Memory

Routledge
Taylor & Francis Group

ISSN: 0965-8211 (Print) 1464-0686 (Online) Journal homepage: https://www.tandfonline.com/loi/pmem20

Incidental learning of list membership is affected by serial position in the list

Qiang Jiang & Nelson Cowan

MEMORY
2020, VOL. 28, NO. 5, 669–676
https://doi.org/10.1080/09658211.2020.1761398

Incidental learning of list membership is affected by serial position in the list

Qiang Jiang and Nelson Cowan

Department of Psychological Sciences, University of Missouri, Columbia, MO, USA

ABSTRACT

Cowan, Donnell, and Saults [(2013). A list-length constraint on incidental item-to-item associations. *Psychonomic Bulletin & Review*, 20, 1253–1258] examined incidental memory of whether two words had occurred in the same list or different lists, after the lists had been presented with an orienting task that did not require memorisation. Performance was superior for 3-word lists compared to 6- or 9-word lists, with memory for the longer lists near chance levels. Here we re-examine this phenomenon with methodological modifications to ensure that learning was incidental: we removed potential clues that a memory test would follow, eliminated trials with special mnemonic cues related to the orienting task, eliminated participants who suspected a memory test according to a post-experimental questionnaire, used signal detection measures to distinguish between memory sensitivity and bias, and tested list length with the relative serial position controlled. Incidental memory formed primarily for the most recent part of each list, an effect that was stronger than that of list length. The new evidence helps to constrain theories about the relation between working memory and incidental learning. A capacity-limited approach to the incidental-learning process still is possible but must be modified compared to Cowan et al., and the evidence is favourable to other theoretical approaches as well.

ARTICLE HISTORY
Received 15 December 2019
Accepted 9 April 2020

KEYWORDS
Working memory; incidental learning; serial position effects; capacity limits; focus of attention

The issue stimulating the present research is how limitations of the capacity of short-term memory may affect long-term learning. We examine how the length of a list of words to be processed, without instructions to remember the list, affects incidental long-term learning of list membership. This reflects a type of incidental learning that is likely to be important in daily life, for example to answer questions like the following: *Was it Mariah who answered Tim, or am I thinking of remarks that I read in two separate passages?* The issue examined here, with an incidental list-learning procedure, pertains broadly to whether the ability to answer questions like this depends on the length of the passages and/or on the placement of the remarks within the passages.

The specific purpose of the research is to follow up on results by Cowan et al. (2013). The impetus for their study was to examine a prediction of the embedded processes account of working memory (Cowan, 1988, 1999, 2016; most recent account, 2019). According to that account, working memory is stored in a temporarily-activated portion of long-term memory. That portion consists of various features of items recently perceived or thought of. Critically, within it, up to several (typically one to four) items are held in a more integrated form called the focus of attention. One property of that focus was said to be the association of concurrently-held items, leading to new learning of multi-item associations in long-term memory. This new long-term learning was said to include not of all items in working memory, only the items held concurrently in the focus of attention. Moreover, this long-term associative learning was not supposed to require the intention of learning these associations.

Cowan et al. (2013) carried out an experiment to examine this prediction of the account. They examined an ability to indicate whether two probe words had been presented in the same list or different lists, when the lists had been presented with an orienting task that did not require memorisation. The expectation was that items within three-word lists typically could fit in the focus of attention concurrently, whereas items within longer (six- or nine-word) lists could not. Therefore, associations between words within a list should form more reliably for three-word lists compared to six- or nine-word lists.

In Cowan et al. (2013), lists were presented with the words simultaneous on the screen, for a time period proportional to the list length. When each list was presented, the orienting task was to indicate which word seemed most interesting (Figure 1A). Participants did not know that, after this list-judgment phase of the experiment ended, they would be asked to carry out an associative memory task for words that had appeared in these lists. In this supposedly incidental memory task (Figure 1B), participants always received two probe words that they were

CONTACT Nelson Cowan cowann@missouri.edu Department of Psychological Sciences, University of Missouri, McAlester Hall, Columbia, MO 65211, USA

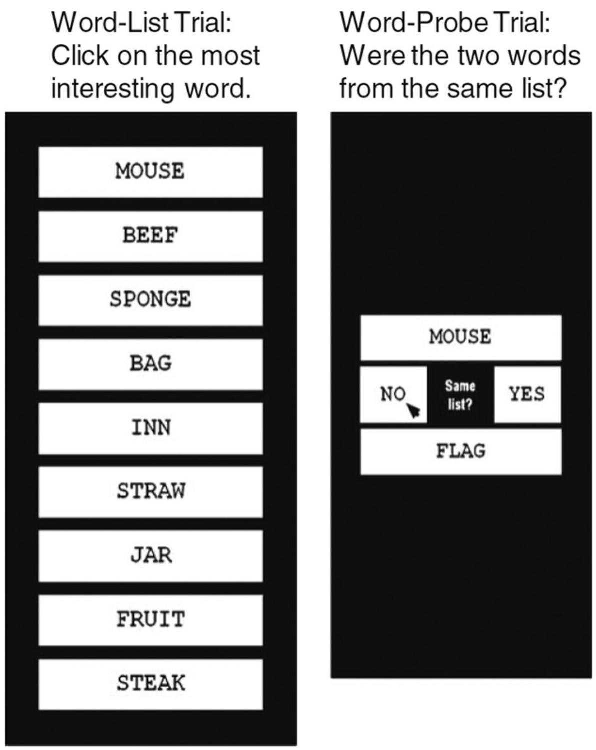

Figure 1. From Cowan et al. (2013, Figure 1), an illustration of the test displays. **Left-hand panel**, a 9-item list from the most-interesting-word judgment task; **right-hand panel**, a trial from the word-probe memory test phase, with the correct answer (no) marked, indicating that *mouse* and *flag* had not been presented in the same list in the most-interesting-word phase of the experiment.

to judge to have come from the same list or from different lists of the first experimental phase.

The serial positions of the two words to be compared on a memory trial, to be judged to have come from the same list or from different lists in the most-interesting-word task, differed by one position in their lists of origin. Both words came from the same triad of serial positions, within lists of the same length. For example, if the first word had come from Position 5 of a six-word list, the other word came from Position 4 or Position 6 of a six-word list (either from the same list or from a different list, and that was the question for the participant to answer). As another example, if the first word happened to come from Position 7 of a nine-word list, the other word came from Position 8 or 9 of the same list or of a different nine-word list. Thus, inter-word distance was controlled across list lengths.

As hypothesised, Cowan et al. (2013) found that memory for whether two words came from the same list was higher for three-word lists than for six- or nine-word lists. Performance was low overall, but exceeded chance for three-item lists, at about 59% correct. Thus, the conclusion was that items were associated with other items in a manner that sometimes preserved memory of their membership in the same list, at least for three-word lists. This learning could result from the concurrent presence of these items in the focus of attention. Performance for the longer lists was at 53–54% correct overall. This slightly better-than-chance performance could be expected theoretically as well, because the tested items would sometimes, but not consistently, be present concurrently in the focus of attention.

Given the theoretical implications of this finding for accounts of the relation between working memory and long-term memory, here we re-examined the conclusions of Cowan et al. (2013). We did so because we have thought of potential weaknesses of that study. We ask whether the result will hold up with stronger controls to ensure that learning was incidental, whether the findings could instead be explained by serial position effects rather than list length effects, what are the theoretical implications of the new findings. Several concerns with the procedure of Cowan et al. (2013) make us question their conclusions. Given the small magnitude of effects obtained by Cowan et al. and the potential theoretical importance of effects on incidental learning for many different theories of memory, we thought it important to conduct a study that corrects shortcomings in the design that we noticed in hindsight.

First, Cowan et al. (2013) conducted the testing within a space marked "working memory laboratory," which may have caused many participants to guess that there would be a memory test. To address this concern, we ran the present experiment in a borrowed laboratory with no marking related to memory.

Second, some of the trials in the experiment would not be pure ones for examining incidental recall, namely trials in which at least one of the two probe words had been selected as most-interesting in their lists. In those trials, there is a heightened chance that there might be an enhanced memory of the relation between the probes, if they were from the same list, because the selected most-interesting word was assessed as more interesting than any other list word. Moreover, many participants did not have such a trial in many of the conditions. Therefore, unlike Cowan et al. (2013), we eliminated these trials from detailed consideration.

Third, Cowan et al. (2013) had no way to eliminate from consideration participants who may have suspected a memory test. We did eliminate these participants, on the basis of a questionnaire that we placed at the end of the session.

Fourth, Cowan et al. (2013) did not examine the entire word-triad serial position function for each list length. This is important because Cowan et al. did not examine the possibility that what they took to reflect a list length effect could actually have been a recency effect (relatively good memory performance for word pairs drawn from the final triad of serial positions in a list in the most-interesting-word task). Given that Cowan et al. averaged results across serial positions, the result would reflect the last triad of words in the list more heavily for shorter lists. If there is a memory advantage for those serial positions, a serial position effect can be the underlying reason for an apparent list length effect. We examined the serial position functions in the present study and analyzed for list length effects using only comparable serial positions, either the first triad in lists of each length or the last triad.

Fifth, given that there are possible effects of bias in responding, we used signal detection measures (Macmillan & Creelman, 2004) to estimate the strength of memory free of effects of bias to respond that probe items were from the same list, or from different lists. Such a bias theoretically might change with list length or serial position.

Sixth, and finally, we used the most-interesting-word results to ask whether there is evidence of greater attention to the more recent serial positions at the time when the most-interesting-word response was made, a finding that would help to explain a recency effect in memory.

Method

Participants

There were 61 participants (50 female, 11 male). Based on a questionnaire after the memory test asking whether such a test was suspected, 47 said they had not suspected a memory test (42 female, 5 male), whereas the other 14 did suspect one. All participants were native English speakers with the possible exception of one in the group that did not suspect a memory test, who did not provide the information.

Our sample size should be sufficient according to a power analysis (Faul et al., 2007) based on the effect size for list length reported by Cowan et al. (2013, p. 1255), namely $\eta_p = .09$. With that effect size for the analysis reported, 40 participants should result in a power of over .9 to detect an effect of list length. For that calculation, correlation between conditions was estimated at .2 based on the past results.

Apparatus, stimuli, and procedure

Design

Unlike Cowan et al., the present study was conducted in an unmarked laboratory, to yield no clues that there might be a memory test. Most other details of the method were identical to Cowan et al. (2013). A *list-judgment phase* was followed by a *recognition test* phase. In the list-judgment phase, on each trial a list of 3, 6, or 9 words was presented concurrently, the task being to select the word that was most interesting, by a mouse click (Figure 1, left). This task was followed by a recognition task in which, on each trial, two words were to be judged to have come from the same list or from different lists, by a mouse click (Figure 1, right). In either case, the words came from lists of the same length. Finally, a questionnaire was administered asking participants in the un-forewarned group if they had suspected a memory test and, in both groups, asking about any strategies used in the two tasks.

Stimuli and procedure

In the word lists for the most-interesting-word judgment task, words appeared in a column at the centre of the screen with 11-mm-tall lettering (Figure 1, left). The presentation duration was 4.5 s for 3-word lists, 9.0 s for 6-word lists, and 13.5 s for 9-word lists. Participants read each list aloud and then mouse-clicked on the word deemed most interesting before it disappeared from the screen. Within the 36 lists (12 of each length), no word was re-used. The words were common, monosyllabic nouns with two to six letters, taken from the MRC Psycholinguistic Database (Fearnley, 1997) with a Kučera and Francis written frequency of 1–1207 and scores between 591–670 on concreteness, 364–646 on familiarity, and 459–667 on imagery. Words with multiple meanings were excluded, as were a few words that seemed unusual.

The two probe words on each trial of the recognition task came from the same serial position triad of their list or their respective lists (i.e. both from serial positions 1–3, both from positions 4–6, or both from positions 7–9), always lists of the same length. Even when they came from different lists, they were never from identical serial positions of their respective lists, but from different positions within the same triad. For example, pairs of serial positions that sometimes occurred included 4 and 5, or 4 and 6, but never 3 and 4 (because they come from different triads) and never 4 and 4 (i.e. never identical positions). Thus, memory data on probe words drawn from lists of the most-interesting-word task were equated across list lengths for the inter-probe-word distance in serial positions. Of a probe word pair in the recognition test, either item could be placed on the left versus right. The comparison was carried out in such a manner that each word from every list appeared once in the recognition test, either in a same-list trial or in a different-list trial, for a total of 108 recognition test trials in a random order.

Cowan et al. (2013, p. 1255) explained that "for two thirds of the memory trials, the probe words came from the same list. This proportion allowed perfect equivalence of serial positions tested for same-list versus different-list trials." For example, consider Words A1, A2, and A3 from a 3-word list and B1, B2, and B3 from a second such list. If, on two same-list trials, the participant happens to receive word pairs [A2,A1] and [B1,B3], then the different-list trial [B2,A3] could occur, with no word repeated in more than one trial of the recognition phase. Thus, inevitably, same-list performance accuracy was based on twice the number of trials as different-list performance accuracy.

Last, participants received a question regarding whether a memory test had been suspected, a questionnaire for strategies for the most-interesting-word judgment task (in which participants were presented with several options and ranked them according to the prevalence of use, omitting unused strategies), and an open-ended question concerning memory retrieval strategies.

Analyses

Signal detection analysis methods were applied only to the memory results for participants who did not suspect a memory test. The d′ measure of sensitivity to the common list membership of probe items was calculated as the z score of the proportion hits, i.e. correctly-identified pairs from the same list, minus the z score of the proportion of false alarms, i.e. pairs incorrectly said to come from the same list. A measure of bias was also used, –[z(hits) plus z(false alarms)], such that more positive scores reflected a greater tendency to indicate that the items were from different lists. To allow calculation of signal detection measures, a proportion correct of 1.0 in any participant in any condition was converted to 0.99, and a proportion correct of 0.0 was converted to 0.01. In the inferential tests, we include only participants with data in all relevant cells. We carried out traditional analyses to generate F values and effect sizes (η_p^2) and Bayesian analyses to generate the Bayes Factor for including an effect of list length in the model, as compared to comparable models that omit the effect, BF_{incl} (JASP team, 2019). Here, Bayes Factors of at least 3 are considered non-negligible evidence for an effect, with the strength of the evidence growing continually with the size of the factor and 10 considered reasonably strong evidence. The reciprocal of these levels provide evidence favouring the null hypothesis (BF_{incl}=0.33 for non-negligible evidence and BF_{incl}=0.10 for fairly strong evidence).

To ensure that list length and serial position (in terms of list triads) were not confounded, we carried out two analyses on the memory probe word pair data with each measure. In one analysis, the list length effect was examined using only probe word pairs drawn from the first serial position (first word triad) from each list. In another analysis, the list length effect was examined using only probe word pairs drawn from the last serial position (last word triad) in each list.

Results

Of all 61 participants, 47 did not suspect a memory test, whereas 14 did suspect one. Our results include proportion correct for all memory responses; a d′ measure of sensitivity and a corresponding measure of bias, for only the data considered most important for incidental memory (only participants who did not suspect a memory test, and only trials in which neither memory probe word had been judged most-interesting); an analysis of the serial positions of words judged most interesting within their lists, and a summary of reported use of memory strategies. For the first measure, Table 1 shows the mean proportions correct in each condition in the groups who did not and did suspect a memory test.

Memory sensitivity, d′

The pattern of d′ results for participants who did not suspect a memory test is shown in Figure 2. The dependent measure is the sensitivity to detect that two probe words had come from the same versus different lists in the most-interesting-word task. The analysis of list length using the first serial position (first word triad) of each list showed an effect of list length, $F(2,88) = 5.61$, η_p^2=0.11, BF_{incl}=14.48 (for the three list lengths, respectively, M=0.73, 0.18, and -.10; SD=1.29, 1.15, & 1.12). We will see that this effect occurred because the first word triad of List Length 3 was also its last word triad, with privileged memory. Pairwise tests showed that List Lengths 3 and 9 differed, BF_{incl}=10.70. The first two list lengths were indeterminate, BF_{incl}=1.37, whereas the last two list lengths

Table 1. Memory accuracy in each group by condition.

List Length /Triad	Most-interesting word in probe pair?	Correct Answer	Group: Did not suspect a memory test			Group: Suspected a memory test		
			Mean	SEM	n	Mean	SEM	n
3 /1	No	Different Lists	0.63	0.04	45	0.60	0.09	14
3 /1	No	Same List	0.55	0.03	47	0.57	0.06	14
3 /1	Yes	Different Lists	0.35	0.04	47	0.33	0.09	14
3 /1	Yes	Same List	0.63	0.03	47	0.79	0.04	14
6 /1	No	Different Lists	0.59	0.03	47	0.61	0.05	14
6 /1	No	Same List	0.44	0.02	47	0.49	0.07	14
6 /1	Yes	Different Lists	0.51	0.07	39	0.63	0.11	12
6 /1	Yes	Same List	0.64	0.05	46	0.64	0.08	13
6 /2	No	Different Lists	0.60	0.04	47	0.50	0.08	14
6 /2	No	Same List	0.54	0.03	47	0.57	0.06	14
6 /2	Yes	Different Lists	0.38	0.05	42	0.25	0.10	12
6 /2	Yes	Same List	0.63	0.04	45	0.56	0.08	14
9 /1	No	Different Lists	0.52	0.04	47	0.51	0.06	14
9 /1	No	Same List	0.44	0.02	47	0.48	0.04	14
9 /1	Yes	Different Lists	0.45	0.08	33	0.43	0.20	7
9 /1	Yes	Same List	0.56	0.05	44	0.57	0.11	13
9 /2	No	Different Lists	0.61	0.04	47	0.52	0.07	14
9 /2	No	Same List	0.42	0.02	47	0.48	0.06	14
9 /2	Yes	Different Lists	0.25	0.08	28	0.41	0.11	13
9 /2	Yes	Same List	0.57	0.05	43	0.59	0.10	14
9 /3	No	Different Lists	0.60	0.03	47	0.39	0.07	14
9 /3	No	Same List	0.51	0.03	47	0.59	0.05	14
9 /3	Yes	Different Lists	0.45	0.07	36	0.29	0.13	11
9 /3	Yes	Same List	0.63	0.05	44	0.44	0.10	14

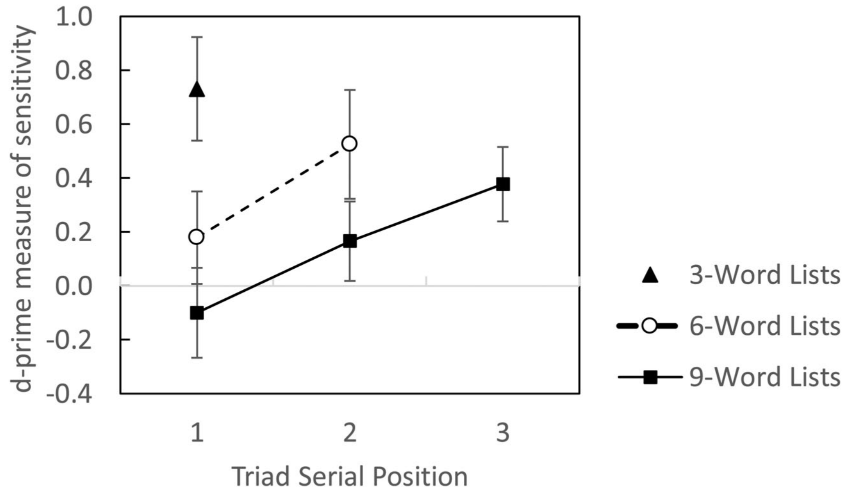

Figure 2. Memory sensitivity (d′) for each triad within each list length for participants who did not suspect a memory test, limited to trials in which the probe did not contain words that had been judged most-interesting within the list. Error bars are standard errors.

were shown not to differ, BF_{incl}=0.31, or 3.23–1 in favour of the null hypothesis.

In contrast to the analysis of the first word triads in each list, the analysis of the last word triads of each list length showed an overall result favouring the null hypothesis, $F(2,88) = 0.97$, η_p^2=0.02, BF_{incl}=0.18, or 5.56–1 in favour of the null hypothesis (for the three list lengths, respectively, M=0.73 0.53, & 0.38; SD=1.29, 1.36, & 0.93). The results suggest that it is the recency of the word triad that makes the key difference for performance, not the primacy of the word triad and not the list length per se.

The results of the present study with participants unaware of the upcoming memory test can be compared to the study of Cowan et al. (2013), in which there is reason to believe that many participants would have expected a memory test, given the advertised name of the laboratory in which they were tested. Unlike the present experiment, a comparison of performance in probe word pairs drawn from the first list triad did not yield an effect of list length. In fact, the outcome strongly supported the null hypothesis, $F(2,136) = 0.38$, η_p^2=0.01, BF_{incl}=0.07 (for the three list lengths, respectively, M=0.55, 0.36, & 0.43; SD=1.53, 1.24, & 1.02). One likely reason for this difference between studies is that, with intentional learning in Cowan et al., the first triad of each list could be learned, even for longer lists, better than would be the case for the first triad of longer lists with incidental learning in the new data.

Like the present study, the comparison of performance on memory probe word pairs drawn from the last word triads for all three list lengths also provided evidence for the null hypotheses, $F(2,136) = 1.90$, η_p^2=0.03, BF_{incl}=0.31 (for the three list lengths, respectively, M=0.55, 0.17, & 0.26; SD=1.15, 1.08, & 1.06). Even with the two groups analyzed together, the list length effect in this analysis gave an indeterminate result favouring the null, BF_{incl}=0.43, with no effect of group, BF_{incl}=0.37, or interaction between group and list length, BF_{incl}=0.08. Thus, the totality of the evidence (recency effects only in the new data; no primacy effects in either study) suggests that the present pattern emphasising recency effects seems to depend on the incidental nature of the memory task.

Response bias

There was no evidence of a change in response bias across conditions. The mean biases (and standard errors) were, for List Length 3, 0.33 (0.24); for the two triads of List Length 6, 0.58 (0.14) and 0.23 (0.20), respectively; and for the three triads of List Length 9, 0.24, 0.65 (0.17), and 0.41 (0.19), respectively. An analyses of the first word triad in each list (comparable to the analysis of d′) supported the null hypothesis that there was no effect of list length, $F(2,88) = 1.37$, η_p^2=0.03, BF_{incl}=0.25, or 4–1 in favour of the null hypothesis, and the same was true in the analysis of the last word triad, $F(2,88) = 0.28$, η_p^2=0.01, BF_{incl}=0.09, or 11.11–1 in favour of the null. The same was true in the data of Cowan et al. (2013), for the first word triad, $F(2,136) = 1.02$, η_p^2=0.02, BF_{incl}=0.13, and the last word triad, $F(2,136) = 1.98$, η_p^2=0.03, BF_{incl}=0.32.

Serial position effects in words participants chose as most-interesting

An examination of the proportion of words judged most interesting when they came from each serial position can provide a clue to how attention was distributed across serial positions in the list. For the group of participants who did not suspect a memory test, in three-word lists, the proportions of most interesting words were .34, .33, and .32, SDs≤0.16, with evidence against a difference between serial positions, $F(2,92) = 0.05$, η_p^2=0.00, BF_{incl}=0.07, or 14.29–1 in favour of the null hypothesis. Similarly, for six-word lists, the proportions were .16, .15, .15, .18, .17, and .21, SDs≤0.13, appearing to favour the more recent positions but the evidence was still against an effect of serial position, $F(5,230) = 1.60$, η_p^2=0.03, BF_{incl}=0.21, or 4.76–1 in favour of the null. For nine-word lists, however, the proportions were .08, .09, .13, .11, .12, .10, .10, .16, and .13, SDs ≤0.14, favouring an effect of serial position,, $F(8,368) = 2.68$, η_p^2=0.06, BF_{incl}=4.67. Pairwise comparisons showed differences with BF_{incl}>3 for Serial Positions 1 vs. 8 (BF_{incl}=7.88), 1 vs. 9 (BF_{incl}=3.56), and 7 vs. 8 (BF_{incl}=3.79). Interest in the last two list items could have occurred because of forgetting of some of the earlier items by the time those later items were read, or simply the words foremost in the focus of attention when the judgment had to be made. It is possible that a similar effect was beginning to play a role also for 6-word lists. Yet, the most recent triad was remembered slightly better in the probe pair task drawn from shorter lists (Figure 2).

The proportions were similar for the participants who said they suspected a memory test: for three-word lists, 0.32, 0.36, and 0.30, SDs≤1.70; for six-word lists, 0.11, 0.14, 0.22, 0.20, 0.17, and 0.16, SDs≤1.45; and for nine-word lists, 0.03, 0.07, 0.13, 0.17, 0.14, 0.10, 0.08, 0.13, and 0.15, SDs≤1.77. In all cases, longer lists seem to involve less selection of the earliest serial positions as containing the most-interesting words, a difference that cannot be attributed to the words used, which were randomised across serial positions.

Strategy questionnaire

All but 2 of the 14 participants who suspected a memory test reported using some memorisation strategy whereas, in stark contrast, of 47 participants who did not suspect a memory test, only 4 mentioned any strategy, and those strategies referred only to a retrieval strategy at the time of recall, not a memorisation strategy during the most-interesting-word task.

Discussion

Recency-effect finding

Cowan et al. (2013) presented a list-judgment task in which the most interesting word in each list was to be selected, followed by a surprise test of memory for which words had been presented together in the same lists. The purpose was to examine the possibility that 3-word lists result in the words usually being contained concurrently in the focus of attention, whereas longer lists require shifting of the focus. As predicted, there was better list source memory for 3-word lists than for longer lists. Unfortunately, Cowan et al. did not ask whether participants suspected a memory test. Given that the experiment was conducted in a marked working memory laboratory, our current assumption is that many participants could have suspected a test. Here we used an unmarked laboratory and examined the comparable procedure, in a group that received a final questionnaire asking whether they had suspected a test, to which most participants responded that they did not. To avoid extraneous mnemonic cues, we limited performance to recognition probe pairs that did not include a word selected by the participant in the orienting task. The result, illustrated in Figure 2, indicates that it is primarily not a short list length that helps in retaining list membership of items for later incidental memory after all, but recency of the serial position triad within the list from which memory probes were drawn. In intentional associative learning, there is usually a primacy effect (e.g. Ebenholtz, 1963) and, although we studied an unusual dependent variable (list membership), the absence of a primacy effect here is further evidence that learning was not intentional, but incidental.

Convergent findings

The key finding of incidental learning of list membership for short lists has not always been analyzed into its serial positions. There are other indications that perception and attention feed some information to long-term memory regardless of any intent to learn the material. In one interesting demonstration of capacity-limited incidental learning, Nairne and Neath (2001) presented lists of 2–9 words for pleasantness ratings. Following a 5-minute geometric filler task, words in each list were presented in alphabetical order, the surprise task being to reproduce the order of items in the list. Performance dramatically declined as a function of the list length, suggesting that shorter lists were better encoded in long-term memory. However, it is difficult to interpret that result fully inasmuch as we have no analysis of errors by serial position. There are many studies of incidental learning of lists, but to our knowledge the other studies have involved much longer lists (e.g. Postman & Adams, 1958; Sahakyan & Delaney, 2005).

A focus of attention interpretation?

Cowan et al. (2013) considered that the incidental learning process includes limited-capacity constraints because it originates from material concurrently in a capacity-limited focus of attention (cf. Fukuda & Vogel, 2011). As evidence favouring an interpretation in which learning depends on the list fitting within the focus of attention, Cowan et al. (2013) pointed to the discontinuous function across list lengths, namely the pattern in which performance for 3-word lists was substantially above 6- or 9-word lists. The present, purer assessment of incidental learning does not match that concept, but it still might be considered consistent with a different but related interpretation. The new interpretation would be that the last triad in each list dwells in the focus of attention longer than earlier triads, because of the absence of displacement from any subsequent list items. In keeping with this interpretation, there was some evidence that words that happened to appear near the end of long lists were judged most-interesting more often than words near the beginning of the list. The finding is consistent with the observation that the end of the list dwells in the focus of attention regardless of the intentions of the participant (Hu et al., 2016). Given that our participants had no memory instructions that would add other serial positions to the focus of attention, it is consistent with the Embedded Processes model of Cowan (1988, 1999, 2001, 2019).

Other theoretical interpretations

There are other principles that might produce a recency effect in incidental learning of associations without referring to the notion of the focus of attention. Our main result is consistent with the notion of the overwriting of each item's features to some extent by successive items (Cowan, 1988; Nairne, 1990) and reminiscent of the mnemonic benefit of minimising retroactive interference in amnesic individuals (Dewar et al., 2009).

Our recognition-of-list-membership results also seem consistent with the free recall literature. Specifically, the recency effects shown in Figure 2 are consistent with the traditional notion that the effect does not depend on a deliberate memorisation process, which is absent from incidental learning. In contrast, the often-observed primacy effect (relatively good memory performance for the first few list items) is supposed to depend to a greater extent on deliberate memorisation. For example, in free recall, preschool children show much smaller primacy effects than older children, presumably because of the developmental growth of deliberate learning strategies as applied most effectively to the beginning of each list; whereas, in contrast, recency effects are more nearly comparable across age groups (e.g. Glidden, 1977). In one study to look at serial position effects for intentional and incidental learning of a single list in adults, making the learning incidental did abolish the primacy effect in free recall, while preserving recency (Marshall & Werder, 1972).

Although the recency effect is often considered to be specific to short-term memory (e.g. Glanzer & Cunitz, 1966), that has not always been the case. For example, the recency effect in immediate recall can be preserved after a distracting period when the learning itself is protracted rather than condensed in time (e.g. Bjork & Whitten, 1974). Bjork and Whitten did not find a recency effect in final free recall but Tzeng (1973) argued that Bjork and Whitten had final free recall performance too low to observe such an effect. Tzeng, using a surprise final free recall at the end of four 10-word lists, did find a strong effect of recency of words within their respective lists in final free recall, but no primacy effect. Thus, the present recency effect in long-term recognition seems consistent with the recall literature in a way that may not depend on the focus of attention.

Conclusions

In sum, Cowan et al. (2013) found an effect of potential theoretical importance, an effect of list length on incidental memory for list membership. The present work, however, uses an improved method of examining incidental learning to establish that the effect is actually one of recency within the list more than list length per se. It would still be possible to adhere to a version of a theoretical view proposed by Cowan et al., in which associations between items in a list that was attended but not deliberately memorised are restricted to just a few items to be associated with one another at a time in the focus of attention. However, in the modified application of that theoretical view, the associations formed within the focus of attention are vulnerable to interference from new associations formed shortly afterward, so that more recent parts of the list result in more durable or stronger representations in memory. Alternatively, it might be enough to consider the temporal distinctiveness of the most recent part of the list compared to earlier portions within the retrieval process (e.g. Bjork & Whitten, 1974), without reference to the focus of attention at the time of encoding. In future work, therefore, the highest priority may be to ask about the mechanism of the present incidental-learning effect of serial position, as well as how it is related to real-world tasks such as language learning.

Acknowledgments

We thank Bret Glass for invaluable help in conducting this study. The research was conducted with support from NICHD Grant R01-HD21338.

Disclosure statement

No potential conflict of interest was reported by the author(s).

Funding

This work was supported by Eunice Kennedy Shriver National Institute of Child Health and Human Development: [Grant Number R01-HD21338].

ORCID

Nelson Cowan http://orcid.org/0000-0003-3711-4338

Data availability

The materials and data are posted online at https://osf.io/ejkpw/.

References

Bjork, R. A., & Whitten, W. B. (1974). Recency sensitive retrieval processes in long term free recall. *Cognitive Psychology*, *6*(173), 189. https://doi.org/10.1016/0010-0285(74)90009-7

Cowan, N. (1988). Evolving conceptions of memory storage, selective attention, and their mutual constraints within the human information processing system. *Psychological Bulletin*, *104*(2), 163–191. https://doi.org/10.1037/0033-2909.104.2.163

Cowan, N. (1999). An embedded-processes model of working memory. In A. Miyake, & P. Shah (Eds.), *Models of working memory: Mechanisms of active maintenance and executive control* (pp. 62–101). Cambridge University Press.

Cowan, N. (2001). The magical number 4 in short-term memory: A reconsideration of mental storage capacity. *Behavioral and Brain Sciences*, *24*(1), 87–185. https://doi.org/10.1017/S0140525X01003922

Cowan, N. (2016). *Working memory capacity. Psychology Press and Routledge Classic Edition*. Routledge. [Original edition 2005. New Foreword to the Classic Edition].

Cowan, N. (2019). Short-term memory based on activated long-term memory: A review in response to Norris (2017). *Psychological Bulletin*, *145*(8), 822–847. https://doi.org/10.1037/bul0000199

Cowan, N., Donnell, K., & Saults, J. S. (2013). A list-length constraint on incidental item-to-item associations. *Psychonomic Bulletin & Review*, *20*(6), 1253–1258. https://doi.org/10.3758/s13423-013-0447-7

Dewar, M., Fernandez Garcia, Y., Cowan, N., & Della Sala, S. (2009). Delaying interference enhances memory consolidation in amnesic patients. *Neuropsychology*, *23*(5), 627–634. https://doi.org/10.1037/a0015568

Ebenholtz, S. M. (1963). Serial position learning and sequential associations. *Journal of Experimental Psychology*, *66*(3S), 353–362. https://doi.org/10.1037/h0048320

Faul, F., Erdfelder, E., Lang, A. G., & Buchner, A. (2007). G*power 3: A flexible statistical power analysis program for the social, behavioral, and biomedical sciences. *Behavior Research Methods*, *39*(2), 175–191. https://doi.org/10.3758/BF03193146

Fearnley, S. (1997). MRC Psycholinguistic Database search program. *Behavior Research Methods, Instruments, & Computers*, *29*(2), 291–295. https://doi.org/10.3758/BF03204829

Fukuda, K., & Vogel, E. K. (2011). Visual short term memory also gates long term memory without explicit retrieval. *Journal of Vision*, *11*(11), 1275. https://doi.org/10.1167/11.11.1275

Glanzer, M., & Cunitz, A. R. (1966). Two storage mechanisms in free recall. *Journal of Verbal Learning & Verbal Behavior*, *5*(4), 351–360. https://doi.org/10.1016/S0022-5371(66)80044-0

Glidden, L. M. (1977). Developmental effects in free recall learning. *Child Development*, *48*(1), 9–12. https://doi.org/10.2307/1128874

Hu, Y., Allen, R. J., Baddeley, A. D., & Hitch, G. J. (2016). Executive control of stimulus-driven and goal-directed attention in visual working memory. *Attention, Perception, & Psychophysics*, *78*(7), 2164–2175. https://doi.org/10.3758/s13414-016-1106-7

JASP Team. (2019). JASP (Version 0.11.1)[Computer software].

Macmillan, N. A., & Creelman, C. D. (2004). *Detection theory: A user's guide*. Psychology Press.

Marshall, P. H., & Werder, P. R. (1972). The effects of the elimination of rehearsal on primacy and recency. *Journal of Verbal Learning and Verbal Behavior*, *11*(5), 649–653. https://doi.org/10.1016/S0022-5371(72)80049-5

Nairne, J. S. (1990). A feature model of immediate memory. *Memory & Cognition*, *18*(3), 251–269. https://doi.org/10.3758/BF03213879

Nairne, J. S., & Neath, I. (2001). Long-term memory span. *Behavioral and Brain Sciences*, *24*(1), 134–135. https://doi.org/10.1017/S0140525X01433929

Postman, L., & Adams, P. A. (1958). Studies in incidental learning: VII. Effects of frequency of exercise and length of list. *Journal of Experimental Psychology*, *56*(1), 86–94. https://doi.org/10.1037/h0047417

Sahakyan, L., & Delaney, P. F. (2005). Directed forgetting in incidental learning and recognition testing: Support for a Two-factor account. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *31*(4), 789–801. https://doi.org/10.1037/0278-7393.31.4.789

Tzeng, O. J. L. (1973). Positive recency effect in a delayed free recall. *Journal of Verbal Learning & Verbal Behavior*, *12*(4), 436–439. https://doi.org/10.1016/S0022-5371(73)80023-4