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Motivation-based selective encoding and retrieval

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Abstract

Rememberers are often motivated to remember certain pieces of information more than they are motivated to remember other pieces. The literature suggests that this motivation results in selective remembering of valuable information and that it yields selective processing of this valuable information during encoding. However, the question of whether or not motivation to remember also elicits selective processing during retrieval is relatively underexplored. To fill this gap, two experiments examined the effect of incentive-based motivation to remember target information on selective encoding and retrieval processes using a paradigm that allowed participants to self-regulate their learning and cued-recall testing under relatively naturalistic settings. The results revealed that motivation yielded selective remembering of the target information and selective processing during encoding (i.e., selective allocation of study time, selective restudy, and selective control over study order), consistent with prior findings. Importantly, the results also revealed that motivation yielded selective processing during retrieval, as rememberers allocated more time to test queries about target information that they were motivated to remember and tended to start the test with these queries. These findings suggest that motivation affects how rememberers answer a cued-recall memory test. More generally, the current research demonstrates that by manipulating motivation and investigating self-regulated learning and remembering, research can advance our understanding of the intricate relationship between motivation, memory, and metacognition.

Keywords Memory · Motivation · Metacognition · Selectivity · Retrieval

Introduction

In many situations, we are motivated to remember certain pieces of information more than we are motivated to remember other pieces. For example, a student who needs to learn four textbook chapters for an upcoming exam might realize that one chapter is more important to learn than the other ones, because it will be worth more points in the exam. The student would therefore have a stronger motivation to remember this chapter than to remember others. Would this motivation to remember eventually affect the student's performance on the exam?

Previous research suggests that, although motivation might not enhance the total amount of information recalled (Ngaosuvan & Mäntylä, 2005; Nilsson, 1987), it does result in selective remembering – that is, better memory for information one is motivated to remember than for information that one is not, or less, motivated to remember (e.g., Castel et al., 2002; Halamish et al., 2019; Murphy & Castel, 2020). Previous research further suggests that motivation to remember elicits selective processing of the valuable information during encoding, which likely underlies its effect on remembering (Castel et al., 2013; Dickerson & Adcock, 2018; Dunlosky & Ariel, 2011). In the present research, we investigated whether motivation to remember similarly elicits selective processing of valuable information during retrieval, an issue that has been relatively underexplored so far.

Motivation to remember and selective remembering

The definition of motivation varies widely based on the field of research. For the current purpose, motivation can be thought of as the desire to achieve a goal that is shaped by the expected value of the goal and that elicits goal-directed behavior (Braver et al., 2014; Dickerson & Adcock, 2018). In the context of intentional learning and explicit remembering, the expected value of remembering may be extrinsically driven by the prospective rewards for remembering (e.g., getting a good grade on an exam) or intrinsically driven by curiosity about the materials or the mere challenge involved in

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remembering (Ryan & Deci, 2000). Hereafter, we focus on motivation to remember that is elicited by prospective extrinsic rewards, but we return to potential implications for intrinsic motivation in the *General discussion* section. Regardless of its origin (extrinsic or intrinsic), the level of motivation to remember (i.e., how strong it is) is expected to affect the cognitive processes involved in learning and, potentially, remembering, and hence, the ultimate memory performance.

Motivation to remember can either be present during encoding or it may only be present later during retrieval (Kassam et al., 2009). For example, while studying for a final exam, a student might realize that some materials will be worth more points on the exam than others, or they may only find this out when taking the exam. It is well documented that motivation to remember certain pieces of information that is present at encoding yields selective remembering of that information (e.g., Adcock et al., 2006; Ariel et al., 2009; Castel, 2008; Castel et al., 2002; Castel et al., 2011; Castel et al., 2013; Dickerson & Adcock, 2018; Eysenck & Eysenck, 1982; Halamish et al., 2019; Hennessee et al., 2018; Kassam et al., 2009; Loftus, 1972; Loftus & Wickens, 1970; Schwartz et al., 2020; Villaseñor et al., 2021; Weiner, 1966, 1967). In studies that have demonstrated this effect, the participants were usually asked to study a list of items for a subsequent memory test. Motivation was manipulated by assigning a point value (e.g., Castel et al., 2002), a prospective monetary reward (e.g., Halamish et al., 2019), or a percentage likelihood that the item would be tested (e.g., Ariel et al., 2009) for each item studied. The results consistently demonstrated that participants selectively recalled more high-point-value items, large reward items, and high likelihood items than low-point-value items, small reward items, and low likelihood items, respectively. In contrast, motivation to remember certain information that is absent at encoding but is later introduced during the retrieval attempt usually fails to yield selective remembering (Kassam et al., 2009; Wasserman et al., 1968; Weiner, 1966; but see Loftus & Wickens, 1970).

Selective encoding processes

What mechanisms underlie the effect of motivation on selective remembering? Some evidence suggests that motivation to remember might affect memory by dopaminergic modulation of hippocampal activity that promotes memory consolidation (e.g., Adcock et al., 2006; Murayama & Kitagami, 2014). Beyond these automatic mechanisms, people may strategically encode and retrieve valuable information and less-valuable information differently (Hennessee et al., 2019), presumably in a way that they believe will enhance their memory for that information. If they regulate their learning and remembering effectively, then motivation to remember will enhance memory.

Indeed, previous research and theory have suggested that a stronger motivation to remember some information than other information (i.e., within-participants manipulations of motivation) results in selective processing of the information during encoding (e.g., the agenda-based regulation framework – Dunlosky & Ariel, 2011; the value-directed remembering framework – Castel et al., 2013). When learners self-regulate their learning, they tend to allocate more study time to information that they are more motivated to remember and they restudy it more often (e.g., Ariel et al., 2009; Castel et al., 2013; Halamish et al., 2019; Koriat et al., 2006). They also tend to study valuable information at the beginning of the study phase, before they study less valuable information, and they sometimes also restudy these items again toward the end of the study phase to enjoy the benefits of primacy and recency, respectively (e.g., Ariel & Dunlosky, 2013; Castel et al., 2013; Cohen et al., 2013). Of course, rememberers may also use qualitatively different encoding strategies for valuable and less valuable information – for example, by processing the valuable information more deeply than the less valuable information (e.g., Cohen et al., 2014; Hennessee et al., 2019)– but this control over study strategy is beyond the scope of the current research and will not be discussed further.

Selective retrieval processes

Does motivation to remember also yield selective processing during retrieval? Evidence suggests that rememberers can control various aspects of retrieval by constraining up-front the information that comes to mind during a memory search or by constraining the report of the retrieved information at the back end (Halamish et al., 2012; Jacoby, Shimizu, Velanova, & Rhodes, 2005b; Koriat et al., 2008). When confronted with a memory query, people initially decide whether to initiate or forgo a memory search based on their preliminary feeling of knowing (Glucksberg & McCloskey, 1981; Reder, 1987). If they initiate a search, rememberers can then control how long to continue searching before quitting (e.g., Malmberg, 2008). When allowed to, rememberers can also control the order in which they recall a list of items (Bhatarah et al., 2008; Klein et al., 2005). Moreover, rememberers can control the strategy that they use to search their memory (Williams & Hollan, 1981). Young adults, for example, control the depth in which they process retrieval cues and tend to reinstate the encoding operations at test (Halamish et al., 2012; Jacoby, Shimizu, Daniels, & Rhodes, 2005a; Jacoby, Shimizu, Velanova, & Rhodes, 2005b; Shimizu & Jacoby, 2005). After information has been retrieved from memory, rememberers can control whether and how to report it by withholding retrieved information that they are not confident about (e.g., Bulevich & Thomas, 2012; Koriat & Goldsmith, 1996; Postma, 1999) or by controlling the level of precision or coarseness (grain size) in which they report that information (e.g., Goldsmith et al., 2002, 2005; Weber & Brewer, 2008).

Although evidence suggests that rememberers can exert control over retrieval, relatively little is known about whether and how motivation to remember affects controlled retrieval processes. Prior research has mainly demonstrated that motivation affects control over memory reporting. Koriat and Goldsmith (1996), for example, demonstrated that when the payoff schedule prioritized memory accuracy over quantity, rememberers adopted a stricter report criterion and withheld more of the retrieved information, thereby improving memory accuracy at the cost of memory quantity. Another relevant line of research suggests that motivation to respond accurately on a memory test, induced through direct instructions (Bulevich & Thomas, 2012) or age-related stereotype threat (Thomas et al., 2020; for a review, see Mazerolle et al., 2021), may improve controlled withholding of retrieved information and, consequently, memory accuracy.

Importantly, whether and how motivation affects controlled retrieval processes beyond reporting has yet to be explored. Interestingly, the evidence that motivation to remember that is introduced only at retrieval does not result in selective remembering (Kassam et al., 2009; Wasserman et al., 1968; Weiner, 1966) implies either that motivation at retrieval does not elicit selective retrieval processes or that it elicits ineffective selective retrieval processes. More evidence is needed to distinguish between these two explanations.

In the current research, we therefore examined whether incentive-based motivation elicits selective retrieval processes on a cued-recall test. We focused on three potential processes through which learners may enhance the retrieval of valuable information on a self-regulated cued-recall test, which echo the previously investigated motivation-based selective encoding processes. First, rememberers might selectively allocate more test time to the valuable information, which has the potential to enhance the amount of information that is successfully retrieved (Roediger & Thorpe, 1978). Indeed, initial evidence suggests that rememberers take longer to answer items that are associated with a higher incentive at testing (Barnes et al., 1999; Loftus & Wickens, 1970). Second, rememberers might repeatedly retest themselves on the valuable information, more than on the less valuable information. For example, after initially answering all the questions in an exam, students may be more likely to go back to questions that are worth more points and try to re-answer them or revisit their answers. Third, rememberers might selectively control test order. They might start the test by answering the more valuable questions, which will make the retention interval shorter and reduce output interference for these items (Roediger & Schmidt, 1980). They might also return to these questions at the end, right before ending the test, and then benefit from context reinstatement elicited by the earlier items (Howard & Kahana, 2002).

The present research

To sum up, it is well established that selective motivation to remember certain information results in selective remembering of that information, and that it yields selective encoding processes. However, less is known about the effect of motivation to remember on selective retrieval processes. We aimed to fill this gap by systematically investigating the effect of incentive-based motivation on selective processing during encoding and retrieval. Figure 1 presents a schematic description of the potential selective encoding and retrieval processes examined. Consistent with prior evidence, we hypothesized that selective motivation to remember during self-regulated learning would yield selective encoding processes. Specifically, we examined whether learners would allocate more study time to the valuable information, restudy it more often, and control study order by starting or ending the study phase with that information. Similarly, we hypothesized that when self-regulating remembering, selective motivation to remember would yield selective retrieval processes. Specifically, we examined whether rememberers would allocate more test time to the valuable information, retest themselves on that information more often, and control test order by either starting or ending the test phase with that information.

We conducted two experiments to investigate motivation-based selective encoding and retrieval processes in the context of an associative memory task, using the same general methodology. The design (see Fig. 2) followed that used by Kassam et al. (2009). Participants studied information concerning six individuals for a later memory test. To examine the effect of motivation to remember, we manipulated the incentives for remembering information related to one of the individuals (hereafter, the target). Prior to the study phase, participants in the no-motivation-to-remember(MTR-N) condition were informed that they would be rewarded 1 point for each fact remembered about each individual. Participants in the motivation-to-remember-at-encoding(MTR-E) condition were offered the same incentives, and, in addition, an extra bonus (i.e., 6 points) for each fact recalled about the target. In an attempt to make selective retrieval processes more salient, and following Kassam et al. (2009), we also included a motivation-to-remember-at-retrieval(MTR-R) condition, in which participants were informed about the extra bonus only just prior to the test.

A unique aspect of our methodology was that participants controlled various aspects of encoding and retrieval in a relatively naturalistic manner. During the study phase, participants self-regulated their learning by deciding how to allocate study time for the different items, whether to go back and

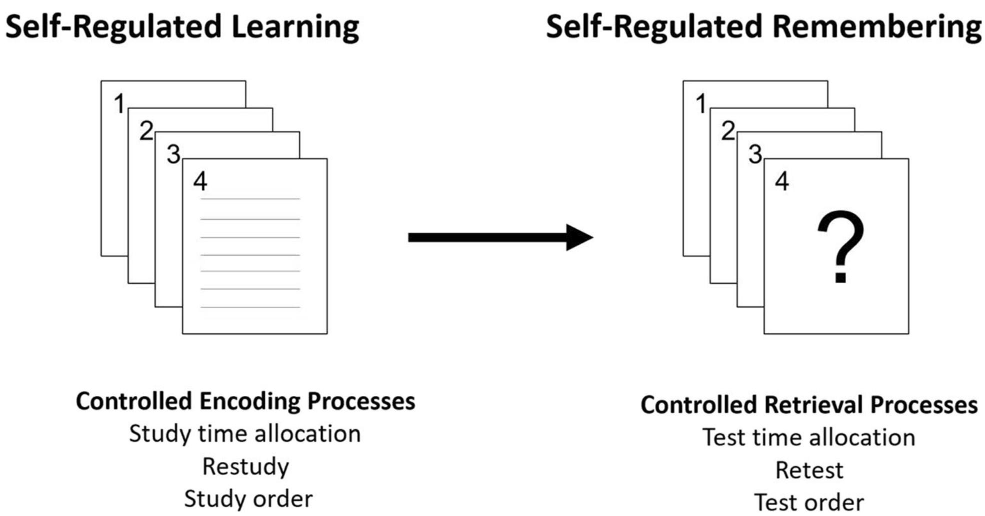

Fig. 1 Potential selective encoding and retrieval processes during self-regulated learning and remembering examined in the current research

restudy items, and in what order to study them (cf. Castel et al., 2013). During the test, participants self-regulated their testing by deciding how to allocate test time for the different items, whether to go back and retest themselves on items, and in what order to answer them. The decisions that the participants made during the study and the test were recorded and later analyzed. This procedure allowed us to simultaneously examine not only the effect of motivation to remember on memory performance but also the effect of motivation to remember on various selective encoding and retrieval processes.

Experiment 1

Method

Participants

In Experiment 1, we a priori decided to recruit 36 participants in each condition. Sensitivity analyzes conducted via G*Power 3 (Faul et al., 2007) with an alpha of .05 and a power of .80 suggested that this sample size would allow us to detect effects of $f = .30$ in analyses of variance (ANOVAs) with three independent groups (i.e., the MTR-E, MTR-R, and MTR-N conditions) or $d = .67$ in pairwise comparisons (two-tailed). These effect sizes are in the range of those obtained in relevant previous studies (Ariel et al., 2009; Castel et al., 2013). The participants were 108 native Hebrew-speaking university students (71 women; mean age = 23.71 years, *SD* = 3.14). They received a fixed payment for their participation and also a monetary performance-based bonus. Participants were randomly assigned to the MTR-E, MTR-R, and MTR-N conditions.

Materials

The materials were developed for the current study and were similar to those used by Kassam et al. (2009). The materials included photographs of six individuals (three males and three females), ostensibly taken from a high-school yearbook. One of the individuals (female) served as the target for all of the participants. The photographs were taken from *pics.stir.ac.uk*.

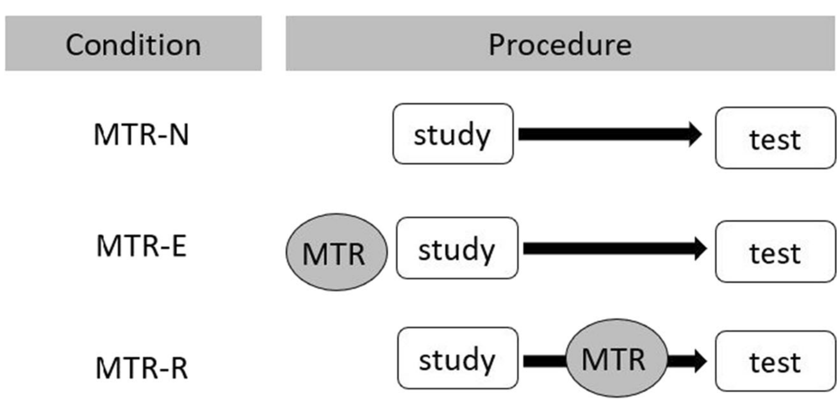

Fig. 2 Schematic representation of the procedure used in Experiments 1 and 2 by condition. *MTR* motivation to remember

Each photograph was accompanied by a full name and three short facts in Hebrew (e.g., "has an identical twin brother," "plays guitar").

Procedure

The procedure included a study phase and a test phase that followed a *self-regulated study-and-test paradigm* developed for the current research. During the study phase, participants were given 1 min to memorize the information for a later memory test. The six photographs were presented on a computer screen simultaneously in two columns of three photographs each during the entire study phase. A countdown timer appeared at the top. Participants had to click on a photograph to see the information related to that individual, which then appeared next to the photograph. They could only see information related to one individual at a time. In particular, when first clicking a photograph, the related information appeared next to it; when clicking another photograph, the information related to that photograph appeared and the information related to the earlier photograph disappeared, and so on. Participants were free to click on the photographs in any order they wanted, and they were able to go back and forth between the photographs as much as they wanted within the given time frame. The experimental program recorded the position and timing of the participant's clicks.

The test phase began after a short 10-s break. The six photographs were again presented on the computer screen simultaneously in two columns of three photographs each during the entire test phase. Participants were instructed to recall the information related to each photograph. They were asked to click a photograph before trying to recall the information related to it, and it was stressed that it was important to refrain from trying to recall information related to a photograph without clicking on it.

Upon clicking on a photograph, four empty fields labeled "name," "fact 1," "fact 2," and "fact 3" appeared next to it, in which the participants could type any of the information that they remembered. They could type information related to only one individual at a time. When first clicking a photograph, they were able to type information related to it; this information was hidden when they clicked another photograph, where they were able to type information related to that second photograph, and so on. When clicking on a photograph for which information had already been typed in, that information reappeared on the screen and the participants were able to modify or add to it. As in the study phase, the participants were free to click on the photographs in any order that they wanted, and they were able to go back and forth between the photographs at will. The experimental program recorded the position and timing of the participant's clicks, as well as the typed-in information. There was no time limit for the test and the participants clicked a button labeled "I'm done, I want to finish the exam" when they wanted to end the test.

The position of the target photograph on the screen out of the six possible positions was orthogonally counterbalanced between participants in the study and test phases. This procedure resulted in 36 different versions of the task. The position of the other five photographs was randomized anew for each participant and phase.

Motivation was manipulated by the incentives offered for correct recall. Before the study phase, all participants were informed that they would be awarded 1 point for each item (name or fact) remembered about an individual, that their goal was to try to earn as many points as possible, and that the points would be converted to a monetary bonus payment at the end of the experiment. Prior to the study phase, participants in the MTR-E condition were further informed that there would be an extra reward for one of the individuals who would be marked by an asterisk during the study phase and that they would be awarded 6 points for each item recalled about this target individual. Participants in the MTR-R condition were only informed about the additional reward after the study phase and prior to the test. The asterisk appeared next to the target's photograph during the study phase for participants in the MTR-E condition, and during the test phase for participants in the MTR-R condition. No reference to an extra reward was given to participants in the MTR-N condition, and the target individual was not marked by an asterisk during either the study phase or the test phase for these participants. At the end of the experiment, the experimenter scored the test and the points earned were converted into a monetary bonus payment at the rate of .25 ILS per point (the conversion rate was unknown to the participants).

Results and discussion

Descriptive statistics by condition for Experiment 1 are presented in Fig. 3.

Recall

First, we examined recall in terms of the proportion of target information recalled and nontarget information recalled (averaged across the five nontargets). A 2 (item type: target/nontarget) × 3 (condition: MTR-E, MTR-R, MTR-N) mixed-design analysis of variance (ANOVA) yielded a significant interaction between item type and condition, $F(2, 105) = 17.99$, $p < .001$, $\eta_p^2 = .26$. In addition, it yielded a significant main effect of item type, $F(1, 105) = 12.68$, $p = .001$, $\eta_p^2 = .11$, suggesting that recall was better for targets ($M = .50$, $SD = .35$) than for nontargets ($M = .38$, $SD = .16$), and a significant main effect of condition, $F(2, 105) = 9.28$, $p < .001$.

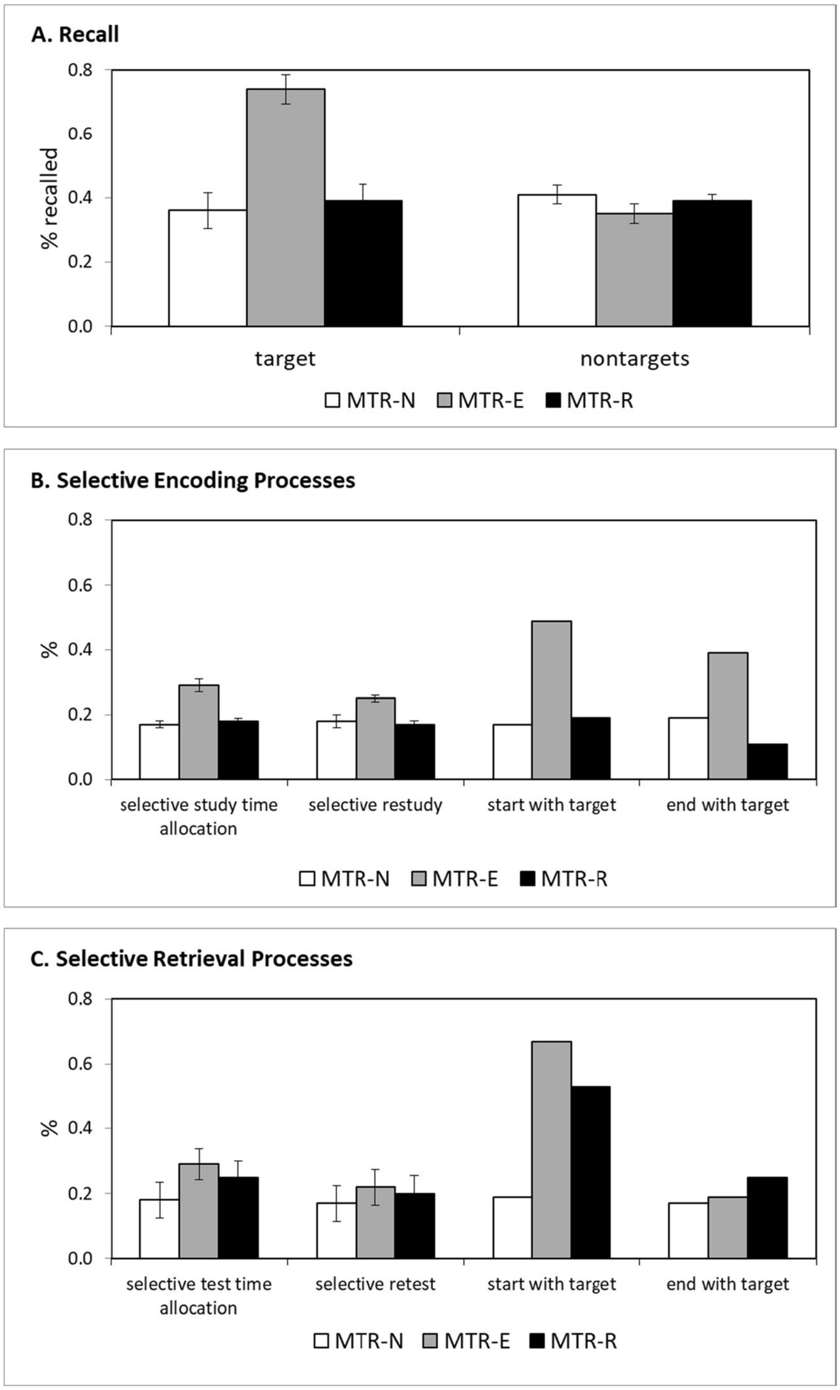

Fig. 3 Descriptive statistics for recall (**panel A**), selective encoding processes (**panel B**), and selective retrieval processes (**panel C**) by condition for Experiment 1. Error bars represent ±1 standard error of the mean

To interpret the interaction, we examined the effect of condition separately for targets and nontargets. For targets, one-way ANOVA revealed a significant effect of condition, $F(2, 105) = 16.96$, $p < .001$, $\eta_p^2 = .24$. Bonferroni-adjusted pairwise comparisons (using a .05 significance level in these and all subsequent Bonferroni-adjusted pairwise comparisons) suggested that participants recalled significantly more target information in the MTR-E condition ($M = .74$, $SD = .28$) than in the MTR-R ($M = .39$, $SD = .31$; $d = 1.18$) and the MTR-N ($M = .36$, $SD = .33$; $d = 1.25$) conditions, but there was no significant difference between the MTR-R and MTR-N conditions ($d = .09$). For nontargets, in contrast, one-way ANOVA suggested that the effect of the condition was not significant, $F(2, 105) = 1.15$, $p = .32$, $\eta_p^2 = .021$ (MTR-E: $M = .35$, $SD = .16$; MTR-R: $M = .39$, $SD = .15$; MTR-N: $M = .41$, $SD = .18$).

These findings suggest that, as expected, introducing motivation to remember at encoding enhanced recall for target information but introducing motivation to remember at retrieval did not. Furthermore, the benefit of motivation to remember at encoding did not come at a significant cost in recall for the nontarget information. Beyond the effect of motivation to remember on recall, of main interest in the current study was its effects on selective encoding and retrieval processes, which are now described in turn.

Selective encoding processes

Selective encoding processes during the study phase were examined in terms of selective allocation of study time, selective restudy decisions, and selective control over study order.

Selective study time allocation Selective allocation of study time was examined by computing, for each participant, the proportion of study time spent on the target. A one-way ANOVA conducted on this variable revealed a significant effect of condition, $F(2, 105) = 23.89$, $p < .001$, $\eta_p^2 = .31$. Bonferroni-adjusted pairwise comparisons suggested that participants spent significantly more time studying the target in the MTR-E condition ($M = .29$, $SD = .10$) than in the MTR-R ($M = .18$, $SD = .05$; $d = 1.39$) and the MTR-N ($M = .17$, $SD = .09$; $d = 1.26$) conditions, but there was no significant difference between the MTR-R and MTR-N conditions ($d = .14$).

In addition, one-sample t-tests revealed that in the MTR-E condition, the proportion of study time spent on the target (.29) was significantly higher than 1/6 (.17), $t(35) = 7.40$, $p < .001$, $d = 1.23$, suggesting that participants spent more time studying the target than would be expected if they had distributed study time equally among the six items. In contrast, the proportion of study time spent on the target was not significantly higher than 1/6 in the MTR-R and MTR-N conditions, $t(35) = 1.44$, $p = .160$, $d = .24$ and $t(35) = .30$, $p = .764$, $d = .05$, respectively. These findings suggest that MTR at encoding resulted in selective study time allocation for the target.

Selective restudy On average, participants made 12.70 ($SD = 4.45$) photograph clicks during the study phase, which suggests that they repeatedly studied at least some of the items. The effect of condition on total number of clicks was not significant, $F(2, 105) = .84$, $p = .433$, $\eta_p^2 = .02$. We were mainly interested in whether or not motivation to remember would lead to more selective restudy. Selective restudy was examined by computing, for each participant, the proportion of clicks on the target's photograph out of the total number of clicks on any of the photographs during the study phase. A one-way ANOVA conducted on this variable revealed a significant effect of condition, $F(2, 105) = 10.35$, $p < .001$, $\eta_p^2 = .17$. Bonferroni-adjusted pairwise comparisons suggested that the proportion of target clicks was significantly larger in the MTR-E condition ($M = .25$, $SD = .08$) than in the MTR-R ($M = .17$, $SD = .05$; $d = .61$) and the MTR-N ($M = .18$, $SD = .09$; $d = .49$) conditions, but there was no significant difference between the MTR-R and MTR-N conditions ($d = .14$).

In addition, one-sample t-tests revealed that in the MTR-E condition, the proportion of target clicks (.25) was significantly higher than 1/6 (.17), $t(35) = 5.71$, $p < .001$, $d = .95$, suggesting that it was larger than would be expected if participants had evenly clicked the six items. In contrast, the proportion of target clicks was not significantly higher than 1/6 in the MTR-R and MTR-N conditions, $t(35) = .76$, $p = .450$, $d = .13$ and $t(35) = .56$, $p = .576$, $d = .09$, respectively. These findings suggest that motivation to remember at encoding resulted in selective restudy of the target.

Selective control over study order We focused on two aspects of selective control over study order: the decision to start the study phase with the target and the decision to end the study phase with the target. A chi-square test of independence revealed a significant relationship between condition and the decision to start the study phase with the target, $\chi^2(2) = 10.25$, $p = .006$. Participants were more likely to start the study phase with the target in the MTR-E condition (.47) than in the MTR-R (.19; $\varphi = .29$, $p = .012$) and the MTR-N (.17; $\varphi = .33$, $p = .005$) conditions, but there was no difference between the MTR-R and MTR-N conditions ($\varphi = .04$, $p = .759$). In the MTR-E condition, the proportion of participants who started the study phase with the target was significantly greater than 1/6 according to a chi-square test for goodness of fit, $\chi^2(1) = 24.20$, $p < .001$, suggesting that it was greater than chance. In contrast, this proportion was not significantly different from 1/6 in the MTR-R and the MTR-N conditions, $\chi^2(1) = .20$, $p = .655$ and $\chi^2(1) = .00$, $p = 1.00$, respectively.

A second chi-square test of independence revealed a significant relationship between condition and the decision to end the study phase with the target, $\chi^2(2) = 8.22$, $p = .016$. Participants were more likely to end the study phase with the target in the MTR-E condition (.39) than in the MTR-R condition (.11; $\varphi = .32$, $p = .006$) and in the MTR-N condition (.19; $\varphi = .21$, $p = .070$), but there was no difference between the MTR-R and MTR-N conditions ($\varphi = .12$, $p = .326$). In the MTR-E condition, the proportion of participants who ended the study phase with the target was significantly greater than 1/6 according to a chi-square test for goodness of fit, $\chi^2(1) = 12.80$, $p < .001$, suggesting that it was greater than chance. In contrast, this proportion was not significantly different from 1/6 in the MTR-R and the MTR-N conditions, $\chi^2(1) = .80$, $p = .371$ and $\chi^2(1) = .20$, $p = .655$, respectively.

The results thus far suggested that motivation to remember at encoding elicited selective encoding processes. Participants who were motivated to remember the target selectively allocated more study time for the target than to the other items, restudied it more, and tended to both start and end the study phase with the target, compared to the participants who were not motivated to remember the target (in the MTR-R and the MTR-N conditions).

Selective retrieval processes

Selective retrieval processes during the test phase were examined in terms of selective allocation of test time, selective retest decisions, and selective control over test order.

Selective test-time allocation On average, participants spent 186.05 s (about 3 min; SD = 119.43) on the test, and the total test time was not affected by condition, $F(2, 105) = .98$, $p = .380$, $\eta_p^2 = .02$. Of interest was whether motivation to remember affected the selective allocation of test time. Selective allocation of test time to the target was examined by computing the proportion of test time spent on the target for each participant. A one-way ANOVA conducted on this variable revealed a significant effect of condition, $F(2, 105) = 4.74$, $p = .011$, $\eta_p^2 = .08$. Bonferroni-adjusted pairwise comparisons suggested that participants spent a significantly larger proportion of test time on the target in the MTR-E condition ($M = .29$, $SD = .16$) than in the MTR-N condition ($M = .18$, $SD = .11$, $d = .80$). The proportion of test time spent on the target in the MTR-R condition was intermediate ($M = .25$, $SD = .18$), and did not significantly differ from either the MTR-E ($d = .22$) or the MTR-N condition ($d = .47$).

In addition, one-sample t-tests revealed that the proportion of test time spent on the target was significantly higher than 1/6 (.17) in both the MTR-E and MTR-R conditions, $t(35) = 4.62$, $p < .001$, $d = .77$ and $t(35) = 2.84$, $p = .007$, $d = .47$, respectively, which suggests that participants spent more test time on the target than would have been expected if they had distributed test time equally among the six items. In contrast, the proportion of test time spent on the target was not significantly different from 1/6 in the MTR-N condition, $t(35) = .78$, $p = .443$, $d = .13$. These analyses suggest that motivation to remember resulted in selective test-time allocation to the target.

Selective retest On average, participants made 20.69 (SD = 15.55) photograph clicks during the test phase, and the effect of condition on total number of clicks was not significant, $F(2, 105) = 2.72$, $p = .071$, $\eta_p^2 = .05$. Of interest was whether motivation to remember affected the selective retest decisions in terms of whether participants were more likely to retest themselves on the target than on other items. Selective retest was examined by computing the proportion of clicks on the target's photograph out of the total number of clicks on any of the photographs during the test phase for each participant. A one-way ANOVA conducted on this variable did not yield a significant effect of condition, $F(2,105) = 1.29$, $p = .279$, $\eta_p^2 = .02$. Nevertheless, one-sample t-tests revealed that the proportion of target clicks during the test was significantly higher than 1/6 in the MTR-E condition ($M = .22$, $SD = .13$), $t(35) = 2.55$, $p = .015$, $d = .42$, but not in the MTR-R ($M = .20$, $SD = .16$) and the MTR-N ($M = .17$, $SD = .09$) conditions, $t(35) = 1.17$, $p = .249$, $d = .20$ and $t(35) = .47$, $p = .644$, $d = .08$.

Selective control over test order We focused on two aspects of selective control over test order: the decision to start the test phase with the target and the decision to end the test phase with the target. A chi-square test of independence revealed a significant relationship between condition and the decision to start the test phase with the target, $\chi^2(2) = 17.06$, p < .001. Participants were more likely to start the test phase with the target in the MTR-E condition (.67) than in the MTR-N condition (.19; $\varphi = .48$, $p < .001$), and in the MTR-R condition (.53) than in the MTR-N condition ($\varphi = .35$, $p = .003$), but there was no significant difference between the MTR-E and MTR-R conditions ($\varphi = .14$, $p = .230$). According to a chi-square test for goodness of fit, the proportion of participants who started the test phase with the target was significantly greater than 1/6 in the MTR-E condition, $\chi^2(1) = 64.80$, $p < .001$, and in the MTR-R condition, $\chi^2(1) = 33.80$, $p < .001$, but not in the MTR-N condition, $\chi^2(1) = .20$, $p = .655$.

In contrast, there was no significant relationship between condition and the decision to end the test phase with the target, $\chi^2(2) = .80$, $p = .671$. Furthermore, according to a chi-square test for goodness of fit, the proportion of participants who ended the test phase with the target was not significantly different from 1/6 in the MTR-E (.19), $\chi^2(1) = .20$, $p = .655$, the MTR-R condition (.25), $\chi^2(1) = 1.80$, $p = .180$, or the MTR-N condition (.17), $\chi^2(1) = .00$, $p = 1.00$. Therefore, motivation to remember at both encoding and retrieval elicited selective control over test order in terms of starting the test phase with the target but not in terms of ending the test phase with the target.

In summary, these results suggest that motivation to remember elicited selective retrieval processes in terms of test time allocation and control over test order but did not elicit selective retesting. Participants who were motivated to remember the target selectively allocated more test time to queries about the target and tended more to start the test by answering queries about the target than participants who were not motivated to remember the target.

Experiment 2

The results of Experiment 1 suggested that introducing motivation to remember at encoding enhanced recall for target information and elicited selective encoding and retrieval processes. Introducing motivation to remember at retrieval also elicited some selective retrieval processes (but obviously, not selective encoding processes), although these processes did not ultimately enhance recall. Experiment 2 was designed as a conceptual replication and extension of Experiment 1, for the sake of generalizability. Whereas Experiment 1 was conducted in the laboratory with Israeli participants using Hebrew materials, Experiment 2 was conducted online, with participants from the USA, using materials in English. In addition, the manipulation of motivation in Experiment 2 was somewhat weaker than in Experiment 1 because participants were not offered monetary bonus payments based on the points awarded for correct recall, and we were interested in whether it would nevertheless yield selective encoding and retrieval processes.

Method

Participants

Based on the effect sizes of the key findings of Experiment 1 (for recall, selective study time allocation, and selective test time allocation), a priori sample size calculations, using G*Power 3 (Faul et al., 2007) with a power of .80 and alpha of .05, suggested a required sample size of up to 36 participants per condition. Given that we expected greater variance when running the task online and because we planned to exclude participants based on a post-experiment questionnaire, we aimed to recruit about 60 participants per condition.

We recruited 179 participants via Prolific (www.prolific.co). Participants were pre-screened using Prolific's demographic filters to be 18- to 30-year-old native-English-speaking students from the USA. They were paid £2.10 for completing the experiment. Participants were randomly assigned to the MTR-E, MTR-R, and MTR-N conditions. We excluded 24 participants who reported in a post-experiment questionnaire that they had participated in a similar experiment before, were multitasking, or had technical problems, and one more participant who skipped the test. The final sample included 154 participants (69 women; mean age = 22.88 years, *SD* = 3.55), with 47–55 participants per condition.

Materials and procedure

The materials were similar to those used in Experiment 1, except that they included different photographs and facts in English (e.g., "She enjoyed playing sports with her friends," "He helped organize the tropical-themed senior prom"), which were taken from Kassam et al. (2009) with minor modifications. The procedure was identical to the procedure for Experiment 1, except that the experiment was conducted online, and the points earned were not converted to a monetary bonus payment.

Results

Descriptive statistics by condition for Experiment 2 are presented in Fig. 4. To preview, the results of Experiment 2 largely replicate the results of Experiment 1.

Recall

A 2 (item type: target/nontarget) × 3 (condition: MTR-E, MTR-R, MTR-N) mixed-design ANOVA on the proportion of information recalled yielded a significant interaction between item type and condition, $F(2, 151) = 16.63$, $p < .001$, $\eta_p^2 = .18$; a significant main effect of condition, $F(2, 151) = 4.07$, $p = .019$, $\eta_p^2 = .05$; but no significant main effect of item type, $F(1, 151) = 3.00$, $p = .085$, $\eta_p^2 = .02$.

To interpret the interaction, we examined the effect of condition separately for targets and nontargets. For targets, a one-way ANOVA revealed a significant effect of condition, $F(2, 151) = 10.51$, $p < .001$, $\eta_p^2 = .12$. Bonferroni-adjusted pairwise comparisons suggested that participants recalled significantly more target information in the MTR-E condition (*M* = .53, *SD* = .34) than in the MTR-R (*M* = .28, *SD* = .32; *d* = .75) and the MTR-N (*M* = .30, *SD* = .26; *d* = .76) conditions, but there was no significant difference in recall between the MTR-R and MTR-N conditions (*d* =.06). In contrast, for nontargets, a one-way ANOVA suggested that the effect of condition was not significant, $F(2, 151) = .79$, $p = .455$, $\eta_p^2 = .01$ (MTR-E: *M* = .30, *SD* = .18; MTR-R: *M* = .34, *SD* = .20; MTR-N: *M* = .34, *SD* = .16). Replicating the results of Experiment 1, these results suggest that introducing motivation to remember at encoding enhanced recall for target information with no significant cost in recall for the nontarget information, whereas introducing motivation to remember at retrieval did not.

Selective encoding processes

Selective study time allocation A one-way ANOVA conducted on the proportion of study time spent on the target revealed a significant effect of condition, $F(2, 151) = 18.76$, $p < .001$, $\eta_p^2 = .20$. Bonferroni-adjusted pairwise comparisons suggested that participants spent significantly more time studying the target in the MTR-E condition (*M* = .27, *SD* = .17) than in the MTR-R (*M* =.15, *SD* = .07; *d* =.94) and the MTR-N (*M* = .15, *SD* = .09; *d* =.92) conditions, but there was no significant difference in study time allocation between the MTR-R and MTR-N conditions (*d* =.03).

In addition, one-sample t-tests revealed that in the MTR-E condition, the proportion of study time spent on the target (.27) was significantly higher than 1/6 (.17),

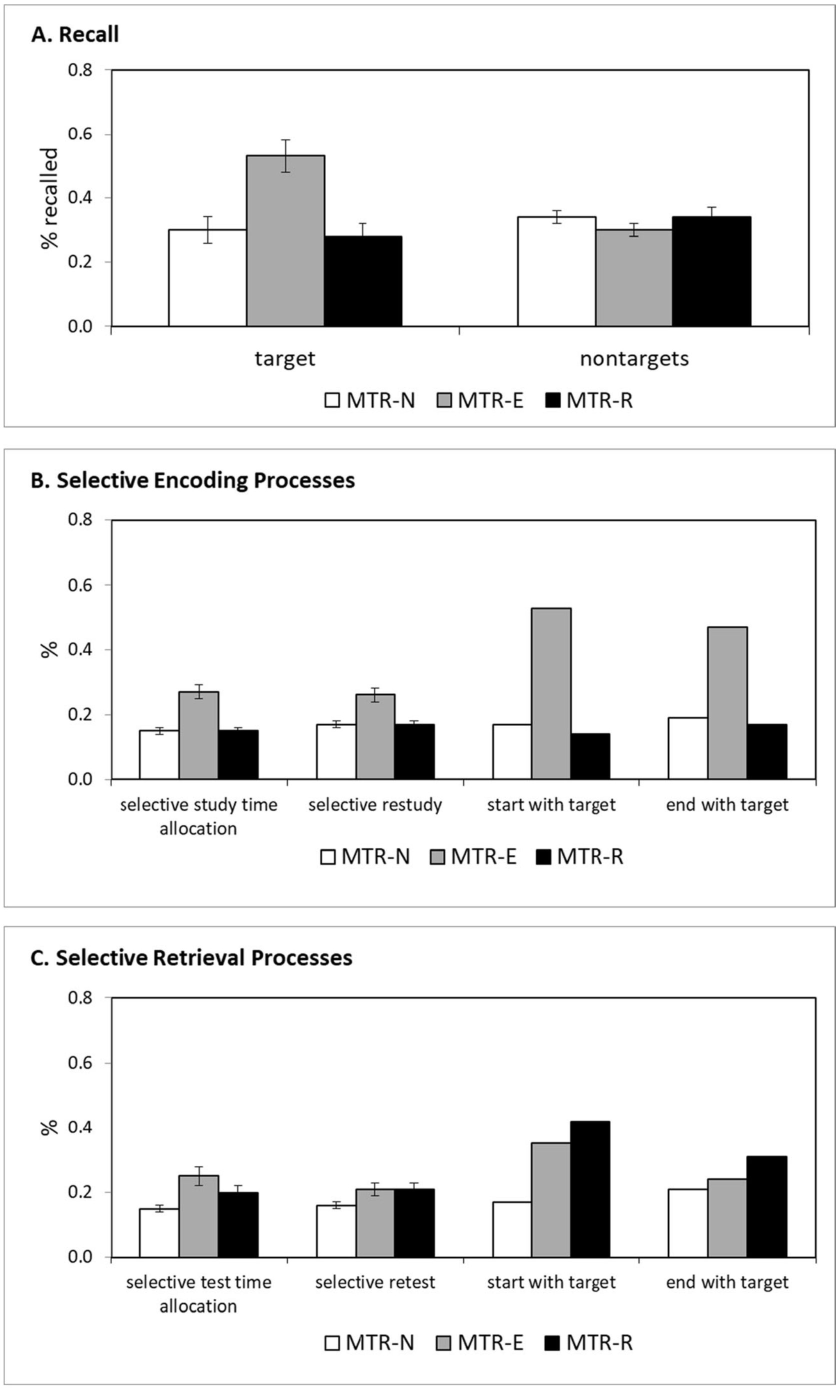

Fig. 4 Descriptive statistics for recall (**panel A**), selective encoding processes (**panel B**), and selective retrieval processes (**panel C**) by condition for Experiment 2. Error bars represent ±1 standard error of the mean

$t(54) = 4.79$, $p < .001$, $d = .65$, which suggests that participants spent more time studying the target than would be expected if they had distributed study time equally among the six items. In contrast, the proportion of study time spent on the target was not significantly higher than 1/6 in the MTR-R and MTR-N conditions, $t(51) = -1.30$, $p = .198$, $d = .18$ and $t(46) = 1.15$, $p = .254$, $d = .17$, respectively. These findings suggest that motivation to remember at encoding resulted in selective study time allocation for the target.

Selective restudy On average, participants made 11.23 (SD = 4.80) photograph clicks during the study phase, which suggest that they repeatedly studied at least some of the items. The effect of condition on total number of clicks was not significant, $F(2, 151) = .78$, $p = .452$, $\eta_p^2 = .01$. A one-way ANOVA conducted on the decision to selectively restudy the target (calculated as in Experiment 1) revealed a significant effect of condition, $F(2, 151) = 14.69$, $p < .001$, $\eta_p^2 = .16$. Bonferroni-adjusted pairwise comparisons suggested that the proportion of target clicks was significantly larger in the MTR-E condition ($M = .26$, $SD = .15$) than in the MTR-R ($M = .17$, $SD = .06$; $d = .82$) and the MTR-N ($M = .17$, $SD = .06$; $d = .81$) conditions, but there was no significant difference between the MTR-R and MTR-N conditions ($d < .01$).

In addition, one-sample t-tests revealed that in the MTR-E condition, the proportion of target clicks (.26) was significantly higher than 1/6 (.17), $t(54) = 4.77$, $p < .001$, $d = .64$, which suggests that the proportion of target clicks was larger than would be expected if they had evenly clicked the six items. In contrast, the proportion of target clicks was not significantly higher than 1/6 in the MTR-R and MTR-N conditions, $t(51) = .21$, $p = .835$, $d = .03$ and $t(46) = .23$, $p = .823$, $d = .03$, respectively. These findings suggest that motivation to remember at encoding resulted in selective restudy of the target.

Selective control over study order A chi-square test of independence revealed a significant relationship between condition and the decision to start the study phase with the target, $\chi^2(2) = 24.62$, $p < .001$. Participants were more likely to start the study phase with the target in the MTR-E condition (.53) than in the MTR-R condition (.14; $\varphi = .42$, $p < .001$) and MTR-N condition (.17; $\varphi = .37$, $p < .001$), but there was no significant difference between the MTR-R and the MTR-N conditions ($\varphi = .05$, $p = .622$). In the MTR-E condition, the proportion of participants who started the study phase with the target was significantly greater than 1/6, according to a chi-square test for goodness of fit, $\chi^2(1) = 51.46$, $p < .001$, suggesting that this was greater than chance. In contrast, this proportion was not significantly different from 1/6 in the MTR-R and the MTR-N conditions, $\chi^2(1) = .39$, $p = .534$ and $\chi^2(1) < .01$, $p = .947$, respectively.

The analysis also revealed a significant relationship between condition and the decision to end the study phase with the target, $\chi^2(2) = 14.70$, $p = .001$. Participants were more likely to end the study phase with the target in the MTR-E condition (.47) than in the MTR-R condition (.17; $\varphi = .32$, $p = .001$) and MTR-N condition (.19; $\varphi = .30$, $p = .003$), but there was no difference between the MTR-R and MTR-N conditions ($\varphi = .15$, $p = .813$). In the MTR-E condition, the proportion of participants who ended the study phase with the target was significantly greater than 1/6, according to a chi-square test for goodness of fit, $\chi^2(1) = 37.07$, $p < .001$, suggesting that this was greater than chance. In contrast, this proportion was not significantly different from 1/6 in the MTR-R and the MTR-N conditions, $\chi^2(1) = .02$, $p = .902$ and $\chi^2(1) = .02$, $p = .647$, respectively.

In summary, these results suggested the motivation to remember at encoding elicited selective encoding processes in terms of selective allocation of study time, selective restudy, and selective control over study order, which replicates the results of Experiment 1.

Selective retrieval processes

Selective test-time allocation On average, participants spent 119.91 s (about 2 min; $SD = 74.03$) on the test. There was a significant effect of condition on total test time, $F(2, 151) = 3.22$, $p = .043$, $\eta_p^2 = .04$, but Bonferroni-adjusted pairwise comparisons suggested that none of the comparisons were statistically significant ($p > .05$; MTR-E: $M = 111.02$, $SD = 61.62$; MTR-R: $M = 140.70$, $SD = 96.73$; MTR-N: $M = 107.31$, $SD = 51.53$).

A one-way ANOVA conducted on selective allocation of test time (the proportion of test time spent on the target out of the total test time) yielded a significant effect of condition, $F(2, 151) = 4.67$, $p = .011$, $\eta_p^2 = .06$. Bonferroni-adjusted pairwise comparisons suggested that participants spent a significantly larger proportion of test time on the target in the MTR-E condition ($M = .24$, $SD = .20$) than in the MTR-N condition ($M = .15$, $SD = .09$, $d = .62$). The proportion of test time spent on the target in the MTR-R condition was intermediate ($M = .20$, $SD = .16$), and did not significantly differ from either the MTR-E condition ($d = .25$) or the MTR-N condition ($d = .40$).

In addition, one-sample t-tests revealed that the proportion of test time spent on the target was significantly higher than 1/6 (.17) in the MTR-E condition, $t(54) = 2.85$, $p = .006$, $d = .38$, suggesting that participants spent more test time on the target than would be expected if they had distributed test time equally among the six items. In contrast, the proportion of test time spent on the target was not significantly different from 1/6 in the MTR-R condition $t(51) = 1.46$, $p = .152$, $d = .20$ (note that, in Experiment 1, this effect was significant), or in the MTR-N condition, $t(46) = 1.52$, $p = .137$, $d = .22$. These analyses suggest that motivation to remember at encoding resulted in selective test time allocation for the target, but motivation to remember at retrieval did not.

Selective retest On average, participants made 10.55 ($SD = 6.66$) photograph clicks during the test phase, and the effect of condition on total number of clicks was not significant, $F(2, 151) = 1.89$, $p = .155$, $\eta_p^2 = .02$. A one-way ANOVA conducted on selective retesting (calculated as in Experiment 1) did not yield a significant effect of condition, $F(2, 151) = 1.95$, $p = .146$, $\eta_p^2 = .03$. However, one-sample t-tests revealed that the proportion of target clicks during the test was significantly higher than 1/6 in the MTR-R condition ($M = .21$, $SD = .14$), $t(51) = 2.32$, $p = .024$, $d = .32$, but not in the MTR-E condition ($M = .21$, $SD = .18$), $t(54) = 1.72$, $p = .09$, $d = .23$, or in the MTR-N condition ($M = .16$, $SD = .07$), $t(46) = .46$, $p = .646$, $d = .07$.

Selective control over test order A chi-square test of independence revealed a significant relationship between condition and the decision to start the test phase with the target, $\chi^2(2) = 7.57$, $p = .023$. Participants were more likely to start the test phase with the target in the MTR-E condition (.35) than in the MTR-N condition (.17; $\varphi = .20$, $p = .046$), and in the MTR-R condition (.42) than in the MTR-N condition ($\varphi = .28$, $p = .006$), but there was no significant difference between the MTR-E and MTR-R conditions ($\varphi = .08$, $p = .409$). According to a chi-square test for goodness of fit, the proportion of participants who started the test phase with the target was significantly greater than 1/6 in the MTR-E condition, $\chi^2(1) = 12.65$, $p < .001$, and in the MTR-R condition, $\chi^2(1) = 24.60$, $p < .001$, but not in the MTR-N condition, $\chi^2(1) <.00$, $p = .947$

In contrast, there was no significant relationship between condition and the decision to end the test phase with the target, $\chi^2(2) =1.31$, $p = .521$. However, according to a chi-square test for goodness of fit, the proportion of participants who ended the test phase with the target was significantly different from 1/6 in the MTR-R condition (.31), $\chi^2(1) = 7.44$, $p = .006$ (note that in Experiment 1, this effect was not significant), but not in the MTR-E (.24), $\chi^2(1) =1.92$, $p = .166$ or in the MTR-N condition (.21), $\chi^2(1) =.72$, $p = .396$.

In summary, the results of Experiment 2 converge with the results of Experiment 1 and provide evidence that motivation to remember elicited selective retrieval processes. An exploratory analysis that examined the correlations between the research variables is reported in the Online Supplementary Material.

General discussion

The present research examined whether and how rememberers selectively process information that they are motivated to remember when they can freely self-regulate their learning and remembering, as they often do in real life. Of main interest was the effect of incentive-based motivation on selective processing during retrieval on a cued-recall test, in addition to the previously reported effects on selective processing during encoding. Two experiments were conducted that used the same design and procedure in different settings. The results of the two experiments, which are schematically presented in Table 1, were overwhelmingly consistent and are therefore discussed together.

Motivation to remember the target information that was present during encoding enhanced memory for that information on the cued-recall test, compared to a condition in which no such motivation was present. Consistent with previous research, this finding suggests that motivation enhanced the binding of the photographs and the related information (e.g., Ariel et al., 2009; Halamish et al., 2019; Hennessee et al., 2018; Kassam et al., 2009; Schwartz et al., 2020; Villaseñor et al., 2021). Furthermore, motivation to remember at encoding elicited selective encoding processes. Participants who were motivated to remember the target information allocated more study time to the target, restudied it more frequently, and tended to both start and end the study phase with the target more than participants who were not motivated to remember the target information.

Importantly, the results also provided novel evidence for selective retrieval processes during a cued-recall test elicited by motivation to remember. Participants who were motivated to remember the target information during encoding allocated more test time to the target and tended to start the test with the target. The motivation to remember present during encoding thus led to selective processing not only during encoding but also during retrieval. However, motivation to remember during encoding did not elicit selective retesting, and participants did not tend to end the test phase with the target.

When motivation to remember the target information was evoked only at retrieval, it also elicited some selective processing: it increased the tendency to start answering the test with the target, but it did not elicit selective allocation of test time or selective retesting. The increased tendency to start the test with the target following motivation at retrieval, however, was clearly ineffective, as it did not ultimately enhance memory for the target information, consistent with previous research (e.g., Kassam et al., 2009).

Taken together, these results demonstrate that motivation to remember affects how rememberers approach and execute a memory search. Motivation to remember thus elicits selective processing at the front end of retrieval (Halamish et al., 2012), beyond the previously demonstrated motivation-based selective processing at the back end, during memory reporting (e.g., Bulevich & Thomas, 2012; Koriat & Goldsmith, 1996; Thomas et al., 2020).

A unique aspect of the current research was that it used a novel *self-regulated study-and-test* paradigm in which participants were free to self-regulate both learning and remembering, as they often do in real-life situations, and their control decisions during study and test were recorded and analyzed. Such self-regulated procedures are commonly used during study to examine self-regulated learning, and specifically have been used to examine motivation-based selective encoding processes (e.g., Castel et al., 2013; Hennessee et al., 2019). In the current research, we extended this procedure to the test phase to examine self-regulation during a cued-recall test and to find whether and how this self-regulation is affected by motivation. This paradigm might be useful in future investigations of the processes involved in self-regulated testing and remembering that are relatively underexplored.

An underlying assumption of the current research was that rememberers engage in selective processes that they believe will enhance their memory for the information they are

Table 1 Schematic representation of the results*

Variable	MTR-E	MTR-R
Recall		
Recall – target	+	−
Recall – non-targets	−	−
Selective encoding processes		
Selective study time allocation	+	
Selective restudy	+	
Selective control over study order – start with target	+	
Selective control over study order – end with target	+	
Selective retrieval processes		
Selective test time allocation	+	−
% Selective retest	−	−
Selective control over test order – start with target	+	+
Selective control over test order – end with target	−	−

*The table presents whether there was (+) or was not (−) a significant effect of motivation (compared to the MTR-N condition) on each of the dependent variables, separately for the MTR-E and MTR-R conditions. This representation is valid for both Experiment 1 and Experiment 2

motivated to remember. The decisions that they make during encoding and retrieval therefore implicitly reveal their metacognitive beliefs about selective processing. The fact that the self-regulatedstudy-and-test paradigm gives insight into metacognition without asking participants to report their metacognitive thoughts explicitly is an important strength of this paradigm, given the recent evidence for reactivity of explicit metacognitive reports (e.g., Double & Birney, 2019; Halamish, 2018; Soderstrom et al., 2015). The results of the present research suggest, for example, that rememberers tend to believe that starting the test phase by answering queries about the valuable information will increase their ability to answer these queries correctly, but that ending the test phase with these queries will not. Of course, whether these beliefs are correct or not awaits future research in which the mnemonic benefit of each component of selective processing will be examined independently of the other components, as well as of rememberers' beliefs and choices.

The present research may have interesting practical implications. In the educational domain, the current research may be useful in identifying the effect of motivation on learning and test-taking and clarifying the ways in which students can enhance learning and test-taking to promote their goals. These goals might be extrinsically driven by prospective incentives as in the current research, but also intrinsically driven by curiosity or interest. When extending the results of the current research to intrinsic motivation, students can be expected to start answering a test with questions on materials that they find more interesting and invest more time in answering these questions.

One open question is whether there are individual differences in selective processing during a test and whether such differences are related to test scores (cf., Dent & Koenka, 2016). To do well on a school exam, for example, a student needs to know how to divide time between the different test questions, which questions to start with, and which questions to return to before submitting the exam. A related open question is whether interventions aimed at improving students' self-regulated learning and remembering could improve academic achievements. These questions await further research.

The present research has several limitations that should be acknowledged. First, the materials in the present study were relatively short and simple, and relatedly, study time was rather short. The effect of motivation to remember on selective retrieval processes remains to be examined with lengthier materials, such as educationally relevant texts and longer study sessions. Second, in the present paradigm and following Kassam et al. (2009), in the motivation conditions only a small proportion (1/6) of the studied materials was regarded as more valuable. Although we believe that this proportion reflects many real-life situations in which selective remembering is required, it might have made selective processing relatively easy. Future research could examine whether multiple selective encoding and retrieval processes would similarly emerge with more balanced proportions of valuable and less-valuable information.

Finally, it is interesting to note that in the present experiments, selective retrieval processes were observed not only when motivation was evoked at retrieval but also and even more so when it was evoked during encoding. Clearly, in the present experiments the motivation that was evoked during the study phase was still internally present during the test because it elicited selective retrieval processes. Future research could examine whether motivation to remember that is evoked at encoding decays over longer retention intervals to the extent that it would not elicit selective retrieval processes, or, alternatively, whether providing a reminder for the motivation to selectively remember some of the information during the test phase would have consequences for selective retrieval processes.

In summary, the results of the present research demonstrated that incentive-based motivation produces selective processing not only during encoding but also during retrieval, as rememberers allocate more test time to test queries about valuable information and tend to start the test by answering these queries. More generally, the current research demonstrates that by manipulating motivation and investigating self-regulated learning and remembering, research can advance our understanding of the intricate relationship between motivation, memory, and metacognition.

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