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Individual differences in encoding strategies and free recall dynamics

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Abstract

Individual differences in encoding strategies and their relation to free recall dynamics were examined. Participants performed a delayed free recall task and following each list reported which strategies they may have used on the prior list. Individual differences in effective encoding strategy use were positively correlated with overall recall performance. Examining recall dynamics suggested that variation in effective encoding strategy use was associated with greater recall, particularly on non-primacy items and slightly more organised recall in terms of recall transitions. However, no differences were found for recall of items at the first serial position, in recall initiation, or in how quickly participants recalled items. Collectively, the results are consistent with the notion that effective encoding strategies increase the strength of items, resulting in a higher likelihood of recovering the items during recall. Individual differences in control processes in the form of effective encoding strategies are critically important for understanding normal variation in memory abilities.

Keywords

Encoding strategy; free recall; individual differences

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Fifty years ago, Atkinson and Shiffrin (1968) published their landmark paper on a general model of the human memory system. An important aspect of the Atkinson and Shiffrin (1968) model was the notion that control processes are critical for learning and retrieval. These control processes include selecting and utilising appropriate encoding strategies, setting up a retrieval plan, selecting and generating appropriate cues to search memory with, as well as various monitoring strategies and decisions to continue searching or not (e.g., Atkinson & Shiffrin, 1968, 1971; Lehman & Malmberg, 2013; Raaijmakers & Shiffrin, 1980; Shiffrin, 1970). In this study, we examined individual differences in control processes by specifically examining variation in encoding strategies and free recall dynamics.

Encoding strategies

Prior research has long suggested that control processes such as encoding strategies are critical for understanding memory (Benjamin, 2008; Nelson & Narens, 1990; Reitman, 1970). Much prior research has demonstrated that control processes in the form of effective encoding strategies (e.g., interactive imagery and sentence generation) result in higher levels of recall than less effective strategies (e.g., passive reading or rote repetition; Bower, 1972; Herrmann, 1987; Richardson, 1998). Furthermore, individual differences in effective encoding strategy use correlate strongly with overall recall performance (Bailey, Dunlosky, & Kane, 2008; Hertzog, McGuire, & Lineweaver, 1998; Martin, Boersma, & Cox, 1965; Richardson, 1998; Unsworth, 2016) and partially account for age differences in memory performance (Hertzog & Dunlosky, 2004). Less effective encoding strategies, however, tend to be negatively related to recall performance (Unsworth, 2016). Although it should be noted that under some conditions, high-ability participants demonstrate more rehearsal than low-ability participants leading to differences in recall (Fagan, 1972; Unsworth & Spillers, 2010). Furthermore, in a recent study examining individual differences in delayed free recall performance, Unsworth (2016) found that roughly 27% of the variance in delayed free recall was due to variation in encoding strategies (roughly 20% accounted for by effective encoding strategies and 7% was accounted for by less effective

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encoding strategies). Thus, prior research supports the notion that individual differences in encoding strategies are strongly related to individual differences in recall performance.

Recall dynamics

While prior research suggests a relation between encoding strategies and recall accuracy, it may be informative to examine free recall dynamics in more detail to get a better idea of how encoding strategies are related to recall accuracy. One way to examine this relation is to break overall accuracy down and examine possible variation in serial position curves. Prior individual differences research suggest considerable variation in serial position curves with much of the variation occurring for primacy items in immediate and delayed free recall, but still some variation in recency items in immediate free recall (Healey & Kahana, 2014; Kahana, Howard, Zaromb, & Wingfield, 2002; Lehman & Malmberg, 2013; Spillers & Unsworth, 2011a; Unsworth, 2019; Unsworth, Brewer, & Spillers, 2011). Variation in primacy and recency has been linked to a number of cognitive abilities such as fluid intelligence, crystallised intelligence, working memory, and processing speed to a name a few (Crawford & Stankov, 1983; Healey, Crutchley, & Kahana, 2014; Horn, Donaldson, & Engstrom, 1981; Unsworth, 2019; Unsworth, Spillers, & Brewer, 2010). Thus, examining individual differences in encoding strategies and their relation to recall accuracy as a function of serial position can provide important information about which items are benefitting from more effective encoding strategies.

While serial position curves provide a breakdown of overall accuracy on free recall tasks, they too can be further broken down. In particular, one can examine probability of first recall (PFR) and conditional response probability (CRP) as a function of lag to obtain assessments of how individuals initiate and transition, respectively, during recall (Howard & Kahana, 1999; Kahana, 2017). PFR provides a means of examining potential differences in how participants initiate recall. In immediate free recall, there tends to be considerable variation in how participants initiate their recall with some participants primarily initiating recall with recency items, other participants initiating recall with primacy items, and yet other participants initiating recall with both primacy and recency, depending on the amount of practice (primacy-recency shift; Goodwin, 1976) with the task (Unsworth et al., 2011; see also Healey & Kahana, 2014; Lehman & Malmberg, 2013). In delayed free recall, there is little variation in how participants initiate recall, with most participants initiating recall with the first presented item, and this does not seem to differ as a function of long-term memory abilities, working memory, or age (Kahana et al., 2002; Spillers & Unsworth, 2011a; Unsworth, 2019). Although recent work by Sahakyan and Kwapil (2018) suggests differences in PFR as a function of schizotypy, with participants with negative schizotypy being less likely to initiate recall with the first presented item compared with control participants and participants with positive schizotypy.

Following recall initiation, one can also examine how participants transition between items during recall. In particular, one can compute the CRP as a function of lag (lag-CRP; Howard & Kahana, 1999; Kahana, 1996), which illustrates the probability that an item from serial position $i + \text{lag}$ is recalled immediately following an item from serial position i. Prior research has found that lag-CRPs have a characteristic form such that recall of an item is generally followed by recall of nearby items with a forward bias (Howard & Kahana, 1999; Kahana, 1996; Murdock, 1974). This has been taken as evidence that participants rely on temporal-contextual relations during recall (Howard & Kahana, 1999; Kahana, 1996; although see Hintzman, 2016 for concerns with this measure and for alternative explanations). Healey and Kahana (2014) found large individual differences in the form of lag-CRPs and a lag-CRP factor (based on an exploratory factor analysis) was found to predict overall recall levels and intelligence in immediate free recall (Healey et al., 2014). In delayed free recall, there are also individual differences in lag-CRPs, which are linked to working and long-term memory abilities (Spillers & Unsworth, 2011a; Unsworth, 2019). Collectively, prior research suggests that examining individual differences in not only overall serial position curves, but also in how participants initiate and transition during recall can be informative.

The work reviewed thus far has focused on which target items tend to be recalled and in what order. However, an examination of recall latency can also be informative in terms of better understanding how participants search for and output target items in free recall tasks. Recall latency refers to the time point during the recall period when any given item is recalled, and mean recall latency is simply the average time it takes to recall items. Prior work has suggested that recall latency distributions provide important information on the dynamics of free recall (Bousfield & Sedgewick, 1944; Indow & Togano, 1970; McGill, 1963; Roediger, Stellon, & Tulving, 1977; Rohrer & Wixted, 1994; Wixted & Rohrer, 1994) and are particularly important for examining search processes (Atkinson & Shiffrin, 1968; Raaijmakers & Shiffrin, 1980; Rohrer, 1996; Shiffrin, 1970; Shiffrin & Atkinson, 1969).

Whereas overall recall accuracy provides an estimate of the number of items that were encoded and subsequently recovered, these items can be recalled either quickly or slowly and this information is captured by recall latency. Recall latency is thought to reflect the number of items within the search and thus reflects relative strength. The larger the search set the longer on average it will take to recall any given item. For example, manipulations such as presentation duration, massed encoding, and levels of processing all lead to an increase in the number of items recalled, but no change in recall latency. This suggests that these manipulations lead to differences in item strengths and recovery, but not necessarily in the size of the search set (e.g., Rohrer, 1996; Rohrer & Wixted, 1994; Wixted & Rohrer, 1994; Unsworth, 2015). Conversely, manipulations such as list-length, proactive interference, retroactive interference, directed forgetting, and spaced encoding lead to changes in the number of items recalled and changes in recall latency, suggesting that the size of the search set is increasing (e.g., Bäuml & Kliegl, 2013; Rohrer & Wixted, 1994; Spillers & Unsworth, 2011b; Unsworth, 2015; Unsworth, Brewer, & Spillers, 2013; Wixted & Rohrer, 1993).

Thus, examining overall recall latency as well as inter-response times (IRTs; the time between recalled items) can be informative in terms of describing the possible differences in how individuals search. Prior individual differences research has suggested that recall latency and IRTs tend to be negatively related with overall recall accuracy, working memory, and fluid intelligence, but positively related to intrusion errors (Unsworth, 2009, 2016). This research suggests that low-ability individuals tend to search through larger search sets consisting of several intrusions compared with high-ability participants (Miller & Unsworth, 2018; Unsworth, 2007; Unsworth & Engle, 2007). At the same time, some low-ability participants tend to recall items at a faster rate than high-ability participants, indicating they are searching through a smaller search set that does not contain all of the target items (e.g., Sahakyan & Kwapil, 2018; Unsworth, 2009, 2019). Finally, some low-ability participants search at the same rate as high-ability participants, indicating that their search sets are roughly the same size, but these low-ability individuals tend to have weaker representations than high-ability individuals and not all of these items are strong enough to be recovered into consciousness (Unsworth, 2009, 2019) This could be due to the fact that these participants are relying on ineffective encoding strategies, which result in the items not being processed at a deep enough level. Examining when items are recalled in addition to examining recall initiations and recall transitions should provide detailed information on the dynamics of free recall.

The Present Study

A main goal of the present study was to examine how variation in effective strategies influence recall dynamics to better understand the correlation between recall performance and strategy use. Although prior research has demonstrated that variation in encoding strategies are related to variation in recall performance, to our knowledge no one has directly examined how individual differences in self-reported encoding strategies are linked to recall dynamics in the form of serial position curves, PFR, lag-CRPs, recall latency, and IRTs. That is, using more effective encoding strategies is related to overall recall performance, but it is not clear how variation in effective encoding strategies are potentially related to individual differences in recall dynamics. Will those participants who report using more effective encoding strategies simply outperform participants reporting using less effective encoding strategies across all serial positions, or are differences localised to certain parts of the curve? Likewise, are differences in encoding strategies related to differences in how participants initiate and transition during recall? Finally, are differences in encoding strategies related to recall latency and IRTs, indicating possible differences in how participants search? For example, in a prior study, Unsworth (2016) found that IRTs in delayed free recall were negatively related to reports of effective strategy use ($r=-.33$), but not to reports of less effective strategy use ($r=-.02$), suggesting that those participants who rely on effective encoding strategies have more efficient search processes than those who rely less on effective encoding strategies. Examining these issues should provide important information on how variation in encoding strategies are related to overall performance differences and recall dynamics in free recall.

To examine these questions, we had participants perform a delayed free recall task and after each list, participants had to indicate which strategies (if any) they had used on the preceding list. While most prior research that has examined individual differences in encoding strategies in free recall have asked participants what strategies they used at the very end of the task (e.g., Hertzog et al., 1998; Unsworth, 2016), other research has asked participants after each list to get a better sense of how frequently each type of strategy is reportedly used (Delaney & Knowles, 2005; Dunlosky & Hertzog, 2001; Dunlosky & Kane, 2007; Sahakyan & Delaney, 2003). Furthermore, asking participants after each list can provide important information on the extent to which some participants switch strategies during the course of the task (Delaney & Knowles, 2005; Sahakyan & Delaney, 2003). That is, with more task experience, people transition from using less effective encoding strategies to using more effective strategies. However, it remains to be seen whether variation exists around this effect and how this may in turn relate to dynamics of free recall. Some high-ability people may start off using the most effective strategies and continue to do so, whereas some less able people may start off using the least effective strategies but never make the switch. It seems like these patterns would at least be associated with differences in recall accuracy across lists. Thus, we used these list-by-list reports to examine the frequency with which participants used different strategies and the possible individual differences in switching encoding strategies during the task. We also asked participants to report their strategy usage at the end of the task to see how well these end-of-task reports correlate with the list-by-list reports. Finally, we also examined individual differences in working memory given that prior research has suggested a link between working memory and encoding strategies, and thus we wanted to examine whether any relations found were due to possible shared variance between encoding strategies and working memory (e.g., Bailey et al., 2008; Dunlosky & Kane, 2007; Unsworth, 2016; Unsworth & Spillers, 2010).

Method

We report how we determined our sample size, all data exclusions, all manipulations, and all measures in our study.

Participants

Participants were 128 individuals recruited from the subject-pool at the University of Oregon. Data were collected over one full academic quarter. Three participants were excluded from the analyses for failing to perform the delayed free recall task correctly (two participants did not type any words and one participant did not type the words as instructed). In addition, three participants failed to complete the strategy reports correctly (i.e., they did not type anything), so they were excluded from those analyses. We determined that a minimum sample size of 120 participants would be sufficient to find correlations in the range of .25-.30, with power of .80 and alpha set at .05 (two tailed), given strong relations between encoding strategies and recall performance seen in prior research. Participants were between the ages of 18 and 35 and received course credit for their participation. Each participant was tested individually.

Materials and procedure

After signing informed consent, all participants completed the Operation span task, the Symmetry span task, the Reading span task, the delayed free recall task, an antisaccade task, and the psychomotor vigilance task in order. The antisaccade and psychomotor vigilance tasks were a part of other studies and are not discussed further.

Tasks

Delayed free recall. Participants performed a delayed free recall task with six lists of 10 words per list. Words were nouns selected from the Toronto word pool (Friendly, Franklin, Hoffman, & Rubin, 1982). Words were initially randomised and placed into the lists and all participants received the exact same lists of words. For each trial, participants were told that they would be presented with a list of words and that following a brief distractor task they would be prompted to recall the words in any order they wished during the recall period. Each trial began with a Ready signal onscreen followed by a series of words presented one at a time (for 4 s per word) in the centre of the screen with a 1-s blank screen in between the presentation of each word. Following the list of words participants engaged in a 16-s distractor task before recall: Participants saw 8 three-digit numbers appear for 2 s each, and were required to write the digits in descending order (e.g., Rohrer & Wixted, 1994; Unsworth, 2007). At recall, participants saw three question marks appear in the middle of the screen, indicating that they needed to begin recalling the words. Participants had 45 s to recall as many of the words as possible in any order they wished. Participants typed their responses and pressed Enter after each response clearing the screen.

At the end of each list, participants were asked to report which strategy (if any) they had used on the preceding list. Specifically, participants saw the following:

Type in the number that corresponds to the strategy you may have used. Choose the one strategy that most closely matches what you did.

When you are done typing in the number press ENTER

1. Read each word as it appeared
2. Repeated the words as much as possible
3. Used a sentence to link the words together
4. Developed mental images of the words
5. Grouped the words in a meaningful way.
6. Did something else

Participants were only allowed to select one strategy per list. These strategy reports were taken from Dunlosky and Kane (2007).

At the end of the task, participants also reported which strategies (if any) they used during the entire task. The same strategies as given above were listed. However, now participants could indicate that they used more than one strategy.

Working memory tasks

Operation span. Participants solved a series of math operations while trying to remember a set of unrelated letters (F, H, J, K, L, N, P, Q, R, S, T, Y). 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. Three trials of each list-length (3-7) were presented, with the order of list-length varying randomly. At recall, letters from the current set were recalled in the correct order by

Table 1. Proportions of reported strategy use.

Strategy					
Read	Repetition	Imagery	Sentence	Grouping	Other
.18 (.02)	.27 (.03)	.16 (.02)	.21 (.02)	.13 (.02)	.04 (.01)

Values in parentheses are standard errors.

clicking on the appropriate letters (see Unsworth, Heitz, Schrock, & Engle, 2005 for more details). Participants received three sets (of list-length two) of practice. For all of the span measures, items were scored if the item was correct and in the correct position. The score was the proportion of correct items in the correct position.

Symmetry span. In this task, participants were required to recall sequences of red squares within a matrix while performing a symmetry-judgement task. In the symmetry-judgement 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 in the preceding displays, in the order they appeared by clicking on the cells of an empty matrix. There were three trials of each list-length with list-length ranging from 2 to 5. The same scoring procedure as Ospan was used (see Unsworth, Redick, Heitz, Broadway, & Engle, 2009 for more task details).

Reading span. Participants were required to read sentences while trying to remember the same set of unrelated letters as Ospan. For this task, participants read a sentence and determined whether the sentence made sense or not (e.g., "The prosecutor's dish was lost because it was not based on fact?"). Half of the sentences made sense while the other half did not. Nonsense sentences were made by simply changing one word (e.g., "dish" from "case") from an otherwise normal sentence. Participants were required to read the sentence and to indicate whether it made sense or not. After participants gave their response, they were presented with a letter for 1 s. At recall, letters from the current set were recalled in the correct order by clicking on the appropriate letters. There were three trials of each list-length with list-length ranging from 3 to 7. The same scoring procedure as Ospan was used (see Unsworth et al., 2009 for more task details).

Composite score. We computed a composite score for the three complex span tasks by *z*-transforming each span score for each participant and then averaging the *z*-scores together ($\alpha = .73$).

Results

Encoding strategies

First, we examined the different encoding strategies that were reported across the six lists. There was a main effect of Strategy report, $F(5, 605) = 11.36$, mean square error (MSE) = .38, $p < .001$, partial $\eta^2 = .09$. As shown in Table 1, participants reported using repetition and sentence generation most frequently, followed by simply reading the words, visual imagery, grouping, and something else. There was also a list by strategy interaction, $F(25, 3{,}025) = 7.25$, MSE = .11, $p < .001$, partial $\eta^2 = .06$. As shown in Figure 1a, participants tended to start off using repetition on the first list, by the second list the use of repetition decreased, while the use of more effective strategies like sentence generation and visual imagery tended to increase.

Because only a few participants reported using every strategy, we divided responses into normatively effective and normatively less effective strategies (e.g., Bailey et al., 2008; Dunlosky & Kane, 2007). Consistent with prior research effective strategies were interactive imagery, sentence generation, and grouping whereas less effective strategies were passive reading and simple repetition (Bailey et al., 2008; Dunlosky & Kane, 2007; Richardson, 1998). Examining effective and less effective strategy use suggested no effect of type of strategy, $F(1, 121) = .93$, MSE = .1.17, $p = .34$, partial $\eta^2 = .008$, suggesting that reported use of effective ($M = .50$, $SE = .03$) and less effective ($M = .44$, $SE = .03$) strategies was similar. There was, however, a significant interaction between type of strategy used and list, $F(5, 605) = 19.04$, MSE = .28, $p < .001$, partial $\eta^2 = .14$. As shown in Figure 1b, less effective strategy use was more common on the first list than effective strategy use, but this switched on the second list and tended to stay that way for the rest of the experiment. Examining accuracy as a function of type of strategy suggested that when participants reported using an effective strategy, their performance was better ($M = .74$, $SE = .02$) than when they reported using a less effective strategy ($M = .60$, $SE = .02$), $t(84) = 7.84$, $p < .001$, $d = .88$. Note that these analyses are based on only those participants who reported using both effective and less effective strategies.

Individual differences in effective encoding strategies

Now we turn to an examination of individual differences in reported strategy use across the different lists. To examine variation in encoding strategies, we computed an effective strategy use variable which was the proportion of lists that participants reported using an effective strategy. On average, participants reported using an effective strategy on roughly half of the lists ($M = .52$, $SD = .33$, range 0-1) and this variable had moderate levels of internal consistency

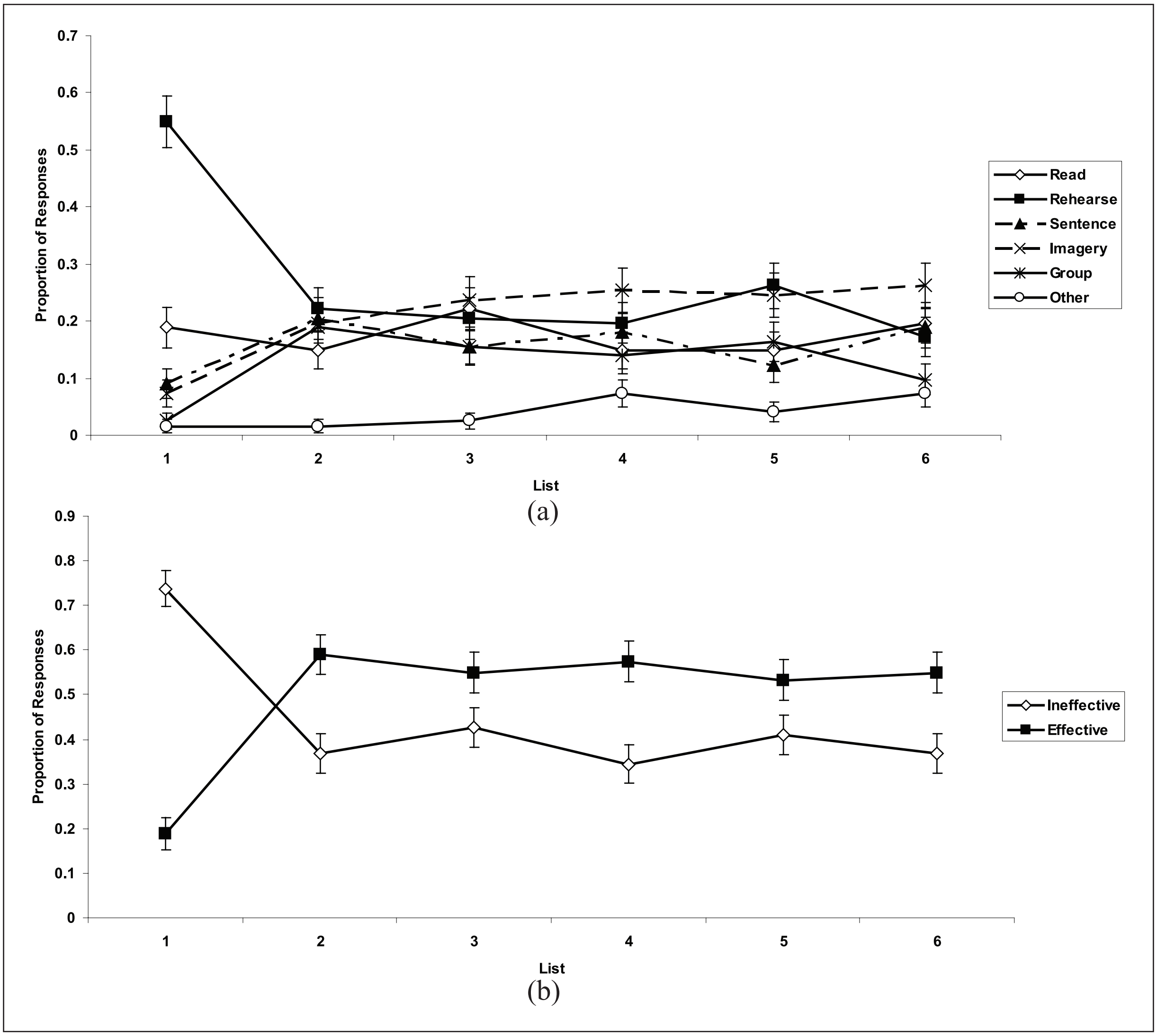

Figure 1. (a) Proportion of strategy reports as a function of list. (b) Proportion of effective and ineffective strategy reports by list. Error bars reflect one standard error of the mean.

($\alpha = .76$). This variable was negatively correlated with ineffective strategy use as would be expected ($r = -.93$, $p < .001$). We used this variable as our index of variation in effective strategy use in the remaining analyses.

First, we examined how the end of the task strategy reports would correlate with the list-by-list reports. As expected, effective strategy use obtained by the list-by-list reports correlated positively with effective strategy use reported at the end of the list ($r = .45$, $p < .001$), but negatively with less effective use reported at the end of the list ($r = -.41$, $p < .001$). Thus, there was general agreement between the two different ways of obtaining strategy reports. For the remainder of the article we only focus on the list-by-list reports.

As noted above, there was evidence that overall, participants started out using a less effective strategy on the first list, but then switched and tended to report using an effective strategy on the second list. However, not all participants demonstrated this effect, so we examined whether there were individual differences in the switch from a less effective strategy to a more effective strategy as a function of individual differences in effective strategy use. That is, although by necessity those scoring high on our effective strategy measure report using effective strategies more than those participants scoring low on the measure, it is possible that there are differences in terms of whether a switch occurs. Therefore, we ran the same analysis as before in terms of examining type of reported strategy and list, but now entered effective strategy use as a covariate in an analysis of covariance (ANCOVA). There was an effective strategy use by type of strategy by list interaction, $F(5, 600) = 5.49$, $MSE = .03$, $p < .001$, partial $\eta^2 = .04$. To illustrate the effects of interest, we present differences in effective strategy use via a quartile split with low effective

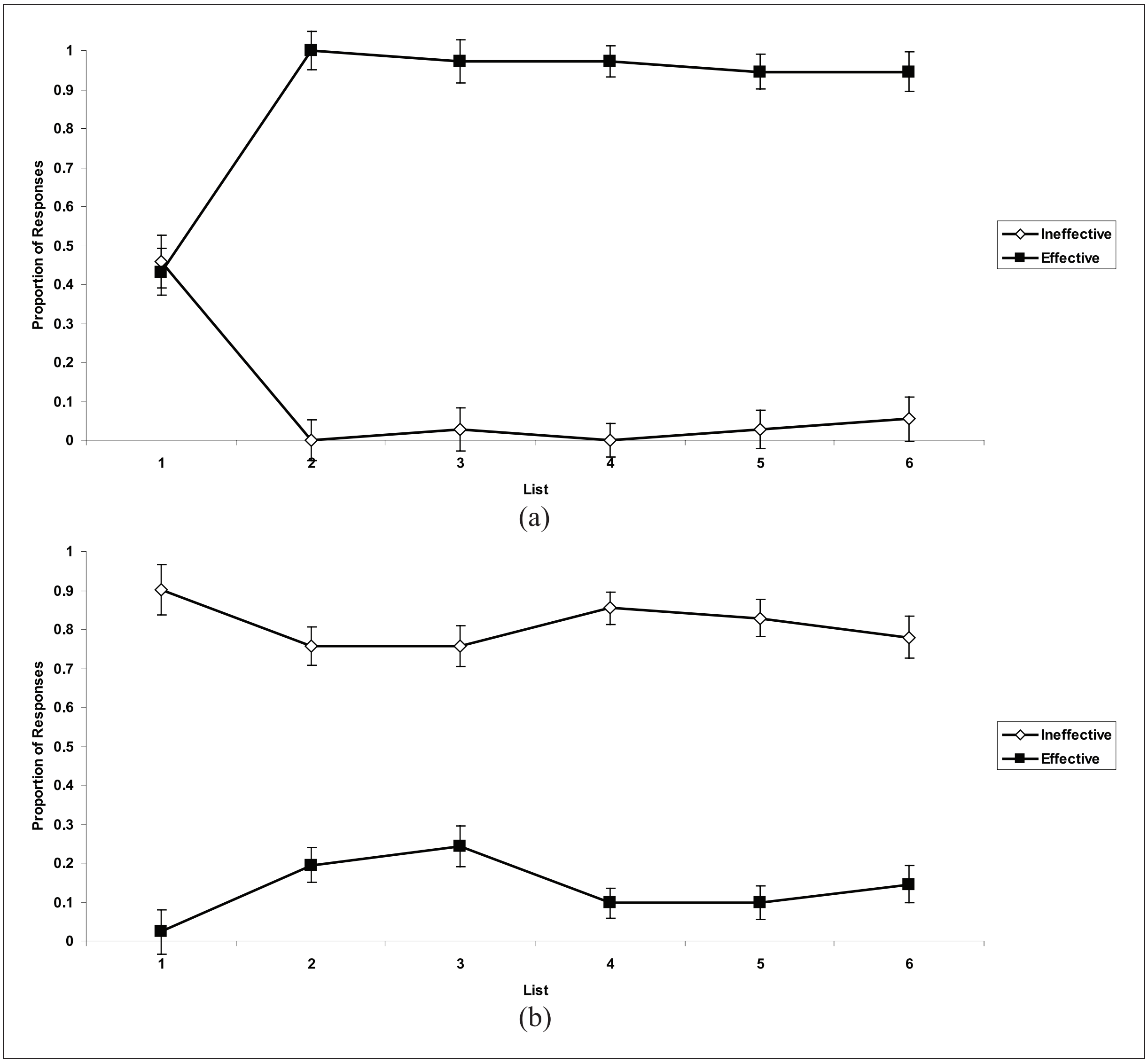

Figure 2. (a) Proportion of effective and ineffective strategy reports by list for high-effective strategy use participants. (b) Proportion of effective and ineffective strategy reports by list for low-effective strategy use participants. Error bars reflect one standard error of the mean.

strategy use (bottom 25%) and high effective strategy use (top 25%). Note, however, that all analyses treated effective strategy use as continuous, rather than as arbitrary, discrete groups (see Supplementary materials for the overall means). As shown in Figure 2a, participants who reported using effective strategies frequently, started out using effective and less effective strategies about equally on the first list, but this drastically changed by the second list with these participants almost exclusively relying on effective strategies for the rest of the task. Participants who reported using effective strategies less often, did not demonstrate any type of switch, but rather relied on these less effective strategies for the duration of the task.

Next, we examined correlations among effective strategy use, recall accuracy, and working memory. There was a positive correlation between effective strategy use and recall accuracy ($r=.44$, $p<.001$), but effective strategy use was not related to working memory ($r=-.04$, $p=.68$).[1] This latter finding is inconsistent with some prior research, which has suggested that high working memory individuals are more likely to use effective strategies than low working memory individuals (Bailey et al., 2008; Dunlosky & Kane, 2007; Turley-Ames & Whitfield, 2003; Unsworth, 2016). This lack of a relation will be discussed further in the section 'Discussion'. Working memory was, however, related to recall accuracy ($r=.32$, $p<.001$) consistent with prior research (e.g., (Unsworth, 2016, 2019).[2]

Next, we examined potential changes in recall accuracy across the six lists as a function of individual differences in effective encoding strategy use by entering effective

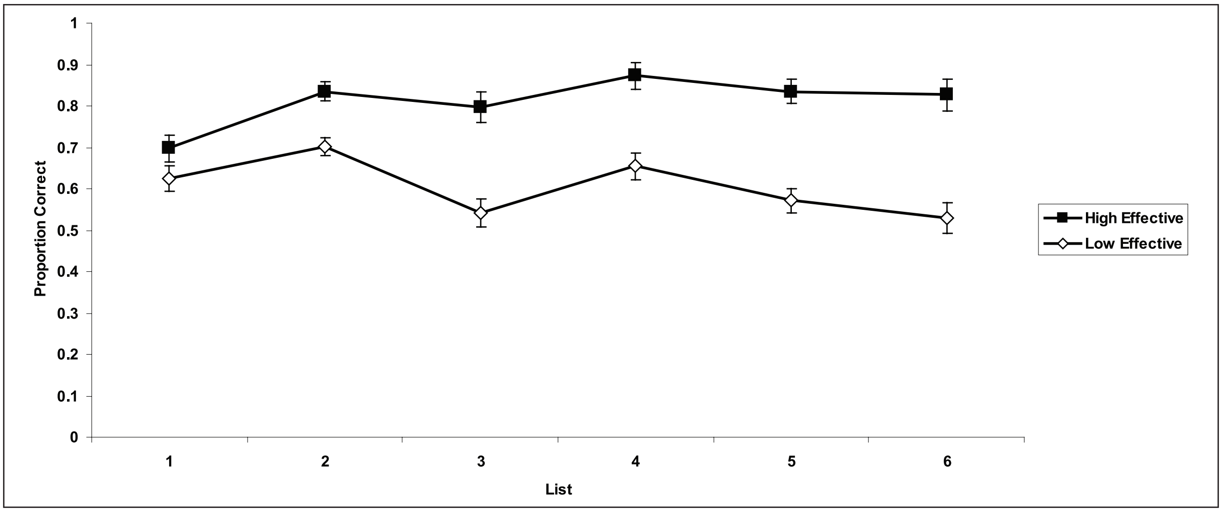

Figure 3. Proportion correct as a function of list for high- and low-effective strategy use participants. Error bars reflect one standard error of the mean.

strategy use in an ANCOVA as covariate. There was a main effect of effective strategy use, $F(1, 120)=28.33$, MSE=.13, $p<.001$, partial $\eta^2=.19$, suggesting that participants who reported using effective strategies more frequently tended to have higher levels of recall. There was also an effective strategy use by list interaction, $F(5, 600)=5.55$, MSE=.03, $p<.001$, partial $\eta^2=.04$. As shown in Figure 3, participants who reported using effective strategies frequently, tended to increase their performance across lists. However, participants who reported using effective strategies less often, tended to decrease their performance across lists.

Examining serial position curves suggested a significant effective strategy use by serial position interaction, $F(9, 1080)=2.44$, MSE=.03, $p=.009$, partial $\eta^2=.02$. As shown in Figure 4a, effective strategy use was not significantly correlated with accuracy at serial position 1 ($r=.13$, $p=.15$), but was significantly correlated (with Bonferroni adjustment for multiple comparisons) at most of the other serial positions (all r's$>.27$, p's$<.003$; only Serial Position 9 did not quite meet the criterion for significance when correcting for multiple comparisons: $r=.24$ $p=.007$). Thus, individuals who relied less on effective strategies had particular problems recalling non-primacy items compared with individuals who relied more on effective strategies.

Examining PFR suggested there was no interaction between effective strategy use and serial position, $F(9, 1{,}080)=.64$, MSE=.01, $p=.76$, partial $\eta^2=.005$. Thus, there was not much evidence for differences in how participants initiated recall, with most participants initiating recall with the first presented item (see Figure 4b).

We next examined how participants transitioned between items during recall by computing lag-CRP functions and seeing if these differed as a function of individual differences in effective strategy use. Effective strategy use did not interact with direction, $F(1, 120)=1.21$, MSE=.011, $p=.27$, partial $\eta^2=.01$. Effective strategy use did interact with lag, $F(4, 480)=2.82$, MSE=.02, $p=.025$, partial $\eta^2=.02$. Importantly, there was a three-way interaction between effective strategy use, direction, and lag, $F(4, 480)=3.20$, MSE=.009, $p=.013$, partial $\eta^2=.03$. As shown in Figure 4c, individual differences in effective strategy use only occurred in the forward direction with a lag of 1 ($r=.18$, $p=.046$), and there were no differences in the backward direction or at any other lags (all r's$<.16$, p's$>.08$). Although, note that the correlation at lag 1 is no longer significant after correcting for multiple comparisons and is in general weak evidence. Thus, participants who relied more on effective encoding strategies demonstrated slightly more organised recall than participants relying less on effective encoding strategies.

Next, we examined whether individual differences in effective encoding strategy use were related to when items were recalled in terms of overall recall latency as well as latency to the first response and IRTs. Effective strategy use did not correlate with overall recall latency ($r=.08$, $p=.39$). Thus, although individuals who reported using effective encoding strategies tended to recall more items than individuals who reported using effective encoding strategies less often, there were no differences in when the items recalled. We further broke overall recall latency down into latency to the first response and IRTs for subsequent items. Typically, participants begin recall approximately 5 s into the recall period and it is possible that there are individual differences in the pause preceding recall. In the current study, recall began on average 4.52 s ($SD=.16$) into the recall period and this was not correlated with effective encoding strategy use ($r=-.04$, $p=.67$). Finally, examining IRTs for subsequent items suggested that this

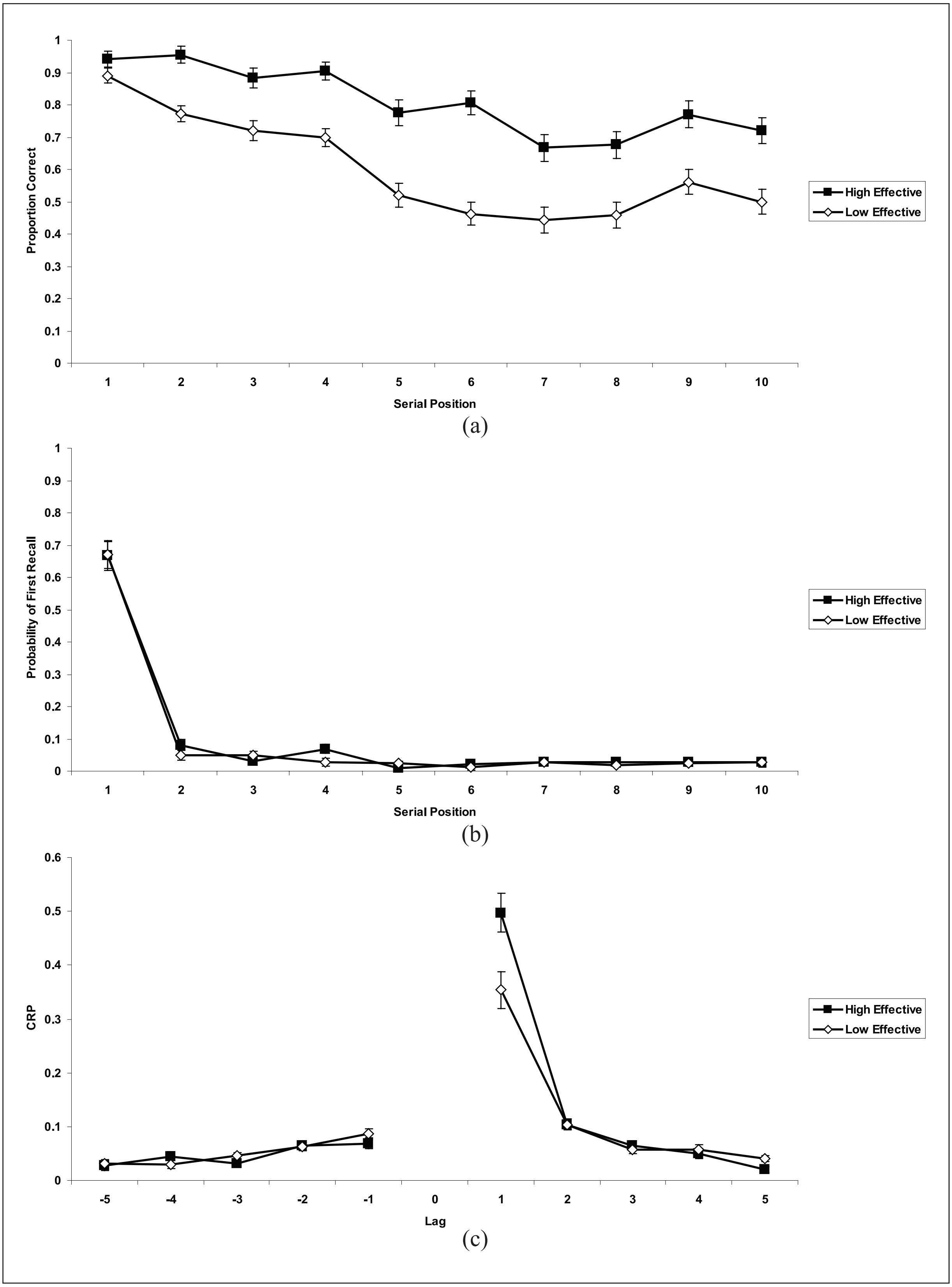

Figure 4. (a) Proportion correct as a function of serial position for high- and low-effective strategy use participants. (b) Probability of first recall as a function of serial position for high- and low-effective strategy use participants. (c) Conditional response probability functions for forward and backward transitions per list as a function of lag for high- and low-effective strategy use participants. Error bars reflect one standard error of the mean.

too was not significantly related to effective encoding strategy use ($r = -.14$, $p = .13$). Collectively, although there were clear differences in overall recall levels as a function of effective encoding strategy use, there was little evidence for differences in terms of when items were recalled.

Discussion

In the present study, we examined individual differences in control processes in terms of effective encoding strategies and their relation with free recall dynamics. Consistent with much prior research, we found that participants reported using a variety of encoding strategies some of which can be considered as relatively effective (e.g., sentence generation, imagery, grouping) and some less effective (e.g., simply reading the words or rote repetition). By examining list-by-list strategy reports we found that, consistent with prior research, participants tended to start off using a less effective strategy, such as repetition on the first list of the experiment, but then rapidly switched to using more effective strategies (Delaney & Knowles, 2005; Sahakyan & Delaney, 2003).

Examining individual differences in effective encoding strategy use suggested a number of interesting findings. Similar to the within subjects analyses, the between subjects analyses suggested that individuals who reported using effective strategies tended to recall more items and to switch strategies more than participants who reported using less effective strategies. This switch of strategies for those participants reporting using effective encoding strategies seemed to be beneficial as these participants tended to increase their performance during the task, whereas those participants who reported using effective encoding strategies less often tended to demonstrate decreases in performance during the task (see also Lehman & Malmberg, 2013). It seems as though the high-performing participants are examining different strategies and settling on more effective strategies to optimise learning, whereas low-performing participants tend to stick with the less effective strategies to their detriment.

We further explored individual differences in effective encoding strategies by examining free recall dynamics. In terms of serial position effects the analyses suggested effective encoding strategy use interacted with serial position such that the correlation with serial position 1 was not significant, but correlations between effective strategy use and recall were significant at all other serial positions. This suggests that effective strategy use does not necessarily result in stronger representations across the board compared with less effective strategy use, but rather suggests that these benefits maybe especially important for non-primacy items. At the same time, it is important to note that in the current data, overall recall accuracy for the first item was very high ($M = .91$, $SD = .14$) and 60.8% of participants recalled the first item correctly on every list leading to a skewed distribution. As such, it is possible that the lack of significant correlation for serial position 1 was due to a ceiling effect that limited the amount of systematic variability that could be detected. Indeed, whereas the standard deviation (*SD*) for serial position 1 was only .14, the standard deviation for serial position 2 was .18 and all remaining standard deviations were greater than .21. Thus, although the current results suggest that effective encoding strategy use interacted with serial position, it is not clear if this interaction is simply a function of a ceiling effect for the first serial position. Additional research is needed to further examine these issues.

Turning to how participants initiated and transitioned during recall, the results for PFR were straightforward in suggesting no differences in how participants initiated recall as a function of effective encoding strategy use. Most participants tended to initiate recall with the first presented item. Examining lag-CRPs suggested a three-way interaction in which the only difference as a function of effective encoding strategy use occurred for forward transitions with a lag of 1. Participants who reported using an effective encoding strategy were slightly more likely to recall items in succession than participants who reported relying on effective encoding strategies less often. This result makes sense given the kinds of strategies that participants endorsed. For example, one of the most common effective encoding strategies that was reported was sentence generation where participants link the words together into a sentence. This strategy naturally lends itself to encoding the words together in a forward order and thus, resulting in a more organised recall output. At the same time, it is important to note that overall there were very few differences in terms of variation in effective encoding strategies and recall transitions, with the correlations being fairly weak. Future research could further test the hypothesis that effective encoding strategies enhance organisational processes by manipulating strategy use via strategy instructions to see if various strategies differentially impact recall dynamics.

Finally, examining when items were recalled during the recall period in terms of overall recall latency, latency to the first response, and IRTs suggested that none of these variables significantly correlated with effective encoding strategy use. Both the correlations with overall recall latency and latency to the first response were near zero. The correlation with IRTs was negative, but relatively weak. Thus, there was little evidence that variation in effective encoding strategy use was differentially related to when items were recalled.

Collectively, these results suggest that the use of effective encoding strategies serves to build stronger representations that are more associated during encoding, which results in better overall recall performance and more organised recall than the use of less effective encoding strategies. In terms of search models (Atkinson & Shiffrin, 1968; Raaijmakers & Shiffrin, 1980; Shiffrin, 1970; Shiffrin & Atkinson, 1969), these results are consistent with the notion that participants who rely on effective encoding strategies and participants who rely on less effective encoding strategies are searching through search sets of roughly the same size (i.e., no differences in sampling), but differences arise in the ability to recover the items during recall. Thus, whereas prior individual differences research has suggested some that variation in recall is due to differences in search efficiency (e.g., Miller & Unsworth, 2018; Sahakyan & Kwapil, 2018; Unsworth, 2007, 2009, 2019), the current results suggest that individual differences in effective encoding strategy use does not necessarily result in differences in search set size, but rather, differences arise due to variation in the strength of the stored item. Future research is needed to examine additional ways in which individual differences in encoding strategies are associated with recall dynamics and how this may change as a function of task variables such as presentation duration of the items, list-length, value of the items, test expectancy, and so on.

Although the current results provide important evidence for individual differences in encoding strategies and their association with recall dynamics, we would be remiss if we did not note some potential issues with the current study. One issue is the extent to which having participants report the strategies in a list-by-list fashion resulted in reactivity effects (e.g., Dunlosky & Hertzog, 2001; Dunlosky & Kane, 2007). That is, it is possible that by providing participants with the strategy report prompt after each list, participants used this information to change their strategies, which they may not have done if there was no strategy report prompt. Evidence consistent with the notion of reactivity effects is that the major switch in strategies occurred between List 1 and List 2, which is where participants first encountered the strategy report prompt. Thus, it is certainly likely that the switch in reported strategies between List 1 and List 2 occurred because participants received the strategy report prompt. The current design cannot rule out this possibility. Perhaps using a more open-ended report where participants are not exposed to other potential strategies would be beneficial for examining these issues (e.g., Delaney & Knowles, 2005). Furthermore, this could be tested by having some participants begin making reports after the second list rather than after the first list and comparing the strategy reports.

To examine possible reactivity effects in more detail, we combined the data from this study with data from Unsworth (2016). Unsworth (2016) used the same delayed free recall task with a 4-s presentation duration, but only asked participants about their strategies at the end of the task (rather than after each list). If asking participants about their strategy use after each list resulted in strong reactivity effects, then we should see differences between the current data and Unsworth (2016) not only in the end of the task strategy reports, but also potentially in the free recall dynamics. Comparing the two data sets suggested no differences in strategy reports for effective strategies or ineffective strategies, and no differences in serial position curves, lag-CRPs, or recall latency.[3] The only significant effect occurred for PFR, where participants were slightly more likely to start with primacy items than participants in Unsworth (2016). These results tentatively suggest that having participants report their strategy usage after each list rather than at the end of the task did not necessarily change their end of the task strategy reports and did not strongly influence their recall performance.

Furthermore, potential reactivity effects did not occur for all participants given that some participants continued to rely on less effective strategies even after being exposed to other potential strategies. Only the high-effective strategy participants, who were more likely to report using effective strategies even on List 1, seemed to demonstrate any reactivity. Thus, this group may have benefitted from the exposure to other potential strategies by updating their knowledge of effective strategies and then actually attempting to use those strategies on subsequent lists. More recent research suggests that during the course of multiple study-test trials in memory tasks, participants do indeed update knowledge of strategies (via performance monitoring), and this updating of strategy knowledge is associated with better subsequent recall performance (Dunlosky & Hertzog, 2000; Hertzog, Lovden, Lindenberger, & Schmiedek, 2017; Hertzog, Price, & Dunlosky, 2008). Thus, the current results provide potentially important information on individual differences in encoding strategy use, but also on who is likely to update their strategy knowledge and use that information to increase their performance on subsequent lists. Future research is needed to better examine individual differences in strategy use and the updating of strategy knowledge.

Another issue with the current study was that we did not find a correlation between effective strategy use and working memory. Prior research has suggested that there is a positive correlation between effective strategy use and working memory (e.g., Bailey et al., 2008; Dunlosky & Kane, 2007; Turley-Ames & Whitfield, 2003; Unsworth, 2016). This is especially true when strategy use is assessed on the working memory tasks themselves (Bailey et al., 2008; Dunlosky & Kane, 2007; Turley-Ames & Whitfield, 2003). In addition, some prior research suggests a correlation between working memory and effective strategy use in delayed free recall. For example, Unsworth (2016) found a correlation of $r = .32$ between a latent working memory factor and a latent effective encoding strategy factor (based on three delayed free recall tasks). In the current study, however, the correlation between effective encoding strategies assessed with the list-by-list reports and working memory was near zero, suggesting no relation. One difference between the current results and prior results is that the correlation found in Unsworth (2016) was a latent correlation derived from a confirmatory factor analysis on multiple measures, rather than a correlation based on an effective encoding strategy measure from a single task. Therefore, we reanalyzed data from Unsworth (2016), which had a similar delayed free recall task where items were presented for 4 s each and a similar sample size (N = 135) and examined the correlation between working memory and strategy use only in that task. The correlation was r = .20. Thus, it does not seem likely that the differences in results were due to the use of latent variable techniques in prior work. An additional difference was that in the prior study, encoding strategies were only assessed at the end of the task and not with list-by-list reports. Thus, perhaps the correlation only occurs for the end of the task reports for some reason. However, the correlation between working memory and effective encoding strategies from the end of the task reports in this study was also near zero and slightly negative (r = −.09). Complicating issues further are the results from another recent study conducted in our laboratory, which demonstrated a correlation of r = .01(N = 139) between working memory and effective strategy use on delayed free recall (Miller, Gross, & Unsworth, 2019). Thus, whereas prior research has suggested a correlation between working memory and effective strategy use, more recent research suggests no relation. We do not have an explanation for these discrepant results, but it seems likely that the correlation between working memory and effective encoding strategy use on delayed free recall may not be as robust as previously thought. Additional research is needed to examine relations between working memory and encoding strategies.

Conclusion

The current study examined individual differences in encoding strategies and their relation to free recall dynamics. Individual differences in effective encoding strategy use were associated with greater recall and more organised recall, but there were no differences in how participants initiated recall or in how quickly participants recalled items. These results suggest that the use of effective encoding strategies served to increase the strength of items stored in the long-term store, and thus increased the probability of recovering the items during recall. Overall, the results are broadly consistent with the notion that control processes are an integral component of the human memory system and that individuals differ in their ability to utilise these control processes.

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Supplementary material

The Supplementary material is available at: qjep.sagepub.com

Notes

1. We also examined variation in the number of strategies used. On average, participants reported using 2.72 (SD = 1.07) strategies. The number of strategies used was correlated with overall accuracy (r = −.25, p = .006), effective strategy use (r = .18, p = .043), but not with working memory (r = −.12, p = .19).
2. For completeness, we also examined correlations with recall errors. Previous list intrusions were related to overall accuracy (r = −.42, p < .001), effective strategy use (r = −.32, p < .001), and working memory (r = −.23, p = .009). Extra-list intrusions were related to overall accuracy (r = −.45, p < .001), effective strategy use (r = −.35, p < .001), but not working memory (r = −.02, p = .82). Repetitions were not related to overall accuracy (r = .06, p = .49), effective strategy use (r = .03, p = .77), or working memory (r = −.03, p = .73).
3. There were no differences in end of the task reports of effective encoding strategies, $t(244)$ = .25, p = .80, or ineffective encoding strategies, $t(244)$ = .95, p = .34. There were no differences in serial position curves, $F(9, 2178)$ = 1.13, MSE = .04, p = .34, partial η^2 = .005, lag-conditional response probability (CRPs), $F(4, 968)$ = .096, MSE = .01, p = .98, partial η^2 = .000, or recall latency, $t(242)$ = −1.09, p = .28. The only significant difference between the current data and Unsworth (2016) occurred for the probability of first recall (PFR) curves, $F(9, 2178)$ = 3.12, MSE = .02, p = .001, partial η^2 = .01, in which participants in this study were more likely to initiate recall with the first item (M = .67) than participants in Unsworth (2016; M = .59).

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