

Study 2 Comparison 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 2 Set Up

Read in Data and Reverse Score

```
# Joined/Merged
study2 <- read.csv("study2-extendedtest-final.csv")
# Blocked -> Interleaved (rows 2-189)
# Interleaved -> Blocked (rows 190-379)

study2 %>% mutate(NewExerciseBlocked.Rev = 7 - NewExerciseBlocked) -> study2
study2 %>% mutate(NewExerciseInterleaved.Rev = 7 - NewExerciseInterleaved) -> study2
study2 %>% mutate(CompareEnjoyable.Rev = 7 - CompareEnjoyable) -> study2
study2 %>% mutate(CompareNewer.Rev = 7 - CompareNewer) -> study2
```

Variables of Interest

Mental Effort (X)

Familiarity/Habits (X)

Perceived Learning (M)

Final Strategy (Y)

Blocked versus Interleaved Compare

1 = Blocked, 6 = Interleaved, 3.5 no preference

Mental Effort

```
study2$compare_effort <- ((study2$CompareMentalEffort + study2$CompareHarderForOthers +
                          study2$CompareEnjoyable.Rev + study2$CompareHarder)/4)
summary(study2$compare_effort)
```

##	Min.	1st Qu.	Median	Mean	3rd Qu.	Max.
##	1.00	4.00	5.25	4.78	5.75	6.00

Perceived Learning

```
study2$compare_learn <- ((study2$CompareRememberAnswers + study2$CompareEffectiveYou +
                          study2$CompareEffectiveAveragePerson + study2$CompareYouStudy
                          Future)/4)
summary(study2$compare_learn)
```

##	Min.	1st Qu.	Median	Mean	3rd Qu.	Max.
##	1.000	1.250	1.750	2.434	3.500	6.000

Familiarity/Habits

```
study2$compare_habits <- ((study2$CompareStructure + study2$CompareFamiliar +
                          study2$CompareNewer.Rev + study2$CompareMatchHabits)/4)
summary(study2$compare_habits)
```

##	Min.	1st Qu.	Median	Mean	3rd Qu.	Max.	NA's
##	0.250	1.500	2.250	2.581	3.250	8.250	1

Final Study Strategy Choice

```
study2$strategy_choice <- (study2$ChooseActivity)

# Dummy Variable Coding for Binomial Family
study2$chooseInterleaved <- ifelse(study2$strategy_choice == "Blocked", 0, 1)
```

Study 2 Mental Effort Mediation

a path

```
# a path
med.compare.effort <- lm(compare_learn ~ compare_effort, data = study2)
summary(med.compare.effort)
```

```
##
## Call:
## lm(formula = compare_learn ~ compare_effort, data = study2)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -2.9537 -0.4485 -0.2166  0.2795  4.7795
##
## Coefficients:
##              Estimate Std. Error t value      Pr(>|t|)
## (Intercept)    7.18937    0.17687   40.65 <0.0000000000000002 ***
## compare_effort -0.99481    0.03579  -27.80 <0.0000000000000002 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.8731 on 375 degrees of freedom
## Multiple R-squared:  0.6733, Adjusted R-squared:  0.6724
## F-statistic: 772.7 on 1 and 375 DF,  p-value: < 0.00000000000000022
```

```
# compare_effort = a path (p < .001)
# R2 = 0.67
```

c prime and b path

```
# c' path and b path
med.compare.learn1 <- glm(chooseInterleaved ~ compare_effort + compare_learn, data = study2, family=binomial)
summary(med.compare.learn1)
```

```
##
## Call:
## glm(formula = chooseInterleaved ~ compare_effort + compare_learn,
##      family = binomial, data = study2)
##
## Deviance Residuals:
##      Min       1Q   Median       3Q      Max
## -2.38640  -0.10750  -0.03764  -0.02551   2.74639
##
## Coefficients:
##              Estimate Std. Error z value      Pr(>|z|)
## (Intercept)   -4.5983     1.9426  -2.367    0.01793 *
## compare_effort -0.9352     0.3386  -2.762    0.00574 **
## compare_learn   2.1786     0.3362   6.480 0.00000000000916 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## (Dispersion parameter for binomial family taken to be 1)
##
##      Null deviance: 407.314  on 376  degrees of freedom
## Residual deviance:  92.355  on 374  degrees of freedom
## AIC: 98.355
##
## Number of Fisher Scoring iterations: 8
```

```
# compare_learn = b path (p < .001)
# partial R2 = 0.59
# c' (direct) = compare_effort (p = 0.01)
# partial R2 = 0.09
```

c path

```
# c path
med.compare.learn2 <- glm(chooseInterleaved ~ compare_effort, data = study2, family=binomial)
summary(med.compare.learn2)
```

```
##
## Call:
## glm(formula = chooseInterleaved ~ compare_effort, family = binomial,
##      data = study2)
##
## Deviance Residuals:
##      Min        1Q    Median        3Q        Max
## -2.2725  -0.3938  -0.1882  -0.1467   3.0124
##
## Coefficients:
##              Estimate Std. Error z value      Pr(>|z|)
## (Intercept)      7.5251     0.9188   8.190 0.000000000000000261 ***
## compare_effort  -2.0086     0.2164  -9.281 < 0.0000000000000002 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## (Dispersion parameter for binomial family taken to be 1)
##
##      Null deviance: 407.31  on 376  degrees of freedom
## Residual deviance: 194.21  on 375  degrees of freedom
## AIC: 198.21
##
## Number of Fisher Scoring iterations: 6
```

```
# compare_effort = c (indirect) (p < .001)
# partial R2 = 0.65
```

Mediation for Mental Effort

```
mediation_compare1 <- mediate(med.compare.effort, med.compare.learn1, sims=1000, boot=TR
UE, treat = "compare_effort", mediator = "compare_learn")
```

```
## Running nonparametric bootstrap
```

```
summary(mediation_compare1)
```

```
##
## Causal Mediation Analysis
##
## Nonparametric Bootstrap Confidence Intervals with the Percentile Method
##
##           Estimate 95% CI Lower 95% CI Upper
## ACME (control)      -0.000604    -0.004985      0.00
## ACME (treated)      -0.001521    -0.007737      0.00
## ADE (control)       -0.000121    -0.000570      0.00
## ADE (treated)       -0.001038    -0.003494      0.00
## Total Effect        -0.001642    -0.008276      0.00
## Prop. Mediated (control) 0.367733     0.175275     0.73
## Prop. Mediated (treated) 0.926055     0.861537     0.98
## ACME (average)      -0.001062    -0.006277      0.00
## ADE (average)       -0.000580    -0.002002      0.00
## Prop. Mediated (average) 0.646894     0.536652     0.85
##
##                               p-value
## ACME (control)          <0.0000000000000002 ***
## ACME (treated)          <0.0000000000000002 ***
## ADE (control)              0.002 **
## ADE (treated)              0.002 **
## Total Effect             <0.0000000000000002 ***
## Prop. Mediated (control) <0.0000000000000002 ***
## Prop. Mediated (treated) <0.0000000000000002 ***
## ACME (average)          <0.0000000000000002 ***
## ADE (average)              0.002 **
## Prop. Mediated (average) <0.0000000000000002 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Sample Size Used: 377
##
##
## Simulations: 1000
```

```
# total effect of -0.002*** (p < .001)
```

Correlation with Mental Effort and Final Study Strategy Decision

```
cor.test(study2$compare_effort, study2$chooseInterleaved, method = "pearson") #-0.73 (p<.001)
```

```
##
## Pearson's product-moment correlation
##
## data: study2$compare_effort and study2$chooseInterleaved
## t = -20.428, df = 375, p-value < 0.00000000000000022
## alternative hypothesis: true correlation is not equal to 0
## 95 percent confidence interval:
## -0.7702748 -0.6741481
## sample estimates:
## cor
## -0.7257345
```

Study 2 Familiarity Mediation

a path

```
# a path
med.compare.habit <- lm(compare_learn ~ compare_habits, data = study2)
summary(med.compare.habit)
```

```
##
## Call:
## lm(formula = compare_learn ~ compare_habits, data = study2)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -3.1786 -0.8293 -0.3735  0.6707  4.1486
##
## Coefficients:
##              Estimate Std. Error t value      Pr(>|t|)
## (Intercept)   1.25950    0.12788   9.849 <0.0000000000000002 ***
## compare_habits 0.45587    0.04179  10.909 <0.0000000000000002 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 1.332 on 374 degrees of freedom
## (1 observation deleted due to missingness)
## Multiple R-squared:  0.2414, Adjusted R-squared:  0.2393
## F-statistic: 119 on 1 and 374 DF, p-value: < 0.00000000000000022
```

```
# compare_habits output = a path (p < .001)
# R2 = 0.24
```

c prime and b path

```
# c' path and b path
med.compare.learn1 <- glm(chooseInterleaved ~ compare_habits + compare_learn, data = stu
dy2, family=binomial)
summary(med.compare.learn1)
```



```
##
## Call:
## glm(formula = chooseInterleaved ~ compare_habits + compare_learn,
##      family = binomial, data = study2)
##
## Deviance Residuals:
##      Min       1Q   Median       3Q      Max
## -2.53977  -0.15013  -0.05807  -0.04211   2.99418
##
## Coefficients:
##              Estimate Std. Error z value      Pr(>|z|)
## (Intercept)   -9.574255    1.242524  -7.705 0.000000000000000130 ***
## compare_habits -0.002523    0.182236  -0.014      0.989
## compare_learn  2.554681    0.333872   7.652 0.000000000000000198 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## (Dispersion parameter for binomial family taken to be 1)
##
##      Null deviance: 406.79  on 375  degrees of freedom
## Residual deviance: 100.50  on 373  degrees of freedom
## (1 observation deleted due to missingness)
## AIC: 106.5
##
## Number of Fisher Scoring iterations: 7
```

```
# compare_learn = b path (p < .001)
# partial R2 = 0.80
# c' (direct) = compare_habits (p = 0.99)
# partial R2 = 0.00
```

c path

```
# c path
med.compare.learn2 <- glm(chooseInterleaved ~ compare_habits, data = study2, family=binomial)
summary(med.compare.learn2)
```

```
##
## Call:
## glm(formula = chooseInterleaved ~ compare_habits, family = binomial,
##      data = study2)
##
## Deviance Residuals:
##      Min       1Q   Median       3Q      Max
## -1.8893  -0.6586  -0.5118  -0.3690   2.2774
##
## Coefficients:
##              Estimate Std. Error z value      Pr(>|z|)
## (Intercept)   -2.79009    0.28464  -9.802 < 0.0000000000000002 ***
## compare_habits  0.54889    0.08113   6.766   0.00000000000133 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## (Dispersion parameter for binomial family taken to be 1)
##
##      Null deviance: 406.79  on 375  degrees of freedom
## Residual deviance: 352.66  on 374  degrees of freedom
## (1 observation deleted due to missingness)
## AIC: 356.66
##
## Number of Fisher Scoring iterations: 4
```

```
# compare_habits = c (indirect) path (p < .001)
# partial R2 = 0.20
```

Mediation for Familiarity/Habits

```
mediation_compare2 <- mediate(med.compare.habit, med.compare.learn1, sims=1000, boot=TRUE,
E, treat = "compare_habits", mediator = "compare_learn")
```

```
## Running nonparametric bootstrap
```

```
summary(mediation_compare2) # ACME = Average calculated mediation effect
```

```
##
## Causal Mediation Analysis
##
## Nonparametric Bootstrap Confidence Intervals with the Percentile Method
##
##           Estimate 95% CI Lower 95% CI Upper
## ACME (control)      0.0432367    0.0205232    0.06
## ACME (treated)      0.0431921    0.0237586    0.06
## ADE (control)      -0.0000718   -0.0143296    0.01
## ADE (treated)      -0.0001164   -0.0212052    0.01
## Total Effect        0.0431203    0.0252258    0.05
## Prop. Mediated (control) 1.0026998    0.6807027    1.57
## Prop. Mediated (treated) 1.0016644    0.8060500    1.39
## ACME (average)      0.0432144    0.0223362    0.06
## ADE (average)      -0.0000941   -0.0180376    0.01
## Prop. Mediated (average) 1.0021821    0.7479585    1.48
##
##                               p-value
## ACME (control)      <0.0000000000000002 ***
## ACME (treated)      <0.0000000000000002 ***
## ADE (control)              0.98
## ADE (treated)              0.98
## Total Effect        <0.0000000000000002 ***
## Prop. Mediated (control) <0.0000000000000002 ***
## Prop. Mediated (treated) <0.0000000000000002 ***
## ACME (average)      <0.0000000000000002 ***
## ADE (average)              0.98
## Prop. Mediated (average) <0.0000000000000002 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Sample Size Used: 376
##
##
## Simulations: 1000
```

```
# total effect of -0.04*** (p < .001)
```

Correlation with Familiarity/Habits and Final Study Strategy Decision

```
cor.test(study2$compare_habits, study2$chooseInterleaved, method = "pearson") #.39 (p<.001)
```

```
##  
## Pearson's product-moment correlation  
##  
## data: study2$compare_habits and study2$chooseInterleaved  
## t = 8.1961, df = 374, p-value = 0.000000000000004001  
## alternative hypothesis: true correlation is not equal to 0  
## 95 percent confidence interval:  
## 0.3009555 0.4726958  
## sample estimates:  
## cor  
## 0.3902145
```