Distinctiveness and Serial Position Functions in Implicit Memory

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Serial position functions, with their characteristic primacy and recency effects, are ubiquitous in episodic memory tasks, and have also been observed in tasks tapping semantic memory. However, only one experiment, Raanaas and Magnussen (2006a), has demonstrated primacy and recency effects in implicit memory using an indirect memory test. In Experiment 1, we replicate this finding and in Experiment 2, we confirm a prediction that holds only if the serial position function observed in Experiment 1 was a “real” serial position function. These results confirm the presence of serial position functions in implicit memory and also support a general prediction of the relative distinctiveness principle that serial position functions should obtain whenever a set of items are ordered along a relevant dimension.

As Greene (2007) notes, one approach to the study of memory is to seek general principles that apply widely. An alternate approach holds that general principles are not possible, in part because memory is made up of multiple systems, each of which operates according to its own rules. In this paper, we test a general principle of memory, the relative distinctiveness principle (Surprenant & Neath, 2009), by attempting to replicate Raanaas and Magnussen (2006a) who reported the only convincing demonstration of a serial position function in implicit memory. If this result can be replicated, it further supports the principles approach. If this result cannot be replicated, it weakens the claim of a general system-wide principle and instead supports the view that serial position functions may be unique to particular systems.

The serial position function describes the common finding that people remember the early events in a series quite well (the primacy effect), and also remember the later events in a series quite well (the recency effect), but have difficulty remembering intervening events (for a review, see Neath & Surprenant, 2003). Surprenant and Neath (2009) invoked the relative distinctiveness principle to account for these results: items will be well remembered to the extent that they are more distinct than competing items at the time of retrieval. This principle incorporates ideas from previous researchers (e.g., Crowder, 1976; Koffka, 1935; Murdock, 1960) and can be illustrated using Crowder’s telephone pole analogy. To an observer, the first and last tel-
ephone poles are easier to distinguish than middle poles because they have no neighbours on one side. This gives rise to primacy and recency effects. The asymmetrical nature of the function – whether primacy or recency dominates – is due to the perspective of the observer: If you stand at the end of the sequence of poles, the more recent ones are easier to distinguish from their neighbours, but if you stand at the beginning of the sequence, the earlier items are easier to distinguish than the more recent.

The relative distinctiveness principle predicts that serial position functions should obtain whenever a set of items can be sensibly ordered along a dimension (Neath & Saint-Aubin, 2011) and there is substantial evidence supporting this prediction. Serial position functions have been observed when the task lasts less than 1 second (Neath & Brown, 2006), several minutes (Bjork & Whitten, 1974), days and weeks (Glenberg, Bradley, Kraus, & Renzaglia, 1983), or even months (Huttenlocher, Hedges, & Prohaska, 1992). Although these demonstrations span sensory memory, short-term/working memory, and long-term memory, they are all episodic tasks. A relatively recent series of studies has shown that serial position functions can also be observed in tasks thought to tap semantic memory (for a review, see Neath et al., 2016). What is conspicuously missing are demonstrations of serial position functions in implicit memory tasks.

Tests of episodic memory typically use intentional learning instructions (“study the list for the upcoming memory test”) and also use a direct test (“recall the items that were on the list you just saw”). In contrast, tests of implicit memory are characterized by incidental learning instructions, in which no mention is made of learning the material for a test, and also by indirect tests, such as completing a word stem to make a valid word. There have been reports of serial position functions with incidental learning followed by a direct test (Neath, 1993a), but to our knowledge there is only one study that reports a convincing serial position function with incidental learning and an indirect test; in contrast, there are more studies that offer at best equivocal evidence.

Rybash and Osborne (1991) used either a direct test (free recall and cued recall) or an indirect test (word stem completion) following incidental learning instructions. Only those subjects tested with free recall produced both primacy and recency effects. Both cued recall and word stem completion resulted in recency, but no primacy.

Gershberg and Shimamura (1994) reported three experiments using incidental learning and an indirect test (word stem completion). A control condition using free recall demonstrated both primacy and recency, whereas the results for the indirect test were described as being transient: “serial position effects in implicit tests of memory were observed in the form of both primacy and recency effects. These effects, however, were transient, disappearing over the course of testing” (p. 1377).

Brooks (1994) used intentional learning and compared subsequent cued recall and word stem completion. There was no evidence of primacy or recency for the stem completion task. In a subsequent paper, Brooks (1999) reported both primacy and recency effects using an implicit free association test. However, the effect was observed only for weakly related words and not for strongly related words.

Phaf and Walters (1996) found primacy and recency effects with free recall, but no evidence of primacy effects with word stem completion. Although not specifically stated in the paper, the results shown in their Figure 1 suggest an absence of recency effects as well.

Raanaas and Magnussen (2006b) reported evidence of primacy but no recency using an indirect test based on priming a two-digit number that was an answer to a mathematical problem. Subjects were faster to confirm a
problem was correct when the first two-digit number of the sequence was the answer. However, no recency effect was observed in response time, and neither primacy nor recency was observed when accuracy was the measure.

In contrast to all of the above studies, Raanaas and Magnussen (2006a) reported both primacy and recency effects in an indirect task. Subjects saw four words presented in four different colours and were told that their memory for the location of the colour would be tested. Following presentation of the four words, a direct test was given, in which subjects were asked to indicate which position the word shown in a particular colour had appeared. Following this, an indirect test was given, in which 3 letters were shown and the subject was asked to complete the stem to make a valid word. It is this latter task that resulted in better performance on the first and last items relative to mid-list items.

**Experiment 1**

The purpose of Experiment 1 was to replicate the Raanaas and Magnussen (2006a) experiment. Subjects saw four words presented in four different colours followed by a direct test of colour order and then an indirect test for the words.

**Method**

**Subjects**

Sixty undergraduates from Memorial University of Newfoundland and The College of New Jersey volunteered to participate in exchange for credit in introductory psychology courses or a small honorarium. All indicated they had normal or corrected-to-normal vision, with no incidence of colour blindness, and all identified themselves as native speakers of English. The mean age was 20.37 (SD = 3.45, range 18-35), and 10 identified themselves as male and 50 identified themselves as female.

**Stimuli**

The stimuli were 373 English two-syllable nouns selected from a larger pool obtained from the MRC Psycholinguistic Database (Coltheart, 1983). The larger pool was reduced in size until all words left began with a unique 3-letter combination.

**Procedure**

Subjects were informed that we were interested in memory for colour, but that one problem was ensuring that we were assessing memory for the colour itself rather than memory for the word “red” or the word “blue”. They were informed that in order to minimize the use of verbal labels, they would see and be asked to generate lots of non-colour words.

A trial began after the subject clicked once on the “Start Next Trial” button. Four words were shown in four different colours, red (#FF0000), green (#33CC00), yellow (#FFFF00), and blue (#0066FF), against a black background. The order of the colours was randomly determined for each trial. Each word was visible for 600 ms and followed immediately after the previous word was shown. Then, XXXXXXXXXXX was shown in white for 2 s. Immediately after this disappeared, a word was shown in one of the four colours and the subject clicked on one of four response buttons to indicate whether that colour had been shown first, second, third, or fourth in the list. On half the trials, the word had appeared in the list in the same colour (match condition), and on half the trials a novel word was shown in the colour (no match condition). This was explained to subjects as part of the procedure for attempting to control for the use of verbal colour names. They were informed that it did not matter if the word had been seen or not; they should focus solely on the colour.

Following the direct test, XXXXXXXXXXX was shown in white for 1 s, and then three letters were shown, also in
white. The subject was asked to type in letters to make a valid English word. Subjects were asked to enter the first word that came to mind and to enter the word as quickly as possible. The instructions emphasized that this was part of the procedure to minimize the use of verbal colour names. In the primed condition, the stem could be completed with a word that had appeared on the list; in the no prime condition, the stem could not be completed with a word that had appeared on the list.

Each subject saw 56 lists, but it is easier to explain the types of trials by considering 64 lists. Every list contained both a direct and an indirect test; the word in the direct test was never a possible response for the indirect test. Thirty-two lists were “match” and thirty-two were “no match” based on the direct test. Of these, 8 lists tested each of the four serial positions. There were 32 primed and 32 no prime lists for the indirect test. For the 32 lists that had a primed indirect test, each position was assessed 8 times. Half of the “match” lists had a primed indirect test, and half had a no primed indirect test. Similarly, half of the “no match” lists had a primed indirect test, and half had a no primed indirect test. For the direct tests that assessed position 1, there were an equal number of primed indirect tests that assessed positions 1, 2, 3, and 4; the same was true for the other positions assessed by the direct test. When all of this is put together, there are 64 lists. However, 8 lists were not used: Any list in which the direct test and the indirect test assessed the same position was excluded. Thus, 32 no prime lists were shown, but only 24 primed lists were shown.

The order of the trials and the words were randomized for each subject. Thus, a given word might have been in the direct test for Subject N, in a primed indirect test for Subject N+1, in an unprimed test for Subject N+2, and never seen by Subject N+3.

Subjects were told they could take breaks as needed between each trial. At the end of the experiment, the experimenter (who remained in the room to ensure compliance with the instructions) asked the subject “We’re interested in what people think of the experiment. Do you have any comments to make, or was there anything that you’d like to ask about?” The purpose of this question was to get a sense of whether any of the subjects realized the connection between the word stems and the initial lists. Surprisingly, no subject made the connection between the indirect test and the initial set of four words. One reason may be that it was clear that words from the list sometimes appeared in the direct test and sometimes did not, and according to the instructions, this was both intentional and not relevant to the focus of the study.

Results

The unprimed condition serves as a baseline that indicates the proportion of stems that were completed with words in the pool when the target word was not shown. The proportion of stems completed in the unprimed condition was 0.192 compared to 0.368 in the primed condition, a significant difference by a paired sample $t$ test, $t(59) = 11.039, p < .001$.

As can be seen in Figure 1, we observed a serial position function in the indirect test, with evidence of both primacy and recency, just as Raanaas and Magnussen (2006a) observed. This conclusion is supported by four analyses.

First, the proportion of stems completed in the primed condition was analysed by a repeated measures ANOVA with position as the sole variable. The effect of position was significant, $F(3,177) = 4.177, MSE = 0.040, p < .01$. For the second analysis, we examined the quadratic component. The presence of a significant quadratic component does not necessarily indicate the presence of primacy and recency, but a non-significant quadratic component (all else being equal) indicates the absence of primacy or recency or both. The quadratic component was significant, $F(1,57) = 10.884, MSE = 0.036, p < .01$. The third test
follows Raanaas and Magnussen (2006a) in comparing recall at the first and second position (for primacy) and the third and last position (for recency) using two-tailed t tests. For position 1 vs. position 2, \( t(58) = 2.508, p < .05 \), and for position 1 vs. position 4, \( t(58) = 2.328, p < .05 \).

![Figure 1](image-url)

**Figure 1**: Performance in Experiment 1 on direct tests of intentionally-learned material as a function of whether the word at test was the same as the word at encoding (match) or different (no match), and performance on the indirect tests of incidentally-learned material as a function of whether the stem could be completed by one of the words shown in the study phase (primed) or when the word was not shown in the study phase (unprimed). Error bars show the standard error of the mean.

The fourth analysis assessed evidence for primacy and recency by comparing the number of subjects who showed more priming at position 1 than position 2 (for primacy) and more priming at position 4 than position 3 (for recency). Thirty three subjects showed greater priming at position 1 than at position 2, 15 showed the reverse, and 12 showed equivalent priming at both positions. This is significant by a two-tailed sign test, \( p < .01 \). The same analysis was repeated comparing priming at the fourth and third positions to assess evidence for recency. Thirty two subjects showed greater priming at position 4 than position 3, 14 showed the reverse, and 14 were tied. This is also significant by a two-tailed sign test, \( p < .01 \).

We also analysed performance on the direct test. A two match status (match vs. no match) × 4 positions repeated measures ANOVA revealed no effect of match, \( F(1,59) < 1 \). The effect of position was significant, \( F(3,177) = 3.735, MSE = 0.010, p < .05 \), but the quadratic component was not significant, \( F(1,59) < 1 \). The interaction between match status and position was not significant, \( F(3,177) < 1 \).
Discussion

Experiment 1 replicated the important result of Raanaas and Magnussen (2006a): both primacy and recency were observed using an indirect test following incidental learning. We did not replicate finding a serial position function in the direct test and we suspect this may be due to ceiling effects; overall performance on this task was 0.918. Whereas we did not observe an effect of match, Raanaas and Magnussen observed a numerical benefit for the no-match rather than the match condition, although this just failed to reach their adopted significance level.

Given that we successfully replicated the major finding of Raanaas and Magnussen (2006b), the purpose of Experiment 2 was to assess whether the shape of the serial position function observed on an indirect test changes in the same way it does on direct tests. Neath and colleagues (Neath, 1993b; Neath & Knoedler, 1994; Knoedler, Hellwig, & Neath, 1999) have shown that in a variety of episodic tasks, other factors being equal, a test with a short retention interval will result in relatively more recency and relatively less primacy, but as the duration of the retention interval increases, recency decreases and primacy increases. Logically, at some point there should be approximately equal primacy and recency, such as appears to be the case in Figure 1.

If the serial position function observed in the indirect test of Experiment 1 is a “real” serial position function just like those observed with direct tests, then a strong prediction from the relative distinctiveness principle is that if the retention interval is shortened, recency should be enhanced and primacy should be attenuated (see Surprenant & Neath, 2009, for a detailed working of this, including numerical calculations). One part of the prediction – enhanced recency – might be made by any view of implicit memory that includes some form of decaying or less activated representation: shortening the time between presentation and test will mean less decay or a smaller decrease in activation and thus more priming. However, the other part of the prediction is inconsistent with such views: there should be less decay or less activation for both the primacy and the recency items, and therefore, both primacy and recency should be enhanced. The purpose of Experiment 2 was to test this prediction.

Experiment 2

Experiment 2 was identical to Experiment 1 except that the order of the two tests was reversed. If the serial position function observed in the indirect test in Experiment 1 is a “real” serial position function like the ones seen in direct tests of episodic memory, then Experiment 2 should yield a recency effect but no primacy effect because the duration of the retention interval has been decreased.

Method

Subjects

Sixty different undergraduates from Memorial University of Newfoundland and The College of New Jersey volunteered to participate in exchange for credit in introductory psychology courses or a small honorarium. All indicated they had normal or corrected-to-normal vision, with no incidence of colour blindness, and all identified themselves as native speakers of English. The mean age was 20.12 (SD = 2.26, range 18-30), and 6 identified themselves as male and 54 identified themselves as female.

Stimuli and Procedure

The experiment was identical to Experiment 1 except that the indirect test occurred first and the direct test occurred second.

Results and Discussion

A paired sample *t* test indicated significant priming, *t*(59) = 12.435, *p* < .001, with the proportion of stems completed 0.485 in the primed condition compared to 0.206 for the unprimed.
As can be seen in Figure 2, we observed the predicted result: recency, but no primacy. The proportion of stems completed in the primed condition was analysed by a repeated measures ANOVA with position as the sole variable. The effect of position was significant, $F(3,177) = 3.015, MSE = 0.034, p < .05$. Unlike in Experiment 1, the quadratic component was not significant, $F(1,59) < 1$; only the linear component was significant, $F(1,59) = 7.025, MSE = 0.036, p < .05$. The absence of a significant quadratic component indicates that either primacy or recency was not present. Consistent with this, two analyses showed no evidence of primacy but evidence of recency. First, two-tailed $t$ tests found no difference between position 1 and position 2, $t(58) = 0.825, p > .40$, but did find a difference between position 3 and position 4, $t(59) = 2.137, p < .05$. Second, 24 subjects showed greater priming at position 1 than at position 2, but 25 showed the reverse (11 were tied). This is not significant by a two-tailed sign test, $p > .60$. In contrast, the same analysis provided evidence for recency: 29 subjects showed more priming at position 4 than position 3, 15 showed the reverse (16 were tied). This is significant by a two-tailed sign test, $p < .05$.

![Figure 2](image_url)

**Figure 2:** Performance in Experiment 2 on direct tests of intentionally-learned material as a function of whether the word at test was the same as the word at encoding (match) or different (no match), and performance on the indirect tests of incidentally-learned material as a function of whether the stem could be completed by one of the words shown in the study phase (primed) or when the word was not shown in the study phase (unprimed). Error bars show the standard error of the mean.

We also analysed performance on the direct test. A two match status (match vs. no match) $\times$ 4 positions repeated measures ANOVA revealed a significant effect of match, $F(1,59) = 6.586, MSE = 0.043, p < .05$, with better performance in the match (0.768) than in the no match (0.719) condition. However, the effect of position was not
significant, $F(3,177) = 1.578$, $MSE = 0.027$, $p > .15$. The interaction between match status and position was not significant, $F(3,177) = 2.435$, $MSE = 0.023$, $p = 0.066$.

The results of Experiment 2 are as predicted by the relative distinctiveness principle: As in episodic tasks, recency was enhanced and primacy attenuated by shortening the retention interval.

**General Discussion**

Serial position functions are so pervasive that researchers routinely include buffer items in their experiments to eliminate the contribution of primacy and recency effects, regardless of whether their test is recognition (Arndt & Jones, 2008), cued recall (Kerr, 1983), perceptual identification (Mulligan, 1996), or even word fragment completion (Rowe, Valderrama, Hasher, & Lenartowicz, 2006). This belief is supported by numerous studies showing serial position functions in many different kinds of episodic and semantic memory tasks, but there was only one convincing demonstration of primacy and recency effects in implicit memory, Raanaas and Magnussen (2006a).

Experiment 1 replicated Raanaas and Magnussen (2006a), finding evidence of both primacy and recency using an indirect task following incidental learning. Experiment 2 tested a prediction that if the retention interval were shortened, primacy would decrease and recency would increase, just as in explicit memory tests, and this prediction was confirmed.

The two experiments did not replicate the results of the direct test of Raanaas and Magnussen (2006a). In Experiment 1, there was no effect of position, but we attribute this to a combination of ceiling effects and de-emphasizing the role of words. In Experiment 2, performance was lower, as would be expected after increasing the retention interval, but there was still no effect of position. It is possible that the effect here might have been observed with latency measures, but response time was not recorded. However, the lack of serial position effects in the direct test suggests that the serial position effects observed in the indirect task cannot be attributed to contamination from the direct test.

The relative distinctiveness principle (Surprenant & Neath, 2009) states that items with fewer close neighbours will generally be more distinct and therefore better remembered than items with more close neighbours. This principle explains the ubiquitous serial position function by noting that in most cases, the experiment is so well controlled that items differ only in terms of when they were presented. The first and last items have no neighbours on one side, and are therefore more distinct than mid-list items. However, when the duration of the retention interval is increased or decreased, the relative distinctiveness of the first and last items can be affected (see Surprenant & Neath, Chapter 7). A prerequisite is that the items have been ordered along some sensible dimension, often position or relative time (Neath & Saint-Aubin, 2011). As such, this view predicts serial position functions should be observed with indirect tests under the right conditions.

We think that Raanaas and Magnussen (2006a) observed both primacy and recency whereas previous attempts, such as those described in the introduction, generally did not because of their clever design. First, the task induces people to order the items in terms of position by having intentional instructions for colour but by taking advantage of the automatic reading of the words. In contrast, if a list of items is presented with incidental learning instructions such as pleasantness ratings, there is no particular reason why the subjects might represent the items along a dimension of order. Second, the cover story de-emphasized the role of the words. Due to the nature of automatic processing, the words would be read, but the direct test required memory for colour. This, in part, may have
prevented subjects from linking the two parts of the study. Third, a short list was used, which allowed for multiple trials. In contrast, some of the earlier work featured a single list. A fourth factor may be that Raanaas and Magnusson succeeded because their design also included favourable temporal parameters. Had they designed their study like our Experiment 2, it may have appeared to have been just yet another failure to find primacy effects. Timing was not a primary concern for the majority of previous studies.

There are two important consequences of the results from these two experiments. First, we have replicated the only convincing demonstration of serial position functions following an indirect test. This may encourage other researchers to use this paradigm to further investigate serial position effects in implicit memory. Second, we have provided evidence consistent with a key prediction of the principles approach to the study of memory: Serial position functions, as researchers have long suspected – given their proclivity to control for primacy and recency effects regardless of the memory test – are not unique to one particular hypothetical memory system but rather, have been observed in all systems tested so far.

AUTHOR NOTE

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REFERENCES


The stimuli used in the two experiments. Each word begins with a unique 3 letter stem.

abode, account, adult, adverb, alert, alley, amount, anchor, angle, annex, antique, appeal, armor, array, artist, asphalt, athlete, attempt, author, ballot, banker, bargain, basement, baton, beauty, beggar, benzene, berry, bishop, blunder, boating, border, bouquet, bristle, brother, bucket, budget, buffer, builder, burrow, butcher, cabin, camel, candle, captain, carpet, caucus, cavern, cellar, chisel, choir, chuckle, cinder, circle, closet, column, comfort, concrete, copper, corner, costume, cousin, cover, cowhide, cradle, creature, crisis, cruiser, crystal, cuisine, culture, custom, dairy, damage, dancer, daylight, debate, decay, defense, degree, demon, design, device, display, doctor, dogma, donor, doorway, dozen, drama, dresser, driver, duchess, dungeon, dweller, easel, embrace, empty, engine, entrance, errand, escape, essay, estate, ether, event, excuse, exhaust, express, fabric, farewell, fashion, fatigue, fellow, ferry, fever, fiddle, fielder, figure, finance, flannel, flicker, flora, flutter, folly, football, fortune, frenzy, friction, frontage, furnace, gable, gallon, garment, gasket, gesture, giant, ginger, girdle, glitter, glory, goddess, gospel, grizzly, grocer, gutter, hairpin, halter, hamlet, hardware, havoc, hazard, heaven, highway, hobby, hockey, horror, hostage, hotel, humor, hunter, hurdle, husband, hybrid, hygiene, income, infant, insect, issue, jargon, jelly, journal, junction, justice, keeper, kingdom, knuckle, labor, lament, laundry, lawyer, leaflet, lesson, level, lighter, linen, liquid, lobby, locker, lotion, lumber, machine, madman, magnet, maiden, maker, mantle, maple, market, master, measure, medal, meeting, member, menace, message, metal, miner, mixer, moisture, moment, monkey, mortgage, motor, movie, mustard, mutton, muzzle, mystic, namesake, narrow, nation, navel, nectar, nephew, nickel, novel, nozzle, number, nutmeg, oatmeal, object, office, order, organ, outfit, owner, oxide, oyster, package, painter, palette, panic, parcel, pasture, patient, payment, peasant, pepper, permit, phantom, physics, picture, piston, planet, pleasure, pocket, poison, pollen, portrait, poster, powder, prairie, present, pronoun, pulpit, pupil, puzzle, quarrel, question, quiet, racket, railroad, rattle, reading, rebel, receipt, relic, remark, repair, rescue, retreat, reward, ribbon, riddle, robber, rocker, romance, rudder, ruler, rumble, sable, safety, salute, satin, savage, scholar, season, second, segment, seller, sequel, sergeant, session, settler, sewer, shadow, shiver, shovel, shutter, signal, silver, singer, slipper, slumber, soccer, soldier, speaker, station, steeple, story, stranger, stumble, subject, sulphur, supper, surprise, suspect, symbol, system, tailor, tally, taper, teacher, thunder, ticket, timber, token, topic, tourist, tower, tractor, treaty, trial, trolley, tumble, tunnel, turner, twilight, typhoon, ulcer, uncle, under, unrest, upright, vacuum, valley, velvet, venom, vessel, victim, vigil, village, volume, voter, weapon, welcome, whistle, wicket, willow, witness, wizard, worker