Selectively Distracted: Divided Attention and Memory for Important Information

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Abstract

Distractions and multi-tasking are generally detrimental to learning and memory. Nevertheless, people often study while listening to music, in noisy coffee shops, and while intermittently checking their email. 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 1-10 points under full attention, while completing a digit detection task, or while listening to music. Though participants recalled fewer words following digit detection, 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, suggesting 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

The threat of distraction to learning and memory fills campus libraries to capacity come exam time, with students eschewing home comforts (and showers) to maintain undivided attention whilst 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).

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Costs of divided attention during encoding to memory are plentiful (Castel & Craik, 2003; Craik, Govoni, Naveh-Benjamin, & Anderson, 1996; Naveh-Benjamin, Craik, Perretta, & Tonev, 2000), but the effect on memory for important or valuable information, specifically, remains unclear. Is a student's exam performance at the mercy of 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 by settings conducive to devoted focus, like 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 which otherwise result in memory impairments, like insufficient study time (Middlebrooks, Murayama, & Castel, 2016) and advanced age (Castel, McGillivray, & Friedman, 2012). Maintained prioritization of high-value information at the expense of less essential information (Castel et al., 2012), despite memory declines, reflects 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 under divided attention (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 poorer 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; Kelly & Sahakyan, 2003; Sacher, Taconnat, Souchay, & Isingrini, 2009). So, despite acknowledging that divided attention is likely to impair memory, learners are less likely to accurately account for it when evaluating their own performance, potentially decreasing 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 encoding 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). As such, the very method by which selectivity may be best achieved also seems to be the method most impacted 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 the 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, resulting 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, 1 unreported), ranging in age from 18 to 30 years ($M = 20.5$, $SD = 1.75$). Participants received partial credit for a course requirement.

The current experiment is 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, Murayama, Friedman, McGillivray, & Link, 2013; Hayes, Kelly, & Smith, 2013; Middlebrooks, McGillivray, Murayama, & Castel, 2016; Middlebrooks, Murayama, et al., 2016); value-directed remembering and selectivity effects have been repeatedly and robustly found with this conventional sample size.

Materials

Stimuli: The study was designed and presented to participants via the Collector program (Gikeymarcia/Collector, n.d.). Stimuli consisted of 6 lists, each containing 20 words. Word length ranged from 4 to 7 letters and averaged to 8.81 ($SD = 1.57$) on the log-transformed Hyperspace Analogue to Language (HAL) frequency scale, with a range from 5.48 to 12.65. In order to avoid any potential item effects (Murayama, Sakakai, Yan, & Smith, 2014), the studied words in each list were randomly selected without replacement for each participant from a larger word bank of 280 random nouns and verbs (e.g., *twig*, *button*, *taste*). Each of the selected words was then randomly assigned a value ranging from 1 to 10 points, with two words assigned to each point value per list. In this manner, one participant might study *twig* in List 1, while another participant studies *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 in the current study was whether or not familiarity with the background music would impact memory and selective study. It may be easier to ignore background music with which you are very familiar and, thus, perhaps somewhat habituated relative to unfamiliar 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 during study than unfamiliar music.

A pilot study ($N = 48$) was first conducted to select the songs that would serve as background music. Pilot participants were presented with 30-second 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 upon request.

Each of 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 the "Roar" until studying List 4.

Procedure—Participants were randomly assigned to one of four different study conditions: a full attention (FA) condition; a divided attention (DA) condition; a familiar music (FM) condition; and an unfamiliar music (UM) condition. 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 two words per point value in each list. Participants were instructed to remember as many of the presented words as possible while also achieving a maximal 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 seconds per word.

Participants in the DA condition were further told that a series of digits would also be read aloud while they studied and that they were to press the spacebar every time that 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 played, though there could be one or two odd digits in a row (for which the spacebar should *not* be pressed).

Participants in the FM and UM 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-second 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 FM participants reported being familiar with the music and all UM participants reported being unfamiliar with the music, consistent with the pilot responses initially used to select the songs.

Participants in the replication experiment also completed a modified Operation Span (OSpan) 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 towards the valuable information. There were, however, no evident differences in selectivity as a consequence of individual OSpan 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 upon request from the corresponding author.

Results

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

Digit detection performance—Responses on the digit detection task by participants in the DA condition were scored as correct when made between 50-1200 milliseconds of the third odd digit in a sequence being played. (Responses made within the 50 milliseconds following the third odd digit were not recorded as correct as the initiation of any such presses would have been made prior to the third digit being played and 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 spacebar to indicate that three odd digits had been played when, in fact, they had not. There were no participants who completely neglected the digit detection and failed to press the spacebar at any point—all participants identified at least one sequence 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 Materials online presents recall performance separately from the original data collection and the replication. Initial analyses were conducted to determine whether there was an effect of divided attention via digit detection and/or music distractions on overall recall performance, irrespective of item value. Bonferronni adjustments were made in all cases of multiple comparisons post

hoc testing and Greenhouse-Geisser adjustments in the case of sphericity violations. A 4(Condition: Full attention, Divided attention, Familiar music, Unfamiliar music) × 6(List) repeated-measures analysis of variance (ANOVA) revealed a significant effect of list, $F(4.56, 857.92) = 14.26$, $MSE = 0.01$, $p < .001$, $\eta^2_G = .04$, with the total number of items recalled, on average, significantly lower in List 1 than Lists 2-6, $p s_{adj} < .001$. Critically, there was also a significant effect of condition, $F(3, 188) = 15.22$, $MSE = 0.06$, $p < .001$, $\eta^2_G = .11$, with participants in the DA condition recalling significantly fewer items overall than participants in the other conditions ($p s_{adj} < .001$).

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 DA condition diminished participants' ability to remember the items relative to the FA condition, consistent with prior research (Craik et al., 1996; Castel & Craik, 2003; Naveh-Benjamin et al., 2000). Background music in the FM and UM conditions did not, however, similarly impact 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-subject differences in value-based study and recall, hierarchical linear modeling (HLM) was used to analyze recall as a function of list and item value between the four study conditions (Castel et al., 2013; Middlebrooks, McGillivray, et al., 2016; Middlebrooks, Murayama, et al., 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 differ 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 8-10 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, masking variation in strategy implementation. In contrast to mean-based techniques, HLM first clusters the recall data within each participant, thereby accounting for individual differences in any value-based study strategies, and *then* considers differences in the value-recall relationship across study conditions (cf. Middlebrooks, McGillivray, et al., 2016 and Middlebrooks, Murayama, et al., 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, with 0 = *not recalled* and 1 = *recalled*; level 1= items; level 2 = participants) in the current model was modeled as a function of each item's value, the list in which it was presented, and the 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 further 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 FA condition served as the control against which effects of distraction and divided attention on recall and selectivity could be compared, the following results are consistent regardless of the reference group.

Table 2 reports the tested model and its estimated regression coefficients. Table S2 in the Supplemental Materials online presents the estimated regression coefficients from the same model separately for the original data collection and the replication.

As the models are essentially logistic regression models with a dichotomous outcome, the regression coefficients can be interpreted via their exponential (Raudenbush & Bryk, 2002). Specifically, exponential beta, Exp(B), 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) (Muryama, Sakaki, et al., 2014). Exp(B) of more than 1.0 indicates a positive effect of the predictor, while an Exp(B) 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 FA condition ($\beta_{10} = 0.16$, $p < .001$), and this relationship was not significantly different across conditions, $ps > .250$. Thus, participants across all study conditions were $e^{0.16} = 1.17$ times more likely to recall a studied word for each one-unit increase in its value. The odds of recalling a 10-point item, for example, were $e^{0.16 * 10} = 4.88$ times greater than the odds of recalling a 1-point item, demonstrating a clear effect of item importance/value on subsequent memory. There was not a significant effect of List on recall for participants in the FA condition ($\beta_{20} = 0.04$, $p = .08$), nor was there an evident Condition $\times$ List interaction, $ps > .076$. (Note that the use of effect coding in the HLM model, rather than dummy coding, complements the main effect of List reflected by the previous ANOVA.)

There was, however, a significant List $\times$ Value interaction in the FA condition ($\beta_{30} = 0.03$, $p = .001$)—which did not differ across the other conditions, $ps > .550$—such that the relationship between an item's value and the probability of it being later recalled increased with continued task experience. As illustrated in Figure 2, participants were more likely to consider item importance whilst studying and adjust their strategies so as 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.

Bayesian analysis—The nonsignificant effect of study condition in the HLM analyses on the relationship between item value and recall probability suggests that selectivity and value-directed remembering in the current experiment was in no way affected by the music distractors or the digit detection task during study. As these results are based upon 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 upon 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, et al., 2016). Bayes factors as computed in Bayesian analysis makes it possible to directly compare the probability of obtaining the stated results under the null hypothesis H_0 (i.e., no condition differences in the effect of value on recall) against the probability of the results under the alternative hypothesis H_1 (i.e., condition 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 with 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). The resultant Bayes Factor$_{10}$ (BF$_{10}$), which reflects the probability of the data under the alternative hypotheses relative to the null, for Condition was 0.015. In other words, the present data are $1/0.015 = 66.67$ times more likely to be consistent with the null model than with the alternative, providing 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.

Discussion

The results of Experiment 1 indicate that participants who were either distracted by music (regardless of familiarity) 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 and 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 a common method of dividing attention, digit detection performance in Experiment 1 was notably lower than that which has been reported in other studies (e.g., Castel & Craik, 2003; Jacoby, 1991). The nature of the primary task— to not only remember presented items, but to also 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' study, hence their maintained selectivity. 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 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 impacted. (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 tasks were made during each item's presentation, enabling a more detailed analysis than was possible in Experiment 1 of the potential costs and shifts of participants' attention between the studied material and divided attention task.

Method

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

Materials—The to-be-remembered stimuli in Experiment 2 were the same as in Experiment 1.

Procedure—Participants were randomly assigned to one of four study conditions: a full attention (FA) condition; a tone monitoring (TM) condition; a paired tones (PT) condition; and a 1back condition. As in Experiment 1, 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 seconds at a time. Participants in all but the FA condition were further told that they would hear a series of low- (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 second with a 750-millisecond inter-tone interval, resulting in exactly two tones being played during each to-be-remembered item's presentation. The exact tone sequence was generated randomly for each participant, with the only constraints being that the same pitch could not play more than three times in a row.

Participants in the TM condition were instructed to indicate via keyboard after each pitch was played whether it was of low- or high-pitch. Participants in the PT 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 pitch (i.e., one low-pitched and one high-pitched). Participants in the 1back condition were to indicate via keyboard whether the current tone was the same pitch as the previous tone or different pitch. (Across conditions, sticky notes were placed on the appropriate keys to increase ease of responding.) Participants in the TM and 1back conditions thus provided two tone-related responses for each word and participants in the PT condition provided one response after the second tone was played. A prompt to attend to the tone task was presented to participants who failed to respond (correctly or incorrectly) to more than three detections. An example of how the tone-related responses differed across conditions is provided in Figure 3.

In the TM condition, participants were not required to keep track of the tones playing or remember anything about them, but were only to report the pitch of the tone in the moment. Contrastingly, participants in the PT condition had to determine and remember the pitch of the first tone played during a word's presentation and then compare it to the second tone played before providing a response, which should have required more working memory resources than in the TM condition. Working memory demand was presumed to be the most stressed in the 1back condition as 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 3. As in Experiment 1, initial analyses were conducted to determine whether there was an effect of divided attention across the different tone conditions on overall recall performance, irrespective of item value. Bonferroni adjustments were made in all cases of multiple comparisons post hoc testing and Greenhouse-Geisser adjustments in the case of sphericity violations. A 4(Condition: Full attention, Tone monitoring, Paired tones, 1back) $\times$ 6(List) repeated-measures ANOVA revealed a significant effect of condition, $F(3, 92) = 17.20$, $MSE = .05$, $p < .001$, $\eta^2_G = .25$, with participants in the FA condition recalling significantly more items overall than participants in the other conditions ($ps_{adj} < .001$). There was also a significant list $\times$ condition interaction, $F(15, 460) = 2.00$, $MSE = .01$, $p = .01$, $\eta^2_G = .03$. Although total recall did not change significantly across lists in the FA condition ($p > .25$), there was a significant effect of list in the other conditions ($ps < .03$), whereby the total number of items recalled increased with continued task experience. Finally, there was a significant effect of list, $F(4.45, 409.07) = 11.50$, $MSE = .01$, $p < .001$, $\eta^2_G = .05$, such that total recall in the first three lists was significantly lower than in the latter 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, hierarchical linear modeling (HLM) was used to analyze recall as a function of list and item value between the four study conditions. The model used was identical to that of Experiment 1, save for the differences in the actual conditions. Table 4 reports the tested model and its estimated regression coefficients.

Value was a significantly positive predictor of recall performance in the FA condition ($\beta_{10} = 0.21$, $p < .001$) and this relationship between item value and recall likelihood was not significantly different across conditions, $ps > .34$. There was also a significant List $\times$ Value interaction in the FA condition ($\beta_{30} = 0.03$, $p = .01$)—which, again, did not differ across

conditions, ps > .11—such that selectivity increased with continued task experience, as illustrated in Figure 5. These results are consistent with Experiment 1: despite impairing overall recall, the tone detection tasks did not result in significant changes to selectivity relative to the full attention study condition.

Tone detection performance—Responses to the tone detection task across the conditions were scored as correct when made between 50-1750 milliseconds of the respective tone's onset. Accurate tone responding within a list in the TM and 1back conditions was out of 40 (i.e., 2 responses per word) and out of 20 (i.e., 1 response per word) in the PT condition.

A 3(Condition: Tone monitoring, Paired tones, 1back) × 6(List) 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 maintained/remembered in order to provide an accurate response. There was a significant effect of list, $F(2.87, 198.18) = 10.44$, $MSE = 0.03$, $p < .001$, $\eta^2_G = .05$, such that detection accuracy was significantly lower in List 1 than in Lists 2-6, ps$_{adj} < .02$. There was also a significant effect of condition, $F(2, 69) = 4.01$, $MSE = 0.17$, $p = .02$, $\eta^2_G = .07$. Participants in the TM condition accurately responded to a significantly greater proportion of the tone events ($M = .78$, $SD = .19$) than participants in the 1back condition ($M = .66$, $SD = .17$), $p_{adj} = .04$. Tone performance in the PT condition ($M = .77$, $SD = .13$) was also marginally greater than in the 1back condition, $p_{adj} = .07$, but did not significantly differ from the TM condition. So, participants were less able to successfully complete the 1back 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 TM and PT condition suggests that the difference in the two tasks' demands may not have differentially impacted their level of difficulty. Regardless, average performance indicates that participants were actively engaged in the tone tasks, assuaging the concerns in Experiment 1 as to 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 responses in the three tone conditions differed owing to item value, the list in which it appeared, and/or whether the effect of value on tone accuracy changed across lists. (Such an analysis was not possible in Experiment 1 owing to 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 Materials. Although there were no evident effects of value or list on tone response accuracy (see Table S3), there was a significant effect of list on reaction time, such that participants came to make their tone responses significantly faster with continued task experience ($\beta_{20} = -0.02$, $p = .001$; see Table S3). There was also a small, but significant list × value interaction with respect to reaction time, such that value became slightly more predictive of reaction time across lists ($\beta_{30} = 0.003$, $p = .001$), with participants responding

slightly more slowly when concurrently studying a high-value item. In general, however, item value was not predictive of reaction time ($\beta_{10} = 0.002$, $p > .25$).

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 conditions recalled fewer items than those who studied under full attention, recall of the most important items did not differ relative to full attention. Under divided attention, participants may have adjusted 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 Figure 4).

Overall, these results provide a more detailed analysis of attention during encoding of high- and low-value items and 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 impacts selectivity.

In Experiment 1, participants studied the to-be-remembered items while completing a digit detection task or while listening to familiar/unfamiliar background music. Participants in the digit detection condition remembered fewer items overall, 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 dividing participants' attention during study to varying degrees, selectivity was consistently maintained.

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 upon 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 1back tone condition in Experiment 2 was specially intended to place additional demands on working memory reduce relative to the other conditions, yet selectivity was preserved.

There is a dearth of research investigating metamemory judgments made while under divided attention (Barnes & Dougherty, 2007; see Beaman et al., 2014, Kelley & Sahakyan, 2003, and Sacher et al., 2009 for work concerning post-encoding judgments), but the current results intimate that divided attention did not incapacitate metacognitive mechanisms in either of the current experiments, leaving 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 impact 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 understanding 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 information's 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 divided attention impacts on self-regulated study choices. Participants in the current study were unable to control what/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 email during a lecture) and/or control the pacing of their primary task (e.g., if background music in a café is distracting, a learner could choose to re-read 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, thereby making 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 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, providing further evidence that factors that worsen memory do not, necessarily, similarly affect study strategizing.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Acknowledgments

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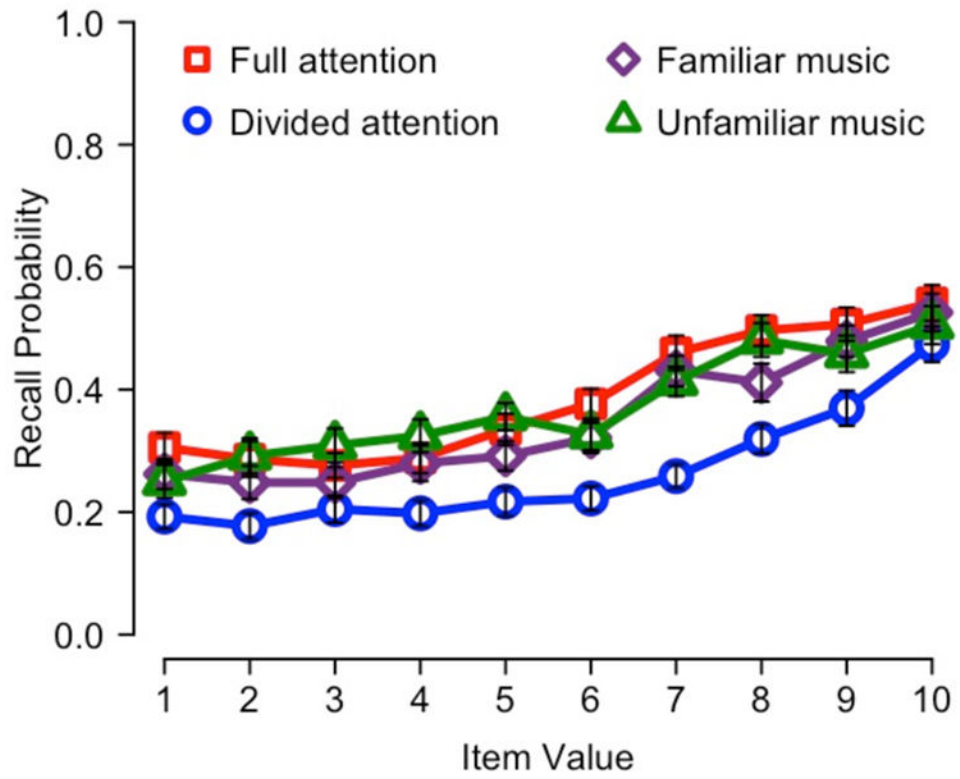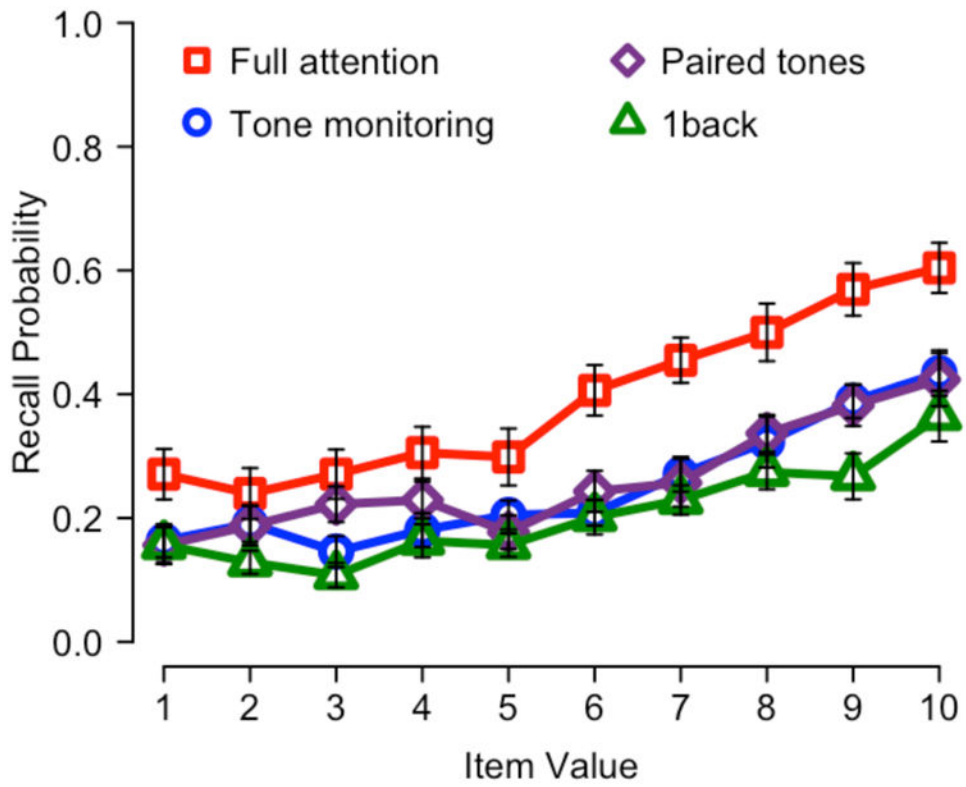
Fig. 1.
Recall probability, averaged across lists, as a function of item value and assigned study condition in Experiment 1.
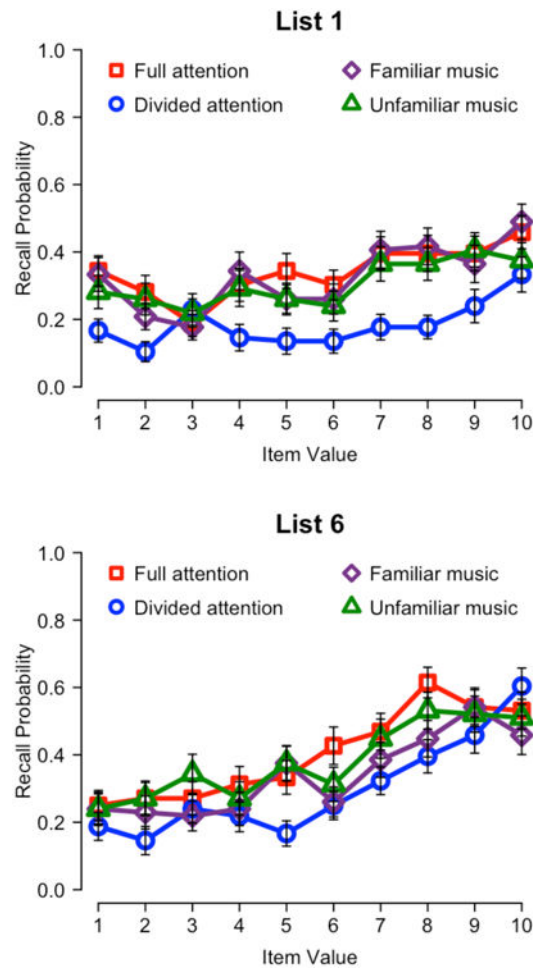
Fig. 2.
Recall probability in Experiment 1 as a function of item value and assigned study condition in List 1 and List 6 (i.e., the final studied list), demonstrating increased attention to value across conditions with continued task experience.
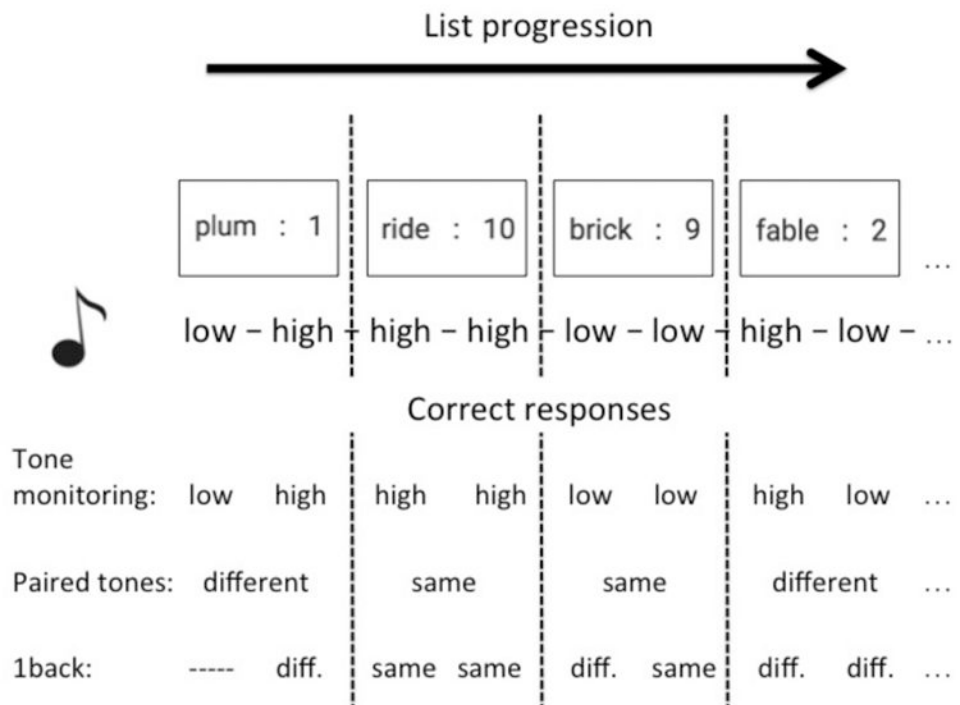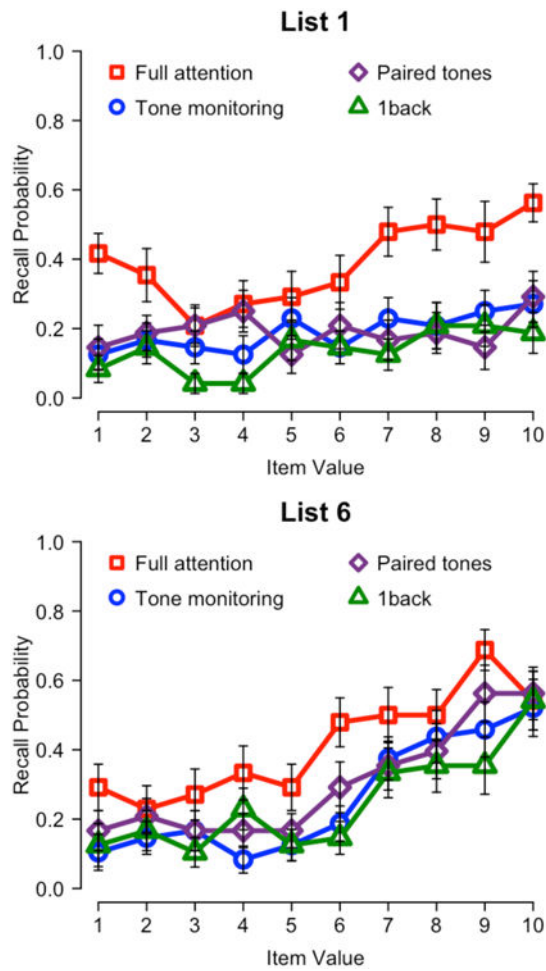
Fig. 3.
An example of a tone sequence distributed across items during study and the correct responses as per the three tone detection conditions.

Fig. 4.
Recall probability, averaged across lists, as a function of item value and assigned study condition in Experiment 2.

Fig. 5.
Recall probability in Experiment 2 as a function of item value and assigned study condition in List 1 and List 6 (i.e., the final studied list), demonstrating increased attention to value across conditions with continued task experience.

Table 1

Recall probability as a function of study condition and list in Experiment 1

Condition	List 1	List 2	List 3	List 4	List 5	List 6	Average
Full attention	0.34 (0.14)	0.38 (0.13)	0.40 (0.15)	0.40 (0.13)	0.41 (0.14)	0.40 (0.13)	0.39 (0.10)
Divided attention	0.18 (0.10)	0.24 (0.09)	0.27 (0.12)	0.29 (0.10)	0.29 (0.11)	0.30 (0.10)	0.26 (0.08)
Familiar music	0.33 (0.14)	0.35 (0.10)	0.36 (0.17)	0.38 (0.18)	0.38 (0.18)	0.34 (0.16)	0.35 (0.11)
Unfamiliar music	0.31 (0.14)	0.37 (0.17)	0.38 (0.13)	0.37 (0.15)	0.37 (0.15)	0.38 (0.18)	0.37 (0.11)

Note. Standard deviations are presented in parentheses.

Table 2

Two-level hierarchical generalized linear model of recall performance predicted by Item Value, List, and Study Condition in Experiment 1

Fixed effects	Coefficient
Intercept (β_{00})	-0.52***
Predictors of intercept	
Cond1: Full attention v. Divided attention (β_{01})	-0.62***
Cond2: Full attention v. Familiar music (β_{02})	-0.20+
Cond3: Full attention v. Unfamiliar music (β_{03})	-0.07
Value (β_{10})	0.16***
Predictors of value	
Cond1: FA v. DA (β_{11})	0.01
Cond2: FA v. FM (β_{12})	0.02
Cond3: FA v. UM (β_{13})	-0.02
List (β_{20})	0.04+
Predictors of list	
Cond1: FA v. DA (β_{21})	0.05+
Cond2: FA v. FM (β_{22})	-0.03
Cond3: FA v. UM (β_{23})	0.01
List × Value (β_{30})	0.03**
Predictors of list × value	
Cond1: FA v. DA (β_{31})	0.01
Cond2: FA v. FM (β_{32})	-0.01
Cond3: FA v. UM (β_{33})	-0.01

Random effects	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. Logit link function was used to address the binary dependent variable.

+ $p < .10$

* $p < .05$

** $p < .01$

*** $p < .001$

Table 3

Recall probability as a function of study condition and list in Experiment 2

Condition	List 1	List 2	List 3	List 4	List 5	List 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)
1back	.14 (.06)	.17 (.07)	.28 (.15)	.24 (.09)	.23 (.08)	.25 (.09)	.21 (.05)

Note. Standard deviations are presented in parentheses.

Table 4

Two-level hierarchical generalized linear model of recall performance predicted by Item Value, List, and Study Condition in Experiment 2

Fixed effects	Recall
Intercept (β_{00})	-0.52***
Predictors of intercept	
Cond1: Full attention v. Tone monitoring (β_{01})	-0.72***
Cond2: Full attention v. Paired tones (β_{02})	-0.67**
Cond3: Full attention v. 1back (β_{03})	-0.98***
Value (β_{10})	0.21***
Predictors of value	
Cond1: FA v. TM (β_{11})	-0.02
Cond2: FA v. PT (β_{12})	-0.05
Cond3: FA v. 1back (β_{13})	-0.05
List (β_{20})	0.01
Predictors of list	
Cond1: FA v. TM (β_{21})	-0.01
Cond2: FA v. PT (β_{22})	0.06
Cond3: FA v. 1back (β_{23})	0.09**
List × Value (β_{30})	0.03**
Predictors of list × value	
Cond1: FA v. TM (β_{31})	0.02
Cond2: FA v. PT (β_{32})	0.03
Cond3: FA v. 1back (β_{33})	0.0003

Random effects	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. Logit link function was used to address the binary nature of the recall outcome.

*
$p < .05$

**
$p < .01$

***
$p < .001$