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Selectively Distracted: Divided Attention and Memory for Important Information

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Abstract

Distractions and multitasking are generally detrimental to learning and memory. Nevertheless, people often study while listening to music, sitting in noisy coffee shops, or intermittently checking their e-mail. The current experiments examined how distractions and divided attention influence one's ability to selectively remember valuable information. Participants studied lists of words that ranged in value from 1 to 10 points while completing a digit-detection task, while listening to music, or without distractions. Though participants recalled fewer words following digit detection than in the other conditions, there were no significant differences between conditions in terms of selectively remembering the most valuable words. Similar results were obtained across a variety of divided-attention tasks that stressed attention and working memory to different degrees, which suggests that people may compensate for divided-attention costs by selectively attending to the most valuable items and that factors that worsen memory do not necessarily impair the ability to selectively remember important information.

Keywords

memory, divided attention, value-directed remembering, selectivity, distractions

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The threat of distraction to learning and memory causes students to fill campus libraries to capacity at exam time, with many eschewing home comforts to maintain undivided attention while studying. Permanent sequestration in a hushed library is, however, plainly impossible, and even coveted study cubicles are breached by sounds of typing and whispered conversations. Moreover, there are many situations in which learners actively multitask despite the importance of later remembering presented information (Calderwood, Ackerman, & Conklin, 2014). The ubiquity of mobile devices has even led professors to dissuade or ban their use during lectures, citing the detrimental effects of multitasking—and the visibility of peers' laptop screens—on learning and comprehension (Fried, 2008; Sana, Weston, & Cepeda, 2013).

Costs of divided attention during encoding to memory are manifold (Castel & Craik, 2003; Craik, Govoni, Naveh-Benjamin, & Anderson, 1996; Naveh-Benjamin, Craik, Perretta, & Tonev, 2000), but the effect of divided attention on memory for important or valuable information, specifically, remains unclear. Does a student's exam performance hinge on a neighbor's radio preferences or the insatiable pull of a messaging app during studying? Or can learners mitigate divided-attention effects by selectively focusing on the most important information, even if some of the less important is lost? The cognitive demands of strategically allocating one's attention may be better met in settings conducive to devoted focus, such as a quiet library. On the other hand, distractions may be less perilous if the learner is cognizant of the potential cost of distraction.

Prior work demonstrates that selective attention to, and memory for, the most critical of to-be-remembered information can be maintained in spite of circumstances that otherwise result in memory impairments, such as insufficient study time (Middlebrooks, Murayama, & Castel, 2016) and advanced age (Castel, McGillivray, & Friedman, 2012; Castel, Murayama, Friedman, McGillivray, & Link,

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2013; Middlebrooks, McGillivray, Murayama, & Castel, 2016). Maintaining prioritization of high-value information at the expense of less-essential information (Castel et al., 2012), despite memory declines, requires an important dissociation between memory itself and the strategizing in which learners engage during encoding. Selective study signifies an awareness of the limitations of one's study conditions (Castel et al., 2012; Dunlosky, Ariel, & Thiede, 2011; Winne & Hadwin, 1998)—that remembering everything is implausible.

People seem broadly aware that memory suffers when attention is divided (Barnes & Dougherty, 2007; Junco & Cotten, 2011), at times even overestimating the degree to which their performance will diminish (Finley, Benjamin, & McCarley, 2014), but this basic knowledge may be insufficient for motivating selective study. Despite anticipating decreased global performance when multitasking, people often fail to apply this knowledge when making item-by-item judgments of encoding quality and retrieval accuracy (Beaman, Hanczakowski, & Jones, 2014; Kelley & Sahakyan, 2003; Sacher, Taconnat, Souchay, & Isingrini, 2009). So despite acknowledging that memory will likely suffer when attention is divided, learners tend not to account for this possibility when evaluating their own performance, which potentially decreases the likelihood of their adopting a selective study strategy.

Relatedly, distracted learners may be less able to execute a value-based study agenda—even if recognizing the fitness of such an approach—owing to reduced cognitive resources (Dunlosky et al., 2011). Divided attention also seems to have a more pronounced impact when learners encode on a deeper, semantic level (Anderson et al., 2000; Craik, 1982), which is precisely the processing in which learners are most likely to engage when studying selectively (Cohen, Rissman, Suthana, Castel, & Knowlton, 2014). Therefore, the very method by which selectivity may be best achieved also seems to be the method most affected by divided attention. Good intentions notwithstanding, divided attention may render selective study relatively unattainable.

Experiment 1

A primary goal of the current research was to examine the effect of divided attention during encoding on the study of, and memory for, valuable information. An additional goal was to investigate whether selectivity is affected by the degree to which the learner is engaged with the distractor—is the learner studying while actively engaged in a concurrent activity or while more passively distracted? In Experiment 1, participants studied to-be-remembered items while completing a digit-detection task or while listening to background music with which they were either familiar or unfamiliar. The costs of a less involving distraction may be less pronounced relative to an attention-dividing activity and, thus, less of an impediment to strategizing. Alternatively, multitasking may be more blatantly injurious to memory, in which case learners may be more likely to prioritize valuable information when multitasking than when merely exposed to a distractor, which would result in better memory for the most important information.

Method

Participants. Participants consisted of 192 undergraduate students at the University of California, Los Angeles (129 female, 62 male, 1 unreported), ranging in age from 18 to 30 years (M = 20.50, SD = 1.75). Participants received partial credit toward a course requirement for completing the experiment. The current experiment was based on a pooled set of original data (N = 96) and replication data (N = 96). The sample size per condition for each period of collection was based on prior research investigating value effects on memory and selectivity (Castel et al., 2013; Hayes, Kelly, & Smith, 2013; Middlebrooks, McGillivray, et al., 2016; Middlebrooks, Murayama, & Castel, 2016); value-directed remembering and selectivity effects have been repeatedly and robustly found with this conventional sample size.

Materials

Stimuli. The experiment was designed and presented to participants using the Collector program (Garcia & Kornell, 2015). Stimuli consisted of six lists, each containing 20 words. Word length ranged from four to seven letters and averaged 8.81 (SD = 1.57, range = 5.48–12.65) on the log-transformed Hyperspace Analogue to Language (HAL) frequency scale (Balota et al., 2007). To avoid potential item effects (Murayama, Sakaki, Yan, & Smith, 2014), we randomly selected the studied words in each list without replacement for each participant from a larger word bank of 280 random nouns and verbs (e.g., *twig, button, taste*). Each selected word was then randomly assigned a value from 1 to 10 points, with two words assigned to each point value per list. Lists varied per participant, so one participant might study *twig* in List 1, while another participant studied *twig* in List 3 or not at all. Furthermore, *twig* might be a 3-point word for one participant but a 10-point word for another participant.

Music distractors. An exploratory point of interest was whether or not familiarity with the background music would affect memory and selective study. It may be easier to ignore background music with which you are very familiar, and, thus, perhaps somewhat habituated to, than to ignore unfamiliar background music (Kang & Lakshmanan, 2017; Röer, Bell, & Buchner, 2014). On the other hand, familiar music has been shown to be more enjoyable than unfamiliar music, leading to greater activation in limbic and reward-based neural structures (Pereira et al., 2011). If familiar music heightens dopaminergic, reward-based neural activity, irrespective of the to-be-remembered item's value, then the potentially greater enjoyment resulting from listening to familiar music relative to unfamiliar music could disrupt the selective role that reward-based regions can serve with respect to remembering valuable information specifically (Cohen et al., 2014). Familiar music may also be more likely to activate related memories and thoughts (e.g., remembering other friends that like this song, remembering the last time you heard the song; Janata, 2009) than unfamiliar music, which could also make familiar music more distracting than unfamiliar music during study.

A pilot study ($N = 48$) was first conducted to select the songs that would serve as background music. Pilot participants were presented with 30-s clips of different lyrical songs, along with the song's title and the name of the artist. Participants rated each song on a number of dimensions, including their familiarity with and liking of the song. Participants could replay the song clips as desired while making their judgments. The 12 chosen songs—6 familiar and 6 unfamiliar—were consistently rated as being well-liked, upbeat, and mood improving. The chosen familiar songs had an average of 126.6 beats per minute (BPM; ranging from 120–129) and the unfamiliar songs an average BPM of 124.5 (ranging from 113–139). A full list of the songs presented during the pilot task, and the 12 songs ultimately selected for the task, is available from the corresponding author.

In the main experiment, the six songs—familiar or unfamiliar as per the study condition—were randomly assigned without replacement to the to-be-learned lists for each participant. So a participant assigned to listen to familiar music might study List 1 while listening to Katy Perry's "Roar," but another participant in the same condition might not hear "Roar" until studying List 4.

Procedure. Each participant was randomly assigned to one of four different study conditions: a full-attention condition, a divided-attention condition, a familiar-music condition, and an unfamiliar-music condition. All of the participants were told that they would be shown a series of word lists, each containing 20 different words, and that each word would be paired with a value ranging from 1 to 10 points, with 2 words per point value in each list. Participants were instructed to remember as many of the presented words as possible while also aiming to maximize their score, a sum of the points associated with each subsequently recalled word. They were told that they would be asked to recall the words from each list at the conclusion of its presentation, after which they would be told their score (out of 110 possible points). The words were presented at a rate of 3 s per word.

Participants in the divided-attention condition were further told that a series of digits would be read aloud while they studied and that they were to press the space bar every time they heard a sequence of three odd digits. The digits (numbers 1–9) were randomly generated with constraints at a rate of 1 per second: unbeknownst to participants, there were exactly eight instances of three-odd-digit sequences per list, and there was never a sequence of four odd digits in a row, though there could be one or two odd digits in a row (following which the space bar should not have been pressed).

Participants in the familiar-music and unfamiliar-music conditions were told that background music would be playing while they studied the to-be-remembered words. It was explained that they did not need to do anything with the music or remember it—it would simply be playing in the background—and that their task was to memorize the items while maximizing their score. Each of the songs played for the full 60-s duration of each list presentation. At the conclusion of the task, participants were also asked to indicate whether they were familiar or unfamiliar with the songs that were played: All participants in the familiar-music condition reported being familiar with the music, and all participants in the unfamiliar-music condition reported being unfamiliar with the music, consistent with the responses from the pilot study initially used to select the songs.

Participants in the replication experiment also completed a modified operation span task (Oswald, McAbee, Redick, & Hambrick, 2015) to determine whether the impact of the digit-detection task or the background music on selectivity would differ as a function of individual differences in working memory capacity (WMC). It was thought that participants with greater WMC might be better able to inhibit the distractors during study and so devote more of their attention toward the valuable information. There were, however, no evident differences in selectivity as a consequence of individual operation-span scores within or between study conditions, consistent with prior research that has also failed to find differences in selectivity based on WMC in healthy younger adults (Castel, Balota, & McCabe, 2009; Cohen et al., 2014; but see Hayes et al., 2013). The results of these analyses are available from the corresponding author.

Results

As mentioned, the current experiment was based on a pooled set of original data ($N = 96$) and replication data ($N = 96$). The results were consistent between data sets; results specific to each data set are provided in the Supplemental Material available online.

Digit-detection performance. Responses on the digit-detection task by participants in the divided-attention condition were scored as correct when made between 50 and 1,200 ms after the third odd digit in a sequence was played. (Responses made within the 50 ms following the third odd digit were not recorded as correct because the initiation of any such presses would have been made prior to the third digit being played and were thus presumptive.) Participants correctly identified an average of 1.87 out of 8 sequences (*SD* = 0.42) throughout the experiment. There were also an average of 1.26 incorrect detections (*SD* = 0.18), wherein participants pressed the space bar to indicate that three odd digits had been played when they had not. All participants identified at least one sequence (correctly or incorrectly) during each studied list.

Overall recall performance. The proportion of items recalled as a function of study condition and list are provided in Table 1. Table S1 in the Supplemental Material separately presents recall performance for the original data collection and the replication.

Initial analyses were conducted to determine whether there was an effect of divided attention via digit detection or music distractions on overall recall performance, irrespective of item value. Bonferroni adjustments were made in all cases of multiple comparisons during post hoc testing, and Greenhouse-Geisser adjustments were made in the case of sphericity violations. A 4 (condition: full attention, divided attention, familiar music, unfamiliar music) × 6 (list: 1–6) repeated measures analysis of variance (ANOVA) revealed a significant effect of list, $F(4.56, 857.92) = 14.26$, $MSE = 0.01$, $p < .001$, generalized η^2 (η^2_G) = .04, with the total number of items recalled, on average, significantly lower in List 1 than in each of Lists 2 through 6, adjusted *p*s < .001. Critically, there was also a significant effect of condition, $F(3, 188) = 15.22$, $MSE = 0.06$, $p < .001$, $\eta^2_G = .11$; participants in the divided-attention condition recalled significantly fewer items overall than did participants in the other conditions (adjusted *p*s < .001).

There were no other significant differences between conditions, nor was there a significant interaction between list and condition. These results confirm that the digit-detection task completed by participants in the divided-attention condition diminished participants' ability to remember the items relative to participants' ability in the full-attention condition, consistent with prior research (Castel & Craik, 2003; Craik et al., 1996; Naveh-Benjamin et al., 2000). Background music in the familiar- and unfamiliar-music conditions did not, however, similarly affect general recall; while it is certainly possible that the music was distracting during study, it was evidently not distracting enough to actually impair recall.

Value-directed remembering and selectivity. Recall performance as a function of item value and study condition is presented in Figure 1. To account for potential within- and between-subjects differences in value-based study and recall, we used hierarchical linear modeling (HLM) to analyze recall as a function of list and item value among the four study conditions (Castel et al., 2013; Middlebrooks, McGillivray, et al., 2016; Middlebrooks, Murayama, & Castel, 2016; Raudenbush & Bryk, 2002). Given the continuous nature of the value scale used in the current task, as opposed to explicit and distinct value categories (e.g., low-, medium-, and high-value items), participants likely differed in terms of how they attended to value during study. A participant who expected to remember many items, for instance, may have intentionally studied all items worth 6 or more points; a less-confident participant may have constrained study to only those items worth 8 to 10 points. Both examples exemplify value-directed study; a mean-based analytic technique (e.g., ANOVA), however, would be unable to detect any direct relationships between item value and recall probability, only whether there were differences, on average, in the recall of particular value points, which would mask variation in strategy implementation. In contrast to mean-based techniques, HLM first clusters the recall data within each participant, which thereby accounted in the current experiment for individual differences in any value-based study strategies, and only then considers differences between conditions, such as in the present value-recall relationship across study conditions (see Middlebrooks, McGillivray, et al., 2016, and Middlebrooks, Murayama, & Castel, 2016, for further explanations regarding the use of HLM in analyzing selectivity and value-directed remembering).

Item-level recall performance (based on a Bernoulli distribution; 0 = not recalled, 1 = recalled; Level 1 = items, Level 2 = participants) was modeled as a function of each item's value, the list in which it was presented, and the

Table 1. Proportion of Recalled Items as a Function of Study Condition and List in Experiment 1

	List						
Condition	1	2	3	4	5	6	Average
Full attention	.34 (.14)	.38 (.13)	.40 (.15)	.40 (.13)	.41 (.14)	.40 (.13)	.39 (.10)
Divided attention	.18 (.10)	.24 (.09)	.27 (.12)	.29 (.10)	.29 (.11)	.30 (.10)	.26 (.08)
Familiar music	.33 (.14)	.35 (.10)	.36 (.17)	.35 (.15)	.38 (.18)	.34 (.16)	.35 (.11)
Unfamiliar music	.31 (.14)	.37 (.17)	.38 (.13)	.42 (.16)	.37 (.15)	.38 (.18)	.37 (.11)

Note: Standard deviations are presented in parentheses.

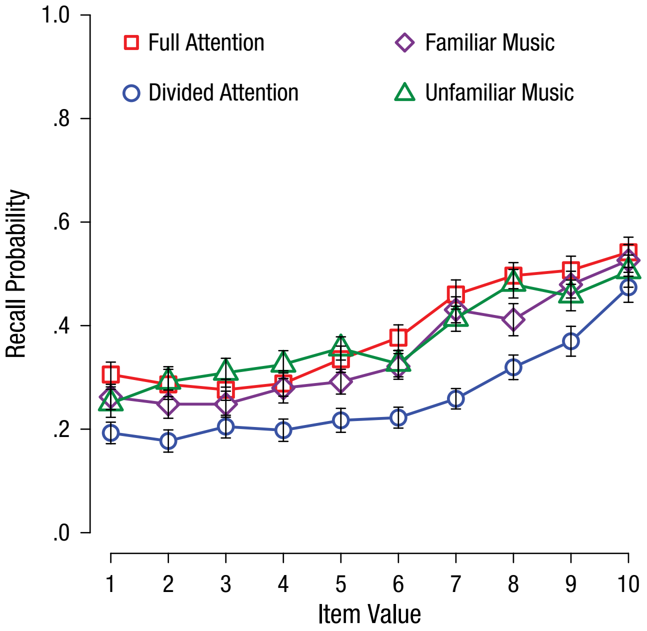


Fig. 1. Results from Experiment 1: mean proportion of items recalled across the six lists as a function of item value and study condition. Error bars show ±1 *SE*.

interaction between value and list. Value and list were entered as group-mean-centered variables, such that value was anchored on the mean value point (5.5) and list was anchored on the mean list (3.5). The model also included the study conditions as Level 2 predictors of those Level 1 effects via three dummy-coded variables, with the full-attention condition as the reference group. Although the full-attention condition served as the control against which effects of distraction and divided attention on recall and selectivity could be compared, the following results were consistent regardless of the reference group.

For the tested model, Table 2 reports the estimated regression coefficients for the fixed effects, and Table 3 reports the variance for the random effects. Table S2 in the Supplemental Material presents the estimated regression coefficients from the same model separately for the original data collection and the replication. Because the models are essentially logistic regression models with a dichotomous outcome, the regression coefficients can be interpreted via their exponential function (Raudenbush & Bryk, 2002). Specifically, exponential beta, Exp(β), is interpreted as the effect of the respective independent variable on the odds ratio of successful recall (i.e., the probability of recalling items divided by the probability of forgetting them; Murayama, Sakaki, et al., 2014). An Exp(β) of more than 1.0 indicates a positive effect of the predictor, while an Exp(β) of less than 1.0 indicates a negative (or diminished) effect of the predictor.

Value was a significantly positive predictor of recall performance in the full-attention condition ($\beta_{10} = 0.16$, $p < .001$), and this relationship was not significantly different across conditions, *p*s > .250. Thus, participants across all study conditions were 1.17 times ($e^{0.16}$) more likely to recall a studied word for each 1-unit increase in its value. The odds of recalling a 10-point item, for example, were 4.88 times ($e^{0.16 \times 10}$) greater than the odds of recalling a 1-point item, which demonstrates a clear effect of item importance or value on subsequent memory. There was not a significant effect of list on recall for participants in the full-attention condition ($\beta_{20} = 0.04$, $p = .077$), nor was there an evident Condition × List interaction, *p*s > .076. (Note that the use of effect coding in the HLM, rather than dummy coding, complements the main effect of list reflected by the previous ANOVA.)

There was, however, a significant List × Value interaction in the full-attention condition ($\beta_{30} = 0.03$, $p = .001$)—which did not differ across the other conditions, *p*s > .250; the relationship between an item's value and the probability of it being later recalled increased with continued task experience. As Figure 2 shows, participants were more likely to consider item importance while studying and adjust their strategies to compensate for their inability to remember all of the presented items as the experiment progressed, regardless of the presence (or extent) of distraction that they experienced during study.

Table 2. Fixed Effects From the Two-Level Hierarchical Generalized Linear Model Predicting Recall Performance From Item Value, List, and Study Condition in Experiment 1

Predictor	β
Intercept (β_{00})	−0.52***
Divided attention vs. full attention (β_{01})	−0.62***
Familiar music vs. full attention (β_{02})	−0.20†
Unfamiliar music vs. full attention (β_{03})	−0.07
Value (β_{10})	0.16***
Divided attention vs. full attention (β_{11})	0.01
Familiar music vs. full attention (β_{12})	0.02
Unfamiliar music vs. full attention (β_{13})	−0.02
List (β_{20})	0.04†
Divided attention vs. full attention (β_{21})	0.05†
Familiar music vs. full attention (β_{22})	−0.03
Unfamiliar music vs. full attention (β_{23})	0.01
List × Value (β_{30})	0.03**
Divided attention vs. full attention (β_{31})	0.01
Familiar music vs. full attention (β_{32})	−0.01
Unfamiliar music vs. full attention (β_{33})	−0.01

Note: The logit link function was used to address the binary dependent variable.
†$p < .10$. **$p < .01$. ***$p < .001$.

Table 3. Random Effects From the Two-Level Hierarchical Generalized Linear Model Predicting Recall Performance From Item Value, List, and Study Condition in Experiment 1

Random effect	Variance
Intercept (person-level; r_0)	0.21***
Value (r_1)	0.01***
List (r_2)	0.03***
List × Value (r_3)	0.001***

Note: The logit link function was used to address the binary dependent variable.
***p < .001.

Bayesian analysis. In the HLM analyses, the nonsignificant effect of study condition on the relationship between item value and recall probability suggests that selectivity and value-directed remembering were in no way affected by the music distractors or the digit-detection task during study. Because these results are based on null-hypothesis testing, though, it is truthfully impossible to claim the absence of such condition effects (despite the large sample size; $N = 192$). Additionally, the reported analyses are based on an aggregate of the original sample and the replication sample, on which interim analyses were conducted. There was no intention to stop data collection contingent on the obtained results, but interim analyses can make the interpretation of obtained p values ambiguous (Murayama, Pekrun, & Fiedler, 2014). Accordingly, a Bayesian analysis was also performed in order to surmount the potential complications of having conducted interim analyses on the pooled data set and to confirm the null effect of condition suggested by the HLM analysis (Middlebrooks, Murayama, & Castel, 2016). Bayes factors as computed in Bayesian analysis make it possible to directly compare the probability of obtaining the stated results under the null hypothesis (i.e., no between-conditions differences in the effect of value on recall) with the probability of the results under the alternative hypothesis (i.e., between-conditions differences; Jarosz & Wiley, 2014).

A two-step approach was used to allow for simpler Bayesian analysis with hierarchical data owing to the difficulty in directly comparing Bayes factors using HLM (see Lorch & Myers, 1990; Murayama, Sakaki, et al., 2014). Specifically, item recall was regressed on item value within each list for each participant using logistic regression. A 4 (condition) × 6 (list) repeated measures Bayesian ANOVA was then conducted on these value slopes using JASP software with default priors (Love et al., 2015). For condition, the resultant Bayes factor$_{10}$ (BF$_{10}$), which reflects the probability of the data under the alternative hypotheses (1) relative to the null hypothesis (0), was 0.015. In other words, the present data are 66.67 times (1/0.015) more likely to be consistent with the null model than with the alternative, which provides strong evidence for a null effect of study condition on the value-recall relationship (Kass & Raftery, 1995). These results confirm that selectivity during study and value-directed remembering was comparable across the study conditions.

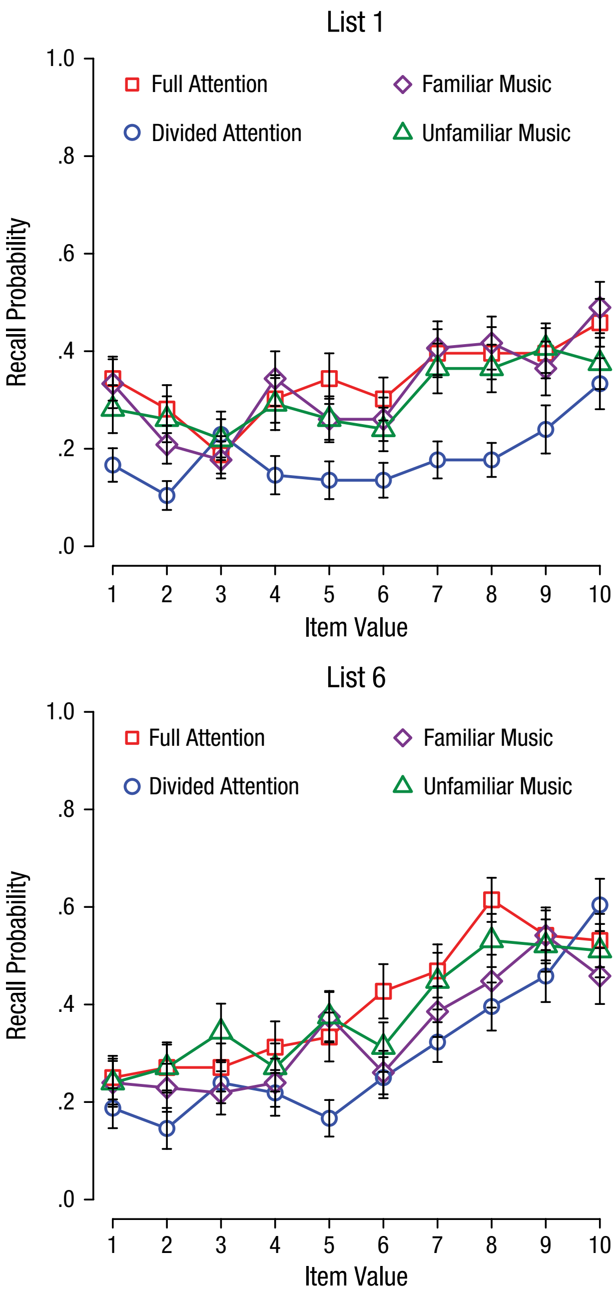


Fig. 2. Results from Experiment 1: mean proportion of items recalled as a function of item value and study condition, separately for List 1 and List 6 (the final studied list). Error bars show ±1 *SE*.

Discussion

The results of Experiment 1 indicate that participants who were either distracted by music (regardless of their familiarity with it) or whose attention was divided by the digit-detection task studied the valuable information as selectively as participants in the full-attention control condition. Memory overall was not impaired by the music distractors relative to memory in the full-attention condition, so the fact that selectivity remained could reflect comparable availability of attentional resources during study. Memory was, however, impaired by the digit-detection task, yet selectivity was maintained.

It is possible, however, that the digit-detection task was simply too difficult for participants and so was largely neglected; although this task is a common method of dividing attention, performance in Experiment 1 was notably lower in this condition than has been reported in other studies (e.g., Castel & Craik, 2003; Jacoby, 1991). The nature of the primary task—not only to remember presented items, but also to consider their values, contrast performance with earlier feedback, evaluate and execute strategies, etc.—may have amplified the difficulty of the digit-detection task. In light of this possibility, it is unclear as to whether selectivity was maintained in spite of divided attention or because attention was not actually divided.

Experiment 2

Experiment 2 was designed in part to address the concern that low digit-detection performance in Experiment 1 reflected a failure to properly divide participants' attention. Experiment 2 also examined the extent to which participants' attending to the divided-attention task may have deviated as a consequence of the studied material's value.

Instead of a digit-detection task, participants' attention in Experiment 2 was divided using three different tone-detection tasks, across which the difficulty, and the extent to which working memory may be required to complete the concurrent task, was increased to determine whether selectivity and value-directed remembering would be differentially affected. (Tone detection was used in place of digits in an effort to reduce the potential conflict between the numbers in the divided-attention task and the values of the to-be-remembered items, which may have contributed to the low digit-detection performance in Experiment 1.) Responses to these tone-detection tasks were made during each item's presentation, which enabled us to execute a more detailed analysis than was possible in Experiment 1 of the potential costs and shifts of participants' attention between the studied material and the divided-attention task.

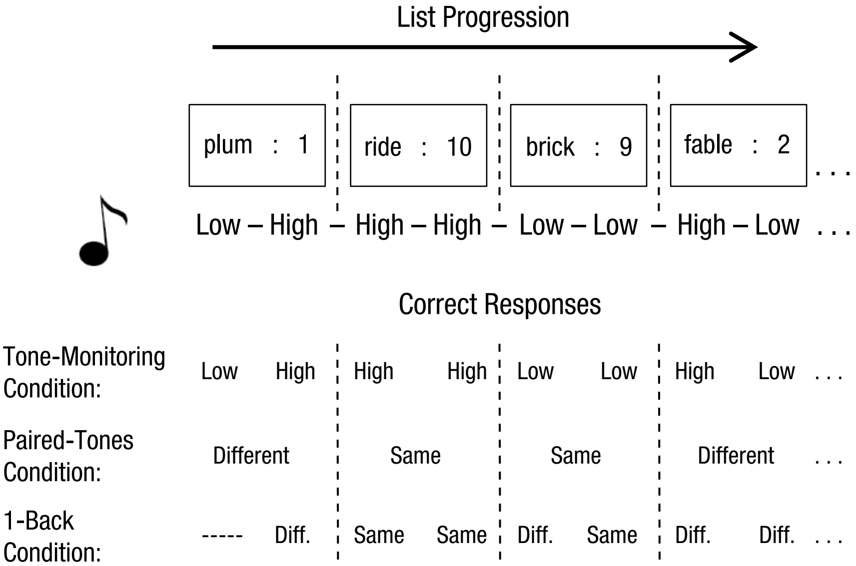
Method

Participants. Participants consisted of 96 undergraduate students at the University of California, Los Angeles (75 female, 20 male, 1 unreported), ranging in age from 18 to 27 years ($M = 20.61$, $SD = 1.44$). Participants received partial credit toward a course requirement for completing the experiment.

Materials and procedure. The to-be-remembered stimuli in Experiment 2 were the same as in Experiment 1. Participants were randomly assigned to one of four study conditions: a full-attention condition, a tone-monitoring condition, a paired-tones condition, and a 1-back condition. As in Experiment 1, all participants were told that they would be shown a series of words lists and that each word would be paired with a value ranging from 1 to 10 points, the goal of the task being to recall as many words as possible at test while also maximizing one's recall score. The words were presented for 3 s at a time. Participants in all but the full-attention condition were further told that they would hear a series of low-pitched (400 Hz) and high-pitched (900 Hz) tones played in the background during study. These tones were played continuously throughout the study of each list, and each tone was played for 1 s with a 750-ms intertone interval, which resulted in exactly two tones being played during each to-be-remembered item's presentation. The exact tone sequence was generated randomly for each participant, the only constraints being that the same pitch could not play more than three times in a row.

Participants in the tone-monitoring condition were instructed to indicate via keyboard whether each pitch they heard was low or high. Participants in the paired-tones condition were to indicate via keyboard whether the two tones played during a word's presentation were the same pitch (i.e., both low pitched or both high pitched) or of different pitches. Participants in the 1-back condition were to indicate via keyboard whether the current tone was the same pitch as the previous tone or a different pitch. (Across conditions, the keys were labeled to increase ease of responding.) Participants in the tone-monitoring and 1-back conditions thus provided two tone-related responses for each word, and participants in the paired-tones condition provided one response after the second tone was played. A prompt to attend to the tone-monitoring task was presented to participants who failed to respond correctly or did not respond to more than three detections in a row. An example of how the tone-related responses differed across conditions is provided in Figure 3.

In the tone-monitoring condition, participants were not required to keep track of the tones playing or remember anything about them, but were only to report the



Tone-Monitoring Condition:	Low	High	High	High	Low	Low	High	Low	. . .
Paired-Tones Condition:	Different		Same		Same		Different		. . .
1-Back Condition:	-----	Diff.	Same	Same	Diff.	Same	Diff.	Diff.	. . .

Fig. 3. Illustration of the design of Experiment 2. As participants saw each to-be-remembered word (along with its point value), they heard two consecutive tones (top rows). Each tone was pseudorandomly chosen to be low or high pitched. In the three experimental conditions (bottom rows), participants had to identify each tone as low or high (tone-monitoring condition), identify the two tones as the same or a different pitch (paired-tones condition), or identify whether each tone was the same as or different from the previous tone (1-back condition). In a fourth condition (the full-attention condition), participants completed the primary task, but no tones were played.

pitch of the tone in the moment. Contrastingly, participants in the paired-tones condition had to determine and remember the pitch of the first tone played during a word's presentation and then compare it with the second tone played before providing a response, which should have required more working memory resources than in the tone-monitoring condition. Working memory demand was presumed to be the most stressed in the 1-back condition because participants had to continuously monitor and compare tones across studied items, repeatedly updating the tone against which they were to compare the currently playing tone.

Results

Overall recall performance. The proportion of items recalled as a function of study condition and list are provided in Table 4. As in Experiment 1, initial analyses were conducted to determine whether there was an effect of divided attention on overall recall performance across the three tone conditions, irrespective of item value. Bonferroni adjustments were made in all cases of multiple comparisons during post hoc testing, and Greenhouse-Geisser adjustments were made in the case of sphericity violations. A 4 (condition: full attention, tone monitoring, paired tones, 1-back) × 6 (list: 1–6) repeated measures ANOVA revealed a significant effect of condition, $F(3, 92) = 17.20$, $MSE = 0.05$, $p < .001$, $\eta^2_G = .25$, with participants in the full-attention condition recalling significantly more items overall than participants in the three other conditions (adjusted ps < .001). There was also a significant List × Condition interaction, $F(13.34, 409.07) = 2.00$, $MSE = 0.01$, $p = .019$, $\eta^2_G = .03$. Although total recall did not change significantly across lists in the full-attention condition ($p > .250$), there was a significant effect of list in the other conditions (ps < .029); the total number of items recalled increased with continued task experience. Finally, there was a significant effect of list, $F(4.45, 409.07) = 11.50$, $MSE = 0.01$, $p < .001$, $\eta^2_G = .05$; total recall in the first three lists was significantly lower than in the last three lists.

These results confirm that the tone-detection task diminished participants' ability to remember the presented items relative to full-attention study, consistent with prior research (Craik et al., 1996; Gardiner & Parkin, 1990). Notably, there were no significant differences in recall among the three tone-detection conditions, despite differences in the demands of the tone task.

Value-directed remembering and selectivity. Recall performance as a function of item value and study condition is presented in Figure 4. As in Experiment 1, HLM was used to analyze recall as a function of list and item value among the four study conditions. The model used

Table 4. Proportion of Recalled Items as a Function of Study Condition and List in Experiment 2

	List						
Condition	1	2	3	4	5	6	Average
Full attention	.39 (.16)	.37 (.18)	.38 (.18)	.39 (.14)	.41 (.16)	.41 (.15)	.39 (.14)
Tone monitoring	.19 (.10)	.24 (.10)	.30 (.16)	.27 (.12)	.25 (.10)	.26 (.09)	.25 (.07)
Paired tones	.19 (.12)	.26 (.14)	.25 (.11)	.26 (.11)	.30 (.13)	.30 (.12)	.26 (.10)
1-back	.14 (.06)	.17 (.07)	.21 (.06)	.24 (.09)	.23 (.08)	.25 (.09)	.21 (.05)

Note: Standard deviations are presented in parentheses.

was identical to that in Experiment 1, save for the differences in the actual conditions. Table 5 reports the estimated regression coefficients for the fixed effects, and Table 6 reports the variance for the random effects.

Value was a significantly positive predictor of recall performance in the full-attention condition (β_{10} = 0.21, $p < .001$), and this relationship between item value and recall likelihood was not significantly different across conditions, *p*s > .250. There was also a significant List × Value interaction in the full-attention condition (β_{30} = 0.03, $p = .008$), which, again, did not differ across conditions, *p*s > .117; selectivity increased with continued task experience, as Figure 5 shows. These results are consistent with those of Experiment 1: Despite impairing overall recall, the tone-detection tasks did not result in significant changes to selectivity relative to the full-attention condition.

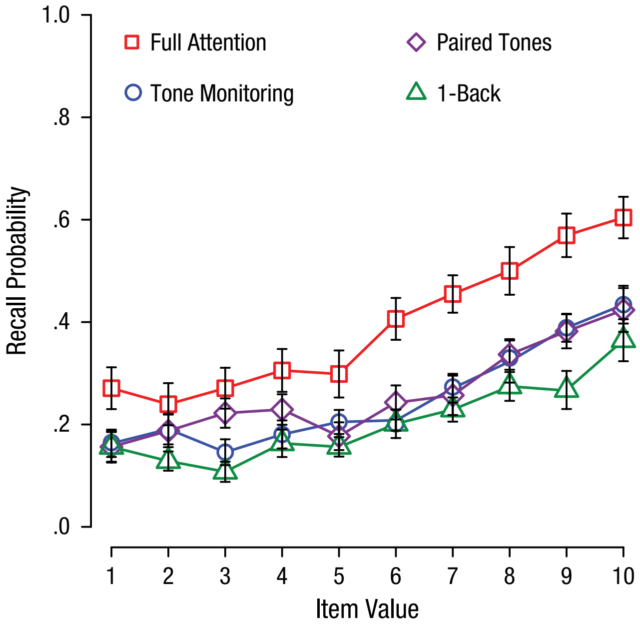


Fig. 4. Results from Experiment 2: mean proportion of items recalled across the six lists as a function of item value and study condition. Error bars show ±1 *SE*.

Tone-detection performance. Responses to the tone-detection task across conditions were scored as correct when made between 50 and 1,750 ms of the respective tone's onset. Accuracy for responses to tones within a list was based on the possible number of responses: 40 (i.e., two responses per word) in the tone-monitoring and 1-back conditions and 20 (i.e., one response per word) in the paired-tones condition.

A 3 (condition: tone monitoring, paired tones, 1-back) × 6 (list: 1–6) repeated measures ANOVA was conducted in order to assess whether overall tone-detection accuracy differed as a consequence of the task demands—namely, the extent to which previously heard tones had to be remembered in order to provide an accurate response. There was a significant effect of list, $F(2.87, 198.18) = 10.44$, $MSE = 0.03$, $p < .001$, $\eta^2_G = .05$; specifically, detection accuracy was significantly lower in List 1 than in Lists 2 through 6, adjusted *p*s < .006. There was also a significant effect of condition, $F(2, 69) = 4.01$, $MSE = 0.17$, $p = .023$, $\eta^2_G = .07$. Participants in the tone-monitoring condition accurately responded to a significantly greater proportion of the tone events ($M = .78$, $SD = .19$) than did participants in the 1-back condition ($M = .66$, $SD = .17$), adjusted $p = .037$. Tone performance in the paired-tones condition ($M = .77$, $SD = .13$) was also marginally greater than in the 1-back condition, adjusted $p = .071$, but did not significantly differ from performance in the tone-monitoring condition. So participants were less able to successfully complete the 1-back tone-detection task than the other tone tasks, consistent with the predicted difference in task difficulty owing to an increase in task demands. That performance did not differ between the tone-monitoring and paired-tones condition suggests that the difference in the two tasks' demands may not have differentially affected their level of difficulty. Regardless, average performance indicates that participants were actively engaged in the tone tasks, which assuaged our concerns in Experiment 1 about the extent to which digit-detection performance actually divided attention.

Two HLM analyses were also conducted to determine whether tone-detection accuracy and the time (in seconds) that it took participants to make their tone-related

Table 5. Fixed Effects From the Two-Level Hierarchical Generalized Linear Model Predicting Recall Performance From Item Value, List, and Study Condition in Experiment 2

Predictor	β
Intercept (β_{00})	–0.52***
Tone monitoring vs. full attention (β_{01})	–0.72***
Paired tones vs. full attention (β_{02})	–0.67**
1-back vs. full attention (β_{03})	–0.98***
Value (β_{10})	0.21***
Tone monitoring vs. full attention (β_{11})	–0.02
Paired tones vs. full attention (β_{12})	–0.05
1-back vs. full attention (β_{13})	–0.05
List (β_{20})	0.01
Tone monitoring vs. full attention (β_{21})	–0.01
Paired tones vs. full attention (β_{22})	0.06
1-back vs. full attention (β_{23})	0.09**
List × Value (β_{30})	0.03**
Tone monitoring vs. full attention (β_{31})	0.02
Paired tones vs. full attention (β_{32})	0.03
1-back vs. full attention (β_{33})	0.0003

Note: The logit link function was used to address the binary nature of the recall outcome.
$^{**}p < .01$. $^{***}p < .001$.

responses in the three tone-detection conditions differed owing to item value or the list in which it appeared, or whether the effect of value on tone accuracy changed across lists. (Such an analysis was not possible in Experiment 1 because of the low digit-detection performance, in terms of both response rates and response accuracy.)

The tested models and their estimated regression coefficients are provided in Table S3 in the Supplemental Material. Although there were no evident effects of value or list on tone-response accuracy, there was a significant effect of list on reaction time: Participants made their tone responses significantly faster with continued task experience (β_{20} = –0.02, p = .001; see Table S3). There was also a small but significant List × Value interaction with respect to reaction time; item value became slightly more predictive of reaction time across lists (β_{30} = 0.003, p = .001), with participants responding slightly more slowly when concurrently studying a high-value item than a low-value item. In general, however, item value was not predictive of reaction time (β_{10} = 0.002, p > .250).

The results of these analyses indicate that participants were not only engaged with the tone-detection tasks, as evidenced by their overall response accuracy, but also that participants did not strategically neglect the tone task when presented with more valuable materials. Rather, participants were engaged throughout study with the concurrent tone task and consistently so across items, regardless of their values.

Discussion

Although participants in the tone-detection conditions recalled fewer items than those in the full-attention condition, recall of the most important items did not differ relative to the full-attention condition. In all but the full-attention condition, participants may have adjusted to this general memory impairment by selectively allocating their attention to the high-value items and refining their strategy with continued task experience, as suggested by performance in later lists (see Fig. 5). Overall, these results provide a more detailed analysis of attention during encoding of high- and low-value items, and they support the main findings from Experiment 1.

General Discussion

Distractions are often unavoidable, and despite a global awareness of consequent impairments (Barnes & Dougherty, 2007; Finley et al., 2014), learners frequently partake in distracting activities that lead to poorer comprehension of and memory for to-be-learned information (Fried, 2008; Sana et al., 2013). The current experiments examined whether divided attention during encoding similarly diminishes selective attendance to valuable information when remembering everything is unachievable, and whether the extent to which learners engage with the distraction during encoding affects selectivity.

In Experiment 1, participants studied the to-be-remembered items while completing a digit-detection task or while listening to familiar or unfamiliar background music. Participants in the digit-detection condition remembered fewer items overall than participants in the other conditions, but there were no significant differences in memory for the higher-valued items across conditions. These results were confirmed in an exact replication of Experiment 1 and upheld in Experiment 2 using a range of tone-detection tasks: Despite the fact that participants' attention was divided during study to varying degrees, selectivity was consistently maintained.

Table 6. Random Effects From the Two-Level Hierarchical Generalized Linear Model Predicting Recall Performance From Item Value, List, and Study Condition in Experiment 2

Random effect	Variance
Intercept (person-level; r_0)	0.22***
Value (r_1)	0.03***
List (r_2)	0.002
List × Value (r_3)	0.003***

Note: The logit link function was used to address the binary nature of the recall outcome.
$^{***}p < .001$.

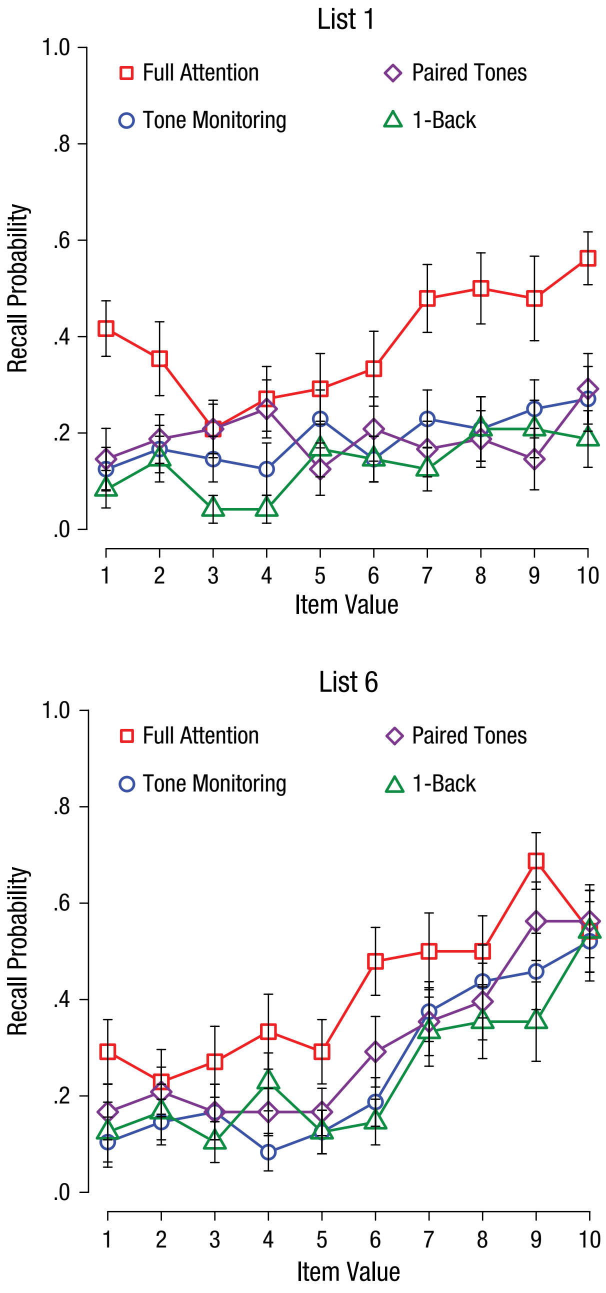


Fig. 5. Results from Experiment 2: mean proportion of items recalled as a function of item value and study condition, separately for List 1 and List 6 (the final studied list). Error bars show ±1 *SE*.

That participants were able to study selectively in spite of the concurrent tasks, and resultant memory impairments, is surprising and warrants further investigation. Divided attention appears most detrimental to elaborative, semantic processing (Anderson et al., 2000; Craik, 1982)—by which value-directed remembering is thought to be best enacted (Cohen et al., 2014)—and so should have compromised the execution of a selective strategy. Moreover, a task designed to decrease available resources should reduce one's ability to study strategically if selecting and executing an optimal strategy depends on working memory availability (Dunlosky et al., 2011). Even if participants decided on a selective strategy in advance of study (though prior work indicates the need for task experience; Castel et al., 2012), limits to cognitive resources have nevertheless been shown to impair execution of that strategy, even if it had been previously implemented successfully (Dunlosky & Thiede, 2004). The 1-back tone condition in Experiment 2 was specially intended to place additional demands on working memory relative to the other conditions, yet selectivity was preserved.

There is a dearth of research investigating metamemory judgments made while participants' attention is divided (Barnes & Dougherty, 2007; see Beaman et al., 2014; Kelley & Sahakyan, 2003; and Sacher et al., 2009, for work concerning postencoding judgments), but the current results intimate that divided attention did not incapacitate metacognitive mechanisms in either of these experiments, which left participants capable of judging their memory capacity, performance, and methods by which they might compensate for additional demands on attention. Accordingly, divided attention may not affect metamemory like it does memory.

The present results do not imply that selectivity will always be impervious to distraction, but they suggest that attentional stressors that impair memory will not necessarily impair study strategizing. In examining the influence of distractions on strategy application, future research should consider situations in which the learner must first determine importance (i.e., when value is not explicitly denoted). The detriment of divided attention to comprehension (Craik, 1982; Sana et al., 2013) may mean that learners inaccurately judge importance; if the learner fails to recognize the value in something when distracted, then the appropriate strategy will not be applied, even if it could have been executed.

Future research should also consider the effect of divided attention on self-regulated study choices. Participants in the current study were unable to control what or when they studied; in real-world situations, however, learners often decide when to engage with a distractor (e.g., deciding when to check one's e-mail during a lecture) or control the pacing of their primary task (e.g., if background music in a café is distracting, a learner could choose to reread a passage). Pashler, Kang, and Ip (2013) reported divided-attention effects on memory when study time was experimenter-paced; when study was self-paced, however, participants compensated for distractions by studying longer. Given the opportunity to self-pace, participants might believe that they can compensate for distractions by slowing their study, which makes them less likely to study selectively and, thus, potentially more likely to forget important information.

Conclusion

The current study examined whether distraction, consistently shown to diminish memory, similarly impairs the strategic study of valuable information. Though dividing participants' attention reduced recall in general, neither active multitasking nor passive exposure to background music prevented their prioritizing high-value items during study. Participants compensated for limitations owing to divided attention by devoting their remaining resources to the most important items, which provides further evidence that factors that worsen memory do not necessarily similarly affect study strategizing.

Action Editor

Kathleen McDermott served as action editor for this article.

Author Contributions

C. D. Middlebrooks and A. D. Castel developed the study concept. All of the authors contributed to the study design, which was programmed by T. Kerr. C. D. Middlebrooks and T. Kerr supervised data collection. C. D. Middlebrooks analyzed and interpreted the data and drafted the manuscript. All of the authors approved the final version of the manuscript for submission.

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Declaration of Conflicting Interests

The authors declared that they had no conflicts of interest with respect to their authorship or the publication of this article.

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Supplemental Material

Additional supporting information can be found at http://journals.sagepub.com/doi/suppl/10.1177/0956797617702502

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