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Theories of Intelligence Influence Self-Regulated Study Choices and Learning

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In student-regulated instruction, guiding one's study effectively and efficiently is crucial for successful learning. Yet, significant variability exists in how effectively learners regulate their own study. Here, we explored whether and how beliefs about the nature of intelligence affect learners' metacognitive control and ultimately the efficacy of their study choices. We manipulated learners' theories of intelligence across two experiments. Learners then studied a list of words for a later memory test, chose half of the words to restudy, and restudied their chosen items. Learners who were persuaded to believe intelligence was malleable chose to restudy more poorly learned items and ultimately learned more than learners who were persuaded to believe intelligence was fixed. Learners' underlying beliefs about the nature of intelligence may affect learners' goals and ultimately their metacognitive control.

Keywords: metacognition, metacognitive control, metacognitive monitoring, self-regulated learning, theory of intelligence

Students and trainees increasingly control their own learning, especially with the advent of distance-based education and freely available training tools on the Internet (Moore & Kearsley, 2011). Learners must monitor and control their own learning in many contexts, from studying for classroom tests to learning a new skill on one's own. Accurately monitoring and effectively control one's learning are crucial skills for a successful learner because the choices that learners make when regulating their own study significantly affect what and how much is learned (Dunlosky & Thiede, 1998; Finley, Tullis, & Benjamin, 2010). Here, we examined how learners' beliefs about intelligence affected their self-monitoring and the effectiveness of their control over study.

The choices that learners make about their study determine how much they remember, maybe even more than individual differences in memory ability (Benjamin, 2008). Typically, learners make effective choices about selecting items for restudy (Kornell & Metcalfe, 2006), using retrieval practice over rereading (Tullis, Fiechter, & Benjamin, 2018; but see Karpicke, 2009), choosing how long to study items (Mazzoni & Cornoldi, 1993), generating external cues to support memory (Tullis & Benjamin, 2015a, 2015b), and selecting how to distribute study time across items (Toppino, Cohen, Davis, & Moors, 2009). Yet, wide variability exists in how effectively individuals regulate their learning; for example, approximately only half of learners choose to allocate study time in a manner that benefits their later memory (Tullis & Benjamin, 2011).

Differences in the effectiveness of metacognitive control may arise from differences in metacognitive monitoring. The monitoring-affects-control hypothesis suggests that learners' monitoring judgments cause the control choices that learners make (Metcalfe & Finn, 2008; Nelson & Leonesio, 1988; Son & Schwartz, 2002). Learners who accurately monitor their learning make more effective choices about which stimuli to restudy and ultimately remember more than learners who inaccurately monitor their learning (Thiede, Anderson, & Theriault, 2003). To correctly monitor their learning, learners must recognize, weigh, and accurately interpret a variety of available and salient cues (Koriat, 1997). Metacognitive cues can include intrinsic stimulus characteristics (e.g., concreteness, Witherby & Tauber, 2017), extrinsic study characteristics (e.g., rereading vs. retrieval practice, Roediger & Karpicke, 2006), and mnemonic cues related to one's individual processing (e.g., encoding fluency, Koriat & Ma'ayan, 2005). Learners perceive a variety of cues and interpret how those cues will impact later memory (Mueller, Dunlosky, Tauber, & Rhodes, 2014).

How learners interpret metacognitive cues could potentially be influenced by their theories of intelligence (TOIs: Miele, Finn, & Molden, 2011; Miele & Molden, 2010). TOIs reflect the degree to which learners think intelligence is an innate, fixed quantity (i.e., entitist theories) or is developed and expanded through effort (i.e., incremental theories; Dweck, Chiu, & Hong, 1995). TOIs can guide learners' behaviors, emotions, and motivations (see Molden & Dweck, 2006). TOIs are likely developed through learners' experiences; for example, the type of feedback they receive during instruction (i.e., "You are talented!" vs. "You work very hard!") can mold the direction and strength of these beliefs (Mueller & Dweck, 1998). Although evidence differs about the influence of TOI on broader learning behaviors and academic achievements (Blackwell, Trzesniewski, & Dweck, 2007; Dweck et al., 1995; Dweck & Leggett, 1988; Sisk, Burgoyne, Sun, Butler, & Macnamara, 2018), recent research suggests that TOIs affect how learn-

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ers interpret encoding fluency when monitoring their learning (Miele et al., 2011; Miele & Molden, 2010). Specifically, Miele and Molden (2010) showed that learners with entitist theories interpreted increased processing fluency as indicating worse learning but learners with incremental views interpreted increased processing fluency as indicating greater learning. In these experiments, processing fluency was manipulated through several different tasks, including presenting texts with either clear (high processing fluency, see Rhodes & Castel, 2008) or unclear font (low encoding fluency), presenting texts in coherent (high processing fluency) or incoherent (low processing fluency) orders, or even requiring learners to furrow their brows (indicating lower processing fluency) or puffing their cheeks (see Stepper & Strack, 1993). Similarly, Miele et al. (2011) examined how theories of intelligence altered learners' interpretation of processing fluency by manipulating the relationship between the cue and target in word pairs and the font size of studied words. Consistently, entitists interpreted processing difficulty as indicating the limits of their ability and predicted worse memory for difficult items. Incrementalists, on the other hand, interpreted processing effort as indicating mnemonic growth and predicted better memory for effortful items. Learners who view intelligence as fixed interpret effortful encoding as implying that they have reached the limits of their ability and predict poor memory for disfluently processed items; learners who view intelligence as malleable interpret effortful encoding as implying greater cognitive engagement and predict strong memory for effortful items.

Previous research shows that theories of intelligence influence metacognitive monitoring. Here, we examined whether learners' theories of intelligence also affect their study choices during self-regulated learning. Across two experiments, we experimentally manipulated learners' TOIs and examined their subsequent restudy choices. Experimentally manipulating TOIs allows us to draw causal conclusions about the impact of TOI on study choices, as in prior research (e.g., Bergen, 1991). If TOIs affect how learners monitor and interpret encoding difficulty (Miele & Molden, 2010), the monitoring-affects-control hypothesis suggests that TOIs should also influence learners' self-regulated study choices. Learners with fixed beliefs about intelligence may view expenditures of effort as indicating that information is too difficult to learn and avoid restudying difficult items. Alternatively, learners with incremental views of intelligence may see encoding difficulty as an opportunity for growth and focus restudy choices on difficult items. Therefore, we predict that incrementalists, who view effortful encoding as indicating mastery and improvement, will choose to restudy more challenging items than entitists, who view effortful encoding as indicating a lack of innate ability.

We test these hypotheses across two experiments. In Experiment 1, we manipulated TOI and measured what learners chose to restudy in a recognition task. In Experiment 2, we extended Experiment 1 by additionally manipulating font size of studied items to (a) more closely mimic the methods of Miele et al. (2011) and (b) control how difficult learners thought each item was. Learners struggle to predict what will be easy or difficult on recognition tests (e.g., Benjamin, 2003); experimentally manipulating font size produces consistency across learners' predictions about difficulty without affecting memory. Experimentally manipulating what learners rate as difficult in Experiment 2 allows us to

draw firmer causal conclusions about how TOI affects both monitoring and control.

Experiment 1

Method

Ethics, consent, and permissions. The University of Arizona Internal Review Board approved this research (Approval #15-007-EDP) prior to its start. For this and subsequent experiments, all subjects read the appropriate consent form and indicated their consent to participate. All subjects could withdraw from the experiment at any time without negative consequences.

Participants. A power analysis using the GPower computer program (Faul, Erdfelder, Buchner, & Lang, 2009) indicated that a total sample of 128 participants would be needed to detect medium-sized effects ($d = 0.50$) using a between-subjects t test with alpha at 0.05 and power of 0.80. We chose a medium effect size because prior research suggests that TOI has a medium-sized effect on metacognitive monitoring judgments (Miele et al., 2011). We created 140 slots for participants on Amazon Mechanical Turk, with the expectation that we would register valid data from at least 128 participants. Ultimately, valid data from 139 participants, who each received \$2 compensation for completing the experiment, were collected.

Materials. We used the same 160 single words from the MRC psycholinguistic Database (Wilson, 1988) that were used in Tullis and Benjamin (2011). For each participant, 80 words were randomly chosen to be studied, whereas the remaining 80 words were used as distractors in the final recognition test.

Procedure. Participants completed the experiment online. Participants were randomly assigned into either an *entitist* or *incremental* group. As in prior research (see Bergen, 1991; Hong, Chiu, Dweck, Lin, & Wan, 1999), participants read a fake psychology article intended to manipulate their theories of intelligence. The *entitist* group read an article that stressed the innate, unchanging nature of intelligence, whereas the *incremental* group read an article that stressed how intelligence can be improved through effort and practice.

Participants then studied a list of 80 words for a later memory test. Words were presented one at a time in black, 45-point Arial font in the middle of the screen in a random order. Participants were asked to make a judgment of learning (JOL) as they viewed each item. For each JOL, participants rated how likely they were to remember each word on a later test on a scale of 1 (*definitely will NOT remember*) to 4 (*definitely will remember*). Given that participants were MTurk workers, we accounted for variability in computer functioning by allowing participants to take as much time as they needed to study the words and make JOLs. After participants made each JOL, they decided whether they would restudy each word or not, with the constraint that only half of the items could be restudied. The numbers of items participants had chosen to restudy and dropped from future study were shown at the bottom of the screen. When finished with the initial study phase, participants restudied their selected items in a new random order. Each chosen item was presented for 4 seconds during the restudy phase, so that memory differences could be attributable to restudy choices (and not restudy time). Participants then took a recognition memory test. In the recognition memory test, 160 words (80

studied and 80 unstudied) were presented one at a time in a new random order. Participants indicated their memory for each word on a scale of 1 (*I am sure I did NOT study that word*) to 4 (*I am sure that I studied that word*).

Finally, participants completed an eight-item TOI questionnaire, as in Hong et al. (1999), which included questions like “No matter who you are, you can significantly change your intelligence level.” Participants rated their agreement with each statement from 1 (*completely disagree*) to 6 (*completely agree*).

Results

First, we examined whether condition influenced participants’ reported beliefs on the final TOI questionnaire to determine whether condition affected TOI. Participants in the *entitist group* endorsed entitist views more strongly ($M = 3.79$ [$SD = 1.46$]) than those in the *incremental group* ($M = 2.59$ [$SD = 1.29$]; $t(137) = 5.15$, $p < .001$, Cohen’s $d = 0.87$).

Second, we examined whether the two groups differed in the time they took during the initial study and choice phases. As shown in Table 1, TOI did not change the amount of initial study/JOL time, $t(137) = 1.08$, $p = .28$, $d = 0.19$, or the amount of time taken for restudy choices, $t(137) = 1.22$, $p = .22$, $d = 0.21$. We also examined whether TOI groups allocated initial study time differentially across items. To do so, we computed the gamma correlation between initial study/JOL time and JOL for each participant. No significant differences emerged between TOI groups ($M_{ent} = 0.04$ [$SD = 0.32$]; $M_{inc} = -0.01$ [$SD = 0.31$]; $t(137) = 1.10$, $p = .31$, $d = 0.16$).

Next, we examined whether TOI influenced metacognitive monitoring, as shown in prior research (Miele & Molden, 2010). We calculated the gamma correlation between JOLs and normative word discriminability. Normative word discriminability indicates how easily words are recognized on the final test (as measured by the performance of a large sample of prior subjects: Tullis & Benjamin, 2011). High discriminability indicates that the item is easily recognized. Typically, gamma correlations between normative word discriminability and JOLs are low for recognition tasks because learners show faulty predictions about what stimuli characteristics support memory on recognition tasks (e.g., Benjamin, 2003). Gamma correlations between JOLs and word discriminability were slightly negative for both the incremental group ($M = -0.01$ [$SD = 0.22$]) and the entitist group ($M = -0.06$ [$SD = 0.24$]). Neither gamma correlations from the incremental group, $t(63) = 0.23$, $p = .81$, $d = 0.05$, nor the entitist group, $t(64) = 1.89$, $p = .06$, $d = 0.25$, were different than 0, indicating that students’ JOLs did not accurately reflect normative word discriminability,¹ which mirrors results from Tullis and Benjamin (2011). Further, we examined whether the gamma correlation between JOLs and word discriminability differed between the two groups. The gamma correlations between the conditions did not differ, $t(137) = 1.23$, $p = .22$, Cohen’s $d = 0.22$.

Most central to our primary hypotheses, we examined the relationship between JOLs and restudy choices to determine whether the two groups selected different items to restudy. Participants’ restudy choices as a function of their JOL are displayed in Figure 1. Both the entitist and incremental groups showed negative gamma correlations between JOLs and restudy choices, indicating that both groups chose to restudy the items they judged to be poorly learned. However, the incremental group showed a stronger preference to restudy the poorly

learned items ($M = -0.54$ [$SD = 0.44$]) than the entitist group ($M = -0.35$ [$SD = 0.55$]), $t(137) = 2.13$, $p = .03$, Cohen’s $d = 0.38$. A histogram of participants’ gamma correlations between JOLs and restudy choices for the two groups is displayed in Figure 2. The histogram suggests that the TOI manipulation slightly shifted the distribution of gammas to the right for the entitist group.

Finally, we compared the recognition memory between the two conditions. Hit and false alarm rates are shown in Table 2. We calculated d_a , a signal detection theoretic measure of memory, as in Tullis, Benjamin, and Ross (2014). The incremental group showed better memory ($M_{da} = 1.74$ [$SD = 0.80$]) than the entitist group ($M_{da} = 1.31$ [$SD = 0.96$]; $t(137) = 2.85$, $p = .01$, Cohen’s $d = 0.49$).²

Discussion

Learners’ TOIs influenced their study choices and ultimately how much they remembered. Although incrementalists and entitists both chose to restudy poorly learned items, incrementalists focused their restudy more heavily on the worst learned items and forwent the best learned items. Learners’ TOIs may affect how learners view the items that they are studying: incrementalists may view poorly learned items as possibilities for growth, whereas entitists may view poorly learned items as revealing their innate limitations. Therefore, incrementalists tend to seek more opportunities to develop themselves through restudying more effortful items, whereas entitists avoid being reminded of their limitations and choose to study less effortful items. Learners’ study choices influenced their memory: incrementalists performed better than entitists on the final recognition test.

Even though learners’ JOLs did not accurately reflect objective word discriminability, their JOLs still shaped what they chose to restudy across both groups. These results corroborate research showing that JOLs have a causal influence on metacognitive control, even when JOLs do not reflect objective item difficulty (e.g., Metcalfe, 2009). TOIs shaped what learners chose to restudy and consequently affected how well they remembered their study information.

Although we found differences in metacognitive control over restudy choices between TOI groups, we did not find significant differences in initial study time. Study time results should be viewed cautiously in these data for several reasons. First, participants were not instructed to allocate different amounts of study

¹ Although JOLs did not accurately reflect normative item discriminability, they did accurately reflect each participants’ learning. We computed gamma correlations between JOLs and recognition ratings for the subset of items that were not restudied (restudying introduces nontrivial noise that artificially reduces the relationship between the JOL and the recognition ratings). Even when examining the relatively homogenous subset of items that were not chosen to be restudied, gamma correlations between JOL and recognition ratings across all participants were marginally greater than zero ($G = 0.09$ [$SD = 0.53$]), $t(123) = 1.87$, $p = 0.07$. In fact, 75 participants showed a positive gamma between predictions and memory (and only 46 showed negative gammas). This indicates that JOLs somewhat accurately predicted later recognition performance.

² Using the signal-detection theoretic analyses, we also compared the recognition criteria learners used across the two groups. The incremental group showed a significantly greater middle criterion than the entitist group ($M_{ent} = 0.77$ [$SD = 0.84$]; $M_{inc} = 1.03$ [$SD = 0.64$]), $t(137) = 2.01$, $p = 0.046$, $d = 0.35$. Because we had no predictions about criteria and this difference does not replicate in Experiment 2, we do not interpret this difference.

Table 1
Study Time

Group	Experiment 1		Experiment 2	
	Initial study/JOL time	Restudy choice time	Initial study/JOL time	Restudy choice time
Entitist	1.99 (1.5)	1.11 (.64)	2.31 (1.37)	1.23 (.67)
Incrementalist	2.25 (1.27)	1.23 (.67)	2.79 (1.75)	1.31 (.67)

Note. Time spent studying and making JOLs and time spent making restudy choices as a function of TOI group and experiment. No difference between TOI groups reached significance. Standard deviations are displayed in parentheses. JOL = judgment of learning.

time across items; rather they were instructed to study and make a JOL for each item. Participants may not see the initial study time as a means of controlling their learning. Second, in our data, initial study time reflects a combination of study and JOL decision time because participants studied the words and made the JOLs simultaneously. We have no clean measures of how long learners spent studying versus spent making JOLs. Finally, our MTurk participants completed the experiment on their own computers in whatever setting they chose. This produced wide variability in the initial study/JOL time within and across participants that likely obscures subtle study time differences. Future studies could examine the relationship between initial study time, JOLs, and TOIs.

TOIs did not influence learners' metacognitive monitoring. Previous research showed that TOIs influenced learner's interpretation of processing difficulty (Miele et al., 2011; Miele & Molden, 2010). Specifically, incrementalists rated disfluent stimuli as better learned than fluent stimuli, whereas entitists rated disfluent stimuli as worse learned than fluent stimuli (Miele et al., 2011). TOI, however, did not affect how learners assigned JOLs to items in our experiment. The lack of effect could arise because (a) TOI did not affect how learners interpreted their processing effort (in contrast to Miele & Molden, 2010) or (b) there was no consistency across learners about which items they thought were difficult (and which were easy). If JOLs are based upon individual, idiosyncratic pro-

cesses, we would be unable to find systematic differences between groups. In other words, if there is no consistency across learners about which items are thought to be easy, determining whether TOI influences how JOLs are assigned will necessarily yield null effects. Therefore, in Experiment 2, we introduced a font size manipulation so that we can control what items learners think are difficult to remember and what items they think are easy. Larger fonts are consistently rated as easier to remember than smaller fonts across learners (e.g., Rhodes & Castel, 2008; Undorf & Zimdahl, 2019), but font sizes do not affect memory. If TOIs affect how learners interpret processing effort (i.e., assign JOLs to items), as in prior research, differences in the relationship between JOLs and font size between groups should exist. If TOI influences interpretation of effort, entitists should view big font sizes as indicating good learning, whereas incrementalists should interpret small font sizes as indicating good learning. Further, we introduced a font size manipulation to more closely mimic the procedures used in Miele et al. (2011) to test whether TOI influences metacognitive monitoring.

Experiment 2 allowed us to control what items learners viewed as difficult and easy, without affecting actual memory. Systematically controlling how difficult learners view items allows us to test whether TOI affects how learners assign JOLs to difficult and easy items. Experiment 2 should provide a clean measure of the impact of theories of intelligence on metacognitive judgments and study behaviors.

Experiment 2

In Experiment 2, we replicated and extended Experiment 1 to test whether TOI influences learners' study behaviors through learner's metacognitive monitoring. Learners studied the same stimuli as in Experiment 1, but the words were presented in different font sizes. Miele et al. (2011, Experiment 2) found that, when words were presented in either big (high encoding fluency, 48-point font) or small font sizes (low encoding fluency, 18-point font), TOIs affected how learners predicted their memory. Entitists rated large-font items as better learned, while incrementalists' ratings were not influenced by size. Similarly, we hypothesize that entitists should rate larger fonts as indicating better memory, whereas incrementalists' ratings may not be affected by font size. As in Experiment 1, we predict that the incremental group should focus restudy choices more heavily on poorly learned items than the entitist group.

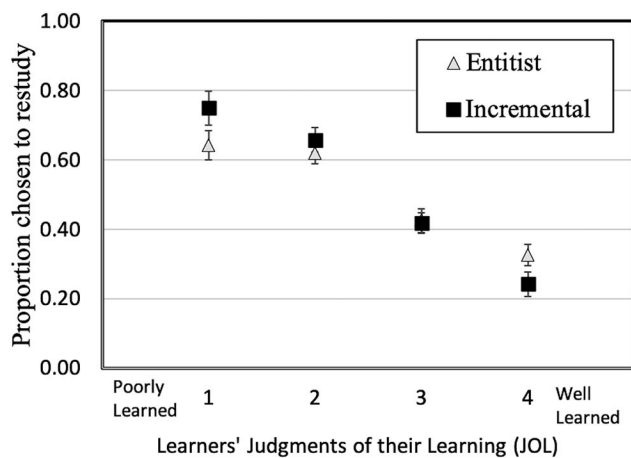


Figure 1. Proportion of items chosen for restudy as a function of learners' reported judgments of learning. Error bars indicate one standard error of the mean above and below the sample mean.

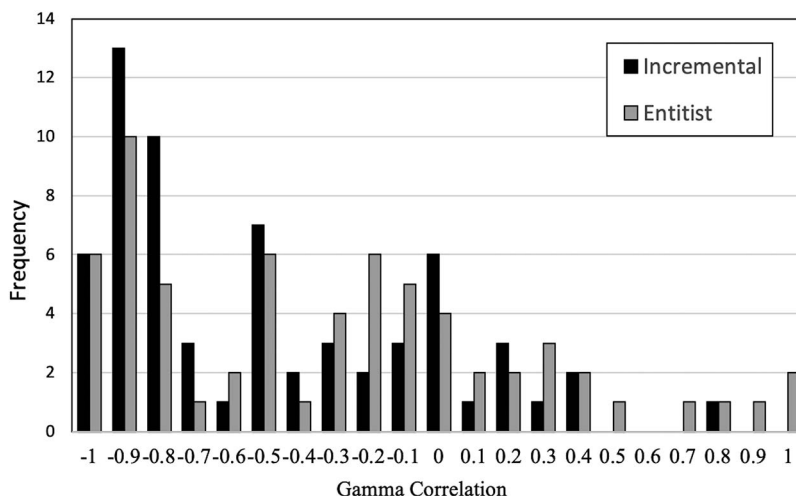


Figure 2. Frequency histogram of the gamma correlation between JOL and study choice. The histogram was constructed in the following way: scores of -1 were grouped in the first bin, scores between -1 (exclusive) and -0.9 (inclusive) were in the next bin, scores between -0.9 (exclusive) and -0.80 (inclusive) were in the third bin, and so on, until the final bin with scores of 1 .

Method

Participants. As in Experiment 1, we created 140 participant slots on MTurk. Ultimately, we received complete data from 130 participants, who each received \$2 compensation for completing the experiment. The study was approved by the IRB of the University of Arizona.

Materials. The materials in Experiment 2 were identical to those in Experiment 1.

Procedure. As in Experiment 1, participants studied a list of 80 words randomly selected from the list of 160 words for a later memory test. Unlike Experiment 1, words were presented in different font sizes during study. Possible font sizes included every even number from 10 to 88. Font sizes were randomly assigned to words such that each font size was used twice during study. During the restudy and test phases, words were presented in 45-point Arial font.

Results

First, we tested whether condition influenced participants' TOIs. The final TOI questionnaire showed that participants in the entitist condition endorsed entitist views of intelligence more strongly ($M = 3.84$ [$SD = 1.37$]) than participants in the incremental group

($M = 2.61$ [$SD = 1.30$]), $t(128) = 5.26$, $p < .001$, Cohen's $d = 0.92$, as in Experiment 1.

Second, we assessed whether TOI influenced how long participants spent during the initial study and choice phases. Like Experiment 1 (and shown in Table 1), TOI did not affect the amount of initial study/JOL time, $t(128) = 1.76$, $p = .08$, $d = 0.31$, or the amount of time taken for restudy choices, $t(128) = 0.76$, $p = .45$, $d = 0.12$. Further, gamma correlations between initial study/JOL time and JOL revealed that TOI did not influence how learners allocated initial study/JOL time across items ($M_{ent} = -0.05$ [$SD = 0.32$]; $M_{inc} = -0.08$ [$SD = 0.31$]; $t(128) = 0.52$, $p = .65$, $d = 0.10$).

Next, we assessed whether font size influenced participants' JOLs by calculating the gamma correlation between JOLs and font size. The gamma correlations were significantly greater than 0 for both the incremental group ($M = 0.05$ [$SD = 0.17$]), $t(62) = 2.52$, $p = .01$, $d = 0.29$, and the entitist group ($M = 0.06$ [$SD = 0.20$]), $t(61) = 2.51$, $p = .01$, $d = 0.30$, indicating that bigger font sizes were associated with bigger JOLs.³ The gamma correlations between JOLs and font size were similar across the incremental group and the entitist group, $t(128) = 0.35$, $p = .73$, Cohen's $d = 0.08$. JOLs as a function of font size and condition are displayed in Figure 3.

Most central to our hypotheses, we examined whether TOI condition impacted restudy choices. As in Experiment 1, we calculated gamma correlations between JOLs and restudy choice. Both groups' gamma correlations were negative, indicating that participants chose to restudy less well-learned items more than well-learned items. However, participants in the incremental con-

Table 2

Recognition Test Performance

Group	Experiment 1		Experiment 2	
	Hit rate	False alarm rate	Hit rate	False alarm rate
Entitist	.73 (.20)	.26 (.22)	.75 (.18)	.21 (.18)
Incrementalist	.78 (.17)	.19 (.15)	.75 (.20)	.23 (.20)

Note. Proportion of hits (ratings of 3s or 4s for studied items) and false alarms (ratings of 3s or 4s for unstudied items) as a function of condition for Experiment 1 and 2. Standard deviations are displayed in parentheses.

³ As in Experiment 1, we computed gammas between JOLs and recognition ratings for the subset of items that were not restudied. Gamma correlations between JOL and recognition ratings across all participants were greater than zero ($G = 0.10$ [$SD = 0.47$]), $t(119) = 2.31$, $p = 0.03$. In fact, 76 participants had positive gamma correlations (only 41 had negative gammas). This indicates that participants use both font size and mnemonic cues when assigning JOLs.

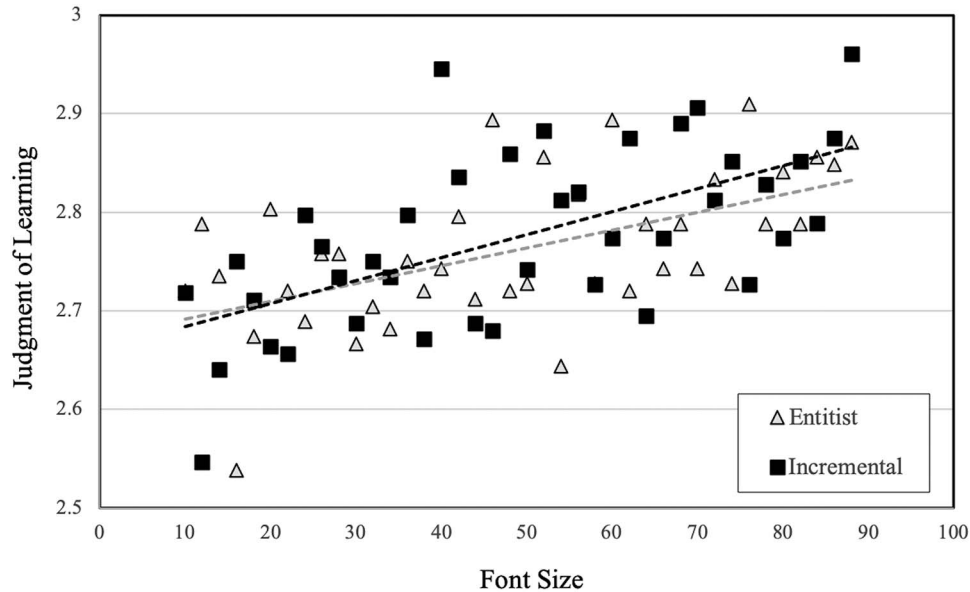


Figure 3. Learners' judgments of learning as a function of font size and TOI condition in Experiment 2.

dition showed a stronger preference to restudy items with low JOLs ($M = -0.49$ [$SD = 0.48$]) than participants in the entitist condition ($M = -0.30$ [$SD = 0.55$]), $t(128) = 2.06$, $p = .04$, Cohen's $d = 0.37$. Restudy choices as function of JOLs are displayed in Figure 4. The histogram of participants' gamma correlations between JOLs and restudy choices for the two groups is displayed in Figure 5. As in Experiment 1, the histogram suggests that TOI slightly shifted the distribution of gammas for the entitists toward the right.

Finally, we compared recognition performance between the entitist and incremental groups. Hit and false alarm rates are displayed in Table 2. As in Experiment 1, recognition performance was calculated using d_a , a signal detection theoretic measure of memory. No significant difference existed in d_a between the en-

titist ($M_{da} = 1.61$ [$SD = 0.93$]) and incremental groups ($M_{da} = 1.54$ [$SD = 0.95$]), $t(128) = 0.69$, $p = .69$, Cohen's $d = 0.07$.⁴

Discussion

In Experiment 2, we manipulated font size to test how TOIs influence metacognitive monitoring and control. TOIs influenced learners' restudy choices. More specifically, as in Experiment 1, incrementalists, who believe effort indicates development, chose more poorly learned items to restudy than entitists, who believe effort indicates a limitation of ability. Even though TOI changed the items selected for restudy, TOI did not influence learners' memory. Learners' restudy choices were influenced by the arbitrary assignment of items to font size conditions, which is unrelated to memory. Therefore, even though two groups choose different items to restudy, their restudy choices did not affect how much they remembered. As in Experiment 1, TOIs did not influence learners' metacognitive monitoring. There was no difference between the two groups in the relationship between JOLs and font sizes, even though we systematically controlled how difficult learners viewed each item. Both groups predicted better memory for items presented in larger fonts, indicating that both groups interpreted processing effort in the same way.

Significant debate exists about how and why font size impacts learners' JOLs. Bigger fonts may enhance learners' processing fluency, and increased fluency can produce higher JOLs (e.g., Rhodes & Castel, 2008). Alternate theories suggest that bigger fonts cause higher JOLs because learners hold beliefs that bigger fonts support better memory than smaller fonts (Mueller et al., 2014). Still, other theories propose that both fluency and beliefs contribute to the impact of font size on JOLs (Blake & Castel,

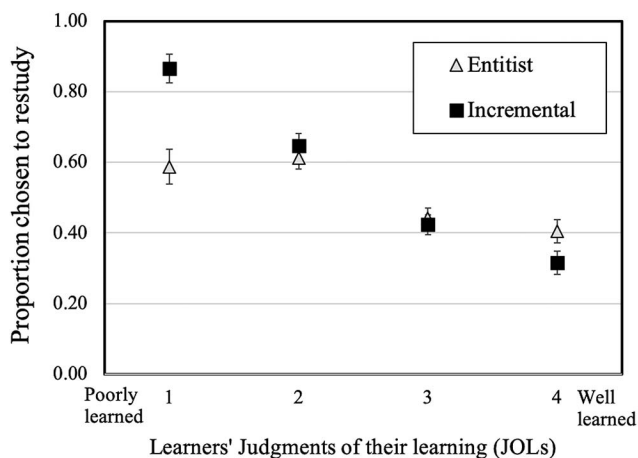


Figure 4. Proportion of items selected for restudy based upon learners' judgments of learning and TOI condition. Error bars show one standard error of the mean above and below the sample mean.

⁴ As in Experiment 1, we compared the three signal-detection theoretic criteria used on the recognition test between the two groups. No significant differences were found ($ps > 0.25$).

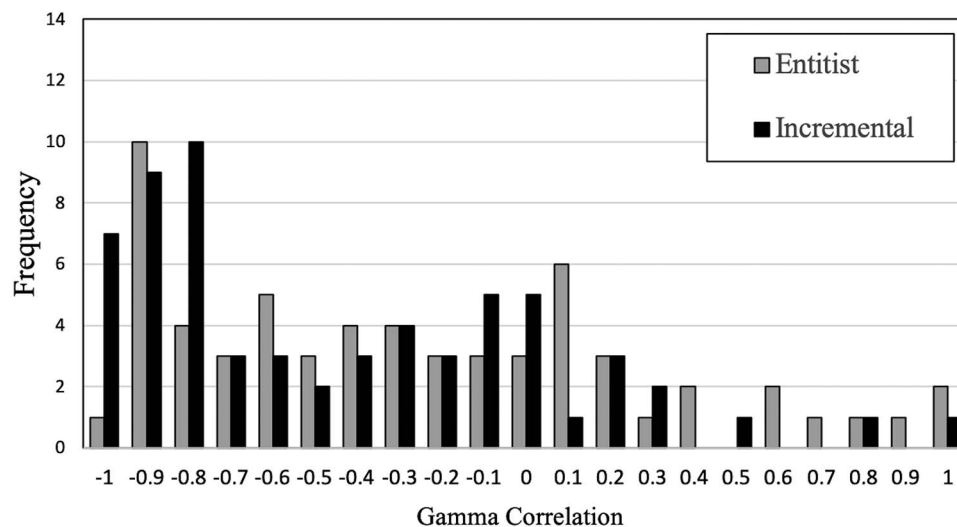


Figure 5. Frequency histogram of the gamma correlation between JOL and study choice. The histogram was constructed in the following way: scores of -1 were grouped in the first bin, scores between -1 (exclusive) and -0.9 (inclusive) were in the next bin, scores between -0.9 (exclusive) and -0.80 (inclusive) were in the third bin, and so on, until the final bin with scores of 1.

2018). Although our experiment was not designed to decipher among these competing theories, our data hint that processing fluency may not be primarily responsible for how font sizes impact JOLs. If TOIs influence how learners interpret processing fluency (as in Miele & Molden, 2010) and font size impacts processing fluency, then TOI should interact with font size. We see no difference in how TOIs influence the interpretation of font size, which hints that the font size/JOLs relationship is not caused exclusively by differential processing fluency (but see Miele et al., 2011).

General Discussion

Across two experiments, we examined the relationship between learners' TOIs and their restudy choices. We found that TOIs influenced which items learners chose to restudy. More specifically, incrementalists choose to restudy more poorly learned items than entitists. However, differences in restudy choices were not driven by differences in metacognitive monitoring across the TOI conditions.

Whereas prior research showed an influence of TOI on metacognitive monitoring, neither of our experiments showed this relationship. Several reasons may underlie this difference. First, prior research relied upon undergraduate students at Columbia University (Miele et al., 2011), and our participants came from MTurk. The TOI of students from elite private universities may not mirror the range of TOIs in the broader populations. Further, entitist students with high abilities often behave differently than entitists with low abilities (e.g., Pintrich, 2000); consequently, entitists in prior research may not respond the same way to challenge as entitists in our sample. The results from the specific sample in prior research may not replicate among more diverse samples. MTurk participants represent greater variation in demographics than Columbia undergraduates, and therefore, our population likely has a greater range in initial TOI beliefs. Specifically, the average age of our sample was 36.8 years, which

likely represents greater diversity than undergraduate students at prestigious universities. On the other hand, it is possible that older participants in our experiment had more stable beliefs about processing effort; manipulating TOIs may not be effective enough to change their interpretation of encoding effort.

Second, prior research utilized two distinct font sizes while we used 40 different font sizes. Integrating a wide array of fonts with a new TOI to make JOLs may be more difficult when there are 40 different options for font size than when there are only two options (Undorf, Söllner, & Bröder, 2018). Interpreting a continuous change in font size may require more cognitive resources than the binary font sizes of Miele et al., 2011. Consequently, learners may not have the requisite cognitive resources available to use beliefs to interpret the mnemonic cue of font size (Yang, Huang, & Shanks, 2018).

Third, learners controlled aspects of their study in both of our experiments but had no control in prior research. Learners controlled the amount of initial time they spent viewing each item and controlled whether they restudied each item or not. When learners have opportunities to control their learning, they may selectively integrate TOI beliefs during the control phase of self-regulation (rather than during the monitoring phase). If the integration of beliefs about intelligence during self-regulated learning is under the control of learners, they may choose whether TOIs impact monitoring, control, or both.

Fourth, across both tasks, we utilize a recognition test. Recognition tests allow us to include a large number of items so that we can calculate precise measurements of memory and correct for decision strategies using signal detection theory (Green & Swets, 1966). Further, recognition tests afford less variation in test strategies between participants (Benjamin, 2008), which allows us to focus on differences between groups during encoding (rather than during test). Unfortunately, however, learners are not attuned the specific demands of recognition tests. Learners' views of encoding

effort during *recognition* may be different than those seen in cued-recall and free recall situations.

Finally, the original results concerning the relationship between TOI and font size reported in Miele et al. (2011) may not replicate. The original paper did not include a direct replication attempt, and direct replications are becoming increasingly valued in psychology (e.g., Maxwell, Lau, & Howard, 2015). In fact, the original sample size was relatively small (at 41 participants). Although six different conceptual replications have shown impressive (and often large) effects of TOI on the interpretation of encoding fluency (Miele & Molden, 2010; Miele et al., 2011), our experiment is the first to closely replicate the procedures concerning the relationship between TOI and metacognition of font size. Further research is needed to examine whether and how widely the effect of TOI on font size replicates. Replication research teasing apart the differences between the current research and prior studies may elucidate the limitations of TOI on metacognitive monitoring.

In contrast to our hypotheses, TOIs did not impact metacognitive control through metacognitive monitoring; rather, TOIs directly influenced study choices without affecting learners' JOLs. TOIs may affect study behavior because they impact learners' goals rather than their interpretation of ongoing encoding processing. Evidence that TOIs impact learners' goals and behaviors aligns with social-cognitive theories of motivation (Blackwell et al., 2007; Dweck & Leggett, 1988; Hong et al., 1999). Entitists may view learning situations as means to measure their ability, so they avoid situations with negative outcomes. Consequently, entitists choose less challenging tasks (Hong et al., 1999) and strategically avoid exerting effort in learning situations (Blackwell et al., 2007). Entitists may choose to restudy items in accordance with the Region of Proximal Learning (RPL) model (Metcalfe & Kornell, 2005), as they are more likely to bypass the most poorly learned items to focus on items just beyond their current level of mastery. Alternatively, incrementalists seek out challenges to learn (Hong et al., 1999) and utilize effortful learning strategies (Blackwell et al., 2007). Incrementalists, who believe effort leads to learning and mastery, might choose to restudy items in accordance with the Discrepancy Reduction (DR) model (Miele & Molden, 2010). They might exert more effort on reducing the greatest discrepancy between current levels of understanding and the goal state to achieve a desired learning goal and choose to study the most poorly learned items (Dunlosky & Hertzog, 1998).

Agenda-based regulation suggests that goals may shift study behavior (Ariel, Dunlosky, & Bailey, 2009). Entitists may shift their goals to focus on easier items, whereas incrementalists may shift their goals to focus on more challenging items. Prior research shows that situational demands can shift learners' strategies from DR to RPL. For example, when no time limits exist, learners choose to restudy the most difficult items for longer periods of time; however, when a severe time limit is imposed, learners shift to choosing easier items to restudy (Metcalfe, 2002). TOI, then, may be an intrinsic belief that shifts goals and ultimately changes how learners allocate study choices across items.

The influence of TOI on restudy choices reveals a slight shifting of restudy choices across learners. Some prior research suggests that learners can show bimodal distributions of study choices (Morehead, Dunlosky, & Foster, 2017), in which many learners focus exclusively on difficult items and many focus exclusively on easy items. TOI in our experiments does not cause such distinct

differences in study choices; rather, most learners showed a strong preference to restudy the poorly learned items. TOI changed the strength of this preference.

Our results show inconsistent effects of TOI condition on final recognition performance. In Experiment 1, incrementalists showed better recognition of studied words than entitists because they chose to restudy more poorly learned items; in Experiment 2, however, no differences on recognition performance existed between TOI groups. Restudy choices in Experiment 2 were largely based upon font size, which was unrelated to item difficulty. More broadly, debate exists about the impact of TOIs on student performance. Some research shows large benefits of incremental TOIs on academic performance (Blackwell et al., 2007), but a recent meta-analysis indicates only a very small effect of TOI interventions on improving students' academic performance (Sisk et al., 2018). Our results emphasize the role of study choice in the relationship between learners' TOIs and their performance. TOIs impact what students choose to study; whether those study choices are appropriate or not depends upon both (a) how accurately learners monitor their learning and (b) the specific situation (for an example where similar monitoring and study choices lead to different outcomes, see Tullis & Benjamin, 2012). Under many circumstances, studying the poorly learned information may be more advantageous than studying well-learned information (Tullis & Benjamin, 2011). However, under different constraints, studying well-learned information may lead to the best learning (e.g., Son & Metcalfe, 2000).

Whether the intervention we used in both of our experiments has long-lasting metacognitive effects remains untested. However, longer, more intense manipulations can alter students' TOIs and learning significantly. For example, eight 25-min TOI interventions over the course of a semester changed how 7th grade students interpreted study effort, used effort-based strategies, and performed on later math tests (Blackwell et al., 2007). Our results show a short-term causal relationship between TOIs and what learners choose to restudy that may underlie some of the larger longer-term benefits of incremental views.

Self-regulated learning can provide large benefits over teacher-controlled learning, as learners can tailor their instruction to their specific, individual needs. However, the benefits that self-regulated learning provides may be diminished through learners' ineffective choices. Because learners' study choices impact how well they learn information (Thiede et al., 2003; Tullis & Benjamin, 2011), understanding the factors influencing study choices is critical to support effective and efficient learning. TOIs may be an important factor that directly impacts learners' choices and consequently their learning.

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