

Study 2 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

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

Variables of Interest

Mental Effort (X)

Familiarity/Habits (X)

Perceived Learning (M)

Final Strategy (Y)

Mental Effort

```
study2$effort_diff <- ((study2$TiredInterleaved + study2$MentallyExhaustingInterleaved +
  study2$DifficultInterleaved + study2$BoringInterleaved) / 4) -
  ((study2$TiredBlocked + study2$MentallyExhaustingBlocked +
  study2$DifficultBlocked + study2$BoringBlocked) / 4)
summary(study2$effort_diff)
```

```
##      Min. 1st Qu.  Median    Mean 3rd Qu.    Max.
## -2.5000 -0.2500  0.5000  0.4052  1.0000  3.7500
```

Perceived Learning

```
study2$learn_diff <- ((study2$RememberAnswersInterleaved + study2$MemoryAnswersInterleaved +
  study2$HelpingToLearnInterleaved + study2$LearnAnswersInterleaved) / 4) -
  ((study2$RememberAnswersBlocked + study2$MemoryAnswersBlocked +
  study2$HelpingToLearnBlocked + study2$LearnAnswersBlocked) / 4)
summary(study2$learn_diff)
```

```
##      Min. 1st Qu.  Median    Mean 3rd Qu.    Max.
## -4.7500 -1.2500 -0.5000 -0.4861  0.2500  3.5000
```

Familiarity/Habits

```
study2$habits_diff <- ((study2$ClassStructureInterleaved + study2$FamiliarMethodInterleaved +
  study2$NewExerciseInterleaved + study2$MatchHabitsInterleaved) / 4) -
  ((study2$ClassStructureBlocked + study2$FamiliarMethodBlocked +
  study2$NewExerciseBlocked + study2$MatchHabitsBlocked) / 4)
summary(study2$habits_diff)
```

```
##      Min. 1st Qu.  Median    Mean 3rd Qu.    Max.    NA's
## -3.2500 -1.0000 -0.2500 -0.4269  0.0000  2.2500      4
```

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.effort <- lm(learn_diff ~ effort_diff, data = study2)
summary(med.effort)
```

```
##
## Call:
## lm(formula = learn_diff ~ effort_diff, data = study2)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -5.7626 -0.6106  0.0125  0.6067  3.7336
##
## Coefficients:
##              Estimate Std. Error t value      Pr(>|t|)
## (Intercept) -0.23361    0.05760  -4.056    0.0000608 ***
## effort_diff -0.62310    0.05391 -11.558 < 0.0000000000000002 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 1.035 on 375 degrees of freedom
## Multiple R-squared:  0.2626, Adjusted R-squared:  0.2607
## F-statistic: 133.6 on 1 and 375 DF,  p-value: < 0.00000000000000022
```

```
# effort_diff = a path (p < .001)
# R2 = 0.26
```

c prime and b path

```
# c' path and b path
med.learn1 <- glm(chooseInterleaved ~ effort_diff + learn_diff, data = study2, family=bi
nomial)
summary(med.learn1)
```

```
##
## Call:
## glm(formula = chooseInterleaved ~ effort_diff + learn_diff, family = binomial,
##      data = study2)
##
## Deviance Residuals:
##      Min       1Q   Median       3Q      Max
## -2.09677  -0.61969  -0.32451  -0.06798   2.54507
##
## Coefficients:
##              Estimate Std. Error z value      Pr(>|z|)
## (Intercept)  -1.0709      0.1552  -6.899 0.000000000000523 ***
## effort_diff   -0.1405      0.1921  -0.731      0.465
## learn_diff     1.5055      0.2033   7.407 0.000000000000013 ***
## ---
## 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: 282.53  on 374  degrees of freedom
## AIC: 288.53
##
## Number of Fisher Scoring iterations: 6
```

```
# learn_diff = b path (p < .001)
# partial R2 = 0.33
# c' (direct) = effort_diff (p = 0.47)
# partial R2 = 0.00
```

c path

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

```
##
## Call:
## glm(formula = chooseInterleaved ~ effort_diff, family = binomial,
##      data = study2)
##
## Deviance Residuals:
##      Min        1Q      Median        3Q        Max
## -1.6455  -0.7142  -0.5377  -0.2953   2.2653
##
## Coefficients:
##              Estimate Std. Error z value      Pr(>|z|)
## (Intercept)  -1.0278      0.1295  -7.938 0.000000000000000205 ***
## effort_diff  -0.8331      0.1456  -5.721 0.00000001061838003 ***
## ---
## 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: 368.71  on 375  degrees of freedom
## AIC: 372.71
##
## Number of Fisher Scoring iterations: 4
```

```
# effort_diff = c path (indirect) (p < .001)
# partial R2 = 0.15
```

Mediation for Mental Effort

```
mediation_1 <- mediate(med.effort, med.learn1, sims=1000, boot=TRUE, treat = "effort_diff", 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	p-value
## ACME (control)	-0.1140	-0.1506	-0.08	<0.0000000000000002
## ACME (treated)	-0.1074	-0.1521	-0.07	<0.0000000000000002
## ADE (control)	-0.0198	-0.0681	0.04	0.54
## ADE (treated)	-0.0133	-0.0471	0.03	0.54
## Total Effect	-0.1273	-0.1725	-0.08	<0.0000000000000002
## Prop. Mediated (control)	0.8957	0.6909	1.28	<0.0000000000000002
## Prop. Mediated (treated)	0.8442	0.5589	1.39	<0.0000000000000002
## ACME (average)	-0.1107	-0.1502	-0.08	<0.0000000000000002
## ADE (average)	-0.0165	-0.0577	0.03	0.54
## Prop. Mediated (average)	0.8700	0.6242	1.34	<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: 377
##
##
## Simulations: 1000
```

$p < .001$

Correlation with Mental Effort and Final Study Strategy Decision

```
cor.test(study2$effort_diff, study2$chooseInterleaved, method = "pearson") #-0.31 (p<.001)
```

```
##
## Pearson's product-moment correlation
##
## data: study2$effort_diff and study2$chooseInterleaved
## t = -6.3606, df = 375, p-value = 0.000000005854
## alternative hypothesis: true correlation is not equal to 0
## 95 percent confidence interval:
## -0.4004384 -0.2179247
## sample estimates:
## cor
## -0.3120578
```

Study 2 Familiarity Mediation

a path

```
# a path
med.habit <- lm(learn_diff ~ habits_diff, data = study2)
summary(med.habit)
```

```
##
## Call:
## lm(formula = learn_diff ~ habits_diff, data = study2)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -3.7920 -0.7030 -0.0711  0.6934  3.4879
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept) -0.34068    0.06912  -4.929 0.00000125 ***
## habits_diff  0.35275    0.07650   4.611 0.00000552 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 1.177 on 371 degrees of freedom
## (4 observations deleted due to missingness)
## Multiple R-squared:  0.05421, Adjusted R-squared:  0.05166
## F-statistic: 21.26 on 1 and 371 DF, p-value: 0.000005516
```

```
# habits_diff output = a path (p < .001)
# R2 = 0.05
```

c prime and b path

```
# c' path and b path
med.learn1 <- glm(chooseInterleaved ~ habits_diff + learn_diff, data = study2, family=bi
nomial)
summary(med.learn1)
```



```
##
## Call:
## glm(formula = chooseInterleaved ~ habits_diff + learn_diff, family = binomial,
##      data = study2)
##
## Deviance Residuals:
##      Min       1Q   Median       3Q      Max
## -2.09294  -0.61757  -0.31124  -0.07214   2.53216
##
## Coefficients:
##              Estimate Std. Error z value      Pr(>|z|)
## (Intercept) -1.12247    0.16647  -6.743    0.0000000000155 ***
## habits_diff  0.05867    0.19645   0.299      0.765
## learn_diff   1.57500    0.18940   8.316 < 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: 397.93  on 372  degrees of freedom
## Residual deviance: 274.51  on 370  degrees of freedom
## (4 observations deleted due to missingness)
## AIC: 280.51
##
## Number of Fisher Scoring iterations: 6
```

```
# learn_diff = b path (p < .001)
# partial R2 = 0.42
# c' (direct) = habits_diff (p = 0.77)
# partial R2 = 0.04
```

c path

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

```
##
## Call:
## glm(formula = chooseInterleaved ~ habits_diff, family = binomial,
##      data = study2)
##
## Deviance Residuals:
##      Min       1Q   Median       3Q      Max
## -1.0018  -0.7265  -0.6786  -0.5697   2.0812
##
## Coefficients:
##              Estimate Std. Error z value      Pr(>|z|)
## (Intercept)  -1.1205     0.1349  -8.304 <0.0000000000000002 ***
## habits_diff   0.3078     0.1608   1.914    0.0556 .
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## (Dispersion parameter for binomial family taken to be 1)
##
##      Null deviance: 397.93  on 372  degrees of freedom
## Residual deviance: 394.16  on 371  degrees of freedom
## (4 observations deleted due to missingness)
## AIC: 398.16
##
## Number of Fisher Scoring iterations: 4
```

```
# habits_diff = c path (indirect) (p = 0.06) # marginal significance
# partial R2 = 0.05
```

Mediation for Familiarity/Habits

```
mediation_2 <- mediate(med.habit, med.learn1, sims=1000, boot=TRUE, treat = "habits_diff", 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)	0.07498	0.03743	0.12	<0.0000000000000002
## ACME (treated)	0.07594	0.03761	0.12	<0.0000000000000002
## ADE (control)	0.00747	-0.03498	0.06	0.758
## ADE (treated)	0.00843	-0.04060	0.06	0.758
## Total Effect	0.08341	0.02551	0.16	0.004
## Prop. Mediated (control)	0.89899	0.53204	2.10	0.004
## Prop. Mediated (treated)	0.91039	0.57717	1.98	0.004
## ACME (average)	0.07546	0.03738	0.12	<0.0000000000000002
## ADE (average)	0.00795	-0.03743	0.06	0.758
## Prop. Mediated (average)	0.90469	0.55756	2.03	0.004

```
##
## 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: 373
##
##
## Simulations: 1000
```

Correlation with Familiarity/Habits and Final Study Strategy Decision

```
cor.test(study2$habits_diff, study2$chooseInterleaved, method = "pearson") # .10 (p=.05)
```

```
##
## Pearson's product-moment correlation
##
## data: study2$habits_diff and study2$chooseInterleaved
## t = 1.9287, df = 371, p-value = 0.05453
## alternative hypothesis: true correlation is not equal to 0
## 95 percent confidence interval:
## -0.001925632 0.199163851
## sample estimates:
## cor
## 0.09963635
```