LEARNING WHAT TO LEARN: THE EFFECTS OF TASK EXPERIENCE ON
STRATEGY SHIFTS IN THE ALLOCATION OF STUDY TIME

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TABLE OF CONTENTS

LIST OF FIGURES.....	iv
LIST OF TABLES.....	v
ACKNOWLEDGMENTS.....	vi
INTRODUCTION.....	1
Overview of Current Experiments.....	4
METHOD - EXPERIMENT 1	7
Participants.....	7
Materials and Procedure.....	7
Results and Discussion.....	10
INTRODUCTION - EXPERIMENT 2.....	17
METHOD.....	19
Participants.....	19
Materials and Procedure.....	19
Results and Discussion.....	20
INTRODUCTION - EXPERIMENT 3.....	26
METHOD.....	30
Participants.....	30
Materials and Procedure.....	30
Results and Discussion.....	33
GENERAL DISCUSSION.....	38
REFERENCES.....	42

LIST OF FIGURES

FIGURES

- 1 Means across individuals' proportion of test relevant items selected for restudy on each trial in Experiment 1. Error bars represent standard error of the mean.
- 2 The proportion of individuals who selected at least 70% (top panel) or 90% (bottom panel) of the test relevant items on a given trial and all subsequent trials in Experiment 1.
- 3 Means across individuals' proportion of test relevant items selected for restudy on each trial in Experiment 2. Error bars represent standard error of the mean.
4. The proportion of individuals who selected at least 70% (top panel) or 90% (bottom panel) of the test relevant items on a given trial and all subsequent trials in Experiment 2.
5. The agenda-based regulation framework embedded in Cowan's (1988) information processing framework. Agenda construction is displayed in the above figure. This figure was adapted from Dunlosky, Ariel, and Thiede (2011).

LIST OF TABLES

TABLES

- 1 Means across individuals proportion of correct recall.
- 2 Partial correlations between individual difference measures and the proportion of test-relevant items selected for restudy on each trial controlling for baseline proportion of test-relevant items selected on trial 1 in Experiment 3
- 3 Correlations between individual difference measures and whether participants shifted to the appropriate allocation strategy by trial 4 using a lenient (70% selection rate on each trial) and a strict criterion (90% selection rate on each trial).

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INTRODUCTION

The value associated with learning information determines the utility of committing it to memory (Castel, 2008). For students, the value of an item is often related to whether or not learning it will increase the likelihood they perform well academically. To illustrate this point, consider two items that have a different probability of appearing on an upcoming test. For one of these items, there is a high probability (e.g. 90%) that the student will be tested on this item and for the other item there is a low probability (e.g. 30%). The question is, which item is this student more likely to study? Students in this situation typically prefer to select for study the item with a 90% probability of being tested, because they are less likely to be rewarded for learning the item with the lower probability of appearing on the test (Ariel, Dunlosky, & Bailey, 2009). According to the agenda-based regulation (ABR) framework of study time allocation, the students described above are constructing an agenda – or simple plan – to prioritize high reward items for study and using this agenda when making study decisions (Ariel et al., 2009; Dunlosky & Ariel, 2011). The ABR framework assumes that learners construct agendas in response to environmental conditions to achieve their learning goals efficiently. Learners then use this agenda to regulate their study by comparing potential study items to the criteria outlined by the agenda. If an item meets these criteria, learners are expected to select it for study and if it does not, they should opt not to study it.

In the example just described and research examining the influence of item value on memory, the value of each item is always explicitly labeled during study (e.g., Ariel, Dunlosky, & Bailey, 2009; Bijleveld, Custers, & Aarts, 2009; Castel, 2008; Castel, Balota, & McCabe, 2009; Castel, Benjamin, Craik, & Watkins, 2002; Castel, Farb, & Craik, 2007; Dunlosky & Thiede, 1998; Kahneman & Pevler, 1969; Soderstrom & McCabe, 2011). That is, each item is marked with a specific numerical value that indicates the reward associated with later recalling it. Unfortunately for learners, items are not typically presented with labels that identify how valuable they are to learn for an upcoming exam. Which raises the question, how do learners identify which items are valuable for them to study? The current experiments provide one answer to this question. Before describing these experiments in more detail, I first briefly review previous research on the allocation of study time.

Previous research has emphasized that learners' monitoring of their memory for to-be-learned material drives their study allocation decisions (Metcalf & Finn, 2008; Koriat, Ma'ayan, & Nussinson, 2006; Nelson & Leonesio, 1988; Thiede, Anderson, & Theriault, 2003; Thiede & Dunlosky, 1999). Given this emphasis on monitoring, research on the allocation of study-time has focused extensively on the role that item difficulty plays in learners' study decisions. Over four decades of research and roughly 70 published articles examining the influence of item difficulty on study-time allocation have revealed that learners typically allocate more time to studying normatively more difficult material than to easier material (for reviews and exceptions to this modal outcome, see Dunlosky & Ariel, 2011; Son & Metcalfe, 2000).

Despite the central role monitoring plays in the regulation of study (Metcalf & Finn, 2008; Koriat, Ma'ayan, & Nussinson, 2006; Nelson & Leonesio, 1988; Thiede, Anderson, & Theriault, 2003), monitoring is not the only factor that influences learners' study decisions (for reviews, see Greene & Azevedo, 2007; Winne & Hadwin, 1998). The reward associated with learning items (Ariel, Dunlosky, & Bailey, 2009, Dunlosky & Thiede, 1998; Soderstrom & McCabe, 2011), a learner's interest in the to-be learned material (Son & Metcalfe, 2000), their intrinsic motivation (Pintrich, 2000; Pintrich & De Groot, 1990), and even reading habits can influence how learners allocate their study-time (Ariel, Al-Harty, Was, & Dunlosky, 2011; Dunlosky & Ariel, 2011).

To illustrate the influence of item reward on learners' study decisions, which is the focus of the present research, consider findings from Ariel, Dunlosky, and Bailey (2009). They examined whether study decisions are influenced more by the reward value of an item or the normative difficulty of learning it. Participants studied 30 paired associates of varying difficulty (easy or difficult) that were slated with either a low or a high point value (1 point or 5 points), and they were allowed to select half the items for restudy. Participants selected a higher proportion of 5 point items than 1 point items for restudy regardless of how difficult items were to learn, which suggests that learners prioritize the items for study that they will receive the highest reward for learning regardless of their normative difficulty. These findings are consistent with other research on the influence of item value on memory, which typically indicate that people allocate more cognitive resources to learning high valued items than lower valued items (Ariel, Dunlosky, & Bailey, 2009; Bijleveld, Custers, & Aarts, 2009; Castel, 2008; Castel,

Balota, & McCabe, 2009; Castel, Benjamin, Craik, & Watkins; 2002; Castel, Farb, & Craik, 2007; Kahneman & Pevler, 1969; Soderstrom & McCabe, 2011).

In the current experiments, research examining the influence of item value on agenda-based regulation was extended to a task where item value was not explicitly labeled. Learners may assign value to items in a number of ways. They can explicitly ask what items will appear on an upcoming text, or they can potentially learn from experience what types of items are likely to be tested. The present experiments investigated this later possibility by examining whether learners' study decisions are sensitive to statistical regularities in the testing environment that signal which items are valuable for them to learn. The main question was, can participants learn from task experience which items are important to study for a future test and apply this knowledge to guide their future study?

Overview of Current Experiments

The general design for the current experiments involved multiple study-test trials in which participants studied English-English and Swahili-English paired associates and were tested consistently on only one type of item across trials (i.e. only English-English or only Swahili-English pairs). On each trial, participants (a) studied paired associates, (b) made ease-of-learning (EOL) judgments, (c) selected items for restudy, and (d) then were tested. During the key restudy phase of the experiment, participants were allowed to select half the items for restudy from a 10 x 2 array. After restudy, participants were tested on half the items. Some participants were only tested on English-English word pairs on each trial and others were only tested on Swahili-English translations. The

procedure above repeated for 4 trials, with new items on each trial. During the task, some participants were told (cued groups) which items they would always be tested on (cued groups) and other participants had to learn from task experience which items were important to study (no cue groups). The purpose of this manipulation was to evaluate the influence of having knowledge about which items are valuable to study on study decisions without having to gain it from task experience.

In this task, the testing phase of each trial is the only source of information about item value for participants in the no cue groups. Note that during initial study trials, participants lack knowledge about which items are important to study to perform well during the testing phases. Thus, participants may allocate their study-time ineffectively to items that they will not be rewarded for learning. However, as participants gain task experience, they can potentially learn which items are important to study to maximize performance. The primary question is, will participants realize that their allocation strategies are ineffective during initial study trials and as a result adapt their allocation strategies on subsequent trials?

In the current experiments, the highest valued items are the test relevant items on each trial. In fact, all other items functionally have no value because remembering them will not contribute to performance. Thus, participants should engage in agenda construction, if they identify the reward structure of the learning task, so that they could prioritize the highest valued items for study (i.e., the test relevant items). In addition to identifying the reward structure of the task, they also have to realize that their allocation strategy on a previous trial was ineffective. Research on knowledge updating about

strategy effectiveness suggests that learners are capable of making this realization (Brigham & Pressley, 1988; Dunlosky & Hertzog, 2000). However, this research has focused primarily on knowledge updating about encoding strategies and not study-time allocation strategies per se. The research that has focused on study-time allocation has examined only self-paced study (e.g. Tauber & Rhodes, 2010, Experiment 4) and not whether people update their knowledge about which items are valuable to select for study. Thus, it is an open question if participants develop this knowledge from task experience alone. Most important, if they fail to do either of the above (i.e., indentify the reward structure of the task and realize that their previous allocation strategies are ineffective for achieving high levels of performance), they will dysregulate their study by allocating time to items that they do not need to learn.

METHOD - EXPERIMENT 1

Participants

One hundred and seventeen participants from Kent State University participated in this experiment for course credit in Introductory Psychology. A 2 (Test item type: English vs. Swahili) x 2 (cue: cued vs. no cue) x 4 (trial: 1, 2, 3, or 4) design was used. Participants were randomly assigned to either the English-Cued group ($n = 42$), English-No cue group ($n = 44$), Swahili-Cued group ($n = 47$), or the Swahili- No cue group ($n = 43$). The cue refers to whether participants were told which items they would be tested on (cued groups) or were not told which items would appear on the test (no cue groups).

Materials and Procedure

Eighty paired associates were used. Half the paired associates were English-English pairs (e.g., Builder – Quest) and half were Swahili-English pairs (e.g., Rakiki – Friend) taken from Nelson and Dunlosky (1994). The experiment consisted of four trials. Trials consisted of an initial study phase, followed by a distracter task, followed by a restudy phase, and finally a test phase. Participants were instructed that the goal of the task was to learn word pairs and they would receive 5 points for every word pair they recalled on the final test. They were instructed to try to earn as many points as possible on each test. During the initial study phase, ten English-English and ten Swahili-English pairs were presented individually on a computer screen in a random order for 2 seconds each. Immediately after studying a pair, participants were prompted to give an ease of

learning (EOL) judgment. They were asked, “How difficult do you feel it would be to learn the pair you just studied at a later time? 1 (very easy), 2, 3, 4, 5, or 6 (very difficult).” After this initial study phase, participants completed a two minute distracter task in which they read texts and answered multiple-choice questions.

After the distracter task, participants were instructed that they could select 10 of the 20 items for restudy and that the items they selected would be presented for 3 seconds each. At this point, participants in the cued groups were instructed that they would only be tested on the word pairs that begin with an English word (English-Cued group) or they would only be tested on word pairs that begin with a Swahili word (Swahili-Cued group). Participants in the no cue groups were not told which type of item would be tested, but they were told they would be allowed to study 10 of the 20 items. Next, participants selected 10 items for restudy from a 10 x 2 array. The position items were presented in the array was randomized. Only the cue word of each pair was presented in the array followed by a question mark (e.g., Rafiki - ?). Participants could select items for restudy by pressing a button positioned to the left of each cue word. If participants selected an item, it was immediately presented for study and remained on the computer screen for 3 seconds.

After selecting and restudying the 10 items, participants were tested on 10 of the items. During this testing phase, the cue word of a pair was presented, and participants were prompted to type the target word. Most important, participants were tested on one type of item consistently across trials. The English-No cue and English-Cued groups were tested on only English-English pairs, and the Swahili-No cue and Swahili-Cued

group were tested on only Swahili-English pairs. Following testing, participants were told how many items out of ten they answered correctly and how many points they earned on that trial. They were encouraged to increase the number of points they earned on the next trial and to try to earn the maximum number of points each trial (50 points). Participants then proceeded to the next trial in which the procedure above was repeated with new pairs.

RESULTS AND DISCUSSION

Item Selection

All effects declared as significant had $p < .05$. The proportion of test relevant items selected for restudy was computed for each group across trials. The test relevant items consisted of English-English pairs for the English-no cue and English-cued groups, and they consisted of Swahili-English pairs for the Swahili-no cue and Swahili-Cued group. Given that participants are only tested on these items across trials, these items are the only items that are valuable for learning. When computing the proportion of the test relevant items selected, the total number of test relevant items were adjusted to account for learners failing to select an item for study that they believed they already knew. Learners typically do not study items that they believe they can already recall (Kornell & Bjork, 2008; Metcalfe & Kornell, 2005), and hence, failing to account for these items will underestimate the degree to which learners are using a value-based agenda to allocate their study. Accordingly, the total number of test relevant items available for study was adjusted for each participant by subtracting the number of items that they recalled but did not select for study. The adjusted total value was used to compute proportions for each participant.

The mean proportions of test relevant items selected across trials for each group are presented in Figure 1. A 2 (Test item type: English vs. Swahili) x 2 (cue: cued vs. no cue) x 4 (trial) ANOVA revealed the cued groups selected a higher proportion of test

relevant items for study than the no cue groups, $F(1,172) = 26.67$, $MSE = 4.37$, $\eta_p^2 = .15$, and participants selected more test relevant English items for study than test relevant Swahili items, $F(1,172) = 4.52$, $MSE = .67$, $\eta_p^2 = .03$. An effect for trial was also significant, $F(3,170) = 5.38$, $MSE = .22$, $\eta_p^2 = .09$. The Cue x Trial interaction was not significant, $F(3,170) = 1.30$, $MSE = .04$, $p = .28$, $\eta_p^2 = .02$, the Test item type x Cue interaction, $F(1,172) = .41$, $MSE = .06$, $p = .52$, $\eta_p^2 = .002$, the Test item type x Trial interaction, $F(3,170) = 2.18$, $MSE = .06$, $p = .09$, $\eta_p^2 = .04$, and the three-way interaction were also not significant, $F(3,170) = .22$, $MSE = .01$, $p = .88$, $\eta_p^2 = .004$.

Figure 1. Means across individuals' proportion of test relevant items selected for restudy on each trial in Experiment 1. Error bars represent standard error of the mean.

Planned comparisons were conducted using t-tests to examine whether participants increased the number of test relevant items they selected across trials in each group. Participants in the English-No cue group selected more test relevant items for

study on trial 4 than on trial 1 and 2. They also selected more test relevant items on trial 3 and 2 (which did not differ) than they did on trial 1, $ts > 2.20$. The Swahili-No cued group selected more items on trials 3 and 4 than on trials 1 and 2, $ts > 1.79$. The proportion of test relevant items selected did not differ across trials for the English-Cued group and the Swahili-Cued group.

Overall these results indicate that participants in no cued groups were able to learn from task experience which items were important to study. As a consequence, they selected a higher proportion of test relevant items on the final trial than on the first trial. Nevertheless, the proportion of test relevant items selected for study by the no cued groups was lower than the cued groups even after multiple trials of experience with the task. These results suggest that many participants failed to learn the reward structure of the task when they were not explicitly instructed which items were valuable to learn for the upcoming test.

Individual Differences in Strategy Shifts

To evaluate potential differences between individuals in acquiring and using knowledge about the reward structure of the task to allocate their study time, the proportion of individuals who consistently selected test relevant items for study on a given trial and all subsequent trials was computed in two ways: One using a lenient criterion in which participants were required to consistently select at least 70% of the test relevant items on a given trial and all subsequent trials and another using a more strict 90% criterion. These data are presented as stacked bar graphs in Figure 2. The black bars in Figure 2 represent the proportion of participants in each group who consistently

selected at least the specified criterion level (70% for the top panel and 90% for the bottom panel) of the test relevant items for restudy on trial 1 and on all subsequent trials. The dark grey bars represent the proportion of individuals who began selecting test relevant items at the specified criterion level on trial 2 and continued selecting at least this criterion level on trials 3 and 4. The light grey bars represent the proportion of individuals who began selecting test relevant items on trial 3 and continued selecting them on trial 4. Finally, the last group of bars (white) represents the proportion of participants who began consistently selecting test relevant items on trial 4. Thus, the height of each bar represents the proportion of participants in each group who shifted towards the appropriate allocation strategy during the task. Inspection of Figure 2 indicates that by trial 4 less than half of the participants in the no cued groups were consistently selecting test relevant items for study. Thus, the majority of participants failed to allocate their study consistently to the most valuable items.

Consistent with these observations, logistical regression analyses examining whether cue and test item type predict the individuals who were consistently selecting the test relevant items by trial 4, indicated that only the cue significantly predicted learners who shifted their allocation to the test relevant items regardless of whether a lenient or strict criterion was used, (Lenient criterion: $B = -.88$, odds ratio = .42; strict criterion: $B = -1.14$, odds ratio = .32). The model fits for these logistical regression were significant for both the lenient criterion, $\chi^2 = (2, N = 176) = 10.29$, and the strict criterion: $\chi^2 = (2, N = 176) = 10.96$. When a lenient criterion was used, the model correctly classified 61% of participants (60% who failed to shift strategies and 61% who shifted to a value-based

agenda) and the model that used a strict criterion correctly classified 77% of participants. However, this later model was extremely poor at predicting participants who consistently shifted towards the appropriate allocation strategy. The model failed to correctly identify a single participant who shifted towards a value-based agenda. Overall, these results indicate that when learners were not explicitly instructed which items were important to study, the majority of participants failed to (a) learn the reward structure of the task or (b) consistently apply this knowledge when allocating their study time. One potential reason for this outcome is that participants were not motivated to seek out strategies to perform well on the task. This hypothesis was evaluated in Experiment 2.

Figure 2. The proportion of individuals who selected at least 70% (top panel) or 90% (bottom panel) of the test relevant items on a given trial and all subsequent trials in Experiment 1.

Recall

Means across individuals' proportion of correct recall on each trial is presented in Table 1. A 2 (test item type) x 2 (cue) x 4 (trial) ANOVA revealed that participants recalled more English items than Swahili items, $F(1,172) = 8.99$, $MSE = 1.70$, $\eta_p^2 = .05$, and participants recalled more items in the cued groups than they did in the no cue groups, $F(1,172) = 6.15$, $MSE = 1.16$, $\eta_p^2 = .04$. This effect for cue occurred because participants in the cued groups were more likely to select the test relevant items for study, and hence, their performance benefited from studying items that were valuable for learning for the upcoming exam. An effect for trial was also significant, $F(3,170) = 9.60$, $MSE = .18$, $\eta_p^2 = .15$. Recall was greater on trial 3 than either trial 1, 2, or 4, $ts > 3.31$.

Relationship between Item Selection and Recall

The relationship between restudy decisions and recall was examined by computing gamma correlations for each participant. Study decisions were significantly correlated with recall on each trial (Trial 1: $M = .61$, $SE = .05$; Trial 2: $M = .61$, $SE = .05$; Trial 3: $M = .63$, $SE = .05$; Trial 4: $M = .61$, $SE = .05$), $ts > 12.57$. These data suggest that participants recall benefited from selecting test relevant items for study.

Table 1. Means across individuals proportion of correct recall.

JOL Group	Trial 1	Trial 2	Trial 3	Trial 4
Experiment 1				
English – No Cue	.36 (.03)	.39 (.04)	.45 (.04)	.37 (.04)
English – Cued	.43 (.04)	.46 (.04)	.47 (.05)	.44 (.05)
Swahili – No Cue	.28 (.03)	.33 (.04)	.33 (.04)	.22 (.03)
Swahili – Cued	.38 (.03)	.35 (.04)	.42 (.04)	.36 (.04)
Experiment 2				
No Cue – No Incentive	.31 (.03)	.24 (.03)	.36 (.04)	.24 (.04)
No Cue – Incentive	.27 (.03)	.25 (.03)	.37 (.04)	.30 (.04)
Cued – No Incentive	.40 (.04)	.37 (.04)	.46 (.04)	.35 (.04)
Cued – Incentive	.36 (.04)	.41 (.04)	.46 (.04)	.42 (.05)
Experiment 3				
No Cue – Incentive	.31 (.02)	.28 (.02)	.44 (.03)	.34 (.03)

Note: Values are means across individual mean values. Standard error of the means are in parenthesis.

INTRODUCTION - EXPERIMENT 2

In Experiment 1, some participants were able to learn from task experience which items were valuable to study. However, analyses at the individual level (Figure 2) revealed that only a small proportion of participants were able to do so. In fact, less than 50% of participants in each of the no cued groups consistently selected test relevant items for study by the end of the experiment. Thus, the majority of participants in the no cued groups dysregulated their study by allocating their time to items that were not valuable for performance. In contrast, approximately 60% of participants in each of the cued groups consistently allocated their study to the test relevant items by trial 4.

Why did the over half of the participants in the no cued groups fail to identify the items that were valuable for them to study? One possibility is that they were not motivated to search for strategies to achieve high levels of performance, because there was no incentive to perform well on each trial. Motivation is an important aspect of self-regulated learning (Bandura & Schunk, 1981; Pintrich, 1999; Pintrich & Groot, 1990; Pintrich & Shrunken, 1996; McCombs & Marzano, 1990; Wolters, 1998; Zimmerman, 1989; Zimmerman, 1990) and it influences task engagement and the strategies learners use to meet their goals (Pintrich & Groot, 1990). Thus, if learners were not motivated to perform well in Experiment 1, they likely would not attempt to search for strategies to maximize performance.

In Experiment 2, an incentive manipulation was used to motivate participants to earn as many points as possible during the experiment. The design was similar to Experiment 1, with the exception that some participants were instructed that the experiment would continue until they earned 200 total points across trials. The purpose of this manipulation was to motivate participants to behave efficiently. The rationale was that most participants are motivated to complete laboratory experiments quickly, and hence, they would be more likely to search for strategies during the restudy phase that would maximize performance and allow them to quickly finish the task.

METHOD

Participants

Two hundred and nine participants from Kent State University participated in this experiment for course credit in Introductory Psychology. A 2 (cue: cued vs. no cue) x 2 (incentive: incentive vs. no incentive) design was used. Participants were randomly assigned to either the Cued-Incentive group ($n = 52$), Cued-No incentive group ($n = 52$), No cue-Incentive group ($n = 51$), or the No cue-No incentive group ($n = 54$).

Materials and Procedures

The materials and procedures used in Experiment 2 were identical to Experiment 1 with the following two exceptions. First, all participants were only tested on Swahili items during the recall phases of each trial. As in Experiment 1, some people were instructed that they would only be tested on the Swahili items (cued groups) and other participants had to learn from task experience (no cue groups). Second, some participants were given an incentive to earn points in the experiment. Participants in the incentive groups were instructed that they could not leave the experiment until they earned 200 total points across trials. Participants were instructed that they would receive 5 points for every item they recalled correctly and they were given feedback at the end of each trial regarding how many points they earned on that trial and how many total points they earned across trials. Despite these instructions the experiment only continued for 4 trials total for all groups (as in Experiment 1).

RESULTS AND DISCUSSION

Item Selection

The proportion of test relevant items selected for study on each trial is presented in Figure 3. A 2 (cue: cued vs. no cue) x 2 (incentive vs. no incentive) x 4 (trial) ANOVA revealed no effect for incentive, $F(1,205) = .41$, $MSE = .09$, $p = .53$, $\eta_p^2 = .002$. However, an effect for Cue group was significant, $F(1,205) = 29.55$, $MSE = 6.50$, $\eta_p^2 = .13$, which occurred because the cue groups selected more test relevant items for study than the no cue groups. An effect for trial was also significant, $F(3,203) = 17.57$, $MSE = 1.09$, $\eta_p^2 = .21$. The Cue x Trial interaction, $F(3,203) = 2.34$, $MSE = .11$, $p = .08$, $\eta_p^2 = .03$, the Cue x Incentive interaction, $F(3,205) = .53$, $MSE = .12$, $p = .47$, $\eta_p^2 = .003$, and the three-way interaction were all not significant, $F(3,203) = .12$, $MSE = .01$, $p = .95$, $\eta_p^2 = .002$. However, an Incentive x Trial interaction was significant, $F(3,203) = .3.44$, $MSE = .22$, $p = .02$, $\eta_p^2 = .05$.

Post hoc analyses examining whether participants in each group increased the number of test relevant items selected for study across trials revealed participants in the cued-incentive group, cued-no incentive, and no cue- no incentive groups selected more test relevant items for study on trial 4 and trial 3 (which did not differ) than they did on trial 1 and trial 2 (which also did not differ) regardless of incentive, $ts > 1.97$. The cued-no incentive group selected more test relevant items for study on trial 4 than on trial 2, $t(51) = 2.49$, but this group did not differ in the number of test relevant items selected for

study on any other trial. These results suggest that participants can learn from task experience which items are important to study and subsequently adapt their study decisions on the next trial. However, once again participants in the no cued groups selected a lower proportion of test relevant items on the final trial than did the cued groups, $ts > 5.00$, which suggests that despite task experience, many participants are failing to learn the reward structure of the task when they are not explicitly told which items they are going to be tested on. Surprisingly, even giving participants an incentive to perform the task efficiently did not increase the proportion of test-relevant items they selected for study, which suggests that lack of motivation is not responsible for failures to select the most relevant items for study.

Figure 3. Means across individuals' proportion of test relevant items selected for restudy on each trial in Experiment 2. Error bars represent standard error of the mean.

Individual Differences in Strategy Shifts

To evaluate individual differences in learning the reward structure of the task and applying this knowledge to allocate study only to the test relevant items (i.e. developing a value-based agenda), the proportion of individuals who selected at least 70% and 90% of the test relevant items for study on a given trial and all subsequent trials was again computed. These data are presented in Figure 4. Inspection of Figure 4 reveals that less than 40% of individuals under a lenient criterion (top panel of Figure 4) and less than 30% using a strict criterion (bottom panel of Figure 4) consistently selected test relevant items for study across trials when they were not cued about which items they would be tested on and not given an incentive to earn points (no cue-no incentive group, first bar in Figure 4). When these participants were given an incentive (no cue-incentive group, second bar), approximately 45% of individuals under a lenient criterion and 38% under a strict criterion consistently selected the test relevant items for study. When participants were told which items they would be tested on regardless of incentive (cued groups, final two sets of bars), nearly 70% of individuals under a lenient criterion and 60% under a strict criterion in each group consistently selected the test relevant items for study.

Logistical regression models were computed to examine whether cue and incentive predict which participants shift towards the appropriate allocation strategy during the task. The regression models were significant for both the lenient criterion, $\chi^2 = (3, N = 209) = 15.40$, and strict criterion, $\chi^2 = (3, N = 209) = 19.88$. However, only cue significantly predicted strategy shifts in the experiment, (Lenient: $B = -1.05$, odds ratio = .35; Strict: $B = -1.22$, odds ratio = .30). Overall both models correctly identified ~ 64%

of participants who consistently selected test relevant items for study and ~ 64% of participants who consistently dysregulated their study by selecting items other than the test relevant items on each trial.

Figure 4. The proportion of individuals who selected at least 70% (top panel) or 90% (bottom panel) of the test relevant items on a given trial and all subsequent trials in Experiment 2.

Recall

The proportion of items recalled across trials for each group is presented in Table 1. A 2 (Cue) x 2 (incentive) x 4 (trial) ANOVA revealed participants recalled more items in the cued group than in the no cue group, $F(1,205)= 12.08$, $MSE = 2.54$, $\eta_p^2 = .06$. An effect for trial was also significant, $F(3,203)= 18.64$, $MSE = .42$, $\eta_p^2 = .22$. This effect

was qualified by a Trial x Incentive interaction, $F(3,203)= 3.14$, $MSE = .10$, $\eta_p^2 = .04$.

This interaction occurred because the incentive group recalled more items on trial 1 than they did on trials 2 or 4, $ts > 2.30$. Participants in the incentive and no incentive groups both recalled more items on trial 3 than on any other trial, $ts > 2.57$.

Relationship between Item Selection and Recall

The relationship between restudy decisions and recall was examined by computing gamma correlations for each participant. Study decisions were significantly correlated with recall on each trial (Trial 1: $M = .49$, $SE = .05$; Trial 2: $M = .74$, $SE = .04$; Trial 3: $M = .65$, $SE = .04$; Trial 4: $M = .72$, $SE = .04$), $ts > 9.62$. The magnitude of this correlation was higher on trials 4, 3 and 2 than on trial 1, $ts > 2.13$. These findings suggest that participants recall benefited from selecting test relevant items for study.

Overall, these results indicate that some learners can learn the reward structure of the study task, and as a result, they make study decisions that are beneficial for performance. However, many participants failed to do so when they were not explicitly told which items they would be tested on, and hence, they dysregulated their study by selecting items for study that were not valuable for performance. Thus, there appear to be individual differences in learners' study allocation strategies in tasks where the reward structure is not obvious. A variety of characteristics of learners could potentially account for the individual differences observed in the current experiments. For example, individual differences in working memory span, need for cognition, and fluid intelligence could potentially moderate learners ability to learn the reward structure of the study task and apply this knowledge to construct and execute a value-based agenda. The potential

influence of these individual difference factors on agenda-based regulation were evaluated in Experiment 3.

INTRODUCTION - EXPERIMENT 3

The ABR framework places study-time allocation in the context of Cowan's (1995; 1988) information processing model (Dunlosky & Ariel, 2011). Cowan's model describes the flow of externally-derived (information encoded from the environment) and internally-derived (representations activated by the central executive to achieve a goal) information through a limited capacity processing system. Agenda construction is illustrated in Cowan's model in Figure 5. During agenda construction, learners must attend to goal-relevant information in their environment (e.g., item reward and other task constraints). According to Cowan's model, this information first enters the information processing system through a sensory store. If sufficient attention is allocated to this information, representations in a long-term storage are activated in a short-term storage system. The central executive can then select a subset of this information to place in the focus of attention. The focus of attention is limited in capacity, and hence, people can only keep a limited amount of information activated in the focus of attention at any time. Moreover, individual differences occur in the size of the focus of attention, with some individuals being able to keep more information in the focus of attention than other individuals (Cowan, 2001).

Consider the constraints that capacity limitations of the focus of attention place on agenda-based regulation in the current task. Assuming learners identify the reward structure of the study task on a given trial, they then must maintain this information in the

focus of attention while they construct an agenda that specifies which items they should select for study. During agenda construction, learners' attention can be captured by goal-irrelevant information from the environment or internally generated goal-irrelevant thoughts (c.f., mind wandering, McVay & Kane, 2009; Smallwood & Schooler, 2006). When goal-irrelevant information captures learners' attention and exceeds the capacity of the focus of attention, this information can replace the goal-relevant information in the focus of attention. Learners must then inhibit this goal-irrelevant information and bring the goal-relevant information back into the focus of attention. If learners do not reactivate this goal-relevant information, they will fail to apply knowledge about the reward structure of the task to construct an agenda. If learners do successfully construct an agenda in face of these distractions, the central executive must then maintain this agenda in the focus of attention while executing it. In summary, capacity limitations may constrain agenda construction and execution, which could lead to dysregulation.

Other characteristics of learners besides memory capacity may also influence agenda construction and execution. Agenda-based regulation can be cognitively demanding (Dunlosky & Thiede, 2004; Thiede & Dunlosky, 1999) and people in general tend to be cognitive misers (Fisk & Taylor, 1984). Thus, participants' motivation or willingness to engage in cognitively demanding tasks may also influence agenda-based regulation. Cacioppo and Petty (1982) refer to this construct as need for cognition. People high in need for cognition enjoy and seek out cognitively demanding tasks, where as people low in need for cognition find cognitively demanding tasks aversive and hence they avoid them. In the current experiments, individual differences in need for cognition

could contribute to learners' willingness to engage in agenda construction (Ariel et al., 2009; Dunlosky & Ariel, 2011).

Figure 5. The agenda-based regulation framework embedded in Cowan's (1988) information processing framework. Agenda construction is displayed in the above figure. This figure was adapted from Dunlosky, Ariel, and Thiede (2011).

A final individual difference characteristic considered here that may affect learners' study allocation strategies is their fluid intelligence. Fluid intelligence reflects people's analytical reasoning and problem solving abilities (Carpenter, Just, Sell, 1990; Snow, Kyllonen, & Marshalek, 1984). General fluid intelligence is related to metacognitive abilities such as reflecting on cognitive strategies, monitoring task performance, and engaging in forward planning (Gray, Chabris, & Braver, 2003; Sternberg, 1985), and hence fluid intelligence may contribute to agenda-based regulation

in a number of ways. For instance, in the current task, participants with lower fluid intelligence may have failed to either reflect on the effectiveness of their allocation strategies during early study trials or may have failed to consider alternative strategies to achieve the task goals. As a result, these participants may have persisted in using an ineffective allocation strategy across trials. Another possibility is that participants with lower fluid intelligence were able to identify that their allocation strategies were ineffective, but poor analytical reasoning skills contributed to selection of ineffective alternative strategies.

To evaluate the potential role of capacity limitations, need for cognition, and fluid intelligence on agenda-based regulation, participants completed the same item selection task as the no cue-incentive group from Experiment 2. Two days later, participants completed 3 additional tasks to assess their fluid intelligence, need for cognition, and working memory span. They completed a computerized version of the Raven's Progressive Matrices task to measure their fluid intelligence (Raven, Raven, & Court, 1998) the need for cognition scale to assess their need for cognition (Cacioppo & Petty, 1988), and an RSPAN task to measure their working memory span (Bailey, in press; Kane et al., 2004).

METHOD

Participants

One hundred and four participants from Kent State University participated in this study for course credit in introductory psychology.

Materials and Procedures

The same materials used in Experiment 1 and 2 were used in Experiment 3. The experiment consisted of two sessions. During the first session participants completed the item selection task administered in previous experiments. The procedure for this task was identical to the procedure for the No cue-Incentive group from Experiment 2. After completing the first session, participants returned 2 days later at the same time they completed session 1 to complete the individual difference tasks. Participants first completed a computerized version of Raven's progressive matrices followed by the need for cognition scale (Cacioppo, Petty, & Kao, 1984). After completing the need for cognition scale participants completed a computerized version of the Reading Span task (RSPAN). The procedure for Raven's progressive matrices, need for cognition scale, and RSPAN task are described in more detail below.

Raven's Progressive Matrices.

A computerized version of Raven's progressive matrices (Raven, Raven, & Court, 1998) was administered to assess non verbal fluid intelligence. The task consisted of 18 trials ordered ascending in their normative difficulty. The trials used were adapted from

Stanovich and Cunningham (1993). One each trial, a display of 3 x 3 array was presented consisting of 8 geometric figures with a missing 9th figure presented in the bottom right-hand position of the array. Participants could choose from 8 potential figures positioned below the 3 x 3 array to complete the pattern. Participants had 12 minutes to complete this task. After 12 minutes expired or participants completed all 18 trials, the need for cognition scale was administered. Performance on Raven's progressive matrices was computed by scoring the proportion of correctly answered items.

Need for Cognition Scale

Need for cognition was measured using the 18 item need for cognition scale (Cacioppo, Petty, & Kao, 1984). The scale measures a person's willingness to engage in effortful cognitive tasks. Participants responded to statements like "I prefer complex to simple problems" and indicated whether the statement was characteristic of them. Participants responded using a 5 point likert scale where 1 indicates that the statement is extremely uncharacteristic of me and 5 indicates that it is extremely characteristic of me. To score the need for cognition scale, items 3, 4, 5, 7, 8, 9, 12, 16, and 17 are reverse scored. Responses to all 18 questions are then summed and low scores indicate the person is low in need for cognition and high scores indicate the person is high in need for cognition. After completing the need for cognition scale, participants completed the RSPAN task to assess their working memory span.

RSPAN Task

A computer-paced version of the RSPAN task (Bailey, in press) modified from Kane et al. (2004) was used in this experiment. In this task, participants were first shown

either a logical or nonsensical sentence and then an unrelated letter. Participants read the sentence (e.g., “Paul used the shovel to dig the hole.”), decided whether or not it made sense, and then studied the letter (e.g., “S”). After the letter was presented, the next sentence-letter dyad appeared on-screen (e.g., “Karen spent the afternoon baking desks.” Followed by a “D”). Participants had 4 seconds to read the sentence and 1 second to study each letter. After the final letter on each trial, a recall cue prompted participants to type the target letters in serial order. The RSPAN task consisted of 15 trials that range from three to seven sentence-letter dyads presented in random order. Performance was computed using partial-credit unit scoring in which the mean proportion of correctly-recalled letters were aggregated over all trials regardless of set size (for rationale, see Conway et al., 2005).

RESULTS AND DISCUSSION

Item Selection

The proportion of test relevant items selected for study on each trial was computed for each participant. Consistent with findings from previous experiments, the proportion of test relevant items selected for study increased across trials (Trial 1: $M = .55$, $SE = .03$; Trial 2: $M = .57$, $SE = .03$; Trial 3: $M = .69$, $SE = .02$; Trial 4: $M = .69$, $SE = .03$). In particular, participants selected more test relevant items for study on trials 3 and 4 than on trials 1 and 2, $t_s > 3.76$.

To parallel analyses from previous experiments, the proportion of individual who selected at least 70% and 90% of the test relevant items on a given trial and all subsequent trials was computed. When a lenient criterion was used for these analyses, roughly 43% of participants consistently selected test relevant items for study across trials (Trial 1: $M = .15$, $SE = .04$, Trial 2: $M = .12$, $SE = .03$, Trial 3: $M = .07$, $SE = .03$, Trial 4: $M = .09$, $SE = .03$). However, when a more strict criterion was used, only 23% of participants consistently studied the most valuable items (Trial 1: $M = .03$, $SE = .02$, Trial 2: $M = .08$, $SE = .03$, Trial 3: $M = .05$, $SE = .02$, Trial 4: $M = .07$, $SE = .03$). Thus, consistent with findings from Experiment 1 and 2, a large proportion of participants failed to either learn the reward structure of the study task or apply this knowledge to construct and execute an agenda.

Individual Differences in Agenda-based Regulation

Most important for evaluating whether individual differences in fluid intelligence, need for cognition, and working memory influence agenda-based regulation, participants' scores on the Raven's progressive matrices task, Need for Cognition scale, and RSPAN task were compared to the proportion of test relevant items selected for study on each trial. Note that the proportion of test relevant items selected for study on Trial 1 cannot be attributed to knowledge about the reward structure of the study task because participants could not learn which items were valuable to study until at least the testing phase of Trial 1. Thus, to evaluate the contribution of each individual difference factor to changes in item selection as learners gain task experience, the proportion of test relevant items selected on Trial 1 was controlled for in all analyses. Accordingly, partial correlations between Raven's, Need for Cognition, and RSPAN scores and the proportion of test relevant items selected for study on Trial 2, Trial 3, and Trial 4 were computed controlling for initial selection levels of test relevant items on Trial 1. These data are presented in Table 2. Inspection of Table 2 reveals that scores on the RPSAN task were significantly associated with selection of test relevant items on Trials 2, 3, and 4. Scores on Raven's progressive matrices and the need for cognition scale were not associated with selection of test relevant items on any trial.

Next, correlations between each individual difference measure and whether participants consistently selected test relevant items across trials for study were computed using a lenient criterion (70% selection rate on each trial) and a strict criterion (90% selection rate on each trial). These data are presented in Table 3. Scores on the RSPAN

task were significantly associated with whether participants shifted towards the appropriate allocation strategy during the task regardless of the criterion used to indicate consistent selection of test-relevant items. Scores on Raven's progressive matrices and the need for cognition scale were not significantly associated with consistent selection of test relevant items across trials.

Table 2. Partial correlations between individual difference measures and the proportion of test-relevant items selected for restudy on each trial controlling for the baseline proportion of test-relevant items selected on Trial 1 in Experiment 3.

Item selection	Trial 2	Trial 3	Trial 4
Ravens	.02	.08	.15
NFC	.03	.08	.13
RSPAN	.25*	.20*	.24*

* $p < .05$

In summary, consistent with predictions of the ABR framework, working memory span was related to whether learners acquired the reward structure of the study task and used this knowledge to construct and execute a value-based agenda. However, need for cognition and fluid intelligence were not associated with agenda-based regulation in the current task. One might expect that need for cognition would affect agenda-based regulation because previous research indicates need for cognition is associated with academic performance (Cacioppo, Petty, Jeffrey, Feinstein, & Jarvis; 1996, Elias, & Ross, 2002; Leone & Dalton, 1988; Sadowski & Gulgoz, 1996, Wang & Newlin, 2000), and one possible way need for cognition may improve academic performance is by

motivating strategic behavior during self-regulated study. Despite the lack of influence of need for cognition on self-regulated study in the current experiment, it is possible that need for cognition may influence other aspects of self-regulated study besides item selection that would contribute to improvements in academic performance. For instance, Dai and Wang (2006) claim that need for cognition contributes to increased topic interest.

Table 3. Correlations between individual difference measures and whether participants shifted to the appropriate allocation strategy by trial 4 using a lenient criterion (70% selection rate on each trial) and a strict criterion (90% selection rate on each trial).

	Lenient criterion shifters (70%)	Strict criterion shifters (90%)
Ravens	.06	.09
NFC	.02	.05
RSPAN	.23*	.21*

* $p < .05$

Perhaps more surprising is that fluid intelligence was not related to selection of test relevant items. Fluid intelligence is typically related to performance on tasks that require forward planning and analytical reasoning. Thus, one might expect that it would be related to engagement in agenda-based regulation. However, given that fluid intelligence was measured using only a single task, it is possible that the current results underestimate its relationship to agenda-based regulation. Further research measuring fluid intelligence and other individual difference factors at the construct level is necessary to get a better estimate of their relationship to agenda-based regulation. Regardless, the current findings provide compelling evidence that individual differences in executive

control factors (e.g., working memory or attentional control) can influence learners' agenda-based regulation of study time.

Recall

The proportion of items recalled on each trial is presented in Table 1. Participants recalled more items on Trial 3 than on any other trial, $ts > 4.42$. Participants also recalled more items on Trial 4 than they did on Trial 1, $t(103) = 2.36$. No other differences across trials were significant.

Relationship between Item Selection and Recall

The relationship between restudy decisions and recall was examined by computing gamma correlations for each participant. Study decisions were significantly correlated with recall on each trial (Trial 1: $M = .56$, $SE = .06$; Trial 2: $M = .61$, $SE = .07$; Trial 3: $M = .62$, $SE = .06$; Trial 4: $M = .61$, $SE = .04$), $ts > 8.62$. The magnitude of these correlations did not differ across trials. Overall, these results suggest that participants' performance benefited from selecting test-relevant items for study.

GENERAL DISCUSSION

When studying for an upcoming exam, learners can maximize their exam performance by selectively allocating their study time to items that will yield the most reward. When learners know which items are the most valuable to learn, they typically prefer to allocate their study to these high valued items over less valuable ones (Ariel et al., 2009; Dunlosky & Thiede, 1998; Soderstrom & McCabe, 2011). In the current experiments, the value associated with learning items was not explicitly presented, and hence participants had to learn from task experience which items were valuable to study. Evidence from three experiments suggests that some learners can learn which items are valuable to study from task experience alone. However, many learners either did not learn the reward structure of study task or failed to exclusively use this knowledge about the reward structure when making study decisions. As a result, a large proportion of learners consistently dysregulated their study by allocating their time to items that were not valuable to performance (i.e. items that they were never tested on).

Why did many learners dysregulate their control of study? One answer to this question is that working memory limitations undermined effective agenda-based regulation. Working memory limitations could have undermined agenda-based regulation for a variety of reasons. Self-regulated study can be cognitively demanding and the current task may have exceeded the working memory of lower span participants (Dunlosky & Thiede, 2004). Consider the burden that the current task exerts on working

memory. To effectively allocate their study-time to test-relevant items, learners must maintain task goals in working memory while they (a) consider strategies to meet these goals, (b) make decisions about which items to study, (c) attempt to encode items they have selected for study, (d) monitor their progress toward achieving the task goals, and (e) update their knowledge about the reward structure of the task across trials. For lower span learners, the combination of these processes may have exceeded these capacity limitations, which would have made constructing and then maintaining an agenda in working memory difficult.

Given that capacity limitations play an important role in self-regulation (Ilkowska & Engla; 2010), one way that educators can increase the effectiveness of students' self-regulated study is by providing them with external aids that limit the burden that self-regulated study exerts on their working memory. One way to do this is by providing students with study guides. Students who study for exams with study guides often outperform students who are not given study guides because study guides highlight which information is most important to study and promote retrieval practice of this important information (Dickson, Miller, & Devoley, 2005; Farnum & Brigham, 1978). Most important, because the most valuable information is made explicit with a study guide, learners do not have to acquire knowledge about item value by themselves nor remember to apply this information when selecting items for study.

Regardless of the source through which learners acquire knowledge about item value, the current experiments suggest that knowing an item is valuable to performance may not always motivate learners to study those items. Consider findings from the cued

groups in Experiments 1 and 2, who were explicitly instructed which items would be tested on each trial. Despite having knowledge about which items would be tested, participants in the cued groups did not exclusively select test relevant items for study across trials. Why did many participants fail to consistently apply this knowledge when making study decisions? One answer to this question is that learners believed that the experimenter was deceiving them when they were instructed which items would be tested. If participants suspected deception, then they may have selected non test relevant items for study because they expected that they would be tested on other items besides those explicitly mentioned. Though possible, one might expect that after multiple trials of task experience in which they were consistently tested on items that they were instructed would be tested, they would alter this belief. Inconsistent with this expectation, participants persisted in selecting non test relevant items for study after multiple trials of task experience, which suggest the current results may not be due to suspicion of deception.

Another possible reason for the poor regulation in the cued groups is that the same working memory limitations that undermined agenda-based regulation in the no cue groups undermined agenda-based regulation in the cued groups. Despite having knowledge about the reward structure of the study task, participants in the cued groups must still apply this knowledge to construct and execute a value-based agenda. During either agenda construction or agenda execution, low span participants may have lost activation of either the task goals or the agenda they constructed, which would have undermined agenda execution in these experiments. Consider findings from Dunlosky

and Theide (2004), which are consistent with this explanation. High and low working memory span participants were explicitly given an agenda to execute during study that specified how to achieve a performance goal in an efficient manner. Namely, participants were instructed that their goal was to recall 6 of 30 items on a final recall test and that the best way to achieve this goal was to select 6 of easiest items for study. High span participants were more likely to successfully execute this agenda than low span participants, which suggests that even when learners are given an agenda they may not have the resources to implement it.

In summary, the current experiments extend research on value-based remembering to contexts where an item's value is not explicitly labeled. Results from three experiments provide evidence that some people can learn from task experience which items are most valuable to study and after gaining this knowledge they can apply it to regulate their future study. However, many people fail to do so and as a result, they dysregulate their study by allocating time to items that are not valuable to performance. Poor self-regulated study was not due to lack of motivation (Experiment 2), but was related to working memory span (Experiment 3). Thus, attentional control processes play an important role in learning about item value and applying knowledge to construct and execute a value-based agenda.

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