Study 1 Mediations

Cognitive Awareness & Study Approach Decision Making

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Abstract

Why do learners not choose ideal study strategies when learning? Past research suggests that learners frequently misinterpret the effort affiliated with efficient strategies as being indicative of poor learning. Expanding on past findings, we explored the integration of study habits into this model. We conducted two experiments where learners experienced two contrasting strategies—blocked and interleaved schedules—to learn to discriminate between images of bird families. After experiencing each strategy, learners rated each according to its perceived effort, learning, and familiarity. Next, learners were asked to choose which strategy they would use in the future. Mediation analyses revealed, for both experiments, that the more mentally effortful interleaving felt, the less learners felt they learned, and the less likely learners were to use it in future learning. Further, in this study, strategy familiarity predicted strategy choice, also mediated by learners' perceived learning. Additionally, Study 2 verified that, in contrast to learners' judgments, the less familiar interleaving schedule resulted in better learning. Consequently, learners are making ineffective learning judgments based on their perceptions of effort and familiarity and, therefore, do not make use of optimal study strategies in self-regulated learning decisions.

Load Packages

```
library(psych)
library(tidyverse)
```

```
## ── Attaching core tidyverse packages ──────────────────────── tidyverse 2.0.0 ──
## ✔ dplyr     1.1.2     ✔ readr     2.1.4
## ✔ forcats   1.0.0     ✔ stringr   1.5.0
## ✔ ggplot2   3.4.2     ✔ tibble    3.2.1
## ✔ lubridate 1.9.2     ✔ tidyr     1.3.0
## ✔ purrr     1.0.1
## ── Conflicts ────────────────────────────────────────── tidyverse_conflicts() ──
## ✖ ggplot2::%+%()   masks psych::%+%()
## ✖ ggplot2::alpha() masks psych::alpha()
## ✖ dplyr::filter()  masks stats::filter()
## ✖ dplyr::lag()     masks stats::lag()
## ℹ Use the conflicted package (<http://conflicted.r-lib.org/>) to force all conflicts
to become errors
```

```
library(mediation)
```

```
## Loading required package: MASS
##
## Attaching package: 'MASS'
##
## The following object is masked from 'package:dplyr':
##
##     select
##
## Loading required package: Matrix
##
## Attaching package: 'Matrix'
##
## The following objects are masked from 'package:tidyr':
##
##     expand, pack, unpack
##
## Loading required package: mvtnorm
## Loading required package: sandwich
## mediation: Causal Mediation Analysis
## Version: 4.5.0
##
##
## Attaching package: 'mediation'
##
## The following object is masked from 'package:psych':
##
##     mediate
```

```
library(powerMediation)
```

Disable Scientific Notation and set.seed

```
options(scipen = 999)
set.seed(1)
```

Study 1 Set Up

Read in Data

```
study1 <- read.csv("study1-final.csv")
# Blocked -> Interleaved (list_one) rows 2-180
# Interleaved -> Blocked (list_two) rows 181-329
```

Variables of Interest

Mental Effort (X)

Familiarity/Habits (X)

Perceived Learning (M)

Final Strategy (Y)

Mental Effort

```
study1$effort_diff <- ((study1$TiredInterleaved + study1$MentallyExhaustingInterleaved +
                          study1$DifficultInterleaved + study1$BoringInterleaved) / 4) -
                       ((study1$TiredBlocked + study1$MentallyExhaustingBlocked +
                            study1$DifficultBlocked + study1$BoringBlocked) / 4)
summary(study1$effort_diff)
```

```
##    Min. 1st Qu.  Median    Mean 3rd Qu.    Max.    NA's
## -2.5000  0.0000  0.5000  0.6349  1.5000  4.7500       1
```

```
effort_diff_x <- study1%>% filter(is.na(effort_diff) == FALSE)
```

Perceived Learning

```
study1$learn_diff <- ((study1$RememberAnswersInterleaved + study1$MemoryAnswersInterleav
ed +
                         study1$HelpingToLearnInterleaved + study1$LearnAnswersInterleav
ed) / 4) -
                       ((study1$RememberAnswersBlocked + study1$MemoryAnswersBlocked +
                           study1$HelpingToLearnBlocked + study1$LearnAnswersBlocked) /4
)
summary(study1$learn_diff)
```

```
##    Min. 1st Qu.  Median    Mean 3rd Qu.    Max.    NA's
##  -4.250  -1.500  -0.750  -0.609   0.250   3.250       1
```

Familiarity/Habits

```
study1$habits_diff <- ((study1$ClassStructureInterleaved + study1$FamiliarInterleaved +
                          study1$NewInterleaved + study1$StudyHabitsInterleaved) / 4) -
                      ((study1$ClassStructureBlocked + study1$FamiliarBlocked +
                           study1$NewBlocked + study1$StudyHabitsBlocked)/ 4)
summary(study1$habits_diff)
```

```
##    Min. 1st Qu.  Median    Mean 3rd Qu.    Max.    NA's
##  -4.250  -1.500  -0.250  -0.593   0.250   3.500       1
```

Final Study Strategy Choice

```
study1$strategy_choice <- (study1$ChooseActivity)

# Dummy Variable Coding for Binomial Family
study1$chooseInterleaved <- ifelse(study1$strategy_choice == "Blocked", 0, 1)
```

Study 1 Mental Effort Mediation

a path

```
# a path
med.effort <- lm(learn_diff ~ effort_diff, data = study1)
summary(med.effort)
```

```
##
## Call:
## lm(formula = learn_diff ~ effort_diff, data = study1)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -3.3209 -0.6723 -0.0225  0.6284  4.0777
##
## Coefficients:
##             Estimate Std. Error t value             Pr(>|t|)
## (Intercept) -0.22863    0.06929  -3.299              0.00108 **
## effort_diff -0.59909    0.05298 -11.309 < 0.0000000000000002 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 1.097 on 326 degrees of freedom
##   (1 observation deleted due to missingness)
## Multiple R-squared:  0.2818, Adjusted R-squared:  0.2796
## F-statistic: 127.9 on 1 and 326 DF,  p-value: < 0.00000000000000022
```

```
  # effort_diff = a path (p < .001)
    # R2 = 0.28
```

c prime and b path

```
# c' path and b path
med.learn1 <- glm(chooseInterleaved ~ effort_diff + learn_diff, data = study1, family=bi
nomial)
summary(med.learn1)
```

```
##
## Call:
## glm(formula = chooseInterleaved ~ effort_diff + learn_diff, family = binomial,
##     data = study1)
##
## Deviance Residuals:
##     Min       1Q   Median       3Q      Max
## -2.6092  -0.5814  -0.3186  -0.0831   2.7847
##
## Coefficients:
##              Estimate Std. Error z value          Pr(>|z|)
## (Intercept) -0.973084   0.169691  -5.734 0.000000009783988 ***
## effort_diff  0.005538   0.165724   0.033             0.973
## learn_diff   1.447244   0.196997   7.347 0.000000000000203 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## (Dispersion parameter for binomial family taken to be 1)
##
##     Null deviance: 355.11  on 327  degrees of freedom
## Residual deviance: 245.16  on 325  degrees of freedom
##   (1 observation deleted due to missingness)
## AIC: 251.16
##
## Number of Fisher Scoring iterations: 6
```

```
  # learn_diff = b path (p < .001)
    # partial R2 = 0.36
  # c' (direct) = effort_diff (p = 0.39)
    # partial R2 = 0.00
```

c path

```
# c path
med.learn2 <- glm(chooseInterleaved ~ effort_diff, data = study1, family=binomial)
summary(med.learn2)
```

```
##
## Call:
## glm(formula = chooseInterleaved ~ effort_diff, family = binomial,
##     data = study1)
##
## Deviance Residuals:
##     Min       1Q   Median       3Q      Max
## -1.4642  -0.7631  -0.5749  -0.3147   2.6402
##
## Coefficients:
##             Estimate Std. Error z value        Pr(>|z|)
## (Intercept)  -0.9267     0.1405  -6.596 0.0000000000422 ***
## effort_diff  -0.6318     0.1372  -4.605 0.0000041165352 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## (Dispersion parameter for binomial family taken to be 1)
##
##     Null deviance: 355.11  on 327  degrees of freedom
## Residual deviance: 330.33  on 326  degrees of freedom
##   (1 observation deleted due to missingness)
## AIC: 334.33
##
## Number of Fisher Scoring iterations: 4
```

```
  # effort_diff = c (indirect) path (p < .001)
    # partial R2 = 0.12
```

Mediation for Mental Effort

```
mediation_1 <- mediate(med.effort, med.learn1, sims=1000, boot=TRUE, treat = "effort_dif
f", mediator = "learn_diff")
```

```
## Running nonparametric bootstrap
```

```
summary(mediation_1)
```

```
##
## Causal Mediation Analysis
##
## Nonparametric Bootstrap Confidence Intervals with the Percentile Method
##
##                            Estimate 95% CI Lower 95% CI Upper
## ACME (control)           -0.100815    -0.143681        -0.08
## ACME (treated)           -0.101036    -0.146330        -0.08
## ADE (control)             0.000754    -0.057061         0.05
## ADE (treated)             0.000533    -0.041514         0.04
## Total Effect             -0.100282    -0.161486        -0.06
## Prop. Mediated (control)  1.005319     0.727165         1.52
## Prop. Mediated (treated)  1.007524     0.627167         1.70
## ACME (average)           -0.100926    -0.144436        -0.08
## ADE (average)             0.000644    -0.049473         0.04
## Prop. Mediated (average)  1.006421     0.676917         1.60
##                                  p-value
## ACME (control)           <0.0000000000000002 ***
## ACME (treated)           <0.0000000000000002 ***
## ADE (control)                         0.97
## ADE (treated)                         0.97
## Total Effect             <0.0000000000000002 ***
## Prop. Mediated (control) <0.0000000000000002 ***
## Prop. Mediated (treated) <0.0000000000000002 ***
## ACME (average)           <0.0000000000000002 ***
## ADE (average)                         0.97
## Prop. Mediated (average) <0.0000000000000002 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Sample Size Used: 328
##
##
## Simulations: 1000
```

```
  # p < .001
# ACME = average causal mediation effect
# ADE = average direct effect
# Total Effect
# Prop. Mediated = proportion of the effect of the IV on the DV that goes through
  # the mediator. (ACME/total effect)
```

Correlation with Mental Effort and Final Study Strategy Decision

```
cor.test(study1$effort_diff, study1$chooseInterleaved, method = "pearson") # r = -.26 (p
<.0001)
```

```
##
##  Pearson's product-moment correlation
##
## data:  study1$effort_diff and study1$chooseInterleaved
## t = -4.9383, df = 326, p-value = 0.000001261
## alternative hypothesis: true correlation is not equal to 0
## 95 percent confidence interval:
##  -0.3617759 -0.1600999
## sample estimates:
##       cor
## -0.2638188
```

Study 1 Familiarity Mediation

a path

```
# a path
med.habit <- lm(learn_diff ~ habits_diff, data = study1)
summary(med.habit)
```

```
##
## Call:
## lm(formula = learn_diff ~ habits_diff, data = study1)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -3.8128 -0.6938 -0.0395  0.7596  3.9045
##
## Coefficients:
##             Estimate Std. Error t value     Pr(>|t|)
## (Intercept) -0.43723    0.07506  -5.825 0.0000000137 ***
## habits_diff  0.28966    0.05232   5.536 0.0000000637 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 1.238 on 326 degrees of freedom
##   (1 observation deleted due to missingness)
## Multiple R-squared:  0.08594,    Adjusted R-squared:  0.08313
## F-statistic: 30.65 on 1 and 326 DF,  p-value: 0.00000006365
```

```
  # habits_diff = a path (p < .001)
    # R2 = 0.09
```

c prime and b path

```
# c' path and b path
med.learn1 <- glm(chooseInterleaved ~ habits_diff + learn_diff, data = study1, family=bi
nomial)
summary(med.learn1)
```

```
##
## Call:
## glm(formula = chooseInterleaved ~ habits_diff + learn_diff, family = binomial,
##     data = study1)
##
## Deviance Residuals:
##      Min        1Q    Median        3Q       Max
## -2.58846  -0.58666  -0.31300  -0.07597   2.71754
##
## Coefficients:
##             Estimate Std. Error z value           Pr(>|z|)
## (Intercept)  -0.9325     0.1669  -5.587 0.0000000230527746 ***
## habits_diff   0.1287     0.1493   0.862              0.389
## learn_diff    1.4156     0.1848   7.658 0.0000000000000188 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## (Dispersion parameter for binomial family taken to be 1)
##
##     Null deviance: 355.11  on 327  degrees of freedom
## Residual deviance: 244.41  on 325  degrees of freedom
##   (1 observation deleted due to missingness)
## AIC: 250.41
##
## Number of Fisher Scoring iterations: 6
```

```
  # learn_diff = b path (p < .001)
    # partial R2 = 0.40
  # c' (direct) = habits_diff (p = 0.39)
    # partial R2 = 0.00
```

c path

```
# c path
med.learn2 <- glm(chooseInterleaved ~ habits_diff, data = study1, family=binomial)
summary(med.learn2)
```

```
##
## Call:
## glm(formula = chooseInterleaved ~ habits_diff, family = binomial,
##     data = study1)
##
## Deviance Residuals:
##     Min       1Q   Median       3Q      Max
## -1.2510  -0.7759  -0.6788  -0.4446   2.1009
##
## Coefficients:
##             Estimate Std. Error z value           Pr(>|z|)
## (Intercept)  -1.0464     0.1369  -7.645 0.0000000000000208 ***
## habits_diff   0.3480     0.1113   3.126            0.00177 **
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## (Dispersion parameter for binomial family taken to be 1)
##
##     Null deviance: 355.11  on 327  degrees of freedom
## Residual deviance: 344.43  on 326  degrees of freedom
##   (1 observation deleted due to missingness)
## AIC: 348.43
##
## Number of Fisher Scoring iterations: 4
```

```
  # habits_diff = c (indirect) path (p = 0.002) # marginal significance
    # partial R2 = 0.06
```

Mediation for Familiarity/Habits

```
mediation_2 <- mediate(med.habit, med.learn1, sims=1000, boot=TRUE, treat = "habits_dif
f", mediator = "learn_diff")
```

```
## Running nonparametric bootstrap
```

```
summary(mediation_2) # ACME = Average calculated mediation effect
```

```
##
## Causal Mediation Analysis
##
## Nonparametric Bootstrap Confidence Intervals with the Percentile Method
##
##                          Estimate 95% CI Lower 95% CI Upper             p-value
## ACME (control)             0.0562       0.0344         0.09 <0.0000000000000002
## ACME (treated)             0.0579       0.0354         0.09 <0.0000000000000002
## ADE (control)              0.0170      -0.0205         0.06                0.39
## ADE (treated)              0.0187      -0.0232         0.07                0.39
## Total Effect               0.0750       0.0270         0.14 <0.0000000000000002
## Prop. Mediated (control)   0.7502       0.4504         1.69 <0.0000000000000002
## Prop. Mediated (treated)   0.7728       0.4873         1.64 <0.0000000000000002
## ACME (average)             0.0571       0.0353         0.09 <0.0000000000000002
## ADE (average)              0.0179      -0.0217         0.06                0.39
## Prop. Mediated (average)   0.7615       0.4712         1.66 <0.0000000000000002
##
## ACME (control)           ***
## ACME (treated)           ***
## ADE (control)
## ADE (treated)
## Total Effect             ***
## Prop. Mediated (control) ***
## Prop. Mediated (treated) ***
## ACME (average)           ***
## ADE (average)
## Prop. Mediated (average) ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Sample Size Used: 328
##
##
## Simulations: 1000
```

```
  # p < .001
```

Correlation with Familiarity/Habits and Final Study Strategy Decision

```
cor.test(study1$habits_diff, study1$chooseInterleaved, method = "pearson") # r = .18 (p =.001)
```

```
##
##  Pearson's product-moment correlation
##
## data:  study1$habits_diff and study1$chooseInterleaved
## t = 3.2283, df = 326, p-value = 0.001372
## alternative hypothesis: true correlation is not equal to 0
## 95 percent confidence interval:
##  0.06902837 0.27898107
## sample estimates:
##       cor
## 0.1760056
```