Memory of Auditory Lists by Rhesus Monkeys (Macaca mulatta)

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Monkeys' auditory memory was tested with increasing list lengths of 4, 6, 8, and 10 sounds. Five-hundred and twenty environmental sounds of 3-s duration were used. In Experiment 1, the monkeys initiated each list by touching the center speaker. They touched 1 of 2 side speakers to indicate whether a single test sound (presented from both side speakers simultaneously) was or was not in the list. The serial-position functions showed prominent primacy effects (good first-item memory) and recency effects (good last-item memory). Experiment 2 repeated the procedure without the list-initiation response and with a variable intertrial interval. The results of both experiments were similar and are discussed in relation to theories and hypotheses of serial-position effects.

The seminal studies of Ebbinghaus (1902) established the serial-position function as a major benchmark for studies of memory. The characteristic U-shape of the serial-position function has been thought to reflect different underlying memory processes. Memory is best at the beginning and end of lists, referred to as primacy and recency effects, respectively. Dissociations of primacy and recency indicate different underlying memory processes for these effects (e.g., Crowder, 1976; Glanzer, 1972; Tulving, 1987; Weiskrantz, 1987). The recency effect is eliminated by delaying recall and filling the delay with distracter activity, whereas other variables such as alcohol, mental retardation, and word frequency selectively affect the primacy effect (e.g., Crowder, 1976).

Only recently have procedures been developed to test similar serial-position effects and memory processes in animals (e.g., Bolhuis & van Kampen, 1988; Buchanan, Gill, & Braggio, 1981; Castro & Larsen, 1992; Kesner & Novak, 1982; Harper, McLean, & Dalrymple-Alford, 1993; Roberts & Kraemer, 1981; Sands & Wright, 1980a, 1980b; Thompson & Herman, 1977; Wright, Santiago, Sands, Kendrick, & Cook, 1985). These experiments have shown similarities of animal and human memory processing, at least with regard to primacy and recency effects for visual list memory. Tests of list memory in other modalities, such as audition, are needed to extend the generality of these comparisons.

Auditory memory has been largely untested in animals, in part because of the difficulty animals have learning auditory tasks. Thompson and Herman (1977) were able to train and test dolphins in an auditory memory task with six-item lists. The serial-position functions showed recency effects, but no primacy effects. It is unclear whether the absence of dolphin primacy effects reflected something about the dolphin's auditory memory system, the specifics of the procedure, or a general animal-human difference. Monkey auditory serial-position functions would be desirable from a number of points of view, but attempts to train monkeys in auditory memory tasks have been unsuccessful (e.g., Thompson, 1980; M. Mishkin, personal communication, December 2, 1992). These failures are puzzling because monkeys have sensitive hearing (Stebbins, 1970, 1971, 1973) and respond to vocal communication (e.g., Seyfarth, Cheney, & Marler, 1980; Zoloth et al., 1979).

Prior to the experiments reported here, we too encountered difficulties training monkeys in auditory memory tasks. We discovered that, among other things, it was necessary for the monkeys to contact the sound source in order to learn the task (cf. Harrison, Downey, Iverson, & Pratt, 1977).

**Experiment 1**

Prior to Experiment 1, both monkeys had been trained and tested extensively in an auditory same-different task similar to the list-memory task described in this article. Their training had been with pairs of many different environmental sounds and music. They performed accurately with pairs of novel sounds, thus demonstrating that they had learned an auditory same-different concept (Wright, Shyan, & Jitsumori, 1990). Concept learning is probably a prerequisite for learning and performing the list-memory task. Following training and testing with pairs of sounds in the same-different task, the first sound of the pair was gradually expanded into a list. The previous second sound of the pair became the test sound, and the monkeys judged whether or not the test matched any list sound. Training was followed by tests with 4, 6, 8, and 10 list items.

**Method**

Subjects. The subjects were 2 male rhesus monkeys (Macaca mulatta). BW was 14 years old and FD was 15 years old at the
The monkeys were maintained in state and federal approved facilities. Both monkeys were given ample access to food and water approximately 2 hr after their experimental sessions. Testing was conducted 5–6 days per week. On days when they did not participate in experimental sessions they were given unrestricted access to food and water and their diet was supplemented with fresh fruit.

Apparatus. The apparatus was a modified monkey cage with a bar removed from three walls. Speakers were positioned outside the gap created by bar removal. The monkeys touched copper screens in front of the speakers, and these touches were communi- cated (via high-impedance circuits) to a computer that controlled the sessions, collected the data, and sequenced the stimuli. Stimuli were digitally stored in a second computer (see Wright, Shyan, et al., 1990, for additional details).

Banana pellets (1 g) were dispensed into a cup inside the cage below the center speaker. Tang orange-drink (3.5 cc) was dispensed adjacent to each side speaker on the side away from the center speaker.

Procedure. A schematic showing list and test presentations is shown in Figure 1. A dim flashing light (green LED with a white plastic alligator clip cover) behind the center-speaker copper screen indicated the beginning of a trial. A touch to the (copper screen) center speaker produced a banana pellet and a list of different sounds. Each sound was played for 3 s with a 1 s interstimulus interval between sounds. Following the list, there was a 1 s delay. A probe or test sound was then played simultaneously from both side speakers for 6 s. Choice responses were accepted after 2 s of test sound. It is important to emphasize that the sounds coming from the two side speakers were always the same sound. There was never a case when the sounds coming from the two side speakers were different. On half the trials, the test sound matched one list sound, and the monkey was required to touch the right-side speaker to obtain a juice reward. On the other half of the trials, the test sound did not match any list sound, and the monkey was required to touch the left-side speaker to obtain a juice reward. Incorrect choices or aborts (not responding by the 6th s of the test sound) were not rewarded and were followed by a 30 s time-out. A 12 s intertrial interval (ITI) followed correct choices or time-outs.

After 30 days of training with a list length of 4 items, there were 10 days of testing. Each daily session contained 32 trials, resulting in 40 tests at each serial position. The list was then lengthened to 6 items. The number of trials and number of test days varied somewhat for the different list lengths tested. Paramount among procedural considerations was to keep the number of tests at each serial position the same (40), regardless of list length. Other considerations included testing all serial positions an equal number of times each session and decreasing the number of daily trials as list length increased so that the monkeys would eagerly complete all sessions. For list-length 6, there were 24 trials tested daily over 20 test days, for a total of 40 tests at each serial position. There were 20 days of training prior to the 20 test days. The list length was then lengthened to 8 items. The procedure was the same, except that there were 16 trials per day. After 20 days of training, there were 40 days of testing for 40 tests at each serial position. The list was then lengthened to 10 items. Twenty trials were tested each day. After 30 days of training, there were 40 days of testing for 40 tests at each serial position. Finally, there was a return to testing at list-length 4, with 10 days of warm-up, 32 trials per day, and 10 test days.

Five-hundred and twenty environmental sounds (e.g., ping pong, walking on gravel, Big-Ben strikes, rooster crows, marching band, owl hoots, fire-engine siren, telephone busy signal, coyote howls, etc.) were used in training and testing. The sounds were selections from 13 sound-effects records (Elektra Records, New York, NY). The sound bites were digitized and stored in a computer (AST 286). The sequence of sounds and composition of trials was determined prior to each session. Sounds were essentially selected at random to make up lists (and nonmatching probes). List composition and same–different trial sequences were new and varied each day.

Results

The results are shown in Figure 2 and are plotted according to performance at each serial position. The performance of both monkeys is similar in terms of performance level and shape of the serial-position functions at each list length. The serial-position functions show good performance at the beginning of each list—a primacy effect. The functions also show comparatively good performance at the end of the list—a recency effect. The dip in the U-shaped function occasionally falls below chance (50% correct) performance, especially for monkey FD. Below chance performance is meaningful in these cases. Consider that items in some serial positions were never remembered. In that case, performance would be zero, not chance. Repeated tests and statistical fluctuation allow for any performance between 0–100%.

Before presenting statistical support for the serial-position
effects shown in Figure 2, rationale for combining the two tests with four list items will be mentioned. The last test was a return to four-item lists as a check for stable performance. Stable performance would be shown by no statistical difference at the serial positions of the two tests. Separate two-way analyses of variance (ANOVARs) on the two tests with four list items showed a serial-position effect (e.g., primacy and recency) but no test effect (i.e., no difference between the two tests) for both subjects. BW showed a highly significant effect of serial position, $F(3,32) = 5.23, p < .005, MSE = 209.0$, no difference between the two tests, $F(1,32) = 0.02, p > .8$, and no significant interaction. Because there were no significant differences between the two tests, the data from the two tests were combined for each subject.

Turning to the statistical tests for serial-position effects, two-way ANOVAs were conducted to determine if there were significant differences for serial-position effects. This was done for each subject by dividing the 40 tests at each serial position into five blocks of eight trials per block. A two-way ANOVA of the four-item serial-position function showed a significant serial-position effect, $F(3,64) = 12.2, p < .001, MSE = 161.3$, a significant subject effect, $F(1,64) = 15.6, p < .001$, but no interaction effect. Weighted contrast tests (to identify primacy and recency effects) showed a significant quadratic component, $F(1,64) = 18.5, p < .001, MSE = 161.4$ (Sokal & Rohlf, 1969, p. 471). A further test (comparison test, Sokal & Rohlf, 1969, p. 226) between the first position (primacy) and the third position (bottom of dip in U-shape) showed a significant primacy effect, $t_6(64) = 4.04, p < .001$. The results from ANOVAs on the other serial-position functions were similar. A two-way ANOVA on list-length 6 showed a significant serial-position effect, $F(5,48) = 5.91, p < .001, MSE = 274.7$, and subject effect, $F(1,48) = 6.41, p < .05$, but no interaction effect. Additional tests showed a significant quadratic component, $F(1,48) = 8.80, p < .01$, and also a significant primacy effect comparing positions one and four, the first position to the bottom of the dip in the function, $t_4(48) = 4.56, p < .001$. An ANOVA on list-length 8 showed a significant serial-position effect, $F(7,64) = 11.5, p < .001, MSE = 210.0$, and subject effect, $F(1,64) = 15.6, p < .001$, but no interaction effect. There was a significant quadratic component, $F(1,64) = 46.2, p < .001$, and also a significant primacy effect comparing positions one and six, the first position to the bottom of the dip in the function, $t_6(64) = 7.52, p < .01$. An ANOVA conducted on list-length 10 showed a significant serial-position effect, $F(9,80) = 6.71, p < .001, MSE = 124.2$, a marginally significant subject effect, $F(1,80) = 6.09, p < .05$, and an interaction effect, $F(9,80) = 2.73, p < .01$. Contrast tests showed a significant quadratic component, $F(1,80) = 41.6, p < .01$, and also a significant primacy effect comparing positions one and three, the first position to the bottom of the dip in the function, $t_8(80) = 3.51, p < .001$.

To summarize, support for serial-position effects is provided by the serial-position functions for individual monkeys being similar, and by significant quadratic components for U-shaped trends to the functions. Further statistical support for primacy effects is provided by significantly greater performance for the first serial position (primacy) compared with the dip in each function.

**Discussion**

The serial-position functions shown in Figure 2 are the first auditory serial-position functions for a nonhuman primate that we are aware of. They show prominent primacy and recency effects, not unlike those found for humans in
auditory list memory tasks. Auditory serial-position functions for the only other animal that we are aware of, the dolphin, showed serial-position recency effects, but no primacy effects (Thompson & Herman, 1977). The finding of serial-position primacy effects for the rhesus monkey is important because it provides a parallel to human memory processing and indicates similar underlying memory processes. Further discussion of underlying memory processes will follow Experiment 2, which addresses an issue related to the validity of primacy effects in animals.

Experiment 2

While we were in the process of conducting Experiment 1, an article appeared asserting that all experiments showing animal primacy effects were flawed (E. A. Gaffan, 1992). This article restated D. Gaffan’s (1983) hypothesis that list-initiation responses (as in Experiment 1) artifically produced primacy effects by drawing disproportionate attention to them. We were surprised that no mention was made of evidence that contradicted this hypothesis (e.g., Wright, 1994; Wright et al., 1985; Wright, Santiago, & Sands, 1983). The rhesus monkey’s visual primacy effect changed systematically with retention interval despite each list being initiated in the same way. If list initiation produced primacy, then there should have been primacy at all retention intervals. But there was no primacy at short intervals. It only appeared after moderate intervals. We reasoned that a direct test might be more difficult to ignore (cf. Castro & Larsen, 1992). To this end, Experiment 1 was repeated but with no list-initiation responses and a variable ITI so that passage of a fixed amount of time could not be a cue for when the next list would be presented. The prediction according to the list-initiation hypothesis is that the primacy effects found in Experiment 1 should disappear in Experiment 2 in the absence of list-initiation responses.

Method

Subjects and apparatus. The monkeys, their maintenance, and the apparatus were the same as in Experiment 1. Experiment 2 was conducted 18 months following Experiment 1, and in the interim the monkeys were tested with four-item auditory lists.

Procedure. The procedure was similar to Experiment 1 except that the monkeys did not initiate the memory lists, and the ITI varied quasirandomly from 12 s to 27 s. The list began immediately at the end of the ITI. There was no flashing LED light at the beginning of the trial as there had been in Experiment 1. There was no banana pellet at the beginning of the trial as there had been in Experiment 1 (for list-initiation responses). To make the overall reward as similar as possible in the two experiments, a banana pellet was given at the time of the juice reward for correct choices. The length of the ITIs was counterbalanced with regard to as many aspects of the experiment (e.g., serial position tested) as was possible. The sequence of ITIs, same-different trials, and the composition of lists varied daily and independently. The ITI followed a reward (juice plus pellet) or a 30-s time-out (an incorrect choice). The number of test sessions and the order of testing were the same as in Experiment 1.

Results

Results for the individual monkeys are shown in Figure 3. The serial-position functions from the 2 monkeys were similar at each list length. All serial-position functions showed prominent primacy effects, and in addition, those for 6-, 8-, and 10-item lists showed recency effects. As in Experiment 1, statistical tests were conducted to substantiate the primacy and recency effects shown in Figure 3. Two-way ANOVAs for effects of serial position and subjects were conducted by dividing the 40 tests at each serial position into five blocks of eight trials per block. A two-way ANOVA of the four-item serial-position function

![Figure 3. Serial-position functions showing memory performance for 2 monkeys, BW and FD, in Experiment 2 where the monkeys did not initiate the lists and the intertrial interval was variable. Filled points are for Same trials where the test matched a list item, and unfilled points are for Different trials where the test matched none of the list items (Diff). The four list lengths were tested in blocks of increasing list length.](image-url)
showed a significant serial-position effect, $F(3, 32) = 16.6$, $p < .001$, $MSE = 162.1$, a marginally significant subject effect, $F(1, 32) = 4.07$, $p < .05$, and no interaction effect. Although there was no quadratic component (i.e., no recency effect), the presence of a primacy effect was shown by a significant linear component, $F(1, 32) = 47.2$, $p < .001$, and by superior performance on the first serial position as opposed to the fourth serial position, $t(32) = 6.15$, $p < .001$. An ANOVA on the six-item serial-position function showed a significant serial-position effect, $F(5, 48) = 7.70$, $p < .001$, $MSE = 184.9$, but no subject effect, $F(1, 48) = 0.51$, $p > .5$, or interaction effect. Additional tests showed a significant quadratic component, $F(1, 48) = 29.1$, $p < .001$, and also a significant primacy effect comparing the first position with the third position, the bottom of the dip in the function, $t(48) = 3.29$, $p < .01$. An ANOVA on list-length 8 showed a significant serial-position effect, $F(7, 64) = 13.2$, $p < .001$, $MSE = 210.0$, but no subject effect, $F(1, 64) = 1.08$, $p > .3$, or interaction effect. Additional tests showed a significant quadratic component, $F(1, 64) = 50.9$, $p < .001$, and also a significant primacy effect comparing the first position with the sixth position, the bottom of the dip in the function, $t(64) = 8.08$, $p < .001$. An ANOVA conducted on list-length 10 showed a significant serial-position effect, $F(9, 80) = 10.1$, $p < .001$, $MSE = 134.3$, but no subject effect, $F(1, 80) = 1.7$, $p > .1$, or interaction effect. Additional tests showed a significant quadratic component, $F(1, 80) = 94.8$, $p < .001$, and also a significant primacy effect comparing the first position with the fifth position, the bottom of the dip in the function, $t(80) = 7.5$, $p < .001$.

Because the monkeys had been highly trained in Experiment 1 to initiate lists, their behavior was closely monitored with an infra-red video system to determine whether list-initiation responses would continue despite suspension of this requirement. If they had continued, these responses could be argued to have the same effect even though there was no response contingency. These responses, center-speaker touches, dropped out immediately after the change in this requirement. No center-speaker touches or hand movements toward the center speaker were ever observed during this experiment. The monkeys typically faced the center speaker during list presentation and then turned to one side or the other during the probe presentation to make their choice response.

Discussion

Primacy effects were shown for all list lengths and were very similar to those from Experiment 1, despite considerable uncertainty as to when the list would begin, and that the monkeys might be distracted when a list began. A comparison of the mean performance from the 2 monkeys is shown in Figure 4. Overall test performance from Experiment 1 versus Experiment 2 was 78.5 versus 68.3%, 71.1 versus 73.9%, 68.5 versus 70.4%, and 70.6 versus 73.2% for list-lengths 4, 6, 8, and 10, respectively. Performance was marginally greater in three out of four cases in Experiment 2 than in Experiment 1. In the case where performance was greater in Experiment 1, there was no 4-item recency effect, possibly due to extensive testing with 4-item lists between the two experiments.

These results, together with those from Castro and Larsen (1992), where no list-initiation response was required in a visual-list memory experiment, contradict the list-initiation hypothesis of D. Gaffan (1983) and E. A. Gaffan (1992). Primacy effects are found in the absence, as well as in the presence, of list-initiation responses in auditory as well as visual memory. Thus, it can be concluded that list-initiation responses were not instrumental in producing the primacy effects. These direct tests of the validity of animal primacy effects increase the chances that primacy effects shown for other animal species with other procedures (e.g., Bolhuis &
van Kampen, 1988; Buchanan, Gill, & Braggio, 1981; Kesner & Novak, 1982; Harper, McLean, & Dalrymple-Alford, 1993; Roberts & Kraemer, 1981) are also bone fide mnemonic effects, other issues notwithstanding (e.g., Kesner, Chiba, & Jackson-Smith, 1994). Animal primary effects (and recency effects) are important theoretically from the standpoint of what they may indicate about the underlying memory processes and of what restrictions they provide on possible explanatory mechanisms that have arisen in relation to human serial-position results.

General Discussion

The serial-position function has been a test bed for the analyses of memory since the pioneering experiments by Ebbinghaus (1902). It was more than a half century after Ebbinghaus’s experiments that the recency effect was shown to be separable from the remainder of the serial-position function by delaying recall and using a distractor task during the delay interval, a task developed to study short-term memory (Brown, 1958; Peterson & Peterson, 1959). This selective removal (dissociation) of the recency effect has been reproduced many times with both recall (e.g., Gardiner, Thompson, & Maskarinec, 1974; Glanzer & Cunitz, 1966; Postman & Phillips, 1965; Roediger &Crowder, 1975) and recognition (e.g., Wright et al., 1985). Other variables that selectively affect recency include knowledge about end-of-list (Watkins & Watkins, 1974) and the modality of the stimuli, with auditory stimuli showing a recency advantage over visual stimuli (e.g.,Crowder, 1986; Crowder & Morton, 1969; Murdock, 1966). The primary effect has also been shown to be selectively affected, completing a double dissociation between primacy and recency. Variables that selectively decrement primacy include fast presentation rates (Glanzer & Cunitz, 1966), low word frequency (Sumby, 1963), larger numbers of language categories in the list (Tulving & Colotla, 1970), long list lengths (Murdock, 1962), short retention delays (Wright et al., 1985), alcohol intoxication (Jones, 1973), and mental retardation (Belmont & Butterfield, 1971).

These dissociations of recency and primacy are supported by neurophysiological evidence. Damage to the prefrontal cortex (Kesner, 1985) or left-posterior temporal lobe (Saffran & Maris, 1975; Weiskrantz, 1987) selectively affects recency, whereas damage to the hippocampus and rhinal cortex selectively affects primacy (e.g., Kesner & Novak, 1982; Kesner, Crutcher, & Beers, 1988). Psychological evidence also supports the primacy–recency dissociation. Diazepam eliminates the recency effect (Castro, 1995), whereas atropine selectively eliminates the primacy effect (Castro, 1997). Taken together, these findings form a coherent body of convergent evidence that primacy and recency represent different memory processes.

Discovering the memory processes responsible for primacy and recency has, however, been another matter. The recency effect has long been considered to reflect short-term memory (STM). In support of this theory, one could point to the retention-delay distractor tasks where recency dissipates in 30 s or less. But this STM theory runs into problems when long-term recency effects are considered. The prototypical long-term recency experiment involves presenting distractor activity between list items as well as during the retention interval (e.g., Bjork & Whitten, 1974). This continuous-distractor task, as it is called, reinstates the recency effect. A strong recency effect is found at delays where it normally would have been eliminated had distractor activity been limited to the retention delay. From the standpoint of STM, the interitem distractor activity should occupy STM and hasten elimination of recency, not the other way around.

If the recency effect represents STM, then other portions of the serial-position function (e.g., the primacy effect) should represent long-term memory (LTM). Although these STM and LTM processes have considerable common sense appeal, they are really little more than labels. They do not explain, for example, how STM and LTM are created, or how STM can be transformed into LTM.

By far the most popular theory of how STM relates to LTM is the dual-store hypothesis or, as it is often called, the modal model. A major mechanism (and assumption) of this theory is rehearsal. In its original formulation, items entered into a short-term store (or primary memory), and if rehearsed sufficiently, they moved to a long-term store (or secondary memory); otherwise they were forgotten (e.g., Atkinson & Shiffrin, 1968; Waugh & Norman, 1965). Although modern versions replace stores with processes (Tulving, 1987), the essential mechanisms of rehearsal, STM, and LTM remain (e.g., Monsink & Raaijmakers, 1988; Modigliani & Hedges, 1987; Raaijmakers & Shiffrin, 1980, 1981). Enthusiasm for this theory was generated from evidence showing a correlation between (frequency) “out loud” rehearsals and the primacy effect (Rundus, 1971). But it was several years before an objective procedure was developed to measure covert as well as overt rehearsal. The “blank-time” procedure showed that as the interval between items (blank time) increased, performance increased (e.g., Intraub, 1980), and that the increase in performance was due to rehearsal (e.g., Proctor, 1983). Indeed, memory for brieﬂy presented items was shown to be nearly as good as for much longer presented items if the difference was made up with blank time. In an experiment of ours, we combined this blank-time procedure with rehearsal manipulations (Wright, Cook, et al., 1990). Memory was tested under conditions where rehearsal was nearly impossible by using uncodeable items (kaleidoscope pictures), and in other conditions where participants could rehearse the same items following kaleidoscope picture-naming training. In still other conditions, participants’ rehearsal was varied by instructions (“Look at each item with a glassy-eyed stare and let the experience of the picture wash over you.”) The blank-time functions (memory performance as a function of blank time) and interviews revealed large differences in rehearsal, but rehearsal had little, if any, effect on the degree of primacy (or recency). Rehearsal benefited memory most in the middle of the serial-position function. Rehearsal, at least in this situation, was not a necessary condition for primacy. So if STM is represented by recency and LTM by primacy, rehearsal cannot be the necessary mechanism to move items from STM to LTM. This conclusion was also supported by
memory experiments with monkeys, which showed no blank-time effect and hence no rehearsal despite primacy effects (Cook, Wright, & Sands, 1991).

Among other prominent theories to account for primacy and recency effects is distinctiveness theory. Lists have a beginning and an end. These end points are thought to be distinctive and have been proposed to account for the primacy and recency effects of the serial-position function (e.g., Bower, 1971; Ebenholtz, 1972; Murdock, 1960). In support of the distinctiveness hypothesis, one could point to such things as the list of United States presidents producing a serial-position function with primacy and recency effects (Roediger & Crowder, 1976). Proponents of the modal model cannot account for such a recency effect. The recency effect extends back to Presidents Franklin Delano Roosevelt and Herbert Clark Hoover, hardly a short-term store or primary memory process. Similar episodic recency effects have been shown for such things as soccer scores by English soccer players (Baddley & Hitch, 1977). Although distinctiveness and such things as the von Restorff effect surely play a role in memory, it is not always easy manipulate them and test them. The case is complicated by the serial-position function not being the static U-shaped function as was originally thought. Instead, it is a function that dynamically changes over time. Whereas recency dissipates with retention interval, just the opposite happens with primacy: Primacy grows during the first few seconds of a retention interval (Korsnes, 1995; Korsnes & Gilinsky, 1993; Neath, 1993; Neath & Knoedler, 1994; Wright et al., 1985).

Although shifts from recency to primacy can be produced by instructing human participants to view (in their mind's eye) the remembered list from the beginning versus the end (Crowder & Neath, 1991), it is somewhat difficult to imagine that these same viewpoint shifts would be adopted in the same way by pigeons, monkeys, and humans, resulting in similar changes in primacy and recency (Wright et al., 1985). In addition to this difficulty, there is the difficulty in accounting for dissociations between primacy and recency with one process such as distinctiveness. How can the distinctiveness for one end of the list be diminished or eliminated, leaving distinctiveness for the other end unchanged?

Because the serial-position function is dynamic and not static, explaining the serial-position effects would seem to depend on dynamically changing processes. Interference has these qualities and seems to have fewer problems than dual-store or distinctiveness theories. Although early proposals of interference sought to account for a static U-shaped serial-position function (e.g., Hull, 1935), interference processes were later shown to change dynamically over time. Proactive interference (PI) is interference from preceding items on the test item, and retroactive interference (RI) is interference from following items on the test item. PI was shown to be weak immediately after learning and to grow slowly with time (e.g., Keppel & Underwood, 1962; Postman & Phillips, 1965; Postman, Stark, & Fraser, 1968), whereas RI was shown to be strong immediately after learning but to dissipate rapidly (e.g., Briggs, 1954; Ceraso & Henderson, 1966; Forrester, 1970; Koppenaal, 1963; Postman et al., 1968; Postman, Stark, & Henschel, 1969; Shulman & Martin, 1970; Silverstein, 1967; Slamecka, 1966; Underwood, 1948a, 1948b). Most research on interference was conducted with paired associates (e.g., A–B, A–D) rather than with serial lists. A set of responses (B) was learned to a set of stimuli (A), and then different responses (D) were learned to the same stimuli (A). Testing for the B responses measured RI (from the D responses) by comparison with a control group (A–B, C–D). Testing for the D responses measured PI (from the B responses).

Although most interference research was conducted with paired associates, similar interference processes may be operating within serial lists. To describe how interference could be instrumental in primacy and recency, consider the visual-list memory experiment with pigeons, monkeys, and people (Wright et al., 1985). In that experiment, recency was initially strong and primacy absent. As delay increased, primacy grew. As it further increased, recency dissipated. If RI was high initially, as indicated by the interference experiments, this could mean that the last items interfered with memory of the first items and thereby prevented a primacy effect. Dissipation of RI could allow the primacy effect to appear, and thereby produce a U-shaped serial-position function. Because PI had been shown to be low immediately after learning, the first list items would not interfere with memory of the last list items. The slow growth of PI could mean that eventually the first list items would interfere with memory of the last items and eventually eliminate the recency effect.

This interference account of primacy and recency effects of the serial-position function does not seem to be contradicted by other research, as was the case for the (dual-store) modal model. The interference account is somewhat less ad hoc than distinctiveness theory in that its dynamic processes are based on research different from, but convergent upon, explaining serial-position effects. Additionally, there are two processes (RI and PI), so the evidence for dissociations of primacy and recency may be more easily accommodated. And finally, interference, as an independent variable, seems to be more amenable to direct manipulation than rehearsal or distinctiveness.

Because the dynamic changes in the primacy and recency effects found in the previous visual-list memory experiment with pigeons, monkeys, and people (Wright et al., 1985) had implications for theories of serial-position effects, a natural extension of the research presented in this article would be to conduct a similar retention interval experiment with auditory memory stimuli. Results showing primacy and recency changes with retention interval similar to those for visual memory would indicate similar auditory and visual memory processes, whereas results different from those for visual memory would indicate different memory processes.

References


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