How Does Stimulus Difficulty Affect Study Time Allocation in Younger Adults?

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Introduction

When you have many chances to study information, learning rates are often maximized by focusing on currently unlearned items.[1,2] To do this, people need to monitor their current learning progress and use that information to guide further efforts. For example, when studying for a test, feeling less confident on some topics relative to others may signal a need to allocate more study to less familiar information.

Study time (ST) is defined as the amount of time (in seconds) an individual spends in the pursuit of learning new information. Decisions related to study time allocation reflect a person's learning goals and perceptions of current performance. These perceptions, in turn, can potentially be influenced by multiple sources of information about one's current state of learning, which are called metacognitive cues.[3,4]

Prior research has emphasized the powerful role of one cue, memory for past test (MPT), on subsequent learning behaviors.[5,6] MPT reflects one's remembrance of prior memory success or failure during a test. Newer research supports the roles of other metacognitive cues on ST in addition to that of MPT,[7] such as: (1) assessments of item difficulty made after an initial study opportunity, (2) subjective memory response confidence during the first test, (3) objective response times during the first test, and (4) subjective response time estimates (how fast they think they responded to test questions).

Previous research on ST allocation used stimuli of similar difficulty. The current work used both easy- and difficult-to-learn stimuli to clarify the relative importance of different metacognitive cues on ST decisions. We hypothesized that the relative impact of metacognitive cues on ST would differ such that some cues would be more predictive of study time than others (consistent with prior work) and these relative weights would also differ as a function of stimulus difficulty (novel to the current work).

Method

Participants

Participants were UWEC students (46 women and 20 men; age *M*=19.31 years, *SD*=1.38) who signed up via the SONA online research pool and received course credit or extra credit for their participation.

Procedure

Participants completed two study-test phases. In each phase, they studied 60 word pairs and were then tested on their memory for each pair. We manipulated the difficulty level of the word pairs (easy or hard). All participants were exposed to 60 easy-to-remember (e.g., REASON-THINK) or 60 hard-to-remember (e.g., CLEMENCY-IDIOM) word pairs.

Phase 1: Word Pair Study

- 60 word pairs of unrelated nouns were presented in a randomized order. Study for each word pair was self-terminated.
- After studying each item, participants made a judgment of learning (JOL) on a scale of 0-100% confidence that they would remember a word pair during test.

Phase 1: Recognition Test

- 120 word pairs (60 intact, 60 rearranged) were presented in a randomized order. Intact items were studied word pairs, and rearranged items paired the first word from one pair with the second word from another pair, sampled without replacement.
- Using designated keys on a keyboard, they entered "YES" for a recognized pair and "NO" for an unrecognized pair.
- After each test trial, participants estimated (1) a confidence judgment (CJ) on a scale of 0-100% (i.e., how confident they were in the accuracy of their prior recognition response), and (2) a response time estimate (on a scale of 0-10s, for the prior recognition response).

Phases 2: Study and Test

- The stimuli and procedure were identical to those of Phase 1.

Results

Table 1: Means Values for Measured Objective and Metacognitive Cues by Task Phase and Stimulus Difficulty

Cue	Stimulus Difficulty	Phase 1 *M (SD)*	Phase 2 *M (SD)*
Study Time (ST)**	Easy**	4.18 (0.51)	1.10 (0.51)
	Hard**	7.26 (0.54)	2.63 (0.54)
Judgment of Learning (JOL)**	Easy**	60.09 (3.83)	83.56 (3.83)
	Hard**	27.52 (4.10)	53.08 (4.10)
Test Confidence Judgment (CJ)*	Easy	92.55 (2.80)	95.29 (2.80)
	Hard**	63.95 (2.99)	71.34 (2.99)
Test Accuracy (ACC)*	Easy	94.44 (2.10)	96.63 (2.10)
	Hard**	67.22 (2.24)	76.40 (2.24)
Test Response Time (RT)**	Easy**	1.59 (0.18)	1.16(0.18)
	Hard**	2.85 (0.19)	2.27 (0.19)
Test RT Estimate (EST)**	Easy**	1.35 (0.18)	1.16 (0.18)
	Hard**	2.48 (0.19)	2.27 (0.19)

Note 1. For all variables but CJ and ACC, there were main effects of both Phase and Stimulus Difficulty. *Main effect of Stimulus Difficulty. **Phase x Stimulus Difficulty interaction.
Note 2. JOL, CJ, and ACC computed in percent; ST, RT, EST, and DIFF computed in seconds.

Table 2: Multi-level Regression Predicting Phase 2 Study Time (ST)

Effect	Hard Items Estimate	Hard Items *SE*	Easy Items Estimate	Easy Items *SE*
Intercept	3.21***	0.45	1.49***	0.08
The average ST for Phase 2 was 3.2 seconds for Hard items and 1.5 seconds for Easy items.				
JOL (Between-Ss)	0.03	0.03	-0.02***	5.60
As participant's average Phase 1 JOL increased by 1%, their average Phase 2 ST decreased by 0.02 seconds for Easy items. No relationship was found for Hard items.				
ACC (Between-Ss)	-4.80	3.91	5.36***	1.57
As a person's average Phase 1 memory accuracy increased, their average Phase 2 ST increased for Easy items. No relationship was found for Hard items.				
ACC (Within-Ss)	-0.58	0.51	-0.59***	0.21
Remembering a word pair during Phase 1 test was associated with a .60 second decrease in ST for Easy items. No relationship was found for Hard items.				
CJ (Within-Ss)	-0.01***	0.003	0.0003	0.002
A 1% increase in Phase 1 recognition CJ for an individual word pair was associated with a decrease of 0.01 seconds in Phase 2 ST for Hard items. No relationship was found for Easy items.				
RT (Between-Ss)	0.39	0.58	0.42**	0.15
As a person's average RT increased by 1 second, their average Phase 2 ST increased by 0.4 seconds for Easy items. No relationship was found for Hard items.				
RT (Within-Ss)	0.21***	0.06	0.06**	0.03
A 1 second increase in Phase 1 RT for an individual word pair was associated with increased Phase 2 ST of .06 seconds for Easy items and 0.2 seconds for Hard items.				
EST (Within-Ss)	-0.08	0.09	0.10~	0.06
A trend existed such that, as a person's estimated Phase 1 RT for an individual word pair increased by 1 second, phase 2 ST increased by 0.1 seconds for Easy items. No relationship was found for Hard items.				

Note. *$p < .10$, **$p < .05$, ***$p < .01$.

Discussion

We designed this study to investigate the relative impact of metacognitive cues on Study time as a function of stimulus difficulty. Multilevel regressions revealed that the metacognitive cues we measured related to subsequent study time differently and that their relative weighting also differed between Easy and Hard word pairs.

Analyses of mean differences via MIXED ANOVAs were also fruitful, and effects occurred in expected directions. We found consistent main effects of Task Phase and Stimulus Difficulty. Participants spent less time studying and responded faster during tests in Phase 2 than in Phase 1; reported higher JOLs and CJs in Phase 2 than in Phase 1; and achieved higher test accuracy in Phase 2 than in Phase 1.

Participants spent more time studying hard word pairs and responded slower during recognition testing for hard word pairs than they did for easy word pairs; reported lower JOLs and CJs for hard word pairs than for easy word pairs; achieved lower test accuracy for hard word pairs than for easy word pairs; and estimated longer response time during tests for hard word pairs than for easy word pairs.

This is, to our knowledge, the first study to show not only that participants use multiple metacognitive performance indices to make decisions related to subsequent study time allocation but also that the relative weighting of these cues is flexible depending upon the level of difficulty presented by the to-be-learned material. That said, the relative weighting of metacognitive cues is likely to have been impacted by ceiling effects in memory performance for Easy word pairs (i.e., with very little variability in performance for Easy items relative to hard items, we may have made a bit of an apples-to-oranges comparison with the Hard word pairs, in which participants found more varied learning success).

Future Directions

Our next study will involve a modified version of the current word pair recognition task that makes use of (1) more word pairs of both difficulty levels, and (2) a third level of intermediate difficulty. Based on the current findings, we predict that having more items will reduce potential ceiling effects in memory performance for Easy word pairs, thereby enhancing the variability in our data. Also, including a condition with items of intermediate difficulty will allow us to examine the full range of potential response variation. This will allow for a more careful examination of the roles of metacognitive cues on study time.

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