p6, aes(x = Related,
                y = Unrelated, group = ItemNo, color = ItemNo))+
  geom_point(position = "jitter")+
  #geom_line(group=1)+
  geom_text(aes(label=ItemNo),hjust=0, vjust=0) +
  theme_few()+
  guides(color = FALSE)+
  theme_few()+
  guides(color = FALSE)+
  xlab("Subjects who rated item as RELATED") + ylab("Subjects who rated item as UNRELATED") +
  ggtitle("Item Judgments for Path Length 6") +
  theme(axis.text = element_text(size = rel(1)),
        axis.title = element_text(face = "bold", size = rel(1)),
        legend.title = element_text(face = "bold", size = rel(1)),
        plot.title = element_text(hjust = .5),
        strip.text.x = element_text(face = "bold", size = rel(1.4)))
```

Item Judgments for Path Length 6

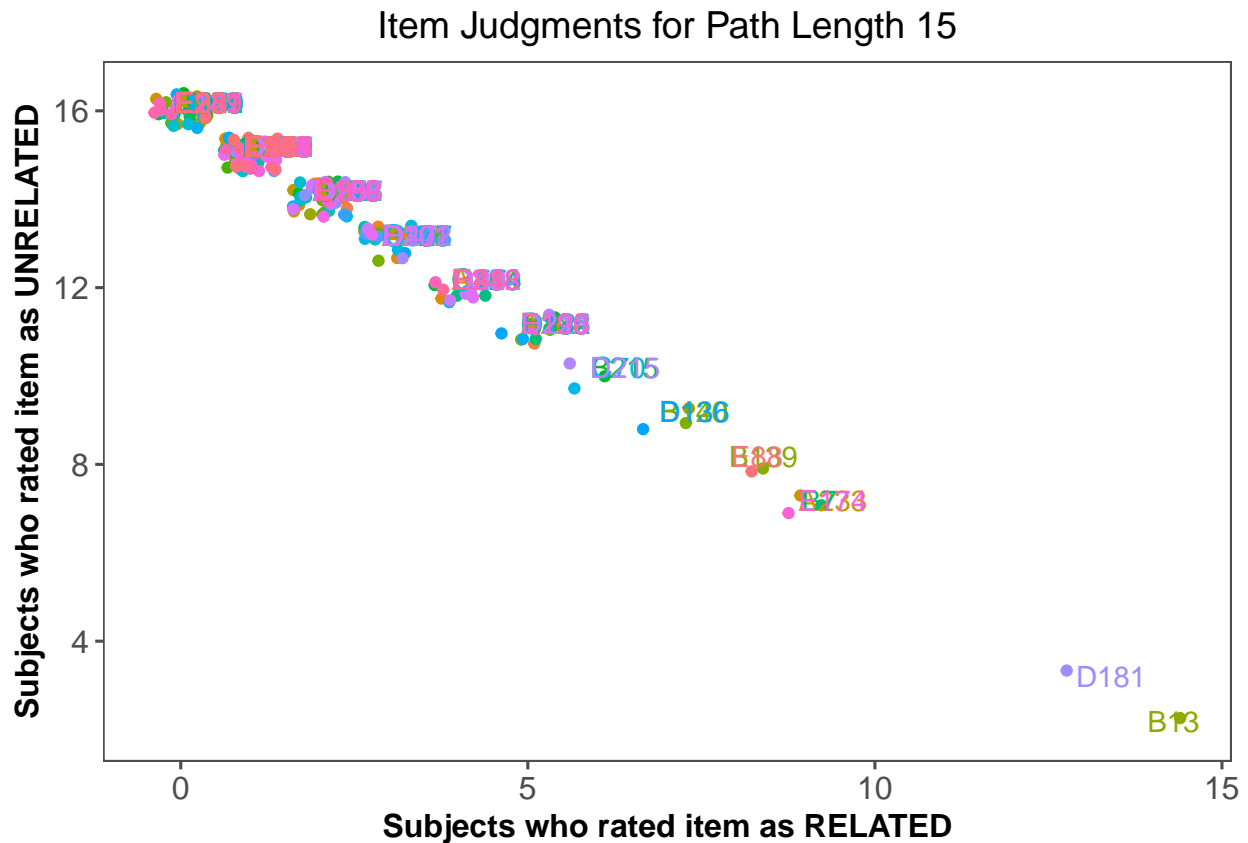


Path Length 15

```
p15 = item_rel_wide %>% filter (pathlength == 15)

p15_sample = p15[1:50,]

ggplot(p15, aes(x = Related,
                y = Unrelated, group = ItemNo, color = ItemNo))+
  geom_point(position = "jitter")+
  #geom_line(group=1)+
  geom_text(aes(label=ItemNo),hjust=0.1, vjust=0.1) +
  theme_few()+
  guides(color = FALSE)+
  theme_few()+
  xlab("Subjects who rated item as RELATED") + ylab("Subjects who rated item as UNRELATED") +
  ggtitle("Item Judgments for Path Length 15") +
  theme(axis.text = element_text(size = rel(1)),
        axis.title = element_text(face = "bold", size = rel(1)),
        legend.title = element_text(face = "bold", size = rel(1)),
        plot.title = element_text(hjust = .5),
        strip.text.x = element_text(face = "bold", size = rel(1.4)))
```



Item Level Analyses

Proportion of Subjects

Plot

```
## we have item_rel_wide and item_rel_rt_wide with RTs and number of subjects
## who called these items related/unrelated for each path length

item_rel_main = merge(item_rel, item_rel_rt,
                      by = c("pathlength", "ItemNo", "Type"))

itemrt_agg = Rmisc::summarySE(item_rel_main,
                              measurevar = "rt",
                              groupvars = c("pathlength", "Type"))

itemrt_agg_collapsed = Rmisc::summarySE(item_rel_collapsed,
                                         measurevar = "rt",
                                         groupvars = c("pathlength"))

item_rel_main$Proportion = item_rel_main$Trials/16

item_agg = Rmisc::summarySE(item_rel_main,
```

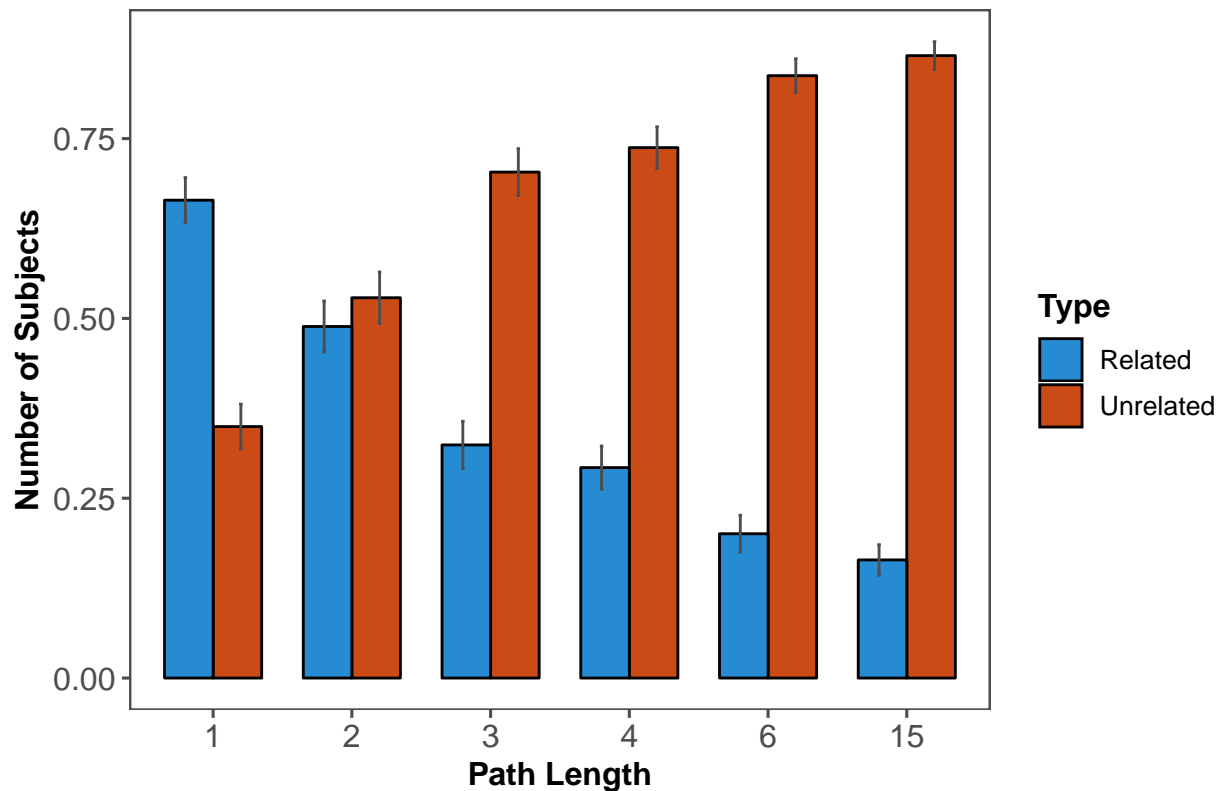
```

        measurevar = "Proportion",
        groupvars = c("pathlength", "Type"))
item_agg$pathlengthfac = ordered(as.factor(as.character(item_agg$pathlength)),
                                levels = c("1", "2", "3", "4", "6", "15"))

item_agg %>%
  ggplot(aes(x = pathlengthfac, y = Proportion, group = Type, fill = Type))+
  # geom_smooth(method = "loess")+
  geom_bar(stat = "identity", position = "dodge", width = 0.7, color = "black")+
  geom_errorbar(aes(ymin=Proportion - ci, ymax=Proportion + ci),
                width=.05, color = "gray30",
                position = position_dodge(0.8))+
  theme_few()+
  scale_fill_solarized()+
  #scale_x_continuous(breaks = c(1,2,3,4,5,6,10,15,20))+
  xlab("Path Length") + ylab("Number of Subjects") +
  ggtitle("Item-Level Subject Counts for Relatedness Judgments") +
  theme(axis.text = element_text(size = rel(1)),
        axis.title = element_text(face = "bold", size = rel(1)),
        legend.title = element_text(face = "bold", size = rel(1)),
        plot.title = element_text(hjust = .5),
        strip.text.x = element_text(face = "bold", size = rel(1.4)))

```

Item-Level Subject Counts for Relatedness Judgments



ANOVA

```
## item_rel_wide has 1200 rows with 0s for items. convert that into wide.

library(tidyr)

## Warning: package 'tidyr' was built under R version 3.4.4
##
## Attaching package: 'tidyr'
## The following object is masked from 'package:Matrix':
##
##     expand

item_prop_data = item_rel_wide %>%
  gather(Type, Trials, Related:Unrelated)

item_prop_data$Proportion = item_prop_data$Trials/16

item_prop_data = item_prop_data[order(item_prop_data$ItemNo),]

item_prop_data$pathlengthfac = ordered(as.factor(as.character(item_prop_data$pathlength)),
                                       levels = c("1", "2", "3", "4", "6", "15"))

library(lme4)
itemrelunrel_aov = aov(data = item_prop_data,
                      Proportion ~ pathlengthfac*Type +
                        Error(ItemNo/(Type)))
summary(itemrelunrel_aov)

##
## Error: ItemNo
##              Df      Sum Sq   Mean Sq F value Pr(>F)
## pathlengthfac    5 2.900e-28  5.896e-29   0.317   0.903
## Residuals      1194 2.223e-25  1.862e-28
##
## Error: ItemNo:Type
##              Df Sum Sq Mean Sq F value Pr(>F)
## Type              1  66.54   66.54   750.4 <2e-16 ***
## pathlengthfac:Type    5  81.84   16.37   184.6 <2e-16 ***
## Residuals           1194 105.88    0.09
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

options(contrasts = c('contr.sum', 'contr.poly'))
library(lsmeans)
library(multcomp)
sem_lsm = lsmeans::lsmeans(itemrelunrel_aov, c("pathlengthfac", "Type"))
prime_effect = cld(sem_lsm, alpha = 0.05,
                   adjust = "tukey", details = TRUE, by = "pathlengthfac")
library(knitr)
kable(subset(prime_effect$comparisons, prime_effect$comparisons$p.value < 0.05))
```

	contrast	pathlengthfac	estimate	SE	df	t.ratio	p.value
1	Related - Unrelated	1	0.328750	0.0297781	1194	11.03999	0

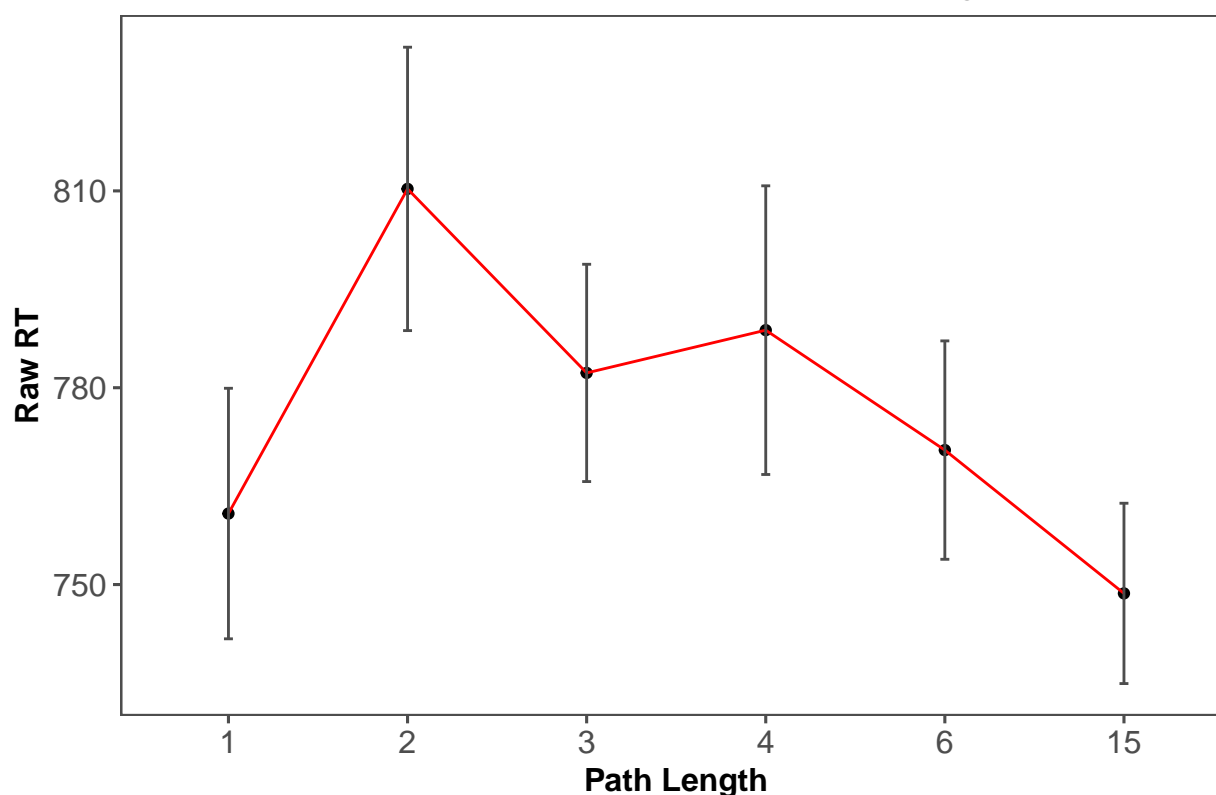
	contrast	pathlengthfac	estimate	SE	df	t.ratio	p.value
3	Related - Unrelated	3	0.406875	0.0297781	1194	13.66356	0
4	Related - Unrelated	4	0.467500	0.0297781	1194	15.69945	0
5	Related - Unrelated	6	0.675000	0.0297781	1194	22.66765	0
6	Related - Unrelated	15	0.730625	0.0297781	1194	24.53564	0

Raw RT Plot Collapsed

```
itemrt_agg_collapsed$pathlengthfac = ordered(as.factor(as.character(itemrt_agg_collapsed$pathlength)),
                                             levels = c("1", "2", "3", "4", "6", "15"))

itemrt_agg_collapsed %>%
  ggplot(aes(x = pathlengthfac, y = rt, group = 1))+
  # geom_smooth(method = "loess")+
  geom_point()+
  geom_line(color = "red")+
  geom_errorbar(aes(ymin=rt - ci, ymax=rt + ci),
                width=.05, color = "gray30",
                position = position_dodge(0))+
  theme_few()+
  #scale_x_continuous(breaks = c(1,2,3,4,5,6,10,15,20))+
  xlab("Path Length") + ylab("Raw RT") +
  ggtitle("Item-Level Raw RTs for Relatedness Judgments") +
  theme(axis.text = element_text(size = rel(1)),
        axis.title = element_text(face = "bold", size = rel(1)),
        legend.title = element_text(face = "bold", size = rel(1)),
        plot.title = element_text(hjust = .5),
        strip.text.x = element_text(face = "bold", size = rel(1.4)))
```

Item-Level Raw RTs for Relatedness Judgments



RT ANOVA Collapsed

```
item_rt_collapsed$pathlengthfac = ordered(as.factor(as.character(item_rt_collapsed$pathlength)),
                                           levels = c("1", "2", "3", "4", "6", "15"))
item_rt_collapsed$ItemNo = as.factor(item_rt_collapsed$ItemNo)
```

```
item_rt_collapsed_aov = aov(data = item_rt_collapsed,
                             rt ~ pathlengthfac)
summary(item_rt_collapsed_aov)
```

```
##              Df    Sum Sq Mean Sq F value    Pr(>F)
## pathlengthfac   5    476614    95323   5.411 6.27e-05 ***
## Residuals    1194   2103333    17616
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
options(contrasts = c('contr.sum', 'contr.poly'))
library(lsmeans)
library(multcomp)
sem_lsm = lsmeans::lsmeans(item_rt_collapsed_aov, c("pathlengthfac"))
prime_effect = cld(sem_lsm, alpha = 0.05,
                   adjust = "tukey", details = TRUE)
library(knitr)
kable(subset(prime_effect$comparisons, prime_effect$comparisons$p.value < 1))
```

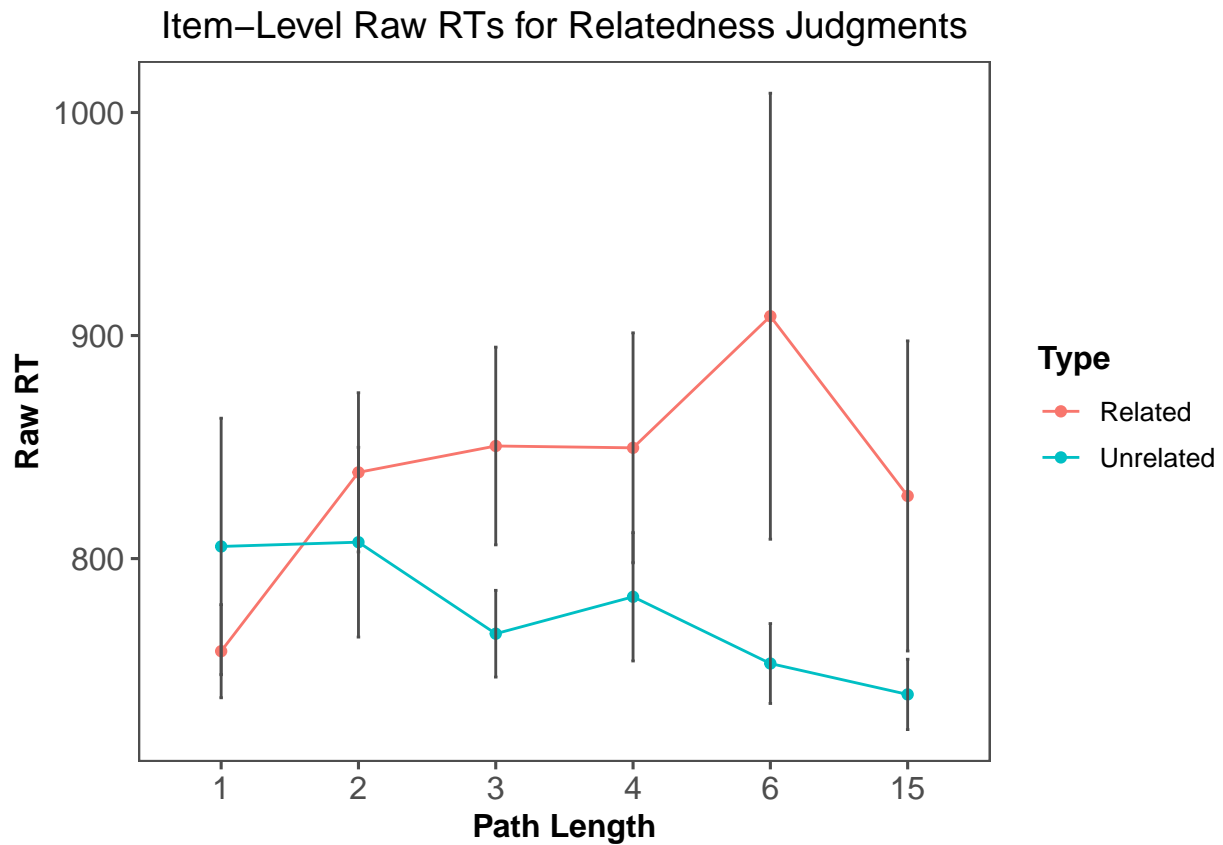
contrast	estimate	SE	df	t.ratio	p.value
1 - 15	12.170625	13.27247	1194	0.9169824	0.9422321
6 - 15	21.844062	13.27247	1194	1.6458169	0.5681637

contrast	estimate	SE	df	t.ratio	p.value
6 - 1	9.673438	13.27247	1194	0.7288345	0.9784016
3 - 15	33.605312	13.27247	1194	2.5319554	0.1156991
3 - 1	21.434687	13.27247	1194	1.6149730	0.5887403
3 - 6	11.761250	13.27247	1194	0.8861385	0.9498706
4 - 15	40.122500	13.27247	1194	3.0229857	0.0306324
4 - 1	27.951875	13.27247	1194	2.1060034	0.2847493
4 - 6	18.278437	13.27247	1194	1.3771688	0.7408261
4 - 3	6.517188	13.27247	1194	0.4910303	0.9964910
2 - 15	61.653438	13.27247	1194	4.6452106	0.0000553
2 - 1	49.482813	13.27247	1194	3.7282282	0.0027675
2 - 6	39.809375	13.27247	1194	2.9993937	0.0328732
2 - 3	28.048125	13.27247	1194	2.1132552	0.2809956
2 - 4	21.530938	13.27247	1194	1.6222249	0.5839069

Raw RT Plot Rel-Unrel

```
itemrt_agg$pathlengthfac = ordered(as.factor(as.character(itemrt_agg$pathlength)),
                                   levels = c("1", "2", "3", "4", "6", "15"))

itemrt_agg %>%
  ggplot(aes(x = pathlengthfac, y = rt, group = Type, color = Type))+
  # geom_smooth(method = "loess")+
  geom_point()+
  geom_line()+
  geom_errorbar(aes(ymin=rt - ci, ymax=rt + ci),
                width=.05, color = "gray30",
                position = position_dodge(0))+
  theme_few()+
  #scale_x_continuous(breaks = c(1,2,3,4,5,6,10,15,20))+
  xlab("Path Length") + ylab("Raw RT") +
  ggtitle("Item-Level Raw RTs for Relatedness Judgments") +
  theme(axis.text = element_text(size = rel(1)),
        axis.title = element_text(face = "bold", size = rel(1)),
        legend.title = element_text(face = "bold", size = rel(1)),
        plot.title = element_text(hjust = .5),
        strip.text.x = element_text(face = "bold", size = rel(1.4)))
```



RT ANOVA Rel-Unrel

```

item_count = group_by(item_rel_main, ItemNo) %>%
  summarise(n = n())

x = which(item_count$n != 2)

missingtrialsitems = item_count[x,][,1]

item_rel_main$pathlengthfac = ordered(as.factor(as.character(item_rel_main$pathlength)),
                                     levels = c("1", "2", "3", "4", "6", "15"))
contrasts(item_rel_main$pathlengthfac) = contr.treatment(6, base = 2)
contrasts(item_rel_main$Type) = contr.treatment(2, base = 2)

item_rel_main_final = item_rel_main %>%
  filter(!ItemNo %in% missingtrialsitems$ItemNo)

item_rt_aov = aov(data = item_rel_main_final, rt ~ pathlengthfac*Type +
                  Error(ItemNo/Type))
summary(item_rt_aov)

##
## Error: ItemNo

```

```

##              Df      Sum Sq Mean Sq F value Pr(>F)
## pathlengthfac    5      759471  151894   1.447  0.205
## Residuals      1069 112191545  104950
##
## Error: ItemNo:Type
##              Df      Sum Sq Mean Sq F value   Pr(>F)
## Type          1      1957921 1957921   19.094 1.37e-05 ***
## pathlengthfac:Type    5      1960483  392097   3.824  0.00194 **
## Residuals           1069 109616185  102541
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

item_rt_aov = lme4::lmer(data = item_rel_main, rt ~ pathlengthfac*Type +
                        (1|ItemNo))
summary(item_rt_aov)

## Linear mixed model fit by REML ['lmerMod']
## Formula: rt ~ pathlengthfac * Type + (1 | ItemNo)
##   Data: item_rel_main
##
## REML criterion at convergence: 32510.6
##
## Scaled residuals:
##      Min       1Q   Median       3Q      Max
## -2.5813 -0.4281 -0.1238  0.2605 22.1734
##
## Random effects:
##   Groups   Name                Variance Std.Dev.
##   ItemNo   (Intercept)         1094      33.07
##   Residual                  97675     312.53
## Number of obs: 2275, groups: ItemNo, 1200
##
## Fixed effects:
##              Estimate Std. Error t value
## (Intercept)      807.339      22.335  36.148
## pathlengthfac1      -1.913      31.832  -0.060
## pathlengthfac3     -41.021      31.507  -1.302
## pathlengthfac4     -24.484      31.546  -0.776
## pathlengthfac5     -54.385      31.507  -1.726
## pathlengthfac6     -68.240      31.507  -2.166
## Type1              31.336      31.534   0.994
## pathlengthfac1:Type1 -78.278      44.629  -1.754
## pathlengthfac3:Type1  52.791      44.911   1.175
## pathlengthfac4:Type1  35.504      44.972   0.789
## pathlengthfac5:Type1 124.329      45.684   2.722
## pathlengthfac6:Type1  57.672      45.602   1.265
##
## Correlation of Fixed Effects:
##              (Intr) pthln1 pthln3 pthln4 pthln5 pthln6 Type1  pt1:T1 pt3:T1
## pthlngthfc1 -0.702
## pthlngthfc3 -0.709  0.497
## pthlngthfc4 -0.708  0.497  0.502
## pthlngthfc5 -0.709  0.497  0.503  0.502
## pthlngthfc6 -0.709  0.497  0.503  0.502  0.503
## Type1       -0.701  0.492  0.497  0.496  0.497  0.497

```

```
## pthlngt1:T1 0.495 -0.706 -0.351 -0.350 -0.351 -0.351 -0.707
## pthlngt3:T1 0.492 -0.345 -0.694 -0.348 -0.349 -0.349 -0.702 0.496
## pthlngt4:T1 0.491 -0.345 -0.348 -0.694 -0.348 -0.348 -0.701 0.495 0.492
## pthlngt5:T1 0.484 -0.339 -0.343 -0.342 -0.682 -0.343 -0.690 0.488 0.485
## pthlngt6:T1 0.484 -0.340 -0.343 -0.343 -0.343 -0.683 -0.692 0.489 0.486
##
## pt4:T1 pt5:T1
## pthlngthfc1
## pthlngthfc3
## pthlngthfc4
## pthlngthfc5
## pthlngthfc6
## Type1
## pthlngt1:T1
## pthlngt3:T1
## pthlngt4:T1
## pthlngt5:T1 0.484
## pthlngt6:T1 0.485 0.477
```

```
car::Anova(item_rt_aov)
```

```
## Analysis of Deviance Table (Type II Wald chisquare tests)
##
## Response: rt
##
##           Chisq Df Pr(>Chisq)
## pathlengthfac    7.5307  5  0.1840642
## Type           21.8948  1  2.88e-06 ***
## pathlengthfac:Type 22.0476  5  0.0005128 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
options(contrasts = c('contr.sum', 'contr.poly'))
library(lsmmeans)
library(multcomp)
sem_lsm = lsmmeans::lsmmeans(item_rt_aov, c("pathlengthfac", "Type"))
```

```
## Loading required namespace: lmerTest
```

```
prime_effect = cld(sem_lsm, alpha = 0.05,
                    adjust = "tukey", details = TRUE)
library(knitr)
kable(subset(prime_effect$comparisons, prime_effect$comparisons$p.value < 1))
```

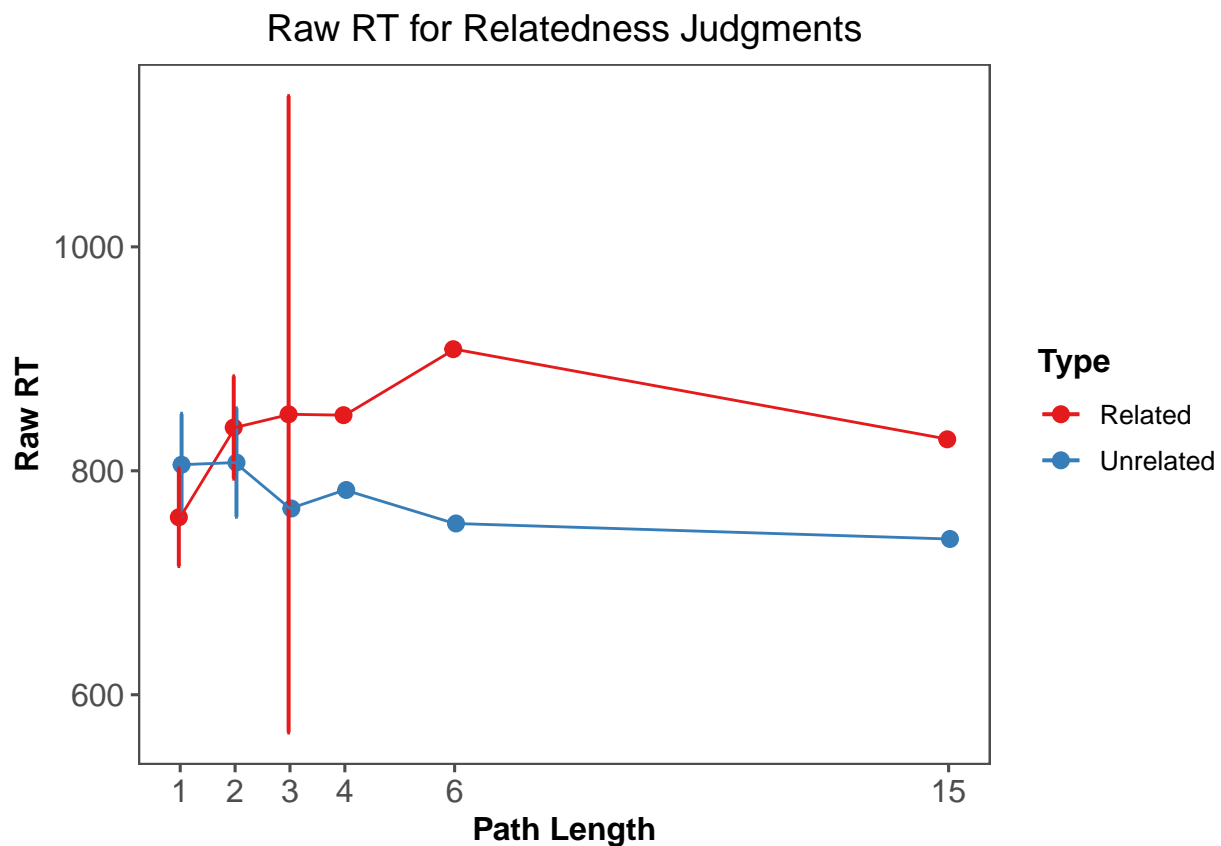
	contrast	estimate	SE	df	t.ratio	p.value
1	6,Unrelated - 15,Unrelated	13.855300	31.42754	2262.762	0.4408649	0.9999994
2	1,Related - 15,Unrelated	19.384171	31.42754	2262.762	0.6167893	0.9999788
3	1,Related - 6,Unrelated	5.528871	31.42754	2262.762	0.1759244	1.0000000
4	3,Unrelated - 15,Unrelated	27.218656	31.42754	2262.762	0.8660766	0.9993953
5	3,Unrelated - 6,Unrelated	13.363356	31.42754	2262.762	0.4252116	0.9999996
6	3,Unrelated - 1,Related	7.834485	31.42754	2262.762	0.2492872	1.0000000
7	4,Unrelated - 15,Unrelated	43.755983	31.46699	2262.764	1.3905359	0.9654713
8	4,Unrelated - 6,Unrelated	29.900683	31.46699	2262.764	0.9502237	0.9985646
9	4,Unrelated - 1,Related	24.371812	31.46699	2262.764	0.7745199	0.9997935
10	4,Unrelated - 3,Unrelated	16.537327	31.46699	2262.764	0.5255452	0.9999959
11	1,Unrelated - 15,Unrelated	66.326457	31.75318	2262.782	2.0888129	0.6309470
12	1,Unrelated - 6,Unrelated	52.471157	31.75318	2262.782	1.6524692	0.8891233
13	1,Unrelated - 1,Related	46.942285	31.58050	1176.256	1.4864328	0.9442871

	contrast	estimate	SE	df	t.ratio	p.value
14	1,Unrelated - 3,Unrelated	39.107801	31.75318	2262.782	1.2316183	0.9864578
15	1,Unrelated - 4,Unrelated	22.570474	31.79223	2262.784	0.7099368	0.9999125
16	2,Unrelated - 15,Unrelated	68.239809	31.50679	2262.767	2.1658761	0.5748196
17	2,Unrelated - 6,Unrelated	54.384509	31.50679	2262.767	1.7261201	0.8562742
18	2,Unrelated - 1,Related	48.855638	31.50679	2262.767	1.5506382	0.9260562
19	2,Unrelated - 3,Unrelated	41.021153	31.50679	2262.767	1.3019781	0.9789933
20	2,Unrelated - 4,Unrelated	24.483826	31.54615	2262.769	0.7761273	0.9997893
22	15,Related - 15,Unrelated	89.008359	32.94154	1269.883	2.7020095	0.2262817
23	15,Related - 6,Unrelated	75.153059	33.10713	2262.851	2.2699963	0.4985311
24	15,Related - 1,Related	69.624188	33.10713	2262.851	2.1029968	0.6207011
25	15,Related - 3,Unrelated	61.789704	33.10713	2262.851	1.8663564	0.7800996
26	15,Related - 4,Unrelated	45.252376	33.14458	2262.853	1.3653024	0.9698516
27	15,Related - 1,Unrelated	22.681903	33.41641	2262.864	0.6787654	0.9999441
28	15,Related - 2,Unrelated	20.768550	33.18237	2262.854	0.6258911	0.9999754
29	2,Related - 15,Unrelated	99.575704	31.62833	2262.774	3.1483071	0.0721858
30	2,Related - 6,Unrelated	85.720404	31.62833	2262.774	2.7102410	0.2216467
31	2,Related - 1,Related	80.191533	31.62833	2262.774	2.5354335	0.3182170
32	2,Related - 3,Unrelated	72.357048	31.62833	2262.774	2.2877288	0.4856636
33	2,Related - 4,Unrelated	55.819721	31.66753	2262.777	1.7626797	0.8380800
34	2,Related - 1,Unrelated	33.249247	31.95193	2262.794	1.0406022	0.9967463
35	2,Related - 2,Unrelated	31.335895	31.53419	1173.275	0.9937118	0.9978307
36	2,Related - 15,Related	10.567345	33.29779	2262.859	0.3173587	1.0000000
37	4,Related - 15,Unrelated	110.595912	32.19513	2262.807	3.4351757	0.0296948
38	4,Related - 6,Unrelated	96.740612	32.19513	2262.807	3.0048217	0.1076850
39	4,Related - 1,Related	91.211741	32.19513	2262.807	2.8330916	0.1667927
40	4,Related - 3,Unrelated	83.377256	32.19513	2262.807	2.5897478	0.2859653
41	4,Related - 4,Unrelated	66.839929	32.06362	1210.660	2.0846030	0.6340048
42	4,Related - 1,Unrelated	44.269455	32.51308	2262.823	1.3615890	0.9704590
43	4,Related - 2,Unrelated	42.356103	32.27249	2262.811	1.3124522	0.9776521
44	4,Related - 15,Related	21.587553	33.83663	2262.880	0.6379935	0.9999701
45	4,Related - 2,Related	11.020208	32.39116	2262.817	0.3402227	1.0000000
46	3,Related - 15,Unrelated	111.345533	32.14904	2262.805	3.4634167	0.0270425
47	3,Related - 6,Unrelated	97.490233	32.14904	2262.805	3.0324459	0.0999425
48	3,Related - 1,Related	91.961362	32.14904	2262.805	2.8604697	0.1560357
49	3,Related - 3,Unrelated	84.126877	31.97849	1204.179	2.6307329	0.2635496
50	3,Related - 4,Unrelated	67.589550	32.18761	2262.807	2.0998623	0.6229696
51	3,Related - 1,Unrelated	45.019076	32.46745	2262.821	1.3865911	0.9661857
52	3,Related - 2,Unrelated	43.105724	32.22652	2262.809	1.3375854	0.9741644
53	3,Related - 15,Related	22.337174	33.79279	2262.879	0.6610041	0.9999572
54	3,Related - 2,Related	11.769829	32.34536	2262.815	0.3638800	0.9999999
56	6,Related - 15,Unrelated	169.520000	33.21922	2262.856	5.1030705	0.0000233
57	6,Related - 6,Unrelated	155.664699	33.05419	1277.387	4.7093788	0.0001735
58	6,Related - 1,Related	150.135828	33.21922	2262.856	4.5195477	0.0004041
59	6,Related - 3,Unrelated	142.301344	33.21922	2262.856	4.2837057	0.0011555
60	6,Related - 4,Unrelated	125.764016	33.25654	2262.857	3.7816324	0.0087714
61	6,Related - 1,Unrelated	103.193543	33.52746	2262.868	3.0778812	0.0881797
62	6,Related - 2,Unrelated	101.280191	33.29420	2262.859	3.0419767	0.0973764
63	6,Related - 15,Related	80.511640	34.81247	2262.912	2.3127242	0.4676484
64	6,Related - 2,Related	69.944296	33.40924	2262.864	2.0935613	0.6275226
65	6,Related - 4,Related	58.924087	33.94631	2262.884	1.7358023	0.8515757
66	6,Related - 3,Related	58.174467	33.90261	2262.883	1.7159288	0.8611253

```
x = sjPlot::plot_model(item_rt_aov, type = "int")

x + geom_line()+
  theme_few()+
  #scale_x_continuous(breaks = c(1,2,3,4,5,6,10,15,20))+
  xlab("Path Length") + ylab("Raw RT") +
  ggtitle("Raw RT for Relatedness Judgments") +
  theme(axis.text = element_text(size = rel(1)),
        axis.title = element_text(face = "bold", size = rel(1)),
        legend.title = element_text(face = "bold", size = rel(1)),
        plot.title = element_text(hjust = .5),
        strip.text.x = element_text(face = "bold", size = rel(1.4)))
```

Warning: Removed 7 rows containing missing values (geom_errorbar).



zRT plot

```
item_rel_rt = group_by(new_sem_z, pathlength, ItemNo, Type) %>%
  summarise_at(vars(rt, zRT_trim), mean)

item_rel_rt_collapsed = Rmisc::summarySE(item_rel_rt,
  measurevar = "zRT_trim",
  groupvars = c("pathlength", "Type"))

item_rel_rt_collapsed$pathlengthfac = ordered(as.factor(as.character(item_rel_rt_collapsed$pathlength)))
```



```

levels = c("1", "2", "3", "4", "6", "15"))

item_rel_rt_collapsed %>%
  ggplot(aes(x = pathlengthfac, y = zRT_trim, group = Type, color = Type))+
  # geom_smooth(method = "loess")+
  geom_point()+
  geom_line()+
  geom_errorbar(aes(ymin=zRT_trim - ci, ymax=zRT_trim + ci),
    width=.05, color = "gray30",
    position = position_dodge(0))+
  theme_few()+
  #scale_x_continuous(breaks = c(1,2,3,4,5,6,10,15,20))+
  xlab("Path Length") + ylab("z-RT") +
  ggtitle("Item-Level z-RTs for Relatedness Judgments") +
  theme(axis.text = element_text(size = rel(1)),
    axis.title = element_text(face = "bold", size = rel(1)),
    legend.title = element_text(face = "bold", size = rel(1)),
    plot.title = element_text(hjust = .5),
    strip.text.x = element_text(face = "bold", size = rel(1.4)))

```



zRT ANOVA Rel-Unrel

```

# item_count = group_by(item_rel_rt, ItemNo) %>%
#   summarise(n = n())
#

```

```

# x = which(item_count$n != 2)
#
# missingtrialsitems = item_count[x,][,1]
#
#
# item_rel_rt$pathlengthfac = ordered(as.factor(as.character(item_rel_rt$pathlength)),
#                                     levels = c("1", "2", "3", "4", "6", "15"))
# contrasts(item_rel_rt$pathlengthfac) = contr.treatment(6, base = 2)
# contrasts(item_rel_rt$Type) = contr.treatment(2, base = 2)
#
# item_rel_rt_final = item_rel_rt %>%
#   filter(!ItemNo %in% missingtrialsitems$ItemNo)
#
#
# item_zrt_aov = aov(data = item_rel_rt_final, zRT_trim ~ pathlengthfac*Type +
#                   Error(ItemNo/Type))
# summary(item_zrt_aov)
# car::Anova(item_zrt_aov)

```

GLHT Test

```

### GLHT combination test

## testing 1,related diff from 2,unrelated
## testing 2,unrelated diff from 3,unrelated
## testing 6, unrelated diff from 15, unrelated
# groups <- read.table('groups.csv',sep=',',header=TRUE,stringsAsFactors=FALSE)
# groups
#
# dummy_codes <- as.matrix(groups[,4:9])
# dummy_codes
#
# fixed_effects <- matrix(fixef(item_zrt_aov))
# fixed_effects
#
# means_matrix <- matrix(rep(0,144),ncol=12,nrow=12)
# means_matrix[,1] <- 1
# means_matrix[,2:6] <- dummy_codes[,2:6]
# means_matrix[,7] <- dummy_codes[,1]
# means_matrix[,8:12] <- dummy_codes[,1]*dummy_codes[,2:6]
# means_matrix
#
# means <- means_matrix %*% fixed_effects
# print(cbind(means,groups[,2:3]))
#
# contrast_matrix <- matrix(c(
#   0,1,-1,0,0,0,0,0,0,0,0,0,
#   0,0,1,0,-1,0,0,0,0,0,0,0,
#   0,0,1,0,0,0,-1,0,0,0,0,0,
#   0,0,0,0,0,0,1,0,-1,0,0,0,
#   0,0,0,0,0,0,0,1,0,-1,0), nrow=5,ncol=12,byrow=TRUE)
# row.names(contrast_matrix) <- c("path 1, related vs. path 2, unrelated",

```

```

#                                     "path 2, unrelated vs. path 3, unrelated",
#                                     "path 2, unrelated vs. path 4, unrelated",
#                                     "path 4, unrelated vs. path 6, unrelated",
#                                     "path 6, unrelated vs. path 15, unrelated")
#
# matrix_for_glht <- contrast_matrix %*% means_matrix
# matrix_for_glht
# glht_sem <- multcomp::glht(item_zrt_aov,
#                             linfct = matrix_for_glht,
#                             alternative = "two.sided", rhs = 0)
# summary(glht_sem)

```

KENETT ANOVAs

```

## for the RT analyses we need to include only related trials for path length 1, and unrelated trials for
## other path lengths

# removing trials below 250 ms

sem_kenett = sem %>% filter(rt > 250)

# removing for each participant, trials which were above or below 2.5 SD for each condition were also d

condition_means = group_by(sem, pathlength) %>%
  summarise_at(vars(rt), mean)
condition_sd = group_by(sem, pathlength) %>%
  summarise_at(vars(rt), sd)

condition_agg = merge(condition_means, condition_sd, by = "pathlength")
colnames(condition_agg) = c("pathlength", "meanrt", "sdrst")
condition_agg$MOE = 2.5*condition_agg$sdrst
condition_agg$lower = condition_agg$meanrt - condition_agg$MOE
condition_agg$upper = condition_agg$meanrt + condition_agg$MOE

sem_kenett = merge(sem_kenett, condition_agg, by = "pathlength")
sem_kenett = dplyr::arrange(sem_kenett, subject)

sem_kenett = sem_kenett %>% filter(rt > lower)
sem_kenett = sem_kenett %>% filter(rt < upper)

## further looking at only "successful trials", i.e., related trials for pathlength 1, and unrelated for

sem_kenett_final = sem_kenett %>% filter((pathlength == 1 & Type == "Related") |
                                         (pathlength == 2 & Type == "Unrelated") |
                                         (pathlength == 3 & Type == "Unrelated") |
                                         (pathlength == 4 & Type == "Unrelated") |
                                         (pathlength == 6 & Type == "Unrelated") |
                                         (pathlength == 15 & Type == "Unrelated") )

```

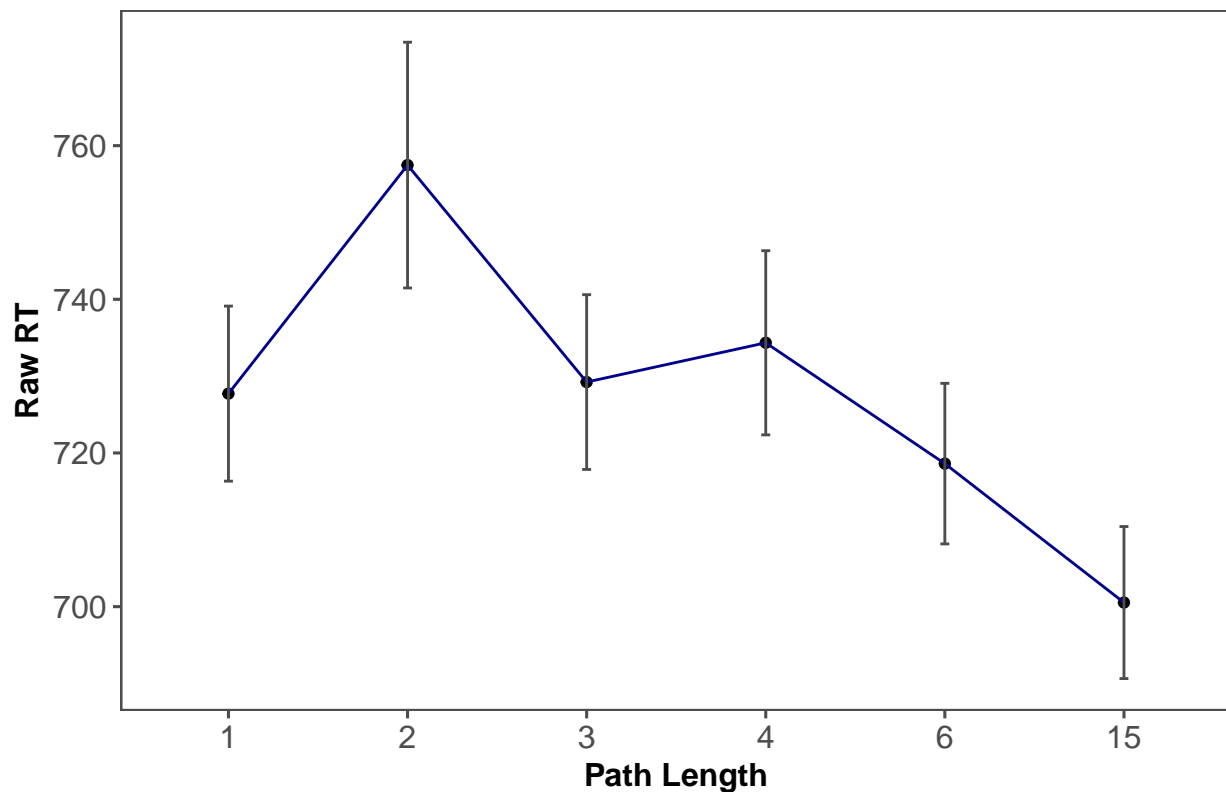
Plotting Final Kenett: Overall

```
sem_kenett_agg = Rmisc::summarySE(sem_kenett_final,
                                   measurevar = "rt",
                                   groupvars = c("pathlength"))

## Raw RT Plot Rel-Unrel
sem_kenett_agg$pathlengthfac = ordered(as.factor(as.character(sem_kenett_agg$pathlength)),
                                       levels = c("1", "2", "3", "4", "6", "15"))

sem_kenett_agg %>%
  ggplot(aes(x = pathlengthfac, y = rt, group = 1))+
  # geom_smooth(method = "loess")+
  geom_point()+
  geom_line(color = "darkblue")+
  geom_errorbar(aes(ymin=rt - ci, ymax=rt + ci),
               width=.05, color = "gray30",
               position = position_dodge(0))+
  theme_few()+
  #scale_x_continuous(breaks = c(1,2,3,4,5,6,10,15,20))+
  xlab("Path Length") + ylab("Raw RT") +
  ggtitle("Kenett Raw RTs for Relatedness Judgments") +
  theme(axis.text = element_text(size = rel(1)),
        axis.title = element_text(face = "bold", size = rel(1)),
        legend.title = element_text(face = "bold", size = rel(1)),
        plot.title = element_text(hjust = .5),
        strip.text.x = element_text(face = "bold", size = rel(1.4)))
```

Kenett Raw RTs for Relatedness Judgments



Kenett Anovas

```
sem_kenett_final$subject = as.factor(sem_kenett_final$subject)
sem_kenett_subject = group_by(sem_kenett_final, subject, pathlength) %>%
  summarize_at(vars(rt), mean)

sem_kenett_item = group_by(sem_kenett_final, pathlength, ItemNo) %>%
  summarise_at(vars(rt), mean)

sem_kenett_subject$pathlengthfac = ordered(as.factor(as.character(sem_kenett_subject$pathlength)),
  levels = c("1", "2", "3", "4", "6", "15"))
sem_kenett_item$pathlengthfac = ordered(as.factor(as.character(sem_kenett_item$pathlength)),
  levels = c("1", "2", "3", "4", "6", "15"))
```

Subject Level Anova

```
kenett_subject_aov = aov(data = sem_kenett_subject, rt ~ pathlengthfac +
  Error(subject/pathlengthfac))
summary(kenett_subject_aov)
```

```
##
## Error: subject
##          Df   Sum Sq Mean Sq F value Pr(>F)
## Residuals 79 11723333 148397
```

```
##
## Error: subject:pathlengthfac
##           Df Sum Sq Mean Sq F value    Pr(>F)
## pathlengthfac    5  234013   46803   10.16 3.63e-09 ***
## Residuals      395 1820284    4608
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

options(contrasts = c('contr.sum', 'contr.poly'))
library(lsmeans)
library(multcomp)
kenett_subject_lsm = lsmeans::lsmeans(kenett_subject_aov, c("pathlengthfac"))
sub_effect = cld(kenett_subject_lsm, alpha = 0.05,
                 adjust = "tukey", details = TRUE)
library(knitr)
kable(subset(sub_effect$comparisons, sub_effect$comparisons$p.value < 0.1))
```

	contrast	estimate	SE	df	t.ratio	p.value
4	3 - 15	31.81818	10.73349	395	2.964383	0.0376087
7	4 - 15	40.92986	10.73349	395	3.813284	0.0021880
11	2 - 15	72.49415	10.73349	395	6.754013	0.0000000
12	2 - 6	52.27590	10.73349	395	4.870353	0.0000238
13	2 - 1	47.05147	10.73349	395	4.383612	0.0002161
14	2 - 3	40.67597	10.73349	395	3.789630	0.0023924
15	2 - 4	31.56430	10.73349	395	2.940729	0.0402553

Plotting Final Kenett: Subject

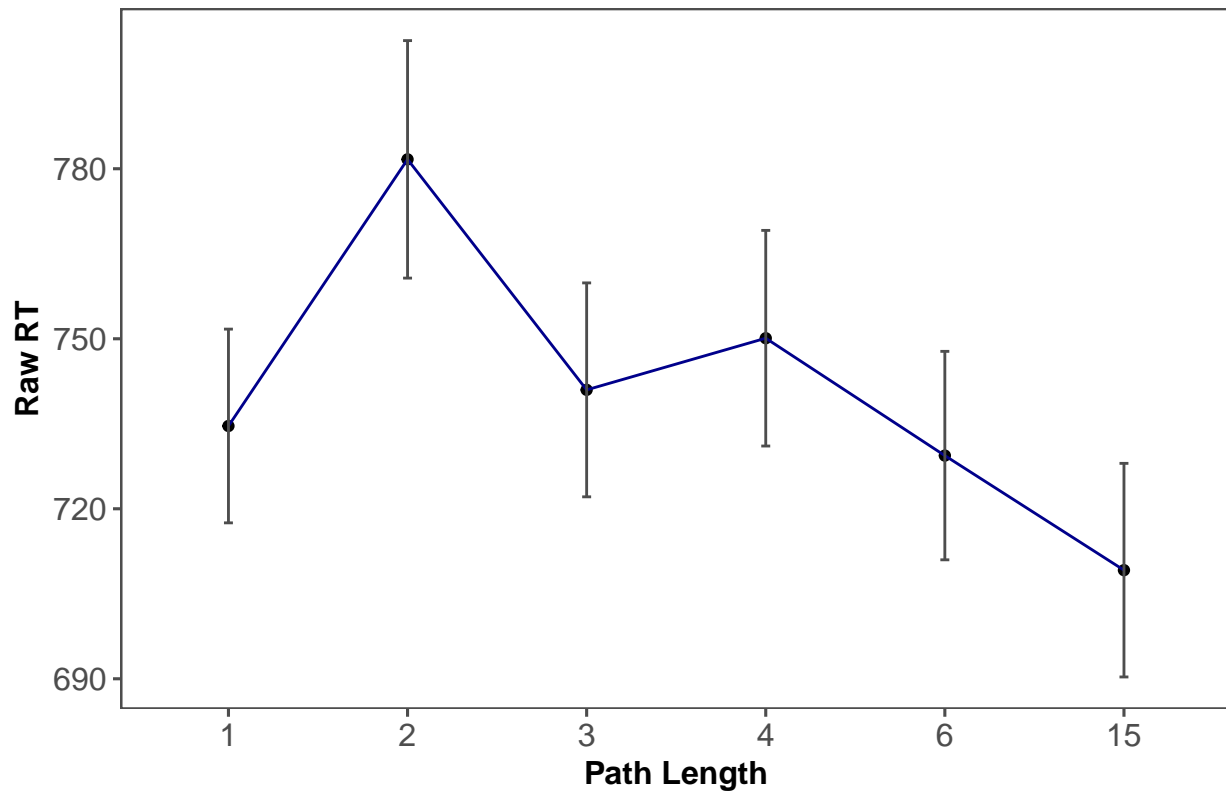
```
sem_kenett_subject_agg = Rmisc::summarySE(sem_kenett_subject,
                                           measurevar = "rt",
                                           groupvars = c("pathlength"))

## Raw RT Plot Rel-Unrel
sem_kenett_subject_agg$pathlengthfac = ordered(as.factor(as.character(sem_kenett_subject_agg$pathlengthfac)),
                                              levels = c("1", "2", "3", "4", "6", "15"))

sem_kenett_subject_agg %>%
  ggplot(aes(x = pathlengthfac, y = rt, group = 1))+
  # geom_smooth(method = "loess")+
  geom_point()+
  geom_line(color = "darkblue")+
  geom_errorbar(aes(ymin=rt - se, ymax=rt + se),
               width=.05, color = "gray30",
               position = position_dodge(0))+
  theme_few()+
  #scale_x_continuous(breaks = c(1,2,3,4,5,6,10,15,20))+
  xlab("Path Length") + ylab("Raw RT") +
  ggtitle("Subject-Level Kenett Raw RTs for Relatedness Judgments") +
  theme(axis.text = element_text(size = rel(1)),
        axis.title = element_text(face = "bold", size = rel(1)),
        legend.title = element_text(face = "bold", size = rel(1)),
```

```
plot.title = element_text(hjust = .5),
strip.text.x = element_text(face = "bold", size = rel(1.4)))
```

Subject-Level Kenett Raw RTs for Relatedness Judgments



```
z_rmisc_kenett = sem_kenett_subject_agg
z_rmisc_kenett$Network = "Association Correlation"
```

Item Level Anova

```
kenett_item_aov = aov(data = sem_kenett_item, rt ~ pathlengthfac)
summary(kenett_item_aov)
```

```
##              Df    Sum Sq Mean Sq F value    Pr(>F)
## pathlengthfac   5    316188    63238   5.441 5.88e-05 ***
## Residuals    1189  13819887    11623
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
options(contrasts = c('contr.sum', 'contr.poly'))
library(lsmeans)
library(multcomp)
kenett_item_lsm = lsmeans::lsmeans(kenett_item_aov, c("pathlengthfac"))
item_effect = cld(kenett_item_lsm, alpha = 0.05,
                  adjust = "tukey", details = TRUE)
library(knitr)
kable(subset(item_effect$comparisons, item_effect$comparisons$p.value < 0.1))
```

	contrast	estimate	SE	df	t.ratio	p.value
2	3 - 15	31.86655	10.78106	1189	2.955791	0.0373919
4	4 - 15	36.49734	10.79459	1189	3.381076	0.0096895
7	1 - 15	42.12936	10.79459	1189	3.902821	0.0014038
11	2 - 15	50.64348	10.82202	1189	4.679669	0.0000470
12	2 - 6	29.02399	10.82202	1189	2.681937	0.0796009

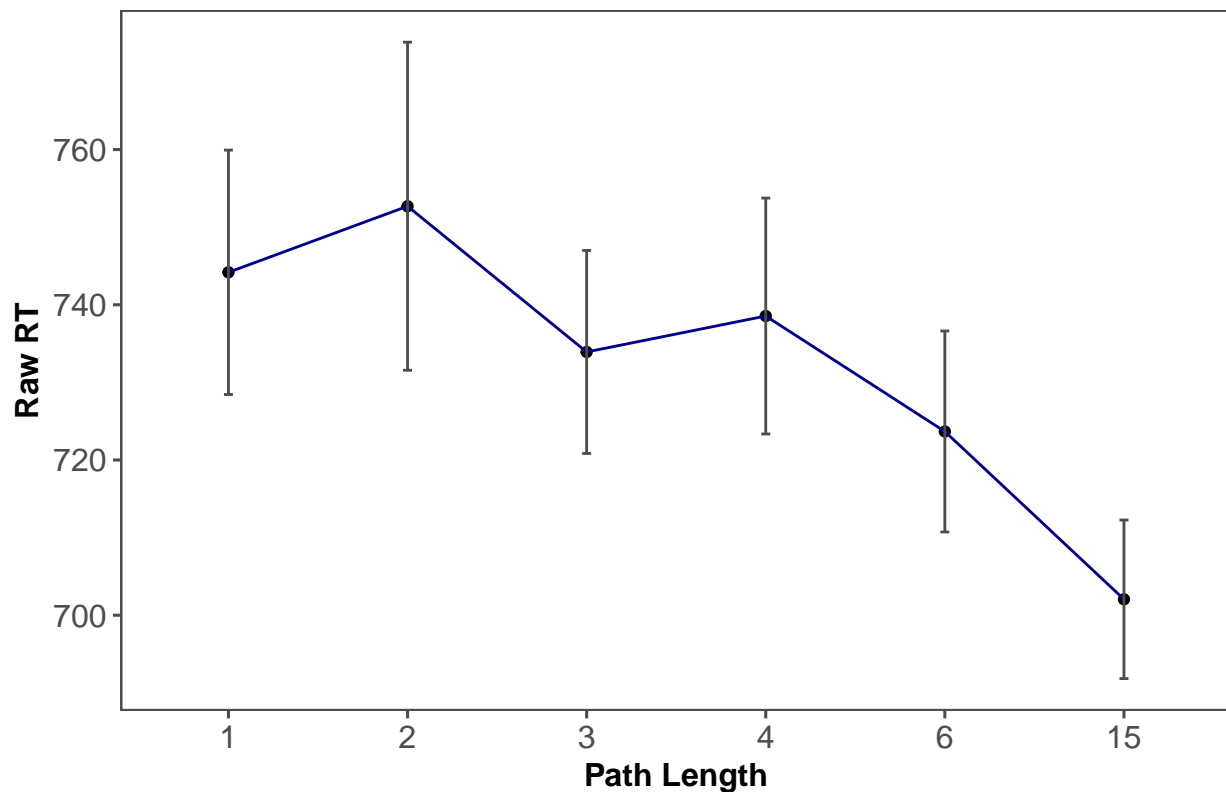
Plotting Final Kenett: item

```
sem_kenett_item_agg = Rmisc::summarySE(sem_kenett_item,
                                       measurevar = "rt",
                                       groupvars = c("pathlength"))

## Raw RT Plot Rel-Unrel
sem_kenett_item_agg$pathlengthfac = ordered(as.factor(as.character(sem_kenett_item_agg$pathlength)),
                                           levels = c("1", "2", "3", "4", "6", "15"))

sem_kenett_item_agg %>%
  ggplot(aes(x = pathlengthfac, y = rt, group = 1))+
  # geom_smooth(method = "loess")+
  geom_point()+
  geom_line(color = "darkblue")+
  geom_errorbar(aes(ymin=rt - ci, ymax=rt + ci),
               width=.05, color = "gray30",
               position = position_dodge(0))+
  theme_few()+
  #scale_x_continuous(breaks = c(1,2,3,4,5,6,10,15,20))+
  xlab("Path Length") + ylab("Raw RT") +
  ggtitle("item-Level Kenett Raw RTs for Relatedness Judgments") +
  theme(axis.text = element_text(size = rel(1)),
        axis.title = element_text(face = "bold", size = rel(1)),
        legend.title = element_text(face = "bold", size = rel(1)),
        plot.title = element_text(hjust = .5),
        strip.text.x = element_text(face = "bold", size = rel(1.4)))
```


item-Level Kenett Raw RTs for Relatedness Judgments



KENETT UNDIRECTED ANOVAs

```
## for the RT analyses we need to include only related trials for path length 1, and unrelated trials for
## other path lengths

# removing trials below 250 ms

sem_kenett_undirected = sem %>% filter(rt > 250)

# removing for each participant, trials which were above or below 2.5 SD for each condition were also removed

condition_means_undirected = group_by(sem, undirected) %>%
  summarise_at(vars(rt), mean)
condition_sd_undirected = group_by(sem, undirected) %>%
  summarise_at(vars(rt), sd)

condition_agg_undirected = merge(condition_means_undirected,
                                condition_sd_undirected, by = "undirected")
colnames(condition_agg_undirected) = c("undirected", "meanrt", "sdrt")
condition_agg_undirected$MOE = 2.5*condition_agg_undirected$sdrt
condition_agg_undirected$lower = condition_agg_undirected$meanrt -
                                condition_agg_undirected$MOE
condition_agg_undirected$upper = condition_agg_undirected$meanrt +
                                condition_agg_undirected$MOE
```

```

sem_kenett_undirected = merge(sem_kenett_undirected,
                              condition_agg_undirected, by = "undirected")
sem_kenett_undirected = dplyr::arrange(sem_kenett_undirected, subject)

sem_kenett_undirected = sem_kenett_undirected %>% filter(rt > lower)
sem_kenett_undirected = sem_kenett_undirected %>% filter(rt < upper)

## further looking at only "successful trials", i.e., related trials for pathlength 1, and unrelated for

sem_kenett_final_undirected = sem_kenett %>%
  filter((undirected == 1 & Type == "Related") |
         (pathlength == 2 & Type == "Unrelated") |
         (pathlength == 3 & Type == "Unrelated") |
         (pathlength == 4 & Type == "Unrelated") )

```

Plotting Final Kenett Undirected: Overall

```

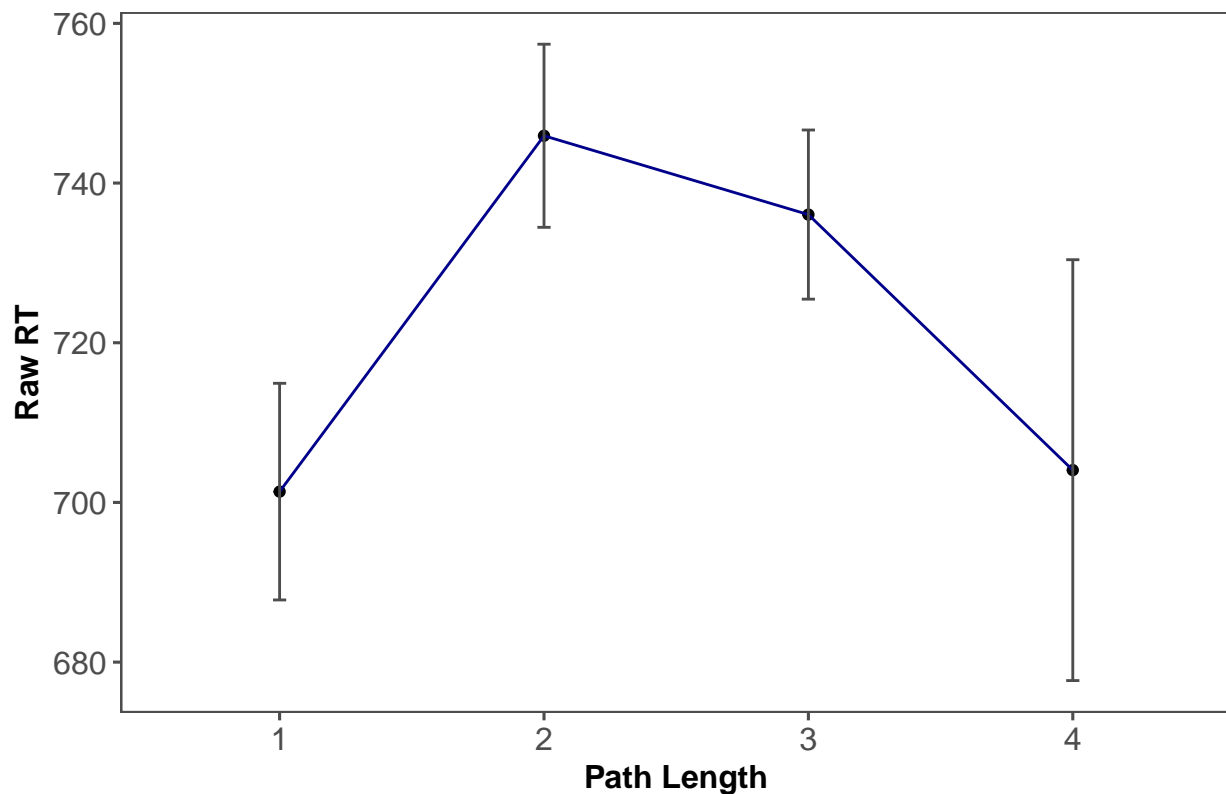
sem_kenett_agg_undirected = Rmisc::summarySE(sem_kenett_final_undirected,
                                              measurevar = "rt",
                                              groupvars = c("undirected"))

## Raw RT Plot Rel-Unrel
sem_kenett_agg_undirected$undirectedfac = ordered(as.factor(as.character(sem_kenett_agg_undirected$undirectedfac)),
                                                  levels = c("1", "2", "3", "4"))

sem_kenett_agg_undirected %>%
  ggplot(aes(x = undirectedfac, y = rt, group = 1))+
  # geom_smooth(method = "loess")+
  geom_point()+
  geom_line(color = "darkblue")+
  geom_errorbar(aes(ymin=rt - ci, ymax=rt + ci),
               width=.05, color = "gray30",
               position = position_dodge(0))+
  theme_few()+
  #scale_x_continuous(breaks = c(1,2,3,4,5,6,10,15,20))+
  xlab("Path Length") + ylab("Raw RT") +
  ggtitle("Steyvers Undirected Raw RTs for Relatedness Judgments") +
  theme(axis.text = element_text(size = rel(1)),
        axis.title = element_text(face = "bold", size = rel(1)),
        legend.title = element_text(face = "bold", size = rel(1)),
        plot.title = element_text(hjust = .5),
        strip.text.x = element_text(face = "bold", size = rel(1.4)))

```

Steyvers Undirected Raw RTs for Relatedness Judgments



Kenett Undirected Anovas

```
sem_kenett_final_undirected$subject = as.factor(sem_kenett_final_undirected$subject)
sem_kenett_subject_undirected = group_by(sem_kenett_final_undirected,
                                          subject, undirected) %>%
  summarize_at(vars(rt), mean)

sem_kenett_item_undirected = group_by(sem_kenett_final_undirected,
                                      undirected, ItemNo) %>%
  summarise_at(vars(rt), mean)

sem_kenett_subject_undirected$undirectedfac = ordered(as.factor(as.character(sem_kenett_subject_undirected$undirected)),
                                                      levels = c("1", "2", "3", "4"))
sem_kenett_item_undirected$undirectedfac = ordered(as.factor(as.character(sem_kenett_item_undirected$undirected)),
                                                    levels = c("1", "2", "3", "4"))
```

Subject Level Anova

```
kenett_subject_aov_undirected = aov(data = sem_kenett_subject_undirected,
                                     rt ~ undirectedfac +
                                     Error(subject/undirectedfac))
summary(kenett_subject_aov_undirected)
```

```
##
```

```
## Error: subject
##           Df Sum Sq Mean Sq F value Pr(>F)
## Residuals 79 7724197    97775
##
## Error: subject:undirectedfac
##           Df Sum Sq Mean Sq F value Pr(>F)
## undirectedfac 3 208291    69430  9.099 1.01e-05 ***
## Residuals    237 1808515    7631
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

options(contrasts = c('contr.sum', 'contr.poly'))
library(lsmeans)
library(multcomp)
kenett_subject_lsm = lsmeans::lsmeans(kenett_subject_aov_undirected,
                                     c("undirectedfac"))
sub_effect = cld(kenett_subject_lsm, alpha = 0.05,
                 adjust = "tukey", details = TRUE)
library(knitr)
kable(subset(sub_effect$comparisons, sub_effect$comparisons$p.value < 0.1))
```

	contrast	estimate	SE	df	t.ratio	p.value
2	3 - 1	45.36665	13.81201	237	3.284580	0.0064192
3	3 - 4	42.91321	13.81201	237	3.106949	0.0113261
4	2 - 1	57.60113	13.81201	237	4.170365	0.0002483
5	2 - 4	55.14769	13.81201	237	3.992734	0.0005030

Plotting Final Kenett Undirected: Subject

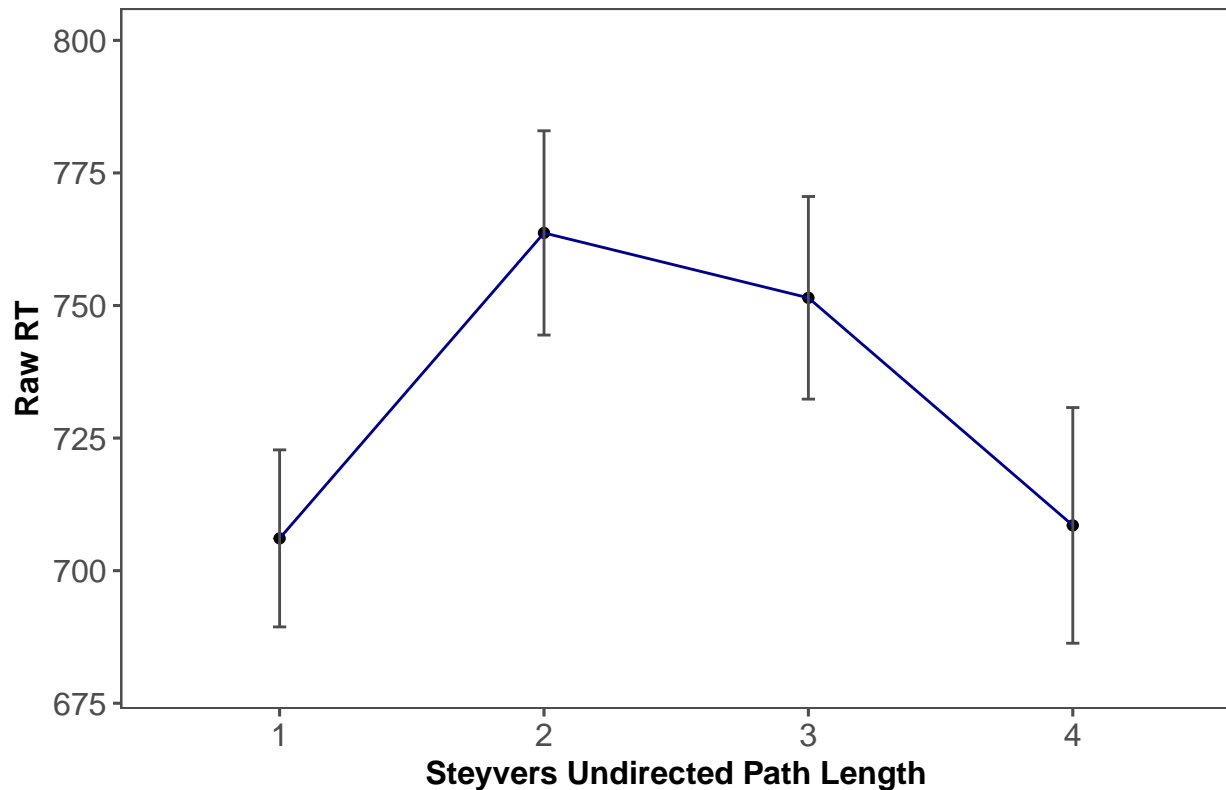
```
sem_kenett_subject_agg_undirected = Rmisc::summarySE(sem_kenett_subject_undirected,
                                                    measurevar = "rt",
                                                    groupvars = c("undirected"))

## Raw RT Plot Rel-Unrel
sem_kenett_subject_agg_undirected$undirectedfac = ordered(as.factor(as.character(sem_kenett_subject_agg_undirected$undirectedfac),
                                                    levels = c("1", "2", "3", "4")))

sem_kenett_subject_agg_undirected %>%
  ggplot(aes(x = undirectedfac, y = rt, group = 1))+
  # geom_smooth(method = "loess")+
  geom_point()+
  geom_line(color = "darkblue")+
  geom_errorbar(aes(ymin=rt - se, ymax=rt + se),
               width=.05, color = "gray30",
               position = position_dodge(0))+
  theme_few()+
  ylim(680,800)+
  #scale_x_continuous(breaks = c(1,2,3,4,5,6,10,15,20))+
  xlab("Steyvers Undirected Path Length") + ylab("Raw RT") +
  ggtitle("Subject-Level Undirected Raw RTs for Relatedness Judgments") +
  theme(axis.text = element_text(size = rel(1)),
```

```
axis.title = element_text(face = "bold", size = rel(1)),
legend.title = element_text(face = "bold", size = rel(1)),
plot.title = element_text(hjust = .5),
strip.text.x = element_text(face = "bold", size = rel(1.4)))
```

Subject-Level Undirected Raw RTs for Relatedness Judgments



```
sem_kenett_subject_agg_undirected$Network = "Undirected Simple Association"
```

KENETT DIRECTED ANOVAs

```
## for the RT analyses we need to include only related trials for path length 1, and unrelated trials for
## other path lengths
```

```
# removing trials below 250 ms
```

```
sem_kenett_directed = sem %>% filter(rt > 250)
```

```
# removing for each participant, trials which were above or below 2.5 SD for each condition were also d
```

```
condition_means_directed = group_by(sem, directed) %>%
  summarise_at(vars(rt), mean)
```

```
condition_sd_directed = group_by(sem, directed) %>%
  summarise_at(vars(rt), sd)
```

```
condition_agg_directed = merge(condition_means_directed,
```

```

            condition_sd_directed, by = "directed")
colnames(condition_agg_directed) = c("directed", "meanrt", "sdrt")
condition_agg_directed$MOE = 2.5*condition_agg_directed$sdrt
condition_agg_directed$lower = condition_agg_directed$meanrt -
            condition_agg_directed$MOE
condition_agg_directed$upper = condition_agg_directed$meanrt +
            condition_agg_directed$MOE

sem_kenett_directed = merge(sem_kenett_directed,
            condition_agg_directed, by = "directed")
sem_kenett_directed = dplyr::arrange(sem_kenett_directed, subject)

sem_kenett_directed = sem_kenett_directed %>% filter(rt > lower)
sem_kenett_directed = sem_kenett_directed %>% filter(rt < upper)

## further looking at only "successful trials", i.e., related trials for pathlength 1, and unrelated for

sem_kenett_final_directed = sem_kenett %>%
  filter((directed == 1 & Type == "Related") |
    (pathlength == 2 & Type == "Unrelated") |
    (pathlength == 3 & Type == "Unrelated") |
    (pathlength == 4 & Type == "Unrelated") |
    (pathlength == 5 & Type == "Unrelated") |
    (pathlength == 6 & Type == "Unrelated") |
    (pathlength == 7 & Type == "Unrelated") |
    (pathlength == 8 & Type == "Unrelated") )

sem_kenett_final_directed$newdirected = ifelse(sem_kenett_final_directed$directed == "Inf" | sem_kenett_
  sem_kenett_final_directed$directed)

sem_kenett_final_directed$directedcollapsed = ifelse(( sem_kenett_final_directed$newdirected == "6" |
  sem_kenett_final_directed$newdirected == "7" |
  sem_kenett_final_directed$newdirected == "8"), "H",
  sem_kenett_final_directed$newdirected)

```

Plotting Final Kenett Directed: Overall

```

sem_kenett_agg_directed = Rmisc::summarySE(sem_kenett_final_directed,
  measurevar = "rt",
  groupvars = c("directedcollapsed"))

## Raw RT Plot Rel-Unrel
sem_kenett_agg_directed$collapsedfac = ordered(as.factor(as.character(sem_kenett_agg_directed$directedcollapsedfac
  levels = c("1", "2", "3", "4", "5", "H")))
sem_kenett_agg_directed = sem_kenett_agg_directed %>% filter(collapsedfac != "NA")
sem_kenett_agg_directed %>%
  mutate(CollapsedDirected = factor(collapsedfac,
    levels = unique(collapsedfac),
    labels = c("1", "2", "3", "4", "5", "5+")))%>%

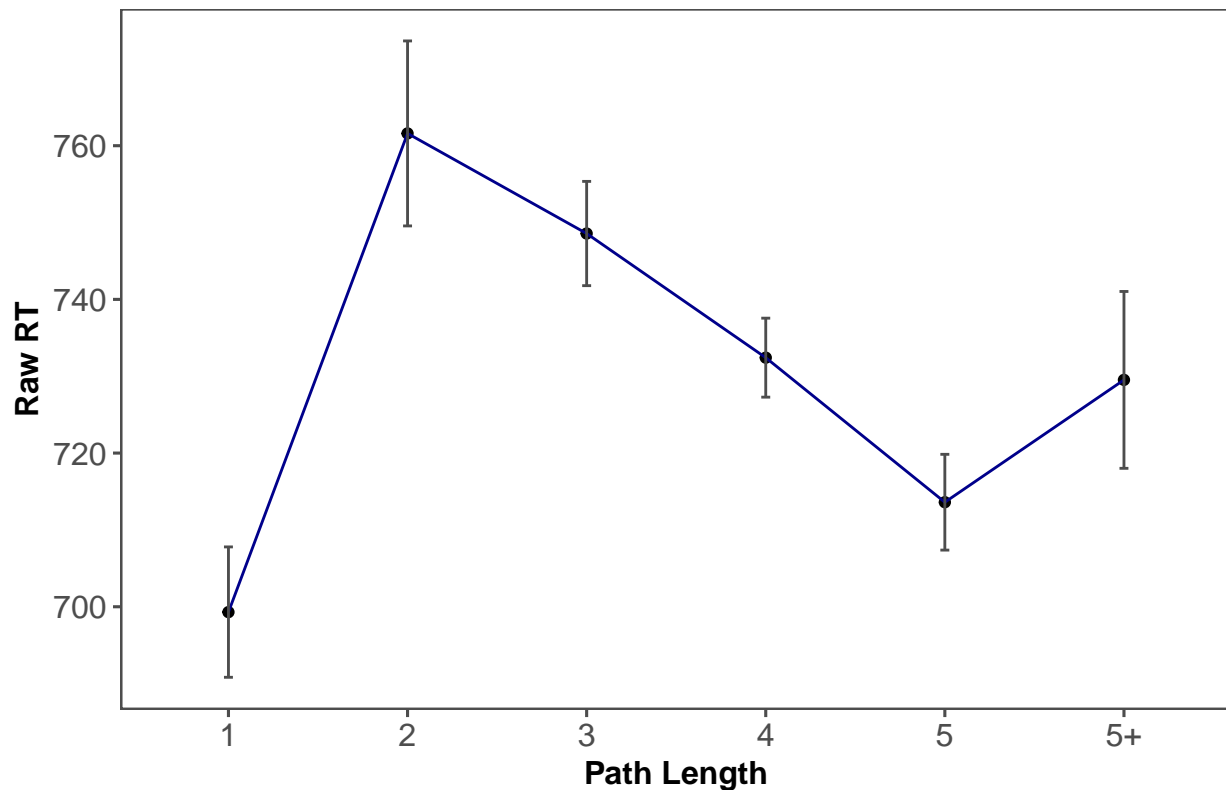
```

```

ggplot(aes(x = CollapsedDirected, y = rt, group = 1))+
# geom_smooth(method = "loess")+
geom_point()+
geom_line(color = "darkblue")+
geom_errorbar(aes(ymin=rt - se, ymax=rt + se),
              width=.05, color = "gray30",
              position = position_dodge(0))+
theme_few()+
#scale_x_continuous(breaks = c(1,2,3,4,5,6,10,15,20))+
  xlab("Path Length") + ylab("Raw RT") +
ggtitle("Steyvers Directed Raw RTs for Relatedness Judgments") +
  theme(axis.text = element_text(size = rel(1)),
        axis.title = element_text(face = "bold", size = rel(1)),
        legend.title = element_text(face = "bold", size = rel(1)),
        plot.title = element_text(hjust = .5),
        strip.text.x = element_text(face = "bold", size = rel(1.4)))

```

Steyvers Directed Raw RTs for Relatedness Judgments



Kenett Directed Anovas

```

sem_kenett_final_directed = sem_kenett_final_directed %>%
  filter(directedcollapsed != "NA")
sem_kenett_final_directed$subject = as.factor(sem_kenett_final_directed$subject)
sem_kenett_subject_directed = group_by(sem_kenett_final_directed,
                                       subject, directedcollapsed) %>%
  summarize_at(vars(rt), mean)

```

```
sem_kenett_item_directed = group_by(sem_kenett_final_directed,
                                   directedcollapsed, ItemNo) %>%
  summarise_at(vars(rt), mean)

sem_kenett_subject_directed$collapsedfac = ordered(as.factor(as.character(sem_kenett_subject_directed$d
  levels = c("1", "2", "3", "4", "5", "H"))
sem_kenett_item_directed$collapsedfac = ordered(as.factor(as.character(sem_kenett_item_directed$directe
  levels = c("1", "2", "3", "4", "5", "H"))
```

Subject Level Anova

```
kenett_subject_aov_directed = aov(data = sem_kenett_subject_directed,
                                   rt ~ collapsedfac +
                                   Error(subject/collapsedfac))
summary(kenett_subject_aov_directed)
```

```
##
## Error: subject
##           Df    Sum Sq Mean Sq F value Pr(>F)
## Residuals 79 12482090  158001
##
## Error: subject:collapsedfac
##           Df    Sum Sq Mean Sq F value    Pr(>F)
## collapsedfac  5   297004    59401  7.444 1.09e-06 ***
## Residuals    395 3152075     7980
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
options(contrasts = c('contr.sum', 'contr.poly'))
library(lsmeans)
library(multcomp)
kenett_subject_lsm = lsmeans::lsmeans(kenett_subject_aov_directed,
                                       c("collapsedfac"))
sub_effect = cld(kenett_subject_lsm, alpha = 0.05,
                 adjust = "tukey", details = TRUE)
library(knitr)
kable(subset(sub_effect$comparisons, sub_effect$comparisons$p.value < 0.1))
```

	contrast	estimate	SE	df	t.ratio	p.value
2	4 - 1	36.79477	14.12439	395	2.605051	0.0984037
4	3 - 1	55.61152	14.12439	395	3.937269	0.0013577
5	3 - 5	47.54306	14.12439	395	3.366025	0.0107694
7	2 - 1	60.21384	14.12439	395	4.263110	0.0003614
8	2 - 5	52.14537	14.12439	395	3.691867	0.0034406
11	H - 1	61.92520	14.12439	395	4.384274	0.0002155
12	H - 5	53.85673	14.12439	395	3.813030	0.0021901

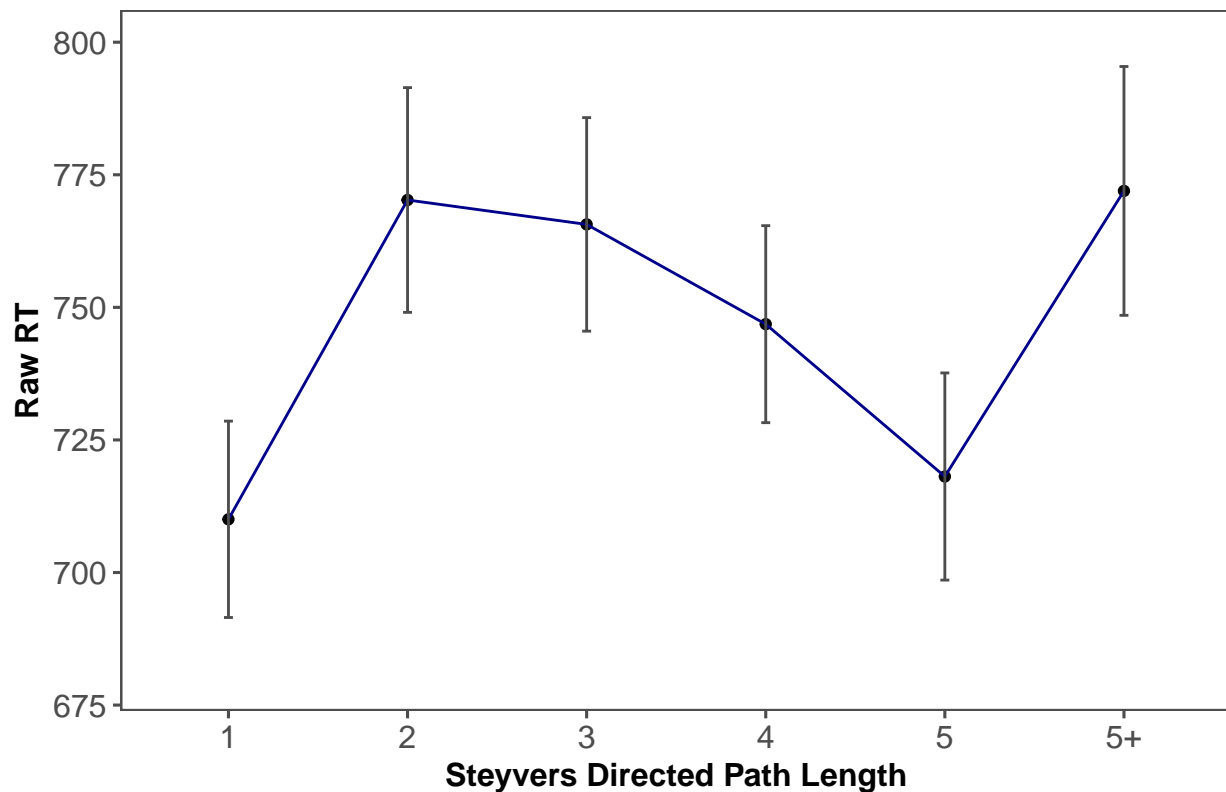
Plotting Final Kenett Directed: Subject

```
sem_kenett_subject_agg_directed = Rmisc::summarySE(sem_kenett_subject_directed,
                                                    measurevar = "rt",
                                                    groupvars = c("collapsedfac"))

## Raw RT Plot Rel-Unrel

sem_kenett_subject_agg_directed %>%
  mutate(CollapsedDirected = factor(collapsedfac,
                                    levels = unique(collapsedfac),
                                    labels = c("1", "2", "3", "4", "5", "5+")))%>%
  ggplot(aes(x = CollapsedDirected, y = rt, group = 1))+
  # geom_smooth(method = "loess")+
  geom_point()+
  geom_line(color = "darkblue")+
  geom_errorbar(aes(ymin=rt - se, ymax=rt + se),
               width=.05, color = "gray30",
               position = position_dodge(0))+
  theme_few()+
  ylim(680,800)+
  #scale_x_continuous(breaks = c(1,2,3,4,5,6,10,15,20))+
  xlab("Steyvers Directed Path Length") + ylab("Raw RT") +
  ggtitle("Subject-Level Directed Raw RTs for Relatedness Judgments") +
  theme(axis.text = element_text(size = rel(1)),
        axis.title = element_text(face = "bold", size = rel(1)),
        legend.title = element_text(face = "bold", size = rel(1)),
        plot.title = element_text(hjust = .5),
        strip.text.x = element_text(face = "bold", size = rel(1.4)))
```

Subject-Level Directed Raw RTs for Relatedness Judgments



```
sem_kenett_subject_agg_directed$Network = "Directed Simple Association"

m1_word2vec = lme4::lmer(data = final_word2vec,
                        zRT_trim ~ word2veccosine*Type +
                        mean_len_c + mean_logf_c + mean_ldtz_c + mean_conc_c +
                        (1|subject) + (1|trial_index) +
                        + (1|target_word))
summary(m1_word2vec)
```

```
## Linear mixed model fit by REML ['lmerMod']
## Formula: zRT_trim ~ word2veccosine * Type + mean_len_c + mean_logf_c +
##          mean_ldtz_c + mean_conc_c + (1 | subject) + (1 | trial_index) +
##          +(1 | target_word)
## Data: final_word2vec
##
## REML criterion at convergence: 46089
##
## Scaled residuals:
##      Min       1Q   Median       3Q      Max
## -2.6062 -0.7117 -0.1885  0.5385  4.0954
##
## Random effects:
##  Groups      Name                Variance Std.Dev.
## target_word (Intercept) 0.022084 0.14861
## trial_index (Intercept) 0.003043 0.05517
## subject      (Intercept) 0.000000 0.00000
## Residual                                0.951935 0.97567
```

```

## Number of obs: 16374, groups:
## target_word, 1740; trial_index, 240; subject, 80
##
## Fixed effects:
##               Estimate Std. Error t value
## (Intercept)      0.087986   0.014777   5.954
## word2veccosine   -0.223374   0.063170  -3.536
## Type1            0.165523   0.013690  12.090
## mean_len_c       0.013915   0.006824   2.039
## mean_logf_c     -0.010788   0.008152  -1.323
## mean_ldtz_c      0.027621   0.063599   0.434
## mean_conc_c     -0.068006   0.010890  -6.245
## word2veccosine:Type1 -0.603561  0.060393  -9.994
##
## Correlation of Fixed Effects:
##              (Intr) wrd2vc Type1  mn_ln_ mn_lg_ mn_ld_ mn_cn_
## word2veccsn -0.712
## Type1        0.453 -0.194
## mean_len_c   -0.010  0.006 -0.037
## mean_logf_c  -0.057  0.070 -0.026 -0.006
## mean_ldtz_c  -0.008  0.011  0.023 -0.366  0.546
## mean_conc_c  0.044 -0.055  0.027  0.239  0.309  0.110
## wrd2vccs:T1 -0.185 -0.105 -0.740 -0.015 -0.009  0.000  0.006

car::Anova(m1_word2vec)

## Analysis of Deviance Table (Type II Wald chisquare tests)
##
## Response: zRT_trim
##               Chisq Df Pr(>Chisq)
## word2veccosine   21.2376  1  4.057e-06 ***
## Type              48.7202  1  2.952e-12 ***
## mean_len_c        4.1577  1   0.04145 *
## mean_logf_c        1.7512  1   0.18573
## mean_ldtz_c        0.1886  1   0.66407
## mean_conc_c       38.9951  1  4.249e-10 ***
## word2veccosine:Type 99.8767  1 < 2.2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

m1_word2vec = lme4::lmer(data = final_word2vec,
                        zRT_trim ~ word2veccosine*Type +
                        mean_len + mean_logf + mean_ldtz + mean_conc +
                        (1|subject) + (1|trial_index) +
                        + (1|target_word))
summary(m1_word2vec)

## Linear mixed model fit by REML ['lmerMod']
## Formula:
## zRT_trim ~ word2veccosine * Type + mean_len + mean_logf + mean_ldtz +
## mean_conc + (1 | subject) + (1 | trial_index) + +(1 | target_word)
## Data: final_word2vec
##
## REML criterion at convergence: 46089
##

```

```

## Scaled residuals:
##      Min       1Q   Median       3Q      Max
## -2.6062 -0.7117 -0.1885  0.5385  4.0954
##
## Random effects:
##      Groups      Name      Variance Std.Dev.
## target_word (Intercept) 0.022084 0.14861
## trial_index (Intercept) 0.003043 0.05517
## subject      (Intercept) 0.000000 0.00000
## Residual                0.951935 0.97567
## Number of obs: 16374, groups:
## target_word, 1740; trial_index, 240; subject, 80
##
## Fixed effects:
##              Estimate Std. Error t value
## (Intercept)      0.360296   0.101422   3.552
## word2veccosine   -0.223374   0.063170  -3.536
## Type1            0.165523   0.013690  12.090
## mean_len         0.013915   0.006824   2.039
## mean_logf        -0.010788   0.008152  -1.323
## mean_ldtz         0.027621   0.063599   0.434
## mean_conc        -0.068006   0.010890  -6.245
## word2veccosine:Type1 -0.603561  0.060393  -9.994
##
## Correlation of Fixed Effects:
##              (Intr) wrd2vc Type1  men_ln mn_lgf mn_ldt mn_cnc
## word2veccsn -0.130
## Type1       0.095 -0.194
## mean_len    -0.600  0.006 -0.037
## mean_logf   -0.668  0.070 -0.026 -0.006
## mean_ldtz   0.013  0.011  0.023 -0.366  0.546
## mean_conc   -0.666 -0.055  0.027  0.239  0.309  0.110
## wrd2vccs:T1 -0.017 -0.105 -0.740 -0.015 -0.009  0.000  0.006

car::Anova(m1_word2vec)

## Analysis of Deviance Table (Type II Wald chisquare tests)
##
## Response: zRT_trim
##              Chisq Df Pr(>Chisq)
## word2veccosine 21.2376 1 4.057e-06 ***
## Type           48.7202 1 2.952e-12 ***
## mean_len       4.1577 1 0.04145 *
## mean_logf      1.7512 1 0.18573
## mean_ldtz      0.1886 1 0.66407
## mean_conc     38.9951 1 4.249e-10 ***
## word2veccosine:Type 99.8767 1 < 2.2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

m1_usual = lmer(data = final_word2vec,
                zRT_trim ~ pathlengthfac*Type +
                  mean_len + mean_logf + mean_ldtz + mean_conc +
                  (1|subject) + (1|trial_index) +
                  + (1|target_word))

```

```
summary(m1_usual)
```

```
## Linear mixed model fit by REML ['lmerMod']
## Formula:
## zRT_trim ~ pathlengthfac * Type + mean_len + mean_logf + mean_ldtz +
##   mean_conc + (1 | subject) + (1 | trial_index) + +(1 | target_word)
##   Data: final_word2vec
##
## REML criterion at convergence: 46130.3
##
## Scaled residuals:
##      Min       1Q   Median       3Q      Max
## -2.5550 -0.7091 -0.1898  0.5449  4.1246
##
## Random effects:
##   Groups      Name      Variance Std.Dev.
## target_word (Intercept) 0.022295 0.14932
## trial_index (Intercept) 0.003316 0.05758
## subject      (Intercept) 0.000000 0.00000
## Residual                0.951665 0.97553
## Number of obs: 16374, groups:
## target_word, 1740; trial_index, 240; subject, 80
##
## Fixed effects:
##              Estimate Std. Error t value
## (Intercept)    0.366114   0.102895   3.558
## pathlengthfac1 -0.155870   0.029720  -5.245
## pathlengthfac3 -0.001137   0.030169  -0.038
## pathlengthfac4 -0.054065   0.030436  -1.776
## pathlengthfac5 -0.039897   0.034469  -1.157
## pathlengthfac6 -0.161613   0.036061  -4.482
## Type1          0.007324   0.019457   0.376
## mean_len        0.013053   0.006836   1.910
## mean_logf       -0.010157   0.008148  -1.247
## mean_ldtz       0.018498   0.063686   0.290
## mean_conc      -0.065859   0.010926  -6.028
## pathlengthfac1:Type1 -0.053286  0.028157  -1.892
## pathlengthfac3:Type1  0.097057  0.028657   3.387
## pathlengthfac4:Type1  0.062215  0.028922   2.151
## pathlengthfac5:Type1  0.119161  0.033198   3.589
## pathlengthfac6:Type1  0.083108  0.034733   2.393
##
## Correlation matrix not shown by default, as p = 16 > 12.
## Use print(x, correlation=TRUE) or
##   vcov(x)          if you need it
```

```
car::Anova(m1_usual)
```

```
## Analysis of Deviance Table (Type II Wald chisquare tests)
##
## Response: zRT_trim
##              Chisq Df Pr(>Chisq)
## pathlengthfac   82.2848  5  2.790e-16 ***
## Type           27.4912  1  1.578e-07 ***
```

```

## mean_len          3.6464  1    0.05619 .
## mean_logf         1.5540  1    0.21255
## mean_ldtz         0.0844  1    0.77147
## mean_conc         36.3362  1  1.661e-09 ***
## pathlengthfac:Type 44.5379  5  1.801e-08 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

anova(m1_usual, m1_word2vec)

## refitting model(s) with ML (instead of REML)

## Data: final_word2vec
## Models:
## m1_word2vec: zRT_trim ~ word2veccosine * Type + mean_len + mean_logf + mean_ldtz +
## m1_word2vec:      mean_conc + (1 | subject) + (1 | trial_index) + +(1 | target_word)
## m1_usual: zRT_trim ~ pathlengthfac * Type + mean_len + mean_logf + mean_ldtz +
## m1_usual:      mean_conc + (1 | subject) + (1 | trial_index) + +(1 | target_word)
##           Df    AIC    BIC logLik deviance  Chisq Chi Df Pr(>Chisq)
## m1_word2vec 12 46063 46155 -23019    46039
## m1_usual    20 46073 46227 -23016    46033 5.8958     8    0.6589

m1_usual_all = lmer(data = final_word2vec,
                    zRT_trim ~ pathlengthfac*Type +
                        word2veccosine*Type +
                        mean_len + mean_logf + mean_ldtz + mean_conc +
                        (1|subject) + (1|trial_index) +
                        + (1|target_word))
summary(m1_usual_all)

## Linear mixed model fit by REML ['lmerMod']
## Formula:
## zRT_trim ~ pathlengthfac * Type + word2veccosine * Type + mean_len +
## mean_logf + mean_ldtz + mean_conc + (1 | subject) + (1 |
## trial_index) + +(1 | target_word)
## Data: final_word2vec
##
## REML criterion at convergence: 46079.8
##
## Scaled residuals:
##      Min       1Q   Median       3Q      Max
## -2.5743 -0.7115 -0.1875  0.5429  4.0950
##
## Random effects:
##   Groups      Name      Variance Std.Dev.
## target_word (Intercept) 0.019492 0.13961
## trial_index (Intercept) 0.003117 0.05583
## subject      (Intercept) 0.000000 0.00000
## Residual                0.950848 0.97511
## Number of obs: 16374, groups:
## target_word, 1740; trial_index, 240; subject, 80
##
## Fixed effects:
##              Estimate Std. Error t value
## (Intercept)    0.438037   0.103913   4.215
## pathlengthfac1 -0.117735   0.030365  -3.877

```

```

## pathlengthfac3      -0.018323   0.030332  -0.604
## pathlengthfac4      -0.073654   0.030764  -2.394
## pathlengthfac5      -0.061243   0.034804  -1.760
## pathlengthfac6      -0.185902   0.036595  -5.080
## Type1               0.106267   0.023845   4.457
## word2veccosine      -0.235247   0.072550  -3.243
## mean_len            0.013298   0.006775   1.963
## mean_logf           -0.011992   0.008099  -1.481
## mean_ldtz           0.018295   0.063057   0.290
## mean_conc           -0.064992   0.010809  -6.013
## pathlengthfac1:Type1 -0.001992   0.028915  -0.069
## pathlengthfac3:Type1 0.066324   0.028943   2.292
## pathlengthfac4:Type1 0.024693   0.029382   0.840
## pathlengthfac5:Type1 0.080734   0.033607   2.402
## pathlengthfac6:Type1 0.036712   0.035328   1.039
## Type1:word2veccosine -0.465325   0.069207  -6.724

##
## Correlation matrix not shown by default, as p = 18 > 12.
## Use print(x, correlation=TRUE) or
##     vcov(x)         if you need it

car::Anova(m1_usual_all)

## Analysis of Deviance Table (Type II Wald chisquare tests)
##
## Response: zRT_trim
##
##           Chisq Df Pr(>Chisq)
## pathlengthfac  53.5578  5  2.584e-10 ***
## Type          37.0328  1  1.162e-09 ***
## word2veccosine 12.6378  1  0.000378 ***
## mean_len       3.8530  1  0.049658 *
## mean_logf      2.1922  1  0.138712
## mean_ldtz      0.0842  1  0.771718
## mean_conc      36.1548  1  1.823e-09 ***
## pathlengthfac:Type 10.2046  5  0.069641 .
## Type:word2veccosine 45.2077  1  1.772e-11 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

anova(m1_word2vec, m1_usual_all)

## refitting model(s) with ML (instead of REML)
## Data: final_word2vec
## Models:
## m1_word2vec: zRT_trim ~ word2veccosine * Type + mean_len + mean_logf + mean_ldtz +
## m1_word2vec: mean_conc + (1 | subject) + (1 | trial_index) + +(1 | target_word)
## m1_usual_all: zRT_trim ~ pathlengthfac * Type + word2veccosine * Type + mean_len +
## m1_usual_all: mean_logf + mean_ldtz + mean_conc + (1 | subject) + (1 |
## m1_usual_all: trial_index) + +(1 | target_word)
##           Df    AIC    BIC logLik deviance Chisq Chi Df Pr(>Chisq)
## m1_word2vec 12 46063 46155 -23019  46039
## m1_usual_all 22 46019 46189 -22988  45975 63.479    10 7.912e-10 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

```

```
anova(m1_usual, m1_usual_all)
```

```
## refitting model(s) with ML (instead of REML)
## Data: final_word2vec
## Models:
## m1_usual: zRT_trim ~ pathlengthfac * Type + mean_len + mean_logf + mean_ldtz +
## m1_usual:      mean_conc + (1 | subject) + (1 | trial_index) + +(1 | target_word)
## m1_usual_all: zRT_trim ~ pathlengthfac * Type + word2veccosine * Type + mean_len +
## m1_usual_all:      mean_logf + mean_ldtz + mean_conc + (1 | subject) + (1 |
## m1_usual_all:      trial_index) + +(1 | target_word)
##           Df   AIC   BIC logLik deviance  Chisq Chi Df Pr(>Chisq)
## m1_usual      20 46073 46227 -23016    46033
## m1_usual_all  22 46019 46189 -22988    45975 57.583      2 3.133e-13 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

Directed Undirected vs word2vec

```
m1_usual_undirected = lmer(data = final_word2vec,
                          zRT_trim ~ undirectedfac*Type +
                          word2veccosine*Type +
                          mean_len + mean_logf + mean_ldtz + mean_conc +
                          (1|subject) + (1|trial_index) +
                          + (1|target_word))
anova(m1_word2vec, m1_usual_undirected)
```

```
## refitting model(s) with ML (instead of REML)
## Data: final_word2vec
## Models:
## m1_word2vec: zRT_trim ~ word2veccosine * Type + mean_len + mean_logf + mean_ldtz +
## m1_word2vec:      mean_conc + (1 | subject) + (1 | trial_index) + +(1 | target_word)
## m1_usual_undirected: zRT_trim ~ undirectedfac * Type + word2veccosine * Type + mean_len +
## m1_usual_undirected:      mean_logf + mean_ldtz + mean_conc + (1 | subject) + (1 |
## m1_usual_undirected:      trial_index) + +(1 | target_word)
##           Df   AIC   BIC logLik deviance  Chisq Chi Df
## m1_word2vec      12 46063 46155 -23019    46039
## m1_usual_undirected 18 45990 46129 -22977    45954 84.601      6
##           Pr(>Chisq)
## m1_word2vec
## m1_usual_undirected 3.994e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
final_word2vec_na = final_word2vec %>%
  filter(!is.na(final_word2vec$directedfac))
```

```
final_word2vec_na = as.data.frame(final_word2vec_na)
```

```
m1_word2vec_na = lmer(data = final_word2vec_na,
                      zRT_trim ~ word2veccosine*Type +
                      mean_len + mean_logf + mean_ldtz + mean_conc +
                      (1|subject) + (1|trial_index) +
```



```

      + (1|target_word))

m1_usual_directed = lmer(data = final_word2vec_na,
                        zRT_trim ~ directedfac*Type +
                        word2veccosine*Type +
                        mean_len + mean_logf + mean_ldtz + mean_conc +
                        (1|subject) + (1|trial_index) +
                        + (1|target_word))

anova(m1_word2vec_na, m1_usual_directed)

## refitting model(s) with ML (instead of REML)

## Data: final_word2vec_na
## Models:
## m1_word2vec_na: zRT_trim ~ word2veccosine * Type + mean_len + mean_logf + mean_ldtz +
## m1_word2vec_na:      mean_conc + (1 | subject) + (1 | trial_index) + (1 | target_word)
## m1_usual_directed: zRT_trim ~ directedfac * Type + word2veccosine * Type + mean_len +
## m1_usual_directed:      mean_logf + mean_ldtz + mean_conc + (1 | subject) + (1 |
## m1_usual_directed:      trial_index) + (1 | target_word)
##
##           Df    AIC    BIC logLik deviance   Chisq Chi Df Pr(>Chisq)
## m1_word2vec_na    12 44347 44439 -22162    44323
## m1_usual_directed 26 44305 44504 -22126    44253 70.873    14 1.341e-09
##
## m1_word2vec_na
## m1_usual_directed ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

```

Kenett models data

```

sem_kenett_final_word2vec = merge(sem_kenett_final, word2vec,
                                by = c("ItemNo", "proc"))
sem_kenett_final_word2vec$quadword2vec = sem_kenett_final_word2vec$word2veccosine^2

word2vec_kenettaov1 = lmer(data = sem_kenett_final_word2vec,
                          rt ~ word2veccosine + quadword2vec +
                          mean_len + mean_logf + mean_ldtz +
                          (1|subject) + (1|trial_index) +
                          + (1|target_word))
summary(word2vec_kenettaov1)

## Linear mixed model fit by REML ['lmerMod']
## Formula:
## rt ~ word2veccosine + quadword2vec + mean_len + mean_logf + mean_ldtz +
##      (1 | subject) + (1 | trial_index) + (1 | target_word)
## Data: sem_kenett_final_word2vec
##
## REML criterion at convergence: 182544.9
##
## Scaled residuals:
##      Min       1Q   Median       3Q      Max
## -2.6297 -0.5942 -0.1694  0.3838  7.2692

```

```

##
## Random effects:
##   Groups      Name      Variance Std.Dev.
## target_word (Intercept) 1824.9  42.72
## trial_index (Intercept)  258.9  16.09
## subject      (Intercept) 23919.7 154.66
## Residual                52717.2 229.60
## Number of obs: 13259, groups:
## target_word, 1891; trial_index, 240; subject, 80
##
## Fixed effects:
##              Estimate Std. Error t value
## (Intercept)    647.355     26.390  24.531
## word2veccosine  235.752     39.552   5.961
## quadword2vec  -473.428     71.088  -6.660
## mean_len         5.274      1.763   2.991
## mean_logf        5.384      2.038   2.642
## mean_ldtz       10.350     16.377   0.632
##
## Correlation of Fixed Effects:
##              (Intr) wrd2vc qdwr2 men_ln mn_lgf
## word2veccsn -0.193
## quadword2vc  0.158 -0.919
## mean_len     -0.459  0.062 -0.072
## mean_logf    -0.490  0.089 -0.065 -0.095
## mean_ldtz     0.090  0.012 -0.001 -0.408  0.535
car::Anova(word2vec_kenettaov1)

## Analysis of Deviance Table (Type II Wald chisquare tests)
##
## Response: rt
##              Chisq Df Pr(>Chisq)
## word2veccosine 35.5278  1 2.514e-09 ***
## quadword2vec  44.3521  1 2.743e-11 ***
## mean_len       8.9470  1 0.002779 **
## mean_logf      6.9779  1 0.008252 **
## mean_ldtz      0.3994  1 0.527396
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

word2vec_kenettaov2 = lmer(data = sem_kenett_final_word2vec,
                           rt ~ word2veccosine + quadword2vec + pathlengthfac +
                               mean_len + mean_logf + mean_ldtz +
                               (1|subject) + (1|trial_index) +
                               + (1|target_word))
summary(word2vec_kenettaov2)

## Linear mixed model fit by REML ['lmerMod']
## Formula: rt ~ word2veccosine + quadword2vec + pathlengthfac + mean_len +
##          mean_logf + mean_ldtz + (1 | subject) + (1 | trial_index) +
##          +(1 | target_word)
## Data: sem_kenett_final_word2vec
##
## REML criterion at convergence: 182456.4

```

```
##
## Scaled residuals:
##      Min       1Q   Median       3Q      Max
## -2.6336 -0.5941 -0.1689  0.3854  7.1563
##
## Random effects:
##      Groups      Name      Variance Std.Dev.
## target_word (Intercept) 1628.8  40.36
## trial_index (Intercept)  265.3  16.29
## subject      (Intercept) 23989.5 154.89
## Residual                52642.0 229.44
## Number of obs: 13259, groups:
## target_word, 1891; trial_index, 240; subject, 80
##
## Fixed effects:
##              Estimate Std. Error t value
## (Intercept)    651.69111   28.21971  23.093
## word2veccosine 177.36116   41.52475   4.271
## quadword2vec  -380.72292   71.84741  -5.299
## pathlengthfac2  42.06863    9.25364   4.546
## pathlengthfac3   8.63385    9.19781   0.939
## pathlengthfac4  15.51614    9.26730   1.674
## pathlengthfac5   0.01536    9.11645   0.002
## pathlengthfac6 -17.70402    9.26477  -1.911
## mean_len        5.10895    1.75091   2.918
## mean_logf        4.72228    2.02331   2.334
## mean_ldtz        7.75045   16.23816   0.477
##
## Correlation of Fixed Effects:
##              (Intr) wrd2vc qdwr2 pthln2 pthln3 pthln4 pthln5 pthln6 men_ln
## word2veccsn -0.269
## quadword2vc  0.124 -0.871
## pthlngthfc2 -0.234  0.044  0.169
## pthlngthfc3 -0.304  0.178  0.092  0.586
## pthlngthfc4 -0.315  0.227  0.056  0.589  0.665
## pthlngthfc5 -0.322  0.226  0.063  0.602  0.676  0.690
## pthlngthfc6 -0.335  0.268  0.031  0.600  0.681  0.699  0.712
## mean_len    -0.447  0.078 -0.069  0.035  0.053  0.048  0.058  0.061
## mean_logf    -0.475  0.110 -0.069  0.007  0.042  0.053  0.054  0.060 -0.090
## mean_ldtz     0.099  0.005 -0.008 -0.039 -0.052 -0.038 -0.031 -0.033 -0.410
##              mn_lgf
## word2veccsn
## quadword2vc
## pthlngthfc2
## pthlngthfc3
## pthlngthfc4
## pthlngthfc5
## pthlngthfc6
## mean_len
## mean_logf
## mean_ldtz    0.531
```

```
car::Anova(word2vec_kenettaov2)
```

```
## Analysis of Deviance Table (Type II Wald chisquare tests)
```

```
##
## Response: rt
##               Chisq Df Pr(>Chisq)
## word2veccosine 18.2433  1  1.944e-05 ***
## quadword2vec   28.0799  1  1.164e-07 ***
## pathlengthfac  60.5216  5  9.483e-12 ***
## mean_len       8.5141  1  0.003524 **
## mean_logf      5.4472  1  0.019599 *
## mean_ldtz      0.2278  1  0.633149
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

anova(word2vec_kenettaov1, word2vec_kenettaov2)

## refitting model(s) with ML (instead of REML)

## Data: sem_kenett_final_word2vec
## Models:
## word2vec_kenettaov1: rt ~ word2veccosine + quadword2vec + mean_len + mean_logf + mean_ldtz +
## word2vec_kenettaov1:      (1 | subject) + (1 | trial_index) + +(1 | target_word)
## word2vec_kenettaov2: rt ~ word2veccosine + quadword2vec + pathlengthfac + mean_len +
## word2vec_kenettaov2:      mean_logf + mean_ldtz + (1 | subject) + (1 | trial_index) +
## word2vec_kenettaov2:      +(1 | target_word)
##               Df      AIC      BIC logLik deviance  Chisq Chi Df
## word2vec_kenettaov1 10 182603 182678 -91292   182583
## word2vec_kenettaov2 15 182553 182665 -91262   182523 60.191     5
##               Pr(>Chisq)
## word2vec_kenettaov1
## word2vec_kenettaov2  1.11e-11 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

ScatterPlot

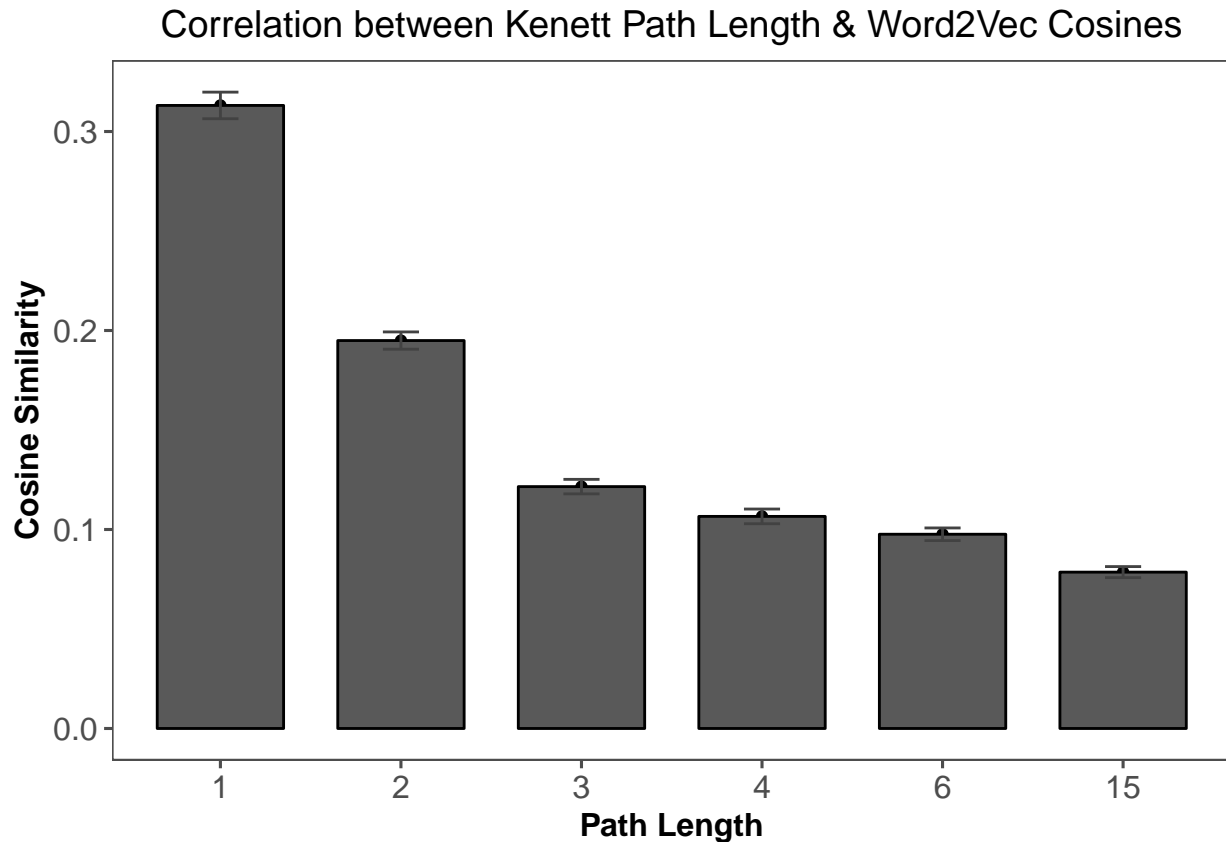
Kenett and Word2Vec

```
final_word2vec_rmisc = Rmisc::summarySE(final_word2vec,
                                         measurevar = "word2veccosine",
                                         groupvars = "pathlength")

item_word2vec = group_by(final_word2vec, ItemNo) %>%
  summarise_at(vars(pathlength,undirected, word2veccosine), mean)
item_word2vec$pathlengthfac = ordered(as.factor(as.character(item_word2vec$pathlength)),
                                     levels = c("1", "2", "3", "4", "6", "15"))

ggplot(final_word2vec_rmisc,
       aes(x = factor(pathlength), y = word2veccosine))+
  geom_point()+
  geom_bar(stat = "identity", position = "dodge", width = 0.7, color= "black")+
  geom_errorbar(aes(ymin=word2veccosine - ci, ymax=word2veccosine + ci),
               width=.2, color = "gray26",
               position = position_dodge(0.7))+
  # geom_smooth(method = "lm")+
  theme_few()+
  xlab("Path Length") + ylab("Cosine Similarity") +
```

```
ggtitle("Correlation between Kenett Path Length & Word2Vec Cosines") +
  theme(axis.text = element_text(size = rel(1)),
        axis.title = element_text(face = "bold", size = rel(1)),
        legend.title = element_text(face = "bold", size = rel(1)),
        plot.title = element_text(hjust = .5),
        strip.text.x = element_text(face = "bold", size = rel(1.4)))
```



RTs and Word2Vec

Mean

```
meanCosine = mean(final_word2vec$word2veccosine)
sdCosine = sd(final_word2vec$word2veccosine)
lowest = meanCosine - 2*sdCosine
low = meanCosine - sdCosine
high = meanCosine + sdCosine
highest = meanCosine + 2*sdCosine

final_word2vec$cosinefac = ifelse(final_word2vec$word2veccosine <= lowest, "Lowest", ifelse(final_word2vec$word2veccosine <= meanCosine, "Mean", ifelse(final_word2vec$word2veccosine <= high, "High", "Highest")))

final_word2vec$cosinefac2 = ordered(as.factor(as.character(final_word2vec$cosinefac)),
  levels = c("Highest", "High", "Mean", "Low", "Lowest"))

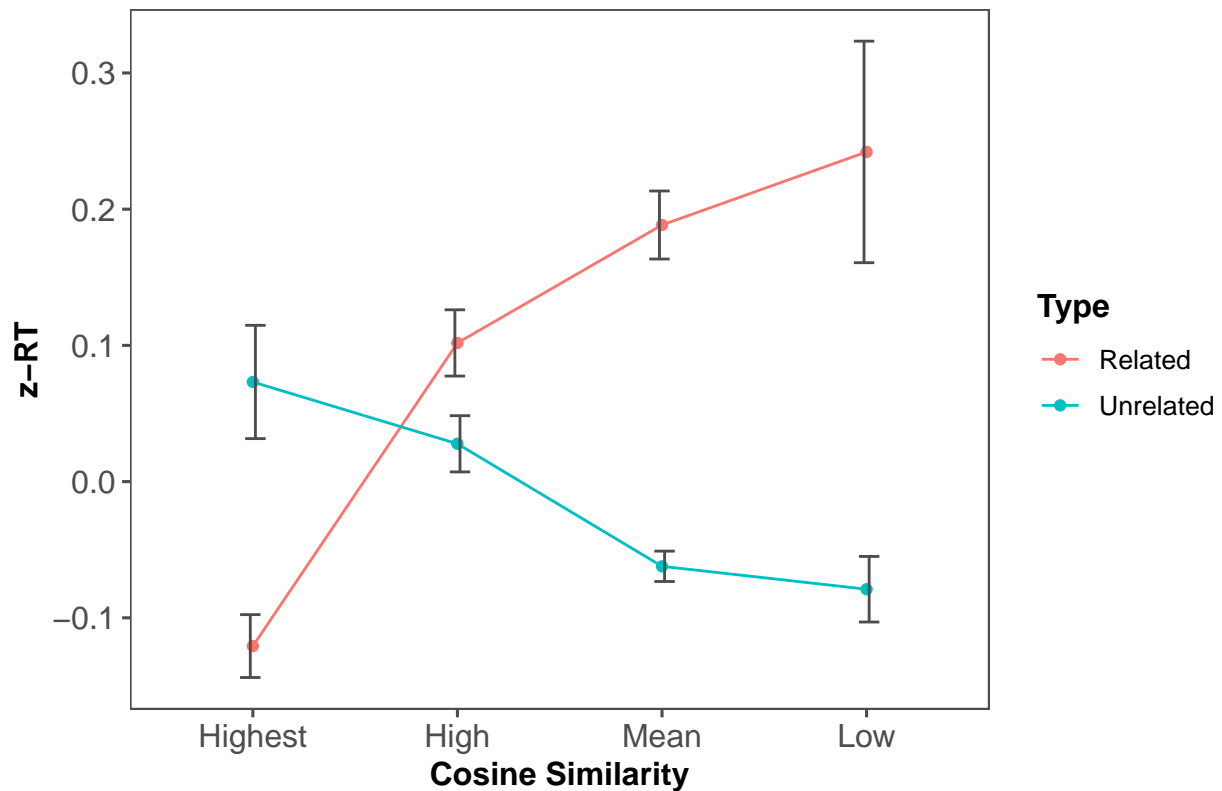
word2vec_cosine_agg = Rmisc::summarySE(final_word2vec,
```

```

                                measurevar = "zRT_trim",
                                groupvars = c("cosinefac2", "Type"))
ggplot(word2vec_cosine_agg,
      aes(x = cosinefac2, y = zRT_trim,
          color = Type, group= Type))+
geom_point()+
geom_line()+
  geom_errorbar(aes(ymin=zRT_trim - se, ymax=zRT_trim + se),
                width=.2, color = "gray30",
                position = position_dodge(0.05))+
theme_few()+
  xlab("Cosine Similarity") + ylab("z-RT") +
ggtitle(" Word2Vec Cosines and RTs for Related/Unrelated Pairs") +
  theme(axis.text = element_text(size = rel(1)),
        axis.title = element_text(face = "bold", size = rel(1)),
        legend.title = element_text(face = "bold", size = rel(1)),
        plot.title = element_text(hjust = .5),
        strip.text.x = element_text(face = "bold", size = rel(1.4)))

```

Word2Vec Cosines and RTs for Related/Unrelated Pairs



Quintile zRT

```

final_word2vec = final_word2vec %>%
  mutate(quantile = ntile(word2veccosine, 5))

count_quintile = group_by(final_word2vec, quantile) %>%
  summarise(count = n())

```

```

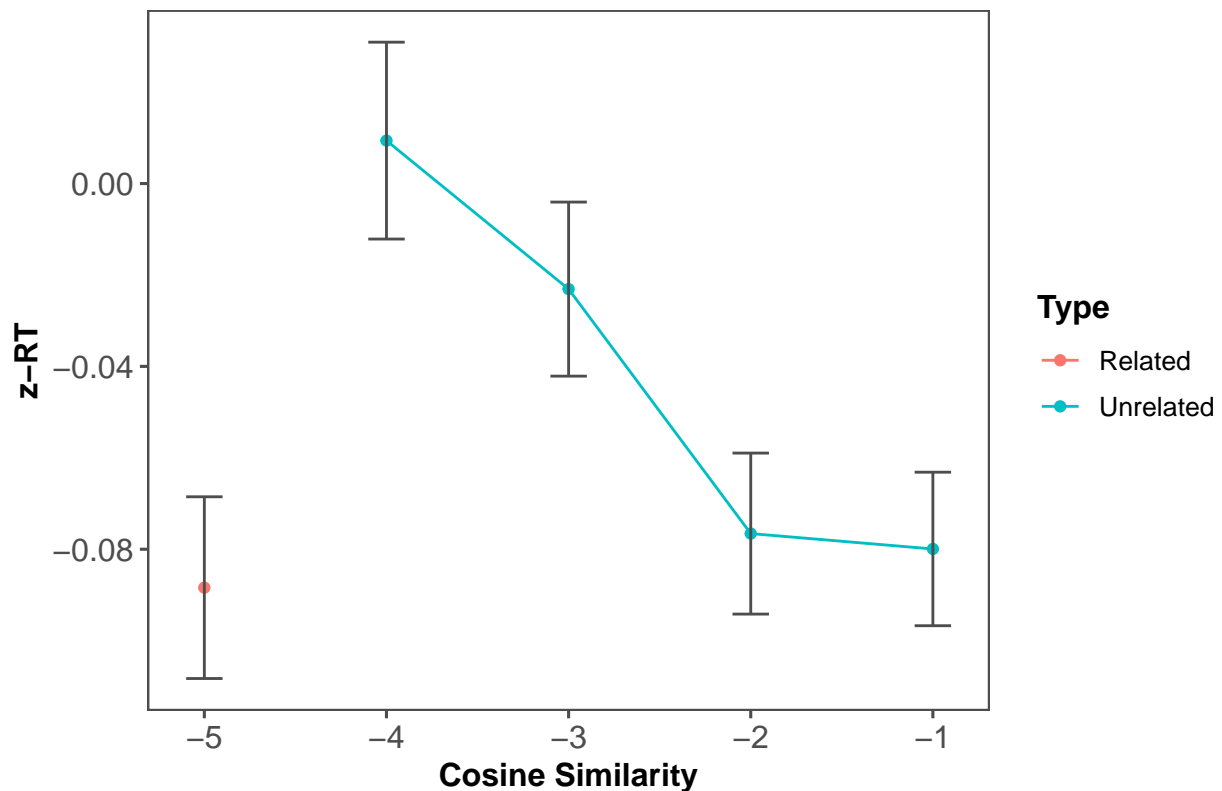
word2vec_cosine_agg = Rmisc::summarySE(final_word2vec,
                                       measurevar = "zRT_trim",
                                       groupvars = c("quantile", "Type"))

word2vec_cosine_agg = word2vec_cosine_agg %>%
  filter((Type == "Related" & quantile == 5) |
         (Type == "Unrelated" & quantile != 5))

## high quintile means lower path length
ggplot(word2vec_cosine_agg,
       aes(x = -quantile, y = zRT_trim,
           color = Type, group= Type))+
  geom_point()+
  geom_line()+
  geom_errorbar(aes(ymin=zRT_trim - se, ymax=zRT_trim + se),
               width=.2, color = "gray30",
               position = position_dodge(0.05))+
  theme_few()+
  xlab("Cosine Similarity") + ylab("z-RT") +
  ggtitle(" Word2Vec Cosines and RTs for Related/Unrelated Pairs") +
  theme(axis.text = element_text(size = rel(1)),
        axis.title = element_text(face = "bold", size = rel(1)),
        legend.title = element_text(face = "bold", size = rel(1)),
        plot.title = element_text(hjust = .5),
        strip.text.x = element_text(face = "bold", size = rel(1.4)))

```

Word2Vec Cosines and RTs for Related/Unrelated Pairs



Quintile ANOVA

```
quintile_agg = group_by(final_word2vec, subject, quantile, Type) %>%
  summarise_at(vars(zRT_trim), mean)

quintile_agg = quintile_agg %>% filter((Type == "Related" & quantile == 5) |
  (Type == "Unrelated" & quantile != 5))

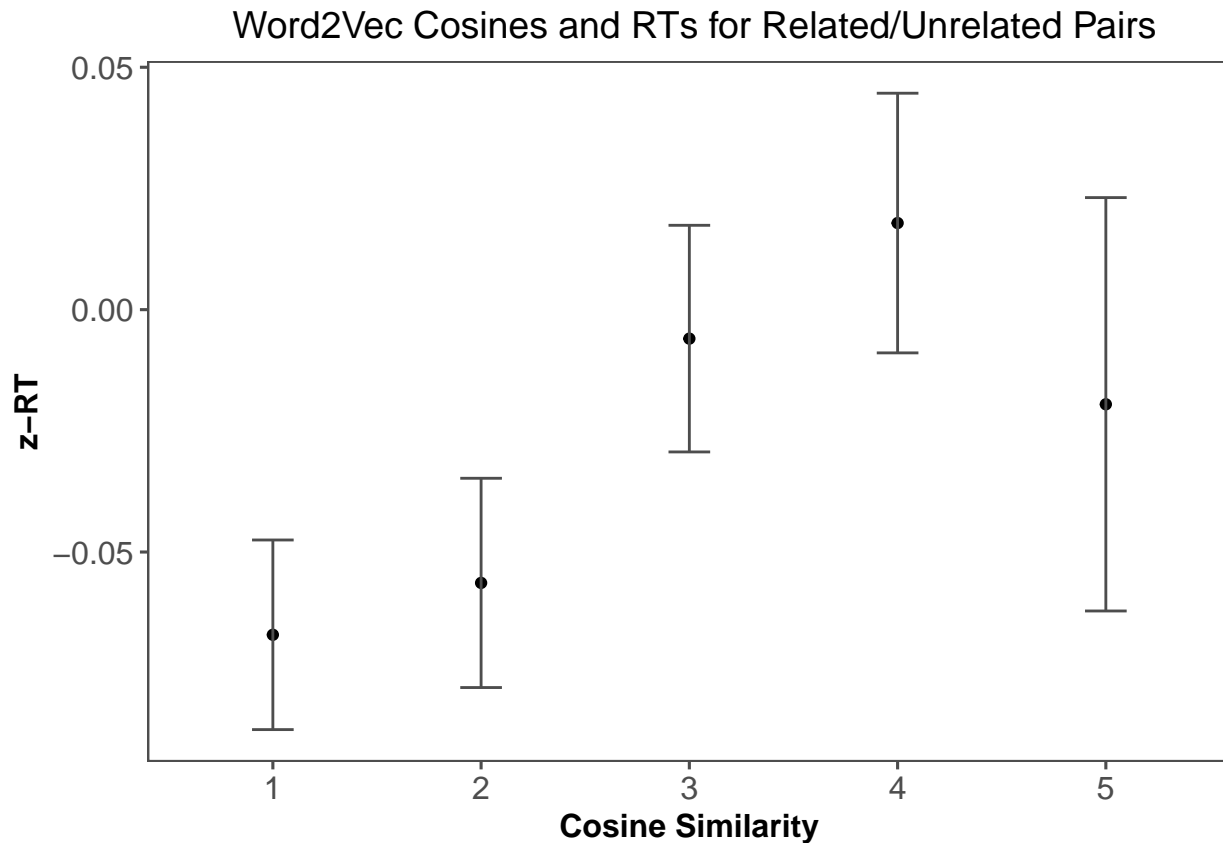
quintile_agg$subject = as.factor(quintile_agg$subject)
quintile_agg$quantile = as.factor(quintile_agg$quantile)
quintile_agg = quintile_agg[, -3]
quintile_aov = aov(data = quintile_agg, zRT_trim ~ quantile +
  Error(subject/quantile))
summary(quintile_aov)
```

```
##
## Error: subject
##           Df Sum Sq Mean Sq F value Pr(>F)
## Residuals  79  2.267  0.0287
##
## Error: subject:quantile
##           Df Sum Sq Mean Sq F value Pr(>F)
## quantile    4  0.398  0.09953   1.393  0.236
## Residuals 316 22.576  0.07144
```

```
quintile_means = Rmisc::summarySE(quintile_agg,
  measurevar = "zRT_trim",
  groupvars = c("quantile"))

ggplot(quintile_means,
  aes(x = quantile, y = zRT_trim)) +
  geom_point() +
  geom_line() +
  geom_errorbar(aes(ymin=zRT_trim - se, ymax=zRT_trim + se),
    width=.2, color = "gray30",
    position = position_dodge(0.05)) +
  theme_few() +
  xlab("Cosine Similarity") + ylab("z-RT") +
  ggtitle(" Word2Vec Cosines and RTs for Related/Unrelated Pairs") +
  theme(axis.text = element_text(size = rel(1)),
    axis.title = element_text(face = "bold", size = rel(1)),
    legend.title = element_text(face = "bold", size = rel(1)),
    plot.title = element_text(hjust = .5),
    strip.text.x = element_text(face = "bold", size = rel(1.4)))
```

```
## geom_path: Each group consists of only one observation. Do you need to
## adjust the group aesthetic?
```

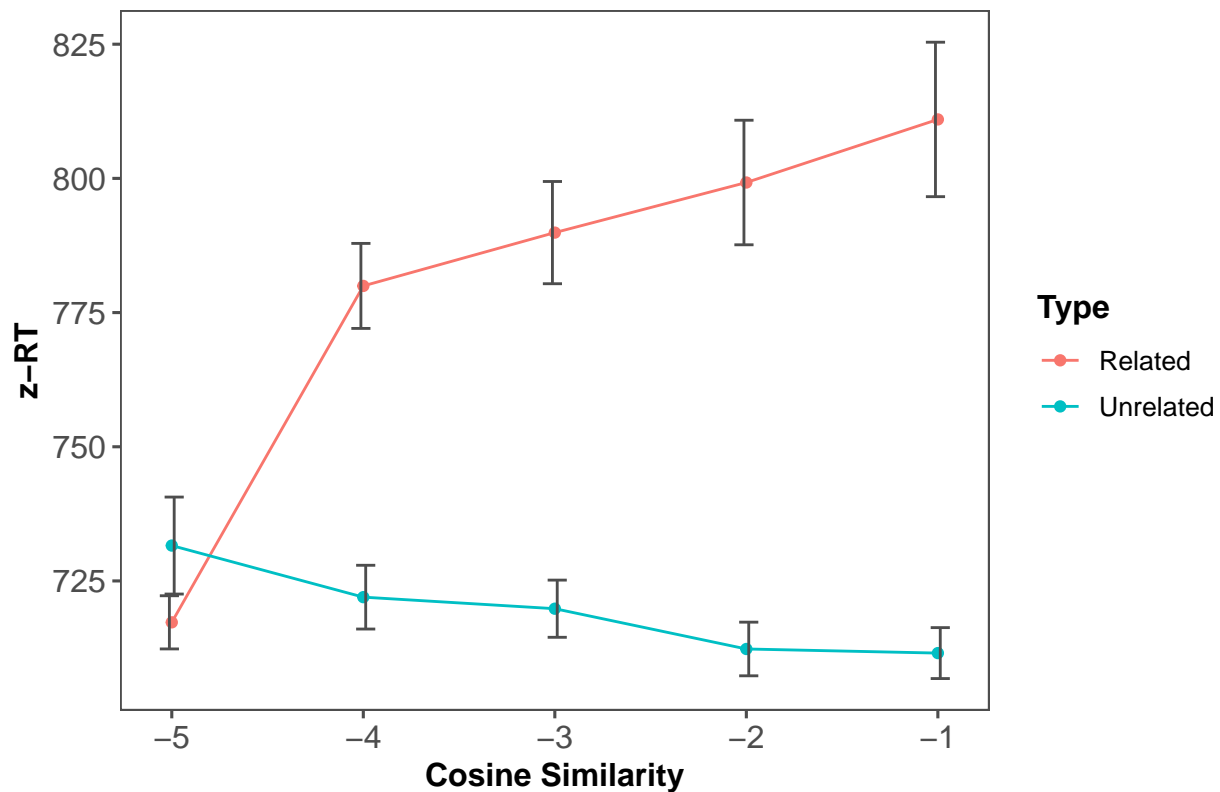



Quintile Raw RT

```
word2vec_cosine_agg = Rmisc::summarySE(final_word2vec,
                                       measurevar = "rt",
                                       groupvars = c("quantile", "Type"))

## high quintile means lower path length
ggplot(word2vec_cosine_agg,
       aes(x = -quantile, y = rt,
           color = Type, group = Type)) +
  geom_point() +
  geom_line() +
  geom_errorbar(aes(ymin = rt - se, ymax = rt + se),
               width = .2, color = "gray30",
               position = position_dodge(0.05)) +
  theme_few() +
  xlab("Cosine Similarity") + ylab("z-RT") +
  ggtitle("Word2Vec Cosines and RTs for Related/Unrelated Pairs") +
  theme(axis.text = element_text(size = rel(1)),
        axis.title = element_text(face = "bold", size = rel(1)),
        legend.title = element_text(face = "bold", size = rel(1)),
        plot.title = element_text(hjust = .5),
        strip.text.x = element_text(face = "bold", size = rel(1.4)))
```

Word2Vec Cosines and RTs for Related/Unrelated Pairs



kenett ANOVA

```
sem_kenett_word2vec = final_word2vec %>% filter(rt > 250)

# removing for each participant, trials which were above or below 2.5 SD for each condition were also d

condition_means_word2vec = group_by(final_word2vec, quantile) %>%
  summarise_at(vars(rt), mean)
condition_sd_word2vec = group_by(final_word2vec, quantile) %>%
  summarise_at(vars(rt), sd)

condition_agg_word2vec = merge(condition_means_word2vec,
                              condition_sd_word2vec, by = "quantile")
colnames(condition_agg_word2vec) = c("quantile", "meanrt", "sdrt")

condition_agg_word2vec$MOE = 2.5*condition_agg_word2vec$sdrt
condition_agg_word2vec$lower = condition_agg_word2vec$meanrt -
  condition_agg_word2vec$MOE
condition_agg_word2vec$upper = condition_agg_word2vec$meanrt +
  condition_agg_word2vec$MOE

sem_kenett_word2vec = merge(sem_kenett_word2vec,
                           condition_agg_word2vec, by = "quantile")

sem_kenett_word2vec = dplyr::arrange(sem_kenett_word2vec, subject)
```

```

sem_kenett_word2vec = sem_kenett_word2vec %>% filter(rt > lower)
sem_kenett_word2vec = sem_kenett_word2vec %>% filter(rt < upper)

sem_kenett_word2vec_main = sem_kenett_word2vec %>%
  filter((Type == "Related" & quantile == 5) |
         (Type == "Unrelated" & quantile != 5))

sem_kenett_word2vec_subject = group_by(sem_kenett_word2vec_main,
                                       subject, quantile) %>%
  summarise_at(vars(rt), mean)

sem_kenett_word2vec_subject$subject = as.factor(sem_kenett_word2vec_subject$subject)
sem_kenett_word2vec_subject$quantile = as.factor(sem_kenett_word2vec_subject$quantile)

sem_kenett_aov_word2vec = aov(data = sem_kenett_word2vec_subject,
                             rt ~ quantile +
                             Error(subject/quantile))
summary(sem_kenett_aov_word2vec)

```

```

##
## Error: subject
##           Df Sum Sq Mean Sq F value Pr(>F)
## Residuals 79 6815377   86271
##
## Error: subject:quantile
##           Df Sum Sq Mean Sq F value Pr(>F)
## quantile    4  10272    2568   0.854  0.492
## Residuals 316 950602    3008

```

```

options(contrasts = c('contr.sum', 'contr.poly'))
library(lsmeans)
library(multcomp)
kenett_subject_lsm = lsmeans::lsmeans(sem_kenett_aov_word2vec,
                                       c("quantile"))
sub_effect = cld(kenett_subject_lsm, alpha = 0.05,
                 adjust = "tukey", details = TRUE)
library(knitr)
kable(subset(sub_effect$comparisons, sub_effect$comparisons$p.value < 0.1))

```

contrast estimate SE df t.ratio p.value ——— ——— — — ——— ———

Kenett plot

```

sem_kenett_word2vec = final_word2vec %>% filter(rt > 250)

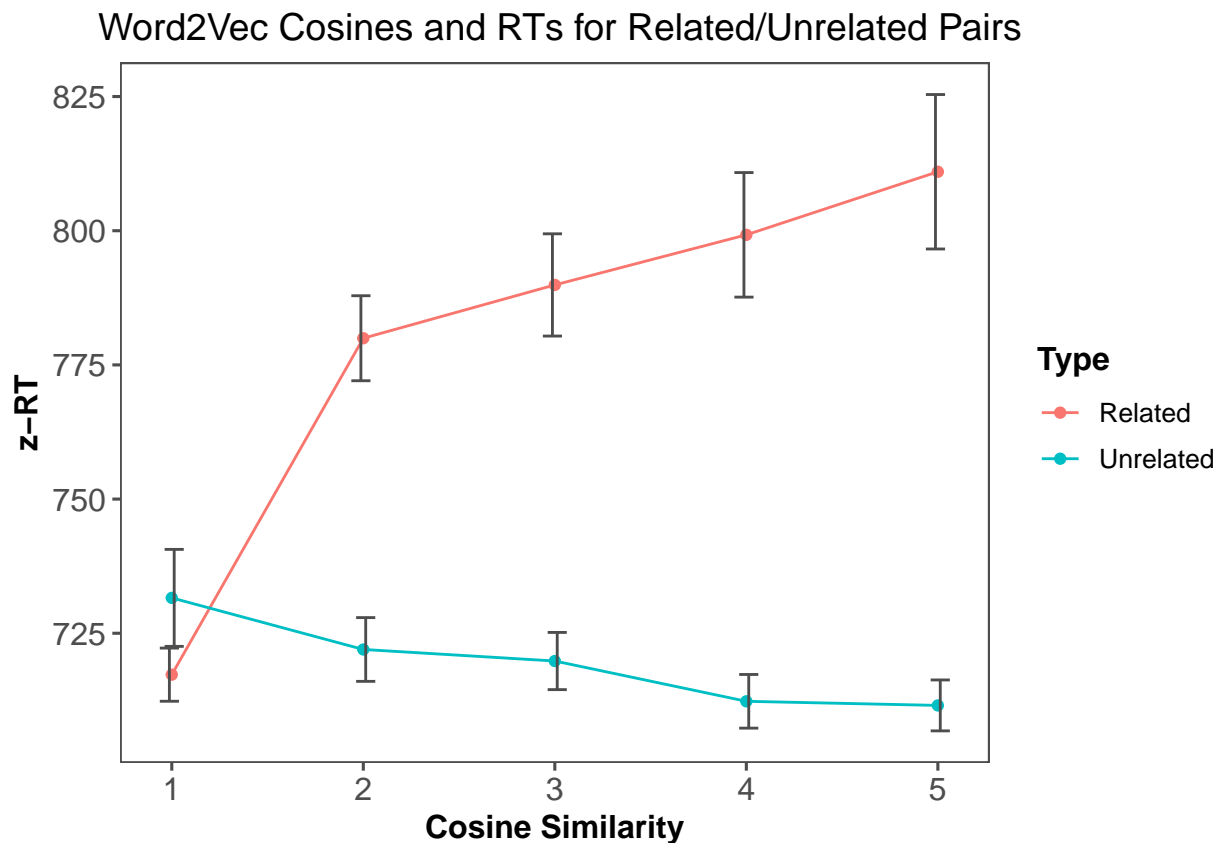
word2vec_cosine_agg_raw = Rmisc::summarySE(sem_kenett_word2vec,
                                           measurevar = "rt",
                                           groupvars = c("quantile", "Type"))
word2vec_cosine_agg_raw$pathlength = c(5,5,4,4,3,3, 2,2,1,1)
ggplot(word2vec_cosine_agg_raw,
       aes(x = pathlength, y = rt,
           color = Type, group= Type))+
  geom_point()+
  geom_line()+

```

```

geom_errorbar(aes(ymin=rt - se, ymax=rt + se),
              width=.2, color = "gray30",
              position = position_dodge(0.05))+
theme_few()+
  xlab("Cosine Similarity") + ylab("z-RT") +
ggtitle(" Word2Vec Cosines and RTs for Related/Unrelated Pairs") +
  theme(axis.text = element_text(size = rel(1)),
        axis.title = element_text(face = "bold", size = rel(1)),
        legend.title = element_text(face = "bold", size = rel(1)),
        plot.title = element_text(hjust = .5),
        strip.text.x = element_text(face = "bold", size = rel(1.4)))

```



```

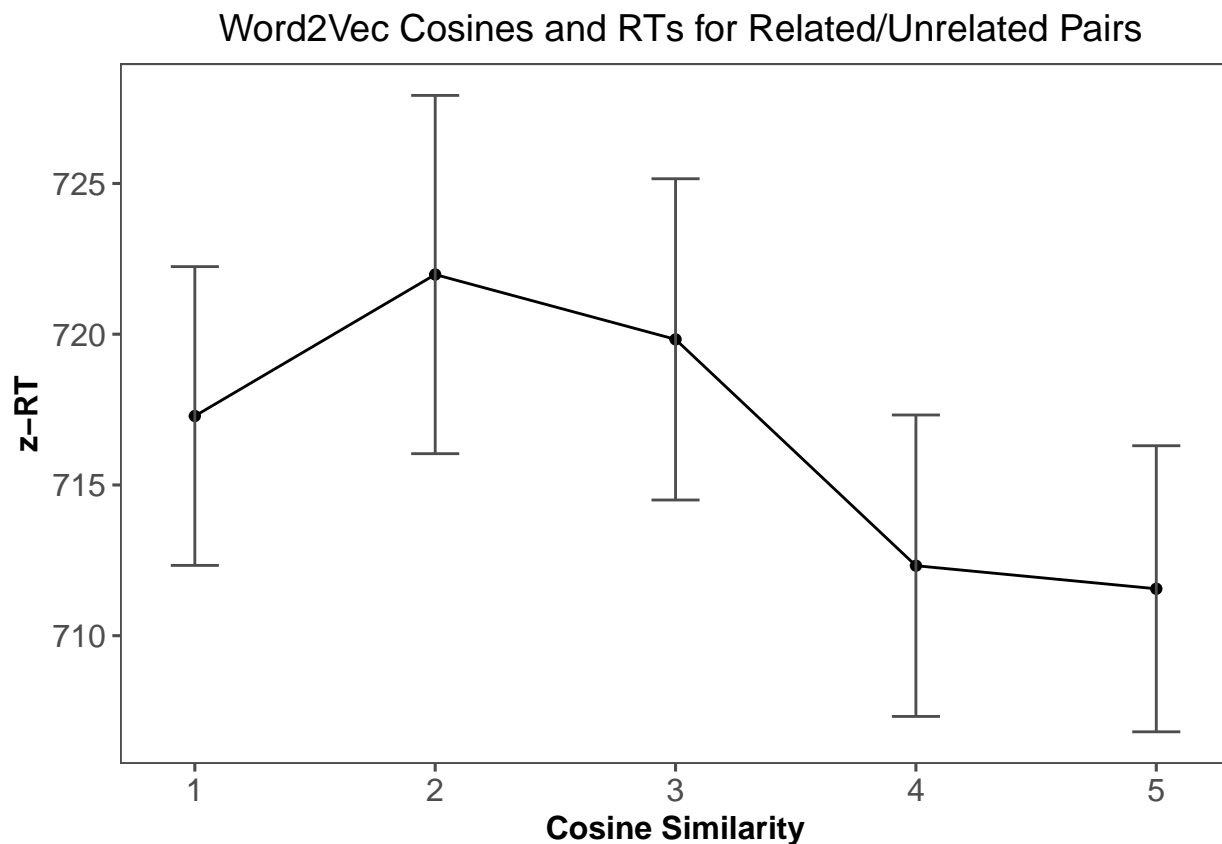
word2vec_cosine_agg_kenett = word2vec_cosine_agg_raw
word2vec_cosine_agg_kenett$Network = "word2vec"
word2vec_cosine_agg_kenett = word2vec_cosine_agg_kenett %>%
  filter((Type == "Related" & pathlength == 1) |
         (Type == "Unrelated" & pathlength != 1))

word2vec_cosine_agg_kenett2 = word2vec_cosine_agg_kenett[,-c(1,2,8)]
x = as.data.frame(matrix(NA, nrow = 5, ncol = 1))
colnames(x) = "pathlength"
x$pathlength = c(5,4,3,2,1)
word2vec_cosine_agg_kenett2 = cbind(x, word2vec_cosine_agg_kenett2)

ggplot(word2vec_cosine_agg_kenett2,
       aes(x = pathlength, y = rt))+
geom_point()+

```

```
geom_line()+
  geom_errorbar(aes(ymin=rt - se, ymax=rt + se),
    width=.2, color = "gray30",
    position = position_dodge(0.05))+
  theme_few()+
  xlab("Cosine Similarity") + ylab("z-RT") +
  ggtitle(" Word2Vec Cosines and RTs for Related/Unrelated Pairs") +
  theme(axis.text = element_text(size = rel(1)),
    axis.title = element_text(face = "bold", size = rel(1)),
    legend.title = element_text(face = "bold", size = rel(1)),
    plot.title = element_text(hjust = .5),
    strip.text.x = element_text(face = "bold", size = rel(1.4)))
```



Combined Plot

Collapsed RelUnrel

```
sem_kenett_subject_agg_undirected = sem_kenett_subject_agg_undirected[, -7]

z_rmisc_kenett = z_rmisc_kenett[, -7]
z_rmisc_kenett$Network = "Association Correlation"

colnames(sem_kenett_subject_agg_directed) = colnames(z_rmisc_kenett)
colnames(sem_kenett_subject_agg_undirected) = colnames(z_rmisc_kenett)
```

```

sem_kenett_subject_agg_directed = sem_kenett_subject_agg_directed %>%
  filter(!pathlength == "H")

z_rmisc_combined = rbind(z_rmisc_kenett,
                          sem_kenett_subject_agg_undirected,
                          sem_kenett_subject_agg_directed,
                          word2vec_cosine_agg_kenett2)

z_rmisc_combined$Network = as.factor(z_rmisc_combined$Network)

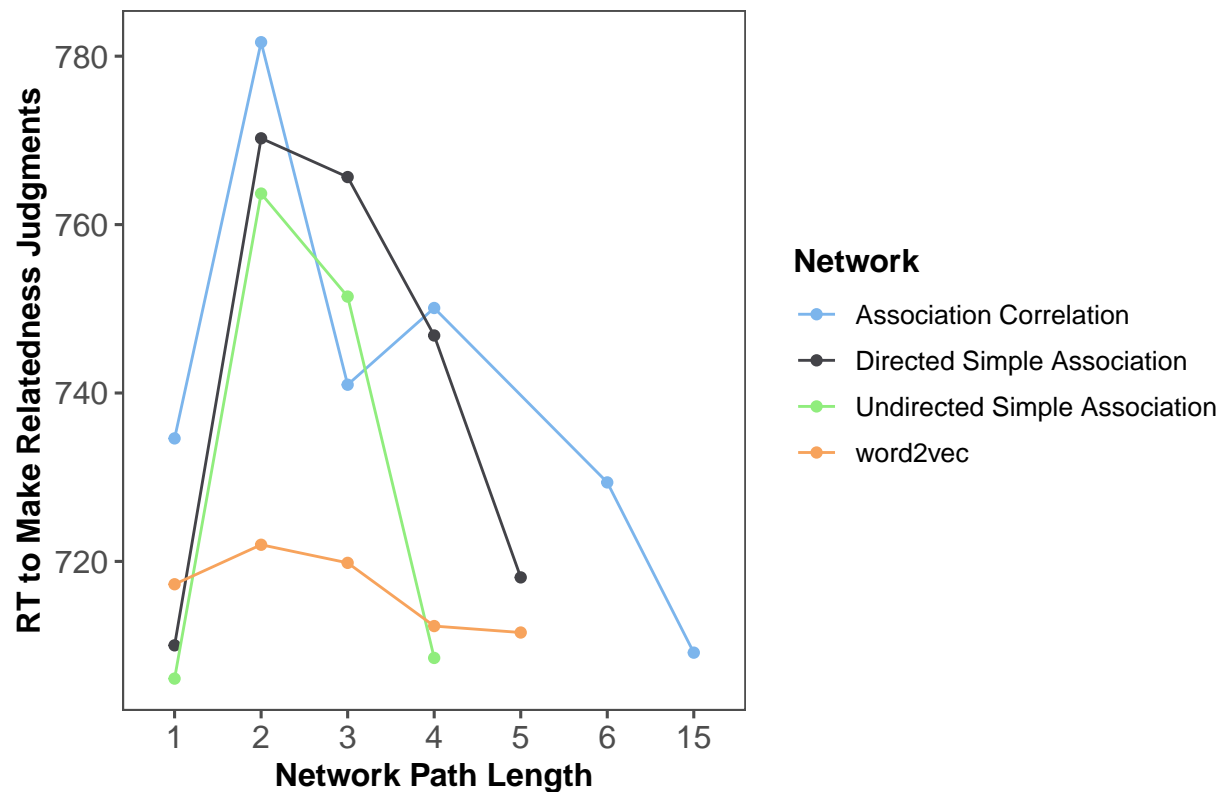
z_rmisc_combined$pathlengthfac = ordered(as.factor(as.character(z_rmisc_combined$pathlength)),
levels = c("1", "2", "3", "4", "5", "6", "15"))

library(ggplot2)
library(ggthemes)

z_rmisc_combined %>%
  ggplot(aes(x = pathlengthfac, y = rt,
             group = Network, color = Network))+
  geom_point()+
  # geom_smooth(method = "loess")+
  geom_line()+
  # geom_errorbar(aes(ymin=rt - ci, ymax=rt + ci),
  #               width=.05, color = "azure3",
  #               position = position_dodge(0))+
  theme_few()+
  scale_color_hc()+
  #scale_x_continuous(breaks = c(1,2,3,4,5,6,10,15,20))+
  xlab("Network Path Length") + ylab("RT to Make Relatedness Judgments") +
  ggtitle("Response Time for Relatedness Judgments by Path Length") +
  theme(axis.text = element_text(size = rel(1)),
        axis.title = element_text(face = "bold", size = rel(1)),
        legend.title = element_text(face = "bold", size = rel(1)),
        plot.title = element_text(hjust = .5),
        strip.text.x = element_text(face = "bold", size = rel(1.4)))

```

Response Time for Relatedness Judgments by Path Length



kenett replication

```
kenett_original = matrix(NA, nrow = 6, ncol = 2)
kenett_original = as.data.frame(kenett_original)
colnames(kenett_original) = c("pathlength", "rt")
kenett_original$pathlength = c(1, 2, 3, 4, 6, 15)
kenett_original$rt = c(704, 870, 930, 844, 793, 770)
kenett_original$sd = c(169, 239, 275, 253, 241, 258)
kenett_original$Network = "Kenett et al., 2017"

kenett_e1 = sem_kenett_agg[,c(1,3,4)]
kenett_e1$Network = "Experiment 1"

kenett_replicate = rbind(kenett_original, kenett_e1)
kenett_replicate$pathlengthfac = as.factor(kenett_replicate$pathlength)

kenett_replicate %>%
  ggplot(aes(x = pathlengthfac, y = rt,
             group = Network, color = Network))+
  geom_point()+
  geom_line()+
  # geom_errorbar(aes(ymin=rt - sd, ymax=rt + sd),
  #               width=.05,
  #               position = position_dodge(0))+
```

```

theme_few()+
scale_color_hc()+
#scale_x_continuous(breaks = c(1,2,3,4,5,6,10,15,20))+
  xlab("Network Path Length") + ylab("RT to Make Relatedness Judgments") +
ggtitle("") +
  theme(axis.text = element_text(size = rel(1)),
        axis.title = element_text(face = "bold", size = rel(1)),
        legend.title = element_text(face = "bold", size = rel(1)),
        plot.title = element_text(hjust = .5),
        strip.text.x = element_text(face = "bold", size = rel(1.4)))

```

