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Working memory capacity, strategic allocation of study time, and value-directed remembering

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ABSTRACT

To further elucidate the relationship between working memory capacity (WMC) and long-term memory (LTM), the present study investigated how individual differences in WMC relate to strategic encoding and subsequent retrieval in a self-regulated value-directed remembering paradigm. Participants were given 2 min to study lists of words that varied in explicit value and then were asked to freely recall the words they had just studied. In Experiment 1, participants were not given any guidance on effective encoding strategies. The strategy that led to the highest point totals was to ignore the low-value items altogether, and high-WMC participants were more likely to use this strategy. In Experiment 2, half of participants received an instruction on how to best allocate their study time at the beginning of the task, and half received this instruction after three of the six lists. Equating participants on the use of an effective strategy from the beginning of the task eliminated WMC-related differences in task performance. Together the results support the conclusion that low-WMC individuals spontaneously use effective encoding strategies less often than high-WMC individuals. But when instructed to do so, WMC-related differences are greatly attenuated. Therefore, one of the major reasons for the WMC-LTM relationship seems to be the differential development and execution of task-appropriate strategies during encoding of to-be-remembered information.

Introduction

At nearly every moment in our waking lives, we are bombarded with an abundance of information. But both our time and attention are limited. Therefore, we attend to what is important to us and we devote our time in a similar goal-directed manner. This process is not perfect. Occasionally we are captured by irrelevant information in the environment and by irrelevant internal thoughts (i.e., mind-wandering), and we occasionally waste time. But we are largely adaptive in the use of our time and mental energy. Although we all have this skill, people differ substantially in how they choose to devote their time and attention, as well as how well they maintain and execute their goals. The maintenance and execution of such goals is a crucial determinant of working memory capacity (WMC), an important individual difference at the cognitive level that correlates with a host of other important cognitive abilities (Engle & Kane, 2004). WMC correlates with fluid intelligence (Engle, Tuholski, Laughlin, & Conway, 1999) and reading comprehension (Daneman & Carpenter, 1980), as well as our ability to resist mind-wandering and external distraction (Kane et al., 2007; Robison & Unsworth, 2015; Unsworth & McMillan, 2014), especially in contexts where our attention is demanded by the task at hand.

Another instance in which WMC seems to be important is long-term memory (LTM). Prior studies have shown that

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individuals with greater WMC are generally better at tasks that require recalling information from LTM, and this has been demonstrated using tasks including immediate free recall (e.g., Unsworth & Engle, 2007), delayed and continuous distractor free recall (e.g. Unsworth, 2007), recognition and source recognition (e.g. Unsworth & Brewer, 2009), and verbal fluency (e.g. Rosen & Engle, 1997). Specifically, individuals with low-WMC have difficulties dealing with proactive interference and show slower recall, which suggests low-WMC individuals have an enlarged search-set compared to high-WMC individuals (Kane & Engle, 2000; Lilienthal, Rose, Tamez, Myerson, & Hale, 2015; Unsworth, 2007; Unsworth & Brewer, 2009). Low-WMC individuals also have difficulty self-generating cues for search (Unsworth & Spillers, 2010; Unsworth, Brewer, & Spillers, 2013; Unsworth, Spillers, & Brewer, 2012b), and they do not search LTM in a structured manner (Spillers & Unsworth, 2011; Unsworth, Spillers, & Brewer, 2012a).

In addition to examining individual differences during retrieval, recent research has also focused on how variation in WMC relates to strategic differences at encoding. Individuals use different strategies at encoding during tasks that measure WMC, and when controlling for strategy use, the correlation between WMC and reading comprehension actually increases (Turley-Ames & Whitfield, 2003). When given effective strategies to use during encoding, participants benefit, and this is especially the case for low-WMC participants (Turley-Ames & Whitfield, 2003). Bailey, Dunlosky, and Kane (2008) found that the use of normatively effective encoding strategies during tasks measuring WMC (i.e., Operation span and Reading span) correlates with LTM tasks that lend themselves to similar strategies (i.e., paired-associates recall, free recall). Importantly, this partially mediates the relationship between WMC and performance on these measures of LTM. However there is still unique variance in LTM accounted for by individual differences in WMC independent of strategy use. Similarly, Unsworth and Spillers (2010) found that in addition to differences in contextual-retrieval, part of the WMC-LTM relation is due to strategic differences during encoding. Finally, Unsworth (2016) analyzed dynamics at both encoding and retrieval in a delayed free recall task. Greater WMC related to the use of more effective encoding strategies, such as semantic association, fewer intrusions, and better monitoring. Importantly, these various aspects of LTM completely mediated the relation between WMC and successful recall.

One open question in the WMC-LTM relationship is how strategic individuals are when asked to study information that varies in its importance, as well as how memory selectivity relates to WMC. Traditionally, the WMC-LTM relationship is investigated using immediate or delayed free recall tasks as measures of LTM abilities. Participants are given lists of items in a sequential manner and are asked to recall as many items as possible. Therefore, variation in LTM may be due to the selectivity with which participants are using their memory. For example, low-WMC participants may be well aware of their memory limitations and therefore actually choose to remember only a small subset of those items. On a typical 10-item list, low-WMC participants may acknowledge that they will only be able to recall four or five of these items and decide to rehearse these items only. When their performance is examined and we observe 40–50% accuracy, it may actually be the case that these participants are recalling 80–100% of the items that they *chose* to remember. Of course, it could also be the case that low-WMC participants try to remember all the items, and in doing so are only able to encode a rather weak representation of every item. Subsequently they have difficulty recalling many items, not because they had a strong representation of a subset of the items and a nearly non-existent representation of the remaining items, but because they have a weak representation of all items. Therefore, the typical delayed free recall task may limit our ability to understand WMC-related differences in LTM. An alternative paradigm for studying LTM is the value-directed remembering task, which has primarily been used to examine age-related differences in memory.

Using the value-directed remembering paradigm originally developed by Watkins and Bloom (1999), Castel, Benjamin, Craik, and Watkins (2002) gave older and younger adults lists of words that were each paired with a value from 1 to 12. Words were presented sequentially and the values could appear at any point during the list. At recall, participants were given points for recalling the words based on their value and were instructed to try and maximize their point totals. From this task, Castel et al. were able to compute a selectivity index (SI) for each participant. The calculation of the SI is shown below.

$$SI = \frac{\text{subject's score} - \text{chance score}}{\text{ideal score} - \text{chance score}}$$

The ideal score is the maximum number of points based on the number of words recalled. For example, if a participant recalled four words, the ideal score would be 52 (12 + 11 + 10 + 9). The chance score is the average value of items (in this case 6.5). If they recalled the words valued at 12, 10, 7, and 4, their score would be 33, and their SI would be 0.27. An SI of 1 indicates perfect selectivity, 0 indicates chance selectivity, and −1 indicates perfect selectivity for low-value information. When comparing older and younger adults, older adults were actually more selective, even though they recalled fewer words overall (Castel et al., 2002; but see also Hayes, Kelly, & Smith, 2013). These results suggest that as a consequence of a reduced ability to recall information from LTM with advanced age, older adults adapt to memory loss by becoming more selective in what they choose to remember (Castel, 2007). Although older adults and low-WMC young adults are not identical in their cognitive abilities, we may be able to use the findings from aging studies to better understand individual differences in WMC. Despite their lower overall recall abilities, low-WMC individuals may show similar patterns of recall as older adults in a value-directed remembering task. That is, they may recognize their lower LTM abilities and compensate for such by being more selective with their memory.

Despite the many insights the typical value-directed remembering task offers about memory selectivity, it does not allow individuals to differentially allocate study time to high-value words over low-value words. Participants are given each word sequentially for a fixed amount of time. Therefore, it may prevent individuals from being more strategic during the encoding period. In a recent study, Castel, Murayama, Friedman, McGillivray, and Link (2013) gave younger and older adults lists of 30 words to study that varied in value from 1 to 30. Item values were presented simultaneously on the screen and participants studied the words individually by clicking on them. Therefore, participants could choose to study (or not study) words, they could revisit items, and they could allocate study time to the words in a strategic manner. At the end of the two-minute study window, participants freely recalled the words, and the experimenter gave them their score before proceeding to the next list. Older adults were significantly more selective during study compared to younger adults. They spent more time studying each word, studied fewer words overall, and spent more time studying the high-value words compared to younger adults. Although younger adults recalled more words, older adults recalled a similar percentage of the words they studied compared to younger adults, and the average value of the words they recalled was higher than younger adults. Using multi-level modeling, Castel et al. (2013) found that the relationship between point value and study time allocation was stronger for older adults, older adults studied higher value items immediately before the test, and the benefit of study time on successful recall was stronger for older adults. Together the results suggested that older adults were well aware of their LTM impairments and made adjustments to their study time to focus only on high-value information. Whereas young adults may not need to be as selective during study to reach a high level of performance, older adults need to be selective in order to achieve successful memory performance, and they are quite adept at doing so.

With regard to WMC, it may also be the case that despite differences in recall abilities, low-WMC participants may be particularly selective during encoding. Therefore, what may appear to be impaired recall could actually be the result of hyperselectivity during encoding, much like the pattern older adults showed in Castel et al. (2013). If this is the case, then low-WMC participants will actually study fewer words and allocate relatively more time to high-value words than high-WMC participants. However, the opposite case is also possible. Unsworth (2016) found that low-WMC participants were actually less effective with their encoding strategies, and this partially accounted for WMC-related differences in recall. WMC was also unrelated to study time allocation when participants were given unlimited time to study each word. However, there was no incentive to study certain words longer than others as there is in the value-directed remembering paradigm discussed above. Therefore, it is possible that low-WMC participants will actually be less effective during the study time period. If this is the case, they will spread themselves thinly over all the items, despite the fact that they will only be able to recall a small proportion of the items. If that is the case, we should observe a less effective allocation of study time among low-WMC participants compared to high-WMC participants. A third possibility is that high- and low-WMC participants will be equally selective with their study time, and the WMC-related differences in recall with be entirely due to differences on the retrieval end of the task. If that is the case, we should observe no relation between study time allocation and WMC, and WMC-related differences in recall will be due to retrieval-related differences only.

Experiment 1

We used the same task as Castel et al. (2013) to investigate several theoretical issues: (1) How do individual differences in WMC relate to the allocation of study time when participants are given explicit information about item value and a time limit? (2) How do these differences translate into recall performance? and (3) When given an effective study strategy, will WMC-related differences in study-time allocation and recall be attenuated or perhaps disappear altogether?

We used the same task as Castel et al. (2013) to investigate these questions for several reasons. First, the traditional value-directed remembering paradigm, in a sense, forces participants to study all the words and does not allow them to differentially allocate study time to each item. The present task allows participants to study (or not study) items entirely volitionally, so we can investigate which items participants choose to study and for how long participants study each item. Second, the time limit gives participants enough time to study all the items, if they choose to do so, but it is not a long enough time to sufficiently encode and remember all 30 words, so it also forces participants to be strategic. Third, it allows us to simultaneously examine encoding-related differences and retrieval-related differences, and in turn examine how these differences relate to WMC.

In Experiment 1, we gave participants explicit instructions about the structure of the task (e.g., study time, point values, etc.), and we instructed participants to try to maximize their point totals on every list. However, they were given no specific instructions about how to structure their study time. So this aspect of the task was entirely under their own control. In Experiment 2, half of participants were given this same set of instructions, and after three lists we gave participants an effective study strategy (the most effective strategy observed in Experiment 1). The other half of participants were given this strategy at the beginning of the task, and after three lists under this instruction they were told they could use whatever strategy they felt would be best to help them achieve the highest point total. Therefore, Experiment 2 attempted to replicate the findings of Experiment 1 and to test a hypothesis derived from Experiment 1. Specifically, if given an effective study strategy, will WMC-related differences in recall performance be attenuated or disappear? Additionally, when given an effective strategy from the get-go and then told to use whatever strategy they feel will be best, participants will have the opportunity to continue with or abandon the effective strategy. Therefore, we can examine how WMC is related to strategic dynamics over the course of the task. By measuring individual differences in WMC, allowing participants to self-regulate study time allocation, and subsequently attempting to equate participants on their study-time strategies, we sought to further understand the role of WMC in strategic encoding processes and memory selectivity, and how these differences may help us further elucidate WMC-related differences in LTM.

Method

Participants and procedure

Participants were 122 undergraduate students from the human subject pool at the University of Oregon. All participants gave informed consent before participating. We wanted to obtain a sample size large enough to achieve adequate power for correlational analyses and we used the end of the academic term as our stopping rule for data collection. Participants completed the tasks individually. After the value-directed remembering task, participants completed other measures of attention control and visual working memory. However, because they are not the focus of the current investigation, they are not reported here. The full experimental session lasted approximately 2 h and participants were given partial course credit for their participation. The complex span and value-directed remembering task comprised the first hour of the experimental session.

Tasks

Working memory capacity

Operation span. The span tasks were used to measure working memory capacity because they require participants to both process and store information in working memory. In this task, participants solved a series of math operations while trying to remember a set of unrelated letters. Participants were required to solve a math operation, and after solving the operation, they were presented with a letter for 1 s. Immediately after the letter was presented the next operation was presented. At recall participants were asked to recall letters from the current set in the correct order by clicking on the appropriate letters. For all of the span measures, items were scored correct if the item was recalled correctly from the current list in the correct serial position. Participants were given practice on the operations and letter recall tasks only, as well as two practice lists of the complex, combined task. List length varied randomly from three to seven items, and there were two lists of each length for a total possible score of 50. The score was total number of correctly recalled items in the correct serial position.

Symmetry span. Participants recalled sequences of red squares within a matrix while performing a symmetry-judgment task. In the symmetry-judgment task, participants were shown an 8×8 matrix with some squares filled in black. Participants decided whether the design was symmetrical about its vertical axis. The pattern was symmetrical half of the time. Immediately after determining whether the pattern was symmetrical, participants were presented with a 4×4 matrix with one of the cells filled in red for 650 ms. At recall, participants recalled the sequence of red-square locations by clicking on the cells of an empty matrix. Participants were given practice on the symmetry-judgment and square recall task as well as two practice lists of the combined task. List length varied randomly from two to five items, and there were two lists of each length for a total possible score of 28. We used the same scoring procedure as we used in the operation span task.

Reading span. While trying to remember an unrelated set of letters, participants were required to read a sentence and indicated whether or not it made sense. Half of the sentences made sense, while the other half did not. Nonsense sentences were created by changing one word in an otherwise normal sentence. After participants gave their response, they were presented with a letter for 1 s. At recall, participants were asked to recall letters from the current set in the correct order by clicking on the appropriate letters. Participants were given practice on the sentence judgment task and the letter recall task, as well as two practice lists of the combined task. List length varied randomly from three to seven items, and there were two lists of each length for a total possible score of 50. We used the same scoring procedure as we used in the operation span and symmetry span tasks.

Value directed remembering

Participants were instructed that they would be studying lists of words and then asked to recall those lists. They received 2 min to study each list and 2 min to recall each list. Specifically, participants' on-screen instructions said, "In this task, you will be asked to study and recall words. You will see a screen of boxes with numbers on them. You can think of these boxes like flash cards. The number on the box corresponds to the value of the word associated with it. You will get 2 min to study the words, and you will then be asked to recall the words. To view the word associated with a value, click on the number. This will reveal the word. You will only be able to view one word at a time. After 2 min of study time, you will be given 2 min to recall as many words as possible. Your goal is to maximize the number of points you receive on each list. Your score is the number of words you recall multiplied by their value. The values will range from 1 to 30. For example if you recall the words with values 25, 18, 13, and 2. Your score would be 58 (25 + 18 + 13 + 2 = 58). Thus, words associated with higher numbers are more valuable. You will recall the words by typing them into the computer." Because scoring was performed after data collection, participants were not given immediate feedback on their point totals after the recall period. After the recall period, the task automatically moved to the study screen for the next list. The task was designed to match the task developed by Castel et al. (2013) and programmed in E-Prime 2 software. A visualization of the task is shown in Fig. 1. A random list of 210 nouns between three and five letters in length was generated, and these nouns were then randomly assigned to a value. Word-value pairings and list order were the

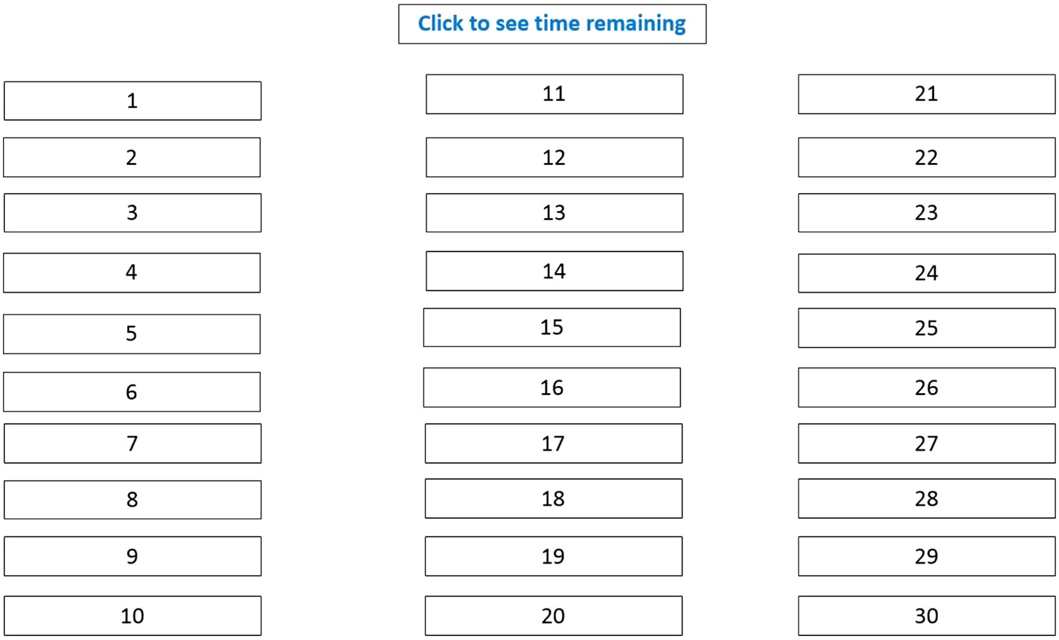

Fig. 1. Depiction of study screen. When participants clicked a box, the word associated with that value appeared. When they clicked on another box, the previously studied word disappeared and the value was shown again. When participants clicked the box at the top, it showed how many seconds they had remaining for study.

same for all participants. Participants completed one practice list during and after which they were allowed to ask the experimenter any questions they had about the task. Participants then completed six lists that were scored and included in the results.

Results

Descriptive statistics for the WMC tasks and the value-directed memory task are shown in Table 1. As can be seen, there was a considerable amount of variability in WMC and performance on the value-directed remembering task. We first standardized the three WMC measures and averaged those *z*-scores to give each participant a single score for WMC. In all subsequent analyses, we treated WMC as a continuous variable. For illustrative purposes, the figures show high- and low-WMC participants, who were categorized as such using a quartile split (32 high-WMC participants and 31 low-WMC participants). However, no statistical analyses compared high- and low-WMC individuals at the group level. Whenever we interpret a null correlation, we report the Bayes Factor in favor of the null hypothesis over the alternative hypothesis. The Bayes Factors reported here can be interpreted as the ratio of evidence in favor of the null hypothesis of $r = 0$. For example, a Bayes Factor of 2 means the null hypothesis is twice as likely to be true given the data.

Overall, participants were sensitive to the value of words, as they spent the majority of their time studying high-value words and less time studying mid- and low-value words. Participants also appeared to spend less time studying low-value words in the second block (Lists 4, 5, and 6) compared to the first block (Lists 1, 2, and 3). These observations were confirmed by a repeated measures ANCOVA on study time allocation with value (high, mid, and low) and block (1 and 2) as within-subjects variables and WMC as a covariate, which revealed an effect of value ($F(2,240) = 190.50$, $p < .001$, partial $\eta^2 = 0.61$), an effect of block ($F(1,120) = 8.11$, $p = .005$, partial $\eta^2 = 0.06$), and a block × value interaction ($F(2,240) = 3.21$, $p = .04$, partial $\eta^2 = 0.03$). The block × value interaction was driven by participants spending less time on the low-value words in block 2 compared to block 1 ($t(121) = 4.04$, $p < .001$). None of the observed effects significantly interacted with WMC (all $ps > .14$).

Point totals were actually slightly lower in the second half of the task, but this effect seemed to be larger for the low-WMC participants compared to the high-WMC participants, as shown in Fig. 2a. A repeated measures ANCOVA with block (Lists 1, 2, and 3 vs. Lists 4, 5, and 6) and WMC as a covariate yielded a marginally significant effect of block ($F(1,120) = 3.54$, $p = .06$) and a significant block × WMC interaction ($F(1,120) = 6.26$, $p = .01$, partial $\eta^2 = 0.05$), suggesting that the drop in points from block 1 to block 2 was greater for participants with lower WMC. Overall, WMC significantly correlated with average point total ($r = .41$, $p < .001$). In other words, participants with greater WMC achieved better task performance in terms of the cumulative value of the words they recalled.

There are a number of reasons why individuals with greater WMC could have been more successful on the task as far as having higher point totals. It is possible that greater WMC allowed those individuals to recall more words overall, which would lead to higher point totals. In addition to examining total number of words recalled, we

Table 1
Descriptive statistics for Experiment 1.

Measure	Mean (*SD*)	Range	Skewness	Kurtosis	α
Operation span	37.84 (8.10)	6–50	−1.16	1.76	0.63
Symmetry span	19.59 (4.80)	6–28	−0.40	−0.29	0.54
Reading span	38.00 (7.40)	14–50	−0.84	0.80	0.61
Point total	247.09 (61.61)	84.33–391.33	−0.03	0.06	0.88
Words studied	23.58 (6.46)	9.33–30.00	−0.64	−0.88	0.92
Words recalled	12.24 (3.18)	6.17–25.33	1.86	1.86	0.87
Recall proportion	0.56 (0.18)	0.21–0.97	0.42	−0.54	0.89
Selectivity index	0.56 (0.38)	−0.87 to 1.00	−1.28	1.35	0.92

Note. $N = 122$. Numbers in parentheses are standard deviations. α = Cronbach's alpha.

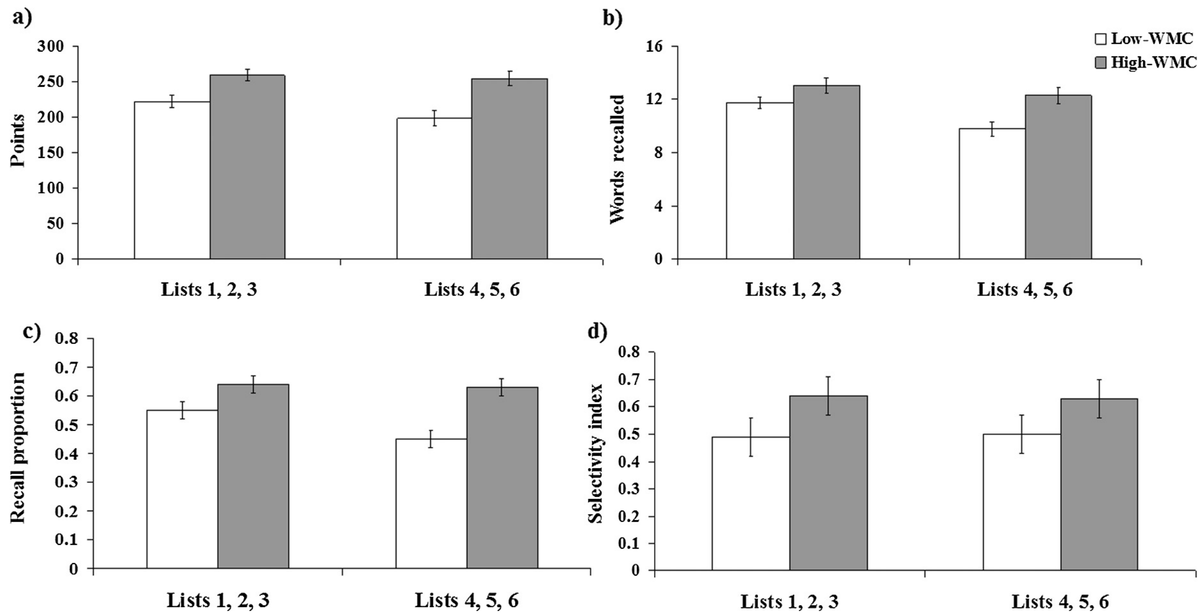

Fig. 2. Task performance as a function of block (Lists 1, 2, and 3 vs. Lists 4, 5, and 6) and WMC (high vs. low) in Experiment 1: (a) Point totals, (b) number of words recalled, (c) proportion of studied words recalled, and (d) selectivity index. Error bars represent one standard error of the mean.

also examined recall proportions, which was the number of words recalled divided by the number of words studied on each list. It is also possible that they were more selective during recall, as indicated by SI. These possibilities are not mutually exclusive, and we investigated each of these measures.

A repeated measures ANCOVA on words recalled with block as a within-subjects variable and WMC as a covariate revealed an effect of block, suggesting that participants recalled fewer words in the second half of the task compared to the first ($F(1,120) = 10.26$, $p = .002$, partial $\eta^2 = 0.08$), but this did not significantly interact with WMC ($p = .10$). Overall, number of words recalled positively correlated with WMC ($r = .36$, $p < .001$). This pattern of results is depicted in Fig. 2b. Therefore one of the reasons WMC related to point totals was that high-WMC participants recalled more words overall, regardless of value.

Although there was no main effect of block ($p = .16$), the repeated measures ANCOVA on recall proportion revealed a significant block × WMC interaction ($F(1,120) = 6.55$, $p = .01$, partial $\eta^2 = 0.05$). Recall proportion dropped over time for participants with lower WMC. Overall, recall proportion significantly correlated with WMC ($r = .35$, $p < .001$). This pattern of results is depicted in Fig. 2c. So another reason WMC related to point totals was that high-WMC participants recalled a higher proportion of the words they chose to study.

Finally, the ANCOVA on SI revealed an effect of block ($F(1,120) = 7.54$, $p = .007$, partial $\eta^2 = 0.05$). Participants became more selective when recalling words over time, but this effect did not interact with WMC ($p = .11$). Overall, SI marginally correlated with WMC ($r = .16$, $p = .08$). The pattern of results is depicted in Fig. 2d. Therefore, high-WMC participants recalled more words and a higher proportion of the words they studied, and they were also slightly more selective in their recall.

Our next set of analyses examined study strategies to investigate two main questions: (1) Which study strategies led to the highest subsequent point totals? and (2) How did use of the various study strategies covary with WMC? Participants used a variety of strategies during the encoding period. As we did not identify any strategies beforehand, we identified various study strategies based on observed patterns in the data. In doing so we identified four general strategies. For each strategy, we coded how many times each participant employed the strategy across the six lists. Some participants used the same strategy for all six lists, others used a combination of strategies across lists. The first strategy we identified was the Study All strategy. When using this strategy, participants viewed every word at least once. Most participants (76%) used the Study All strategy at least once over the course of the six lists. The second strategy we identified was the Focus High strategy. When using this strategy, participants spent 75% or more time on the high-value words. About 47% of participants used the Focus High strategy at least once. The third strategy we identified was the Ignore Low strategy. When using this strategy, participants did not study any of the low-value words. About 50% of participants used this strategy at least once. Finally in an Only High strategy, participants limited their studying to the high-value words. Only about 20% of participants used this strategy. We summed the number of times participants used each of this lists and correlated those strategies with average point totals.[1] More frequent use of the Ignore Low strategy correlated with higher average point totals ($r = .29$, $p < .01$) and more frequent use of the Study All strategy led to lower point totals ($r = -.24$, $p < .01$). Using a Mostly High ($r = .07$, $p = .44$, BF[2] = 6.67) or an Only High strategy ($r = -.01$, $p = .84$, BF = 4) more often did not lead to higher or lower point totals. This suggests that a moderate amount of selectivity during study (ignoring the low-value items) led to the best performance as far as maximizing the recall score. To demonstrate the relationship between study time and recall, we plotted average study time and proportion of recall for words valued 1–30 separately for those who did ($N = 61$) and did not ($N = 61$) use the Ignore Low strategy at least once (Fig. 3). This shows that the spending more time on low-value words was associated with lower recall for high-value words.

We next examined how frequency of use of these different strategies correlated with WMC. WMC did not significantly correlate with frequency of use of any strategy (Ignore Low: $r = .14$, $p = .13$, BF = 2.78; Only High: $r = .11$, $p = .21$, BF = 2.08; Mostly High: $r = .13$, $p = .14$, BF = 3.12; Study All: $r = -.15$, $p = .08$; BF = 2.08). But the direction of the correlations suggests high-WMC participants were slightly more likely to use an effective strategy (Ignore Low) and slightly less likely to use an ineffective strategy (Study All). The results clearly rule out the possibility that low-WMC participants are actually more selective during encoding, which would have led to a negative correlation between WMC and use of the Ignore Low strategy and a positive correlation between WMC and use of the Study All strategy. The results make it harder to disentangle the two remaining possibilities that high-WMC participants are more selective during encoding and that high- and low-WMC participants are equally selective during encoding.

Because the Ignore Low strategy was the most effective, we more closely examined use of this strategy as it related to WMC. As mentioned earlier, the frequency with which individuals used the Ignore Low strategy did not significantly correlate with WMC. However a point-biserial correlation revealed that high-WMC participants were significantly more likely to use the Ignore Low strategy at least once ($r = .23$, $p = .01$). But many low- and mid-WMC participants also used this strategy. When specifically examining average point totals for lists on which participants used the Ignore Low strategy, there was no correlation between WMC and point total ($r = -.06$, $p = .62$, BF = 4.16). However when examining point totals using any other strategy, WMC and point total significantly correlated ($r = .35$, $p < .001$). These two correlations were significantly different from one another ($z = 6.03$, $p < .001$). Together these results suggest that high-WMC participants are significantly more likely to spontaneously use the most effective study strategy, which is part of the reason they scored significantly better than other participants on the value-directed remembering task. However when compared to other participants who also used the most effective strategy, WMC-related differences disappeared. Thus equating participants by providing the most effective strategy may eliminate the advantage for high-WMC individuals.

Discussion

Overall the results revealed several interesting findings when examining study strategies in subsequent performance on the value-directed remembering task. First, participants were sensitive to the value manipulation as they spent most of their time studying high-value words and almost half of participants ended up using a strategy in which they totally ignored the low-value words. Using this strategy (Ignore Low) led to significantly higher point totals, but other strategies did not. In fact, studying all the words actually led to lower point totals.

In regards to individual differences in WMC, the results replicated the well-established finding that high-WMC participants are more effective at recalling information from LTM. However, the correlation between effective strategy use and WMC was rather ambiguous. We could conclusively rule out the possibility that low-WMC participants would actually be more selective during encoding and choose to study a smaller subset of items, as is the case with older adults (Castel et al., 2013). The two remaining possibilities (higher encoding selectivity being positively related to WMC and encoding selectivity and WMC being unrelated) were more difficult to disentangle.

Upon closer examination, although high-WMC participants did not use the Ignore Low strategy significantly more often, they were significantly more likely to use it at least once. Further, the WMC-point total correlation was eliminated when examining average point totals on lists where participants used the Ignore Low strategy. When using any other strategy, high-WMC participants

[1] Note: some strategies are not mutually exclusive. For example, a participant could have employed both the Study All and Focus High strategies on a given list.

[2] Bayes Factors for correlations were calculated using JASP software (JASP Team, 2016).

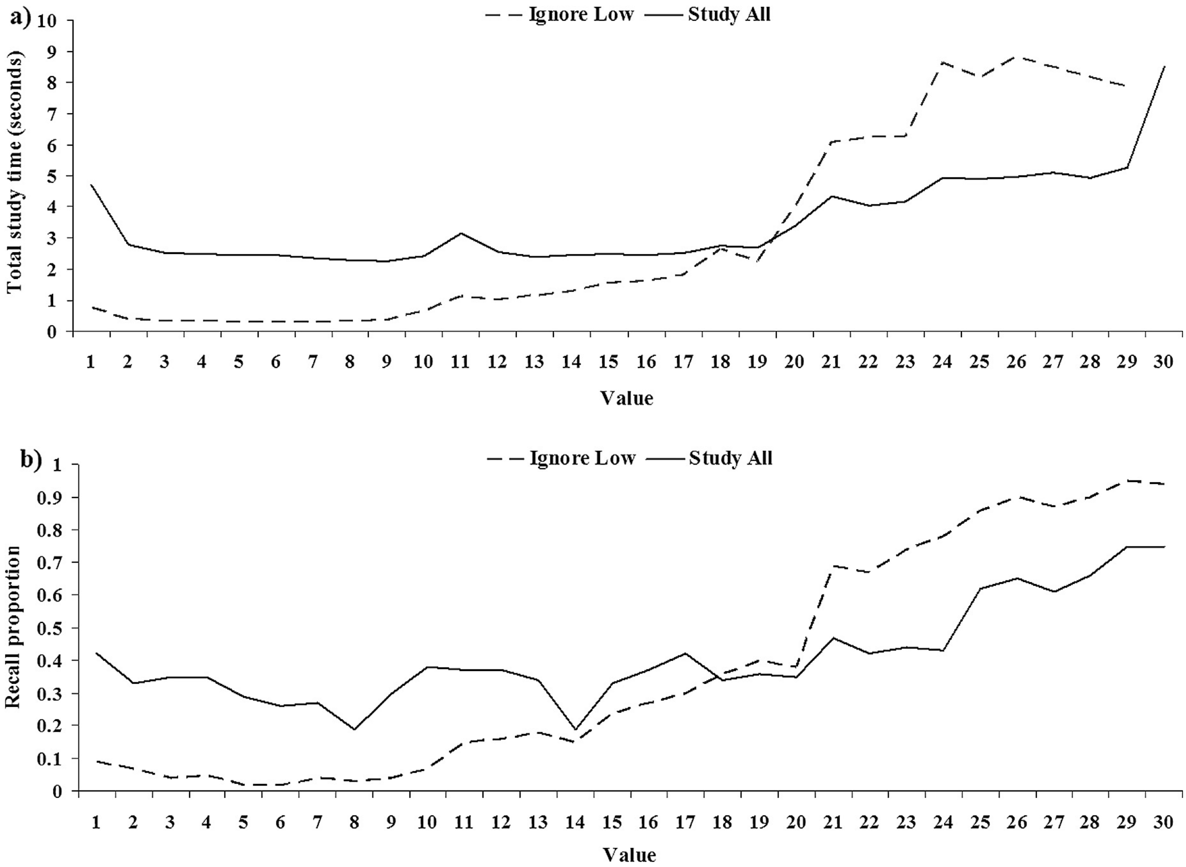

Fig. 3. Total study time and recall proportions as a function of word value for participants who used the Ignore Low and Study All strategies.

significantly outperformed other participants. This pattern of results suggests that effective study strategies may be particularly important for individuals with lower WMC, just as Castel et al. (2013) showed with older adults. Typically low-WMC individuals struggle to recall information from LTM. However it seems that if they use an effective study strategy that focuses on high-value information and ignores low-value information, they can achieve a high level of performance similar to high-WMC individuals.

Experiment 2

The results of Experiment 1 introduced the intriguing possibility that equating participants on strategy use would attenuate or eliminate WMC-related differences in task performance. Therefore Experiment 2 included two conditions. In one condition, participants were given an effective strategy to use before the first list. After the third list, they were told that they could use any strategy they thought would be best for the remaining lists. The instruction manipulation had two purposes. First, we wanted to equate participants on strategy use to see if WMC-related differences would again be attenuated or disappear. Second, we wanted to see if participants would change their strategy when told they could use whatever study strategy they wanted. In the other condition, participants were given the instruction that they could use any study strategy they wanted before the first list. After the third list, they were given the study strategy instructions and were recommended to use that strategy for the remaining lists. For the first three lists, this condition should have replicated the findings of Experiment 1.

Method

Participants and procedure

Participants were 200 undergraduate students from the University of Oregon human subject pool. None of the participants had participated in Experiment 1. Participants completed the same three complex span tasks and value-directed remembering task as in Experiment 1. Again, participants completed other tasks after these tasks as part of a two-hour session, but because they are not the focus of the current study, they will not be discussed further. The complex span and value-directed memory tasks comprised the first hour of the session. All participants gave informed consent prior to beginning the study and were given partial course credit for their participation. We wanted our sample to be large enough to perform correlational analyses with adequate power in both conditions and we collected data over two full academic terms, with the end of the second term as our stopping rule for data collection.

Tasks

Working memory capacity

Operation span. See Experiment 1.

Symmetry span. See Experiment 1.

Reading span. See Experiment 1.

Value-directed remembering

The task was identical to the one used in Experiment 1 with one crucial difference. All instructions preceding the practice list were identical to those in Experiment 1 and were the same across the two conditions. In one condition, participants were given the effective Ignore Low strategy for the task before they started the first scored list. Specifically, the on-screen instructions included a screen that said, "An ideal strategy for this task is to spend the majority of your time studying the high-value words and to ignore the lowest-value words. Try to use this strategy as a way of maximizing your score." After the third list, participants saw a screen that said, "For the next three lists, please use whatever study strategy you think would help you best achieve the highest possible score." In the other condition, participants received this latter instruction before the first list and received the instruction about the Ignore Low strategy after completing the third list. The lists, words, and values were the same as in Experiment 1, and the order of lists matched the strategy instructions. In other words, lists were presented under the same instructions regardless of condition. Participants were randomly assigned to conditions by the task software.

Results

Descriptive statistics for each condition are shown in Table 2. As can be seen there were no differences in WMC across the two conditions. In each condition, the measures showed a fair amount of variability, and skewness and kurtosis values were within acceptable ranges. There were no significant differences between conditions in any of the measures (all *ps* > .08). The number of words studied was slightly lower in the condition in which the strategy instruction was given before the first list, which makes sense considering the difference between conditions. There were no significant differences in scores on the complex span tasks between Experiments 1 and 2 (all *ps* > .10). As in Experiment 1, we standardized the three complex span tasks and averaged these *z*-scores to give each participant a single value for WMC.[3]

Just as in Experiment 1, our first set of analyses focused on task performance in terms of point totals, words recalled, recall proportion, and selectivity. A repeated measures ANCOVA with block (Lists 1, 2, and 3 vs. Lists 4, 5, and 6) as a within-subjects factor, condition (free-then-strategy vs. strategy-then-free) as a between-subjects factor and WMC as a covariate yielded no main effect of block ($p = .85$). But importantly, there was a block × condition interaction ($F(1,197) = 14.25$, $p < .001$, partial $\eta^2 = 0.06$). The pattern of results in depicted in Fig. 4a and b. Participants in both conditions scored significantly higher when they were told to use the Ignore Low strategy. This was the case for both high- and low-WMC participants, as the differences in point total between the strategy instruction and free instruction did not correlate with WMC ($r = .03$, $p = .63$, BF = 9.09). Perhaps most strikingly, there was a significant correlation between WMC and point total when participants were free to use their own strategy on the first three lists ($r = .44$, $p < .001$) and after they were given the optimal strategy in this condition ($r = .46$, $p < .001$). By contrast, when participants were given the optimal strategy from the beginning, the correlation between WMC and point total was no longer significant under either the strategy instruction ($r = .10$, $p = .30$, BF = 5.88) or the free instruction ($r = .07$, $p = .46$, BF = 7.14).[4] In other words, when participants were given the Ignore Low strategy at the beginning of the task, WMC-related differences in task performance were eliminated. But when given this strategy midway through the task, WMC-related differences remained intact. We propose possible reasons for this discrepancy in the General Discussion.

The ANCOVA on number of words recalled did not reveal an effect of block, nor block × WMC or block × condition interactions (all *Fs* < 1). These results are depicted in Fig. 4c and d. Overall, WMC significantly correlated with words recalled under both free instructions ($r = .19$, $p < .01$) and strategy instructions ($r = .23$, $p < .01$). In the free-then-strategy condition, WMC positively correlated with words recalled under both the free instruction ($r = .31$, $p < .01$) and after the strategy instruction ($r = .34$, $p < .001$). In the strategy-then-free condition, WMC did not significantly correlate with number of words recalled under the strategy instruction ($r = .09$, $p = .34$, BF = 5.88) or under the free instruction ($r = .07$, $p = .47$, BF = 7.14).[5] Therefore, one reason WMC-related differences in point totals were eliminated in the strategy-then-free condition was that high- and low-WMC participants recalled roughly the same number of words. However in the free-then-strategy condition, WMC-related differences in number of words recalled remained intact even after the Ignore Low strategy was provided.

With respect to recall proportion, the ANCOVA revealed no main effects of block or condition (both *Fs* < 2), but a significant block × condition interaction ($F(1,197) = 19.03$, $p < .001$, partial $\eta^2 = .08$). Participants recalled a higher proportion of words in both conditions when they were told to use the Ignore Low strategy. This pattern of results is depicted in Fig. 4e and f. WMC-related differences were attenuated but remained largely intact despite conditions. In the free-then-strategy condition, WMC correlated with

[3] Because of computer errors during the Operation span task, two participants' WMC scores are the mean of their standardized Reading span and Symmetry span scores.

[4] The difference between the WMC-point total correlations between conditions was significant for the free instructions ($z = 2.8$, $p = .005$) and the strategy instructions ($z = 2.8$, $p = .005$).

[5] The difference between the WMC-words recalled correlations between conditions was marginally significant for both free instructions ($z = 1.74$, $p = .08$) and strategy instructions ($z = 1.84$, $p = .06$).

Table 2
Descriptive statistics for Experiment 2 separated by condition.

Measure	Mean (*SD*)	Range	Skewness	Kurtosis	α
Strategy-then-free condition (N = 100)					
Operation span	37.47 (7.38)	15–50	−0.61	0.48	0.64
Symmetry span	19.25 (4.64)	8–28	−0.22	−0.70	0.46
Reading span	35.73 (8.73)	12–50	−0.71	0.31	0.72
Point total	236.94 (60.92)	74.33–373.33	−0.17	0.18	0.87
Words studied	19.47 (6.50)	7.17–30	0.74	0.89	0.90
Words recalled	11.61 (3.29)	4.17–22.50	0.08	−1.13	0.91
Recall proportion	0.66 (0.18)	0.26–1.00	0.05	−0.66	0.87
Selectivity index	0.56 (0.33)	−0.45 to 1.00	−0.95	0.33	0.78
Free-then-strategy condition (N = 100)					
Operation span	38.29 (7.08)	18–50	−0.49	−0.18	0.57
Symmetry span	20.26 (4.80)	3–28	−0.68	0.79	0.53
Reading span	37.19 (8.77)	3–50	−1.16	1.89	0.75
Point total	244.87 (67.31)	39–400.17	−0.46	0.74	0.91
Words studied	20.98 (5.94)	8.67–30	−0.20	−1.00	0.88
Words recalled	12.10 (3.11)	4.33–20.17	0.16	−0.15	0.91
Recall proportion	0.63 (0.18)	0.25–1.00	0.02	−0.91	0.87
Selectivity index	0.55 (0.37)	−0.86 to 1.00	−1.52	2.68	0.88

recall proportion under the free instruction ($r = .34$, $p < .001$) and after the strategy instruction ($r = .31$, $p < .01$). In the strategy-then-free condition, WMC marginally correlated with recall proportion under the strategy instruction ($r = .19$, $p = .05$) and significantly under the free instruction ($r = .28$, $p < .01$). Therefore, in neither condition did the Ignore Low strategy help low-WMC participants recall a higher proportion of the words they studied to an extent that WMC-related differences would be eliminated. This is consistent with the general finding that high-WMC individuals are better at retrieving information stored in LTM (Kane & Engle, 2000; Rosen & Engle, 1997; Unsworth, 2007; Unsworth & Engle, 2007).

For SI the ANCOVA revealed no main effects of block or condition (both *F*s < 1), but a significant block × condition interaction ($F(1,197) = 19.98$, $p < .001$, partial $\eta^2 = 0.09$). Participants showed higher selectivity when they were operating under the Ignore Low strategy instruction than when they were free to use any strategy, regardless of condition. This pattern of results is depicted in Fig. 4g and h. In this case, WMC-related differences in selectivity were greatly attenuated when participants were given the optimal strategy instructions at the beginning of the task. In the free-then-strategy condition, WMC significantly correlated with SI under both the free instruction ($r = .35$, $p < .001$) and after the strategy instruction ($r = .34$, $p < .001$). However when given the strategy instruction first, WMC did not correlate with SI under either the strategy instruction ($r = .02$, $p = .80$, BF = 8.87) or the free instruction ($r = .01$, $p = .88$, BF = 8.99).[6]

Collectively, these results suggest that when given the effective strategy for allocating study time at the beginning of the task, low-WMC participants perform roughly equally to high-WMC participants on the task, as far as point totals. WMC was still related to recall proportion, as high-WMC participants were better at retrieving information from LTM, as is typically the case. Interestingly, WMC-related differences were not eliminated in the free-then-strategy condition. When given the strategy instruction halfway through the task, high-WMC participants continued to outperform low-WMC participants.

Our next set of analyses focuses on strategic study time allocation as a function of instructions and condition. Use of the Ignore Low strategy was calculated as a sum of the binary indicator for each list, so scores ranged from zero to three. A repeated measures ANOVA revealed no main effect of block ($F < 1$), but a block × condition interaction ($F(1,197) = 13.59$, $p < .001$, partial $\eta^2 = 0.06$). Participants used the Ignore Low strategy more often when they were instructed to use this strategy than when they were free to use any strategy, regardless of condition. Interestingly, even when participants were told at the beginning of the task that the Ignore Low strategy was the most effective, they did not continue to use it after being told they could use any strategy they thought would be best. Fairly consistent with Experiment 1, when participants were free to use any strategy on the first three lists, WMC positively correlated with use of the Ignore Low strategy ($r = .24$, $p < .05$) and negatively correlated with use of the ineffective Study All strategy ($r = -.19$, $p = .05$). After participants were given the instruction that the effective strategy would be to ignore the low-value items, WMC no longer correlated with use of Ignore Low strategy ($r = .06$, $p = .49$, BF = 7.62).[7] When given the effective strategy at the beginning of the task, WMC was unrelated to use of the Study All strategy under both the strategy instruction ($r = -.05$, $p = .59$, BF = 8.33) and the free instruction ($r = -.09$, $p = .36$, BF = 6.25). Again, we can rule out the possibility that low-WMC participants are actually more selective during encoding. Instead of choosing to remember a smaller subset of items given their LTM difficulties, low-WMC individuals

[6] The difference between the WMC-SI correlations between conditions was significant for both the free instructions ($z = 2.48$, $p = .01$) and the strategy instructions ($z = 2.33$, $p = .01$).

[7] The difference between the WMC-Ignore Low correlations under the free and strategy instructions revealed a marginally significant difference ($z = 1.75$, $p = .07$).

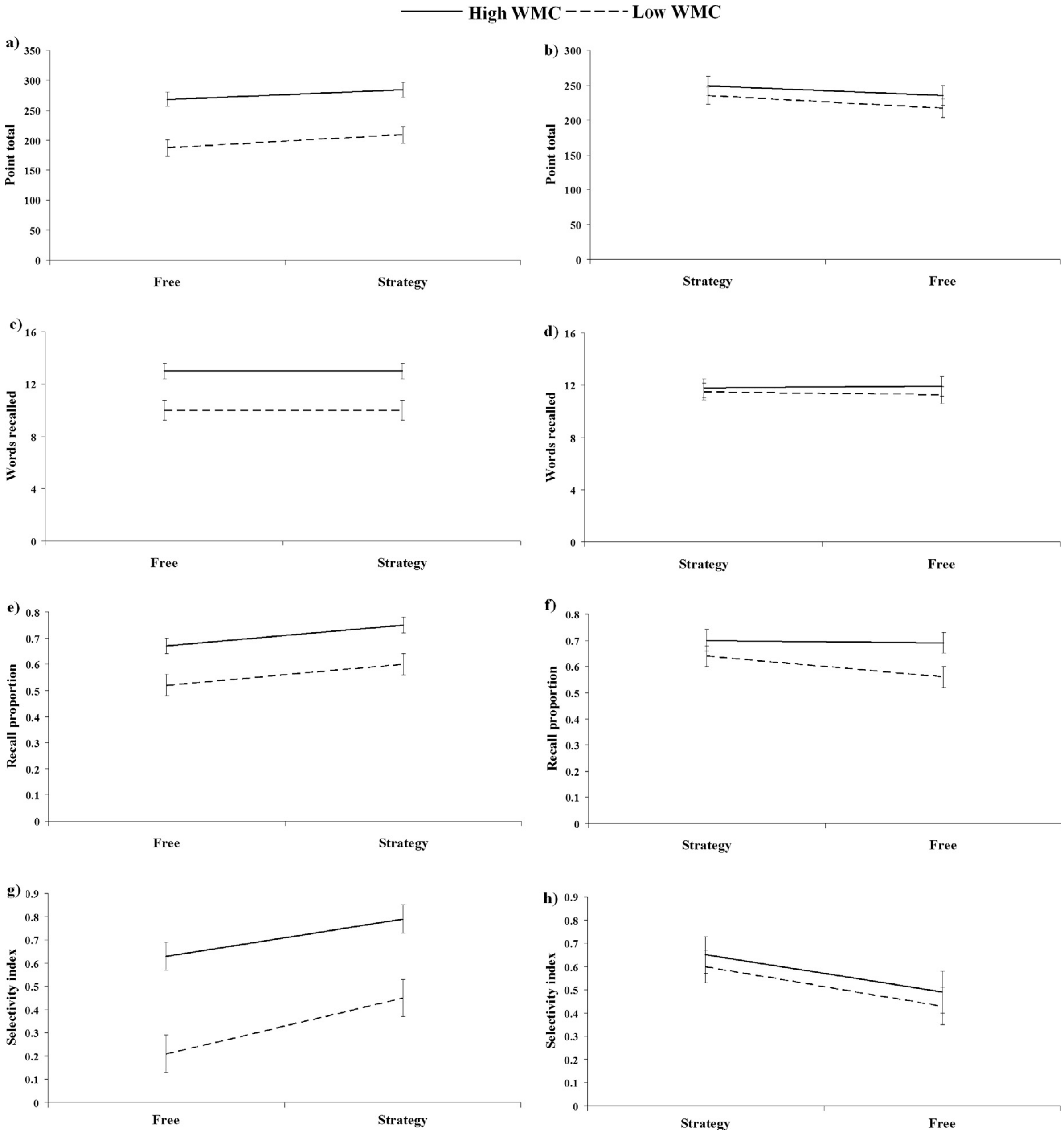

Fig. 4. Task performance as a function of instruction (free vs. strategy), WMC (High WMC vs. Low WMC) and condition (free-then-strategy vs. strategy-then-free) in Experiment 2. Results for the free-then-strategy condition are shown in the left panel, and results for the strategy-then-free condition are shown in the left-panel. *Note.* High- and low-WMC groups represent the upper and lower quartiles of the distribution for graphical purposes. All statistical analyses used WMC as a continuous variable. Error bars represent one standard error of the mean.

seem to spread their study time less strategically over more items than high-WMC participants.

Discussion

Participants completed the value-directed remembering tasks under two conditions, one in which they were given an effective strategy at the beginning of the task and one where they were given the effective strategy half-way through the task. When participants were free to use any strategy at the beginning of the task, high-WMC participants were more strategic during the encoding period, recalled more words, recalled a higher proportion of the words they studied, were more selective in recalling high-value words, and as a result achieved higher point totals. However, when participants were given an effective study strategy at the beginning of the task, WMC-related differences in point totals, number of words recalled, and memory selectivity were eliminated. Together, these results suggest that low-WMC participants spontaneously use effective encoding strategies less often, and this partially accounts for WMC-related differences in LTM.

In the condition in which participants were given the effective strategy halfway through the task, we did not eliminate WMC-related differences in recall. However, this seems to be due to the fact that over time, low-WMC participants are dealing with mounting proactive interference from previous lists, as suggested by the effects of time on task in Experiment 1 on number of words recalled and recall proportions. So although we could equate participants on encoding processes, this manipulation was not sufficient to help low-WMC participants overcome retrieval-related difficulties on the task.

General discussion

In two experiments, we investigated how the well-established relation between WMC and LTM may be partially explained by strategic differences during encoding. We proposed three possibilities for the relation between WMC and selective/strategic encoding. In the first possibility, lower WMC would be related to more selectivity at encoding as low-WMC individuals may choose to study a smaller subset of items than high-WMC individuals, given their LTM difficulties. This possibility is derived from the finding that older adults, as a consequence of having reduced LTM abilities, compensate by being more selective in value-directed remembering (Castel, 2007; Castel et al., 2013). It could also be the case that traditional measurements of LTM (e.g., delayed free recall) have underestimated the LTM of low-WMC individuals because these people simply *choose* to remember a smaller subset of information. A second possibility was that greater WMC would be related to more selectivity/strategic encoding. This possibility comes from previous research showing that WMC relates to the use of strategic encoding strategies (Bailey et al., 2008; Turley-Ames & Whitfield, 2003; Unsworth, 2016; Unsworth & Spillers, 2010). Finally, it could be the case that selective encoding within a value-directed remembering paradigm and WMC are distinct and unrelated individual differences.

The results of Experiment 1 revealed several novel and interesting findings. Not surprisingly, greater WMC led to greater task performance higher point totals, more words recalled, and a higher proportion of studied words recalled. Novel to the current investigation, WMC was slightly, but not overwhelmingly, related to selectivity (i.e., preferential recall of words with high values) and a tendency to be more strategic at encoding. Over the course of the task, participants' point totals dropped, and this effect was larger for low-WMC participants, because they recalled fewer words and a lower proportion of words, but their recall selectivity actually improved over time.

Experiment 1 also revealed one effective strategy. In this strategy, which we called Ignore Low, participants did not spend any time at all studying the low-value items. Other strategies included studying all the items (Study All), spending at least 75% of time on high-value items (Mostly High), and only studying the high-value items (Only High). These findings suggested two things: (1) high-WMC individuals are actually more selective than low-WMC individuals at encoding, and (2) when equated on strategic encoding processes, WMC-related differences in LTM performance may be attenuated or even disappear.

We further examined these findings in Experiment 2. Participants in both conditions in Experiment 2 performed the same value-directed remembering task as Experiment 1 under two sets of instructions, the order of which differed between conditions. Under the "free" instruction, participants were told they could use any strategy they felt would be best to achieve the highest possible point total. Under the "strategy" instruction, participants were given an effective study strategy (Ignore Low): they should spend the majority of their time on the high-value items and to ignore the low-value items altogether. The counterbalancing of instruction order created two conditions: free-then-strategy and strategy-then-free.

When first allowed to use any study strategy, WMC was related to use of the Ignore Low strategy, point totals, number of words recalled, recall proportion, and recall selectivity, which largely replicated Experiment 1. Interestingly, after the strategy instruction, WMC-related differences remained largely intact. When participants were instructed to use the Ignore Low strategy in this condition, WMC was again positively correlated with point totals, words recalled, recall proportion, and selectivity. But when given the strategy instructions at the beginning of the task, WMC-related differences in point totals, number of words recalled, and selectivity were eliminated. However, WMC was still related to proportion of recall, which is consistent with the finding that in general, high-WMC individuals are more effective at retrieving information (e.g., Unsworth, 2016).

With regards to the WMC-LTM relationship, it is clear that at least part of the WMC-related differences in the present study were due to strategic differences at encoding. The balance of the evidence supports the idea that high-WMC participants are actually more selective during encoding than low-WMC participants. We found no evidence for the possibility that low-WMC participants are more selective during encoding, which may have led us to conclude that low-WMC participants have inferior recall. It could have been the case in prior studies that low-WMC participants were actually only trying to remember a small subset of the information, as Castel et al. (2013) observed with older adults. However, this possibility is inconsistent with the evidence in the present study. Rather low-WMC participants tend to be *less* selective during encoding, which leads them to have a rather weak representation of a large set of items.

Together these results replicate the finding that part of the reason individuals with greater WMC are better at encoding information into LTM and subsequently retrieving it is because they are more strategic during encoding periods (Bailey et al., 2008; Unsworth, 2016; Unsworth & Spillers, 2010). One inconsistent finding from the present study was the fact that WMC-related differences in performance did not disappear after the strategy instruction in the free-then-strategy condition of Experiment 2. There are several possibilities for why this was the case. First, it could be the case that low-WMC participants' strategies were "sticky" in the sense that they had trouble adopting the Ignore Low strategy after they had been using another strategy for the first three lists. Examining only this condition, there was a marginal block × WMC interaction for the use of the Ignore Low strategy ($F(1,98) = 2.95$, $p = .09$). Low-WMC participants went from using the Ignore Low strategy an average of 0.90 times under the free instruction to 1.57 times under the strategy instruction, whereas high-WMC participants went from using it an average of 1.63 times to 2.00 times. Importantly the correlation between WMC and use of the Ignore Low strategy was eliminated after this instruction. Therefore, the strategy-stickiness explanation cannot explain the maintenance of WMC-related differences in this condition.

The second possibility is related to the fact that low-WMC participants have particular difficulty dealing with proactive interference and limiting their search set (e.g. Kane & Engle, 2000; Unsworth, 2007). As described in Experiment 1, low-WMC participants had particularly high drops in performance over the course of the task in terms of point totals and recall proportion, which could have been an indicator of proactive interference buildup and a cumulative effect on their search set size. In the free-then-strategy condition of Experiment 2, we were not able to eliminate WMC-related differences in number of words recalled, recall proportion, or selectivity after the strategy instruction. So although we were able to equate high- and low-WMC participants on use of the Ignore Low strategy, it may not have been enough to help them overcome their difficulties dealing with proactive interference and limiting their search set. Therefore, the maintenance of WMC-related differences in task performance in this condition seems related to the particular difficulties low-WMC participants faced during the retrieval portion of the task.

Although we were able to equate participants on their strategies at encoding as far as study time allocation, we do not know what other normatively effective strategies (e.g., sentence formation, visual imagery, etc.) they were using to encode the words. Previous studies (Bailey et al., 2008; Unsworth, 2016) have found that high-WMC participants were more likely to use normatively effective encoding strategies such as sentence formation and semantic association. Therefore, it is possible that in addition to being strategic with their study time allocation, high-WMC participants were also encoding the words with a more effective semantic strategy. But because we did not ask participants about these types of strategies, we do not know how strategy type of this type related to WMC in the present study.

As far as selectivity during retrieval, the relations with WMC were mixed. In Experiment 1, selectivity was marginally related to WMC. This is consistent with previous investigations that had measures of WMC and selectivity (Castel, Balota, & McCabe, 2009; Cohen, Rissman, Suthana, Castel, & Knowlton, 2014). However in the free-then-strategy condition of Experiment 2, SI significantly correlated with WMC under both instructions. This would be consistent with WMC being related to controlled and systematic search of LTM (Rosen & Engle, 1997; Spillers & Unsworth, 2011; Unsworth et al., 2012a, 2013). In a separate study, Hayes et al. (2013) found that individual differences in WMC and speed of processing accounted for age-related differences in selectivity. In the strategy-then-free condition of Experiment 2, the relation was again non-significant. The inconsistency of the present findings beg further investigation of the selectivity-WMC relation.

One limitation of the current study was the lack of explicit feedback after each list, which may have accounted for why participants tended to revert to using the ineffective strategy in Experiment 2. In previous investigations (Castel et al., 2002, 2013) participants were given their point total after each list by the experimenter. Because participants completed the tasks individually with no experimenter present and recall data was scored only after all data had been collected, we were unable to provide feedback after each list. The use of the Ignore Low strategy may seem counter-intuitive to participants in the sense that they would achieve better performance by studying fewer items. Perhaps providing explicit feedback to participants may have reinforced the use of the Ignore Low strategy. Future research can address this possibility.

Another future direction for the present study would be to yoke study-time for low-WMC participants to their more strategic high-WMC counterparts. Previous investigations have controlled number and frequency of rehearsals to equate participants to test various theories (e.g., Dewar, Brown, & Della Sala, 2011; Tan & Ward, 2000). If a major reason LTM differences exist between high- and low-WMC individuals is due to strategic differences at encoding, equating them with yoked study times, rather than a simple strategy instruction, should eliminate WMC-related differences. Future experiments could test this hypothesis.

Conclusions

The results of the present investigation suggest that part of the WMC-LTM relationship can be explained by the differential use of strategic encoding processes among individuals who differ in WMC. Greater WMC was moderately related to the use of an effective encoding strategy during a self-regulated value-directed remembering paradigm in which the value of items explicitly and systematically varied. Importantly, WMC-related differences in task performance were eliminated when were instructed to use this strategy at the beginning of the task. However, when equating participants on strategy use halfway through the task, WMC-related differences in retrieval remained largely intact, especially when the strategy instruction was not given until halfway through the task. Overall, the balance of the evidence from the present study supports the conclusion that low-WMC individuals spontaneously use effective encoding strategies less often than high-WMC participants, and this partially accounts for the WMC-LTM relationship. However, it is clear that low-WMC individuals are capable of executing such a strategy when it is provided. When they do so, their performance is actually quite comparable to high-WMC individuals.

These results further elucidate the WMC-LTM relationship in delineating how WMC-related differences in strategic encoding processes lead to differences in the ability to recall information from LTM.

Author note

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