

## Naming, Rehearsal, and Interstimulus Interval Effects in Memory Processing

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Recognition memory was tested for lists of 6 briefly (0.08 s) presented pictures at different interstimulus intervals (ISI) of 0.08, 1, and 4 s. Experiment 1 showed a 16% performance increase (ISI effect) for increasing ISI for travel slide but not kaleidoscope pictures. Experiment 2 showed that learning names for the kaleidoscope pictures then resulted in a substantial (20%) ISI effect, not attributable solely to the added exposure to the pictures. Experiment 3 required names, color evaluations, or blank stares during list-memory presentations. Interviews established that the most effective memory strategy was chaining the names together, followed by repeating the most current name, and in turn followed by reliance upon only the sensory experience. All groups in Experiments 2 and 3, independent of ISI effects, showed U-shaped serial position functions. Rehearsal is shown to be nonessential and cannot be the general cause of the primacy effect of the serial position function.

Rehearsal is an activity very much a part of our daily lives. We rehearse telephone numbers, addresses, shopping lists, names of new acquaintances, songs, movie scenes, a new tennis stroke—to name but a few examples. Rehearsal in this article is considered to be a subject-controlled, memory-based repetition of material (cf. Johnson, 1980; Watkins & Peynircioglu, 1982). This relatively broad view of rehearsal includes overt as well as covert rehearsal, and visual as well as verbal material.

Rehearsal has been the topic of considerable research, but answers to some basic questions remain elusive (Johnson, 1980). There has been considerable debate, for example, over whether rehearsal is a basic memory mechanism providing the transfer of information from short-term memory to long-term memory. According to this rehearsal hypothesis of long-term memory (Atkinson & Shiffrin, 1968; Waugh & Norman, 1965), additional rehearsals afforded the first list-memory items are thought to move them into long-term memory and produce good memory performance for these initial items,

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the primacy effect of the serial position function. Rehearsal has been used as an explanatory mechanism for many memory phenomena, most of which apparently can do quite well without it, and, in some cases, rehearsal seems to be even contra-indicated (Watkins & Peynircioglu, 1982). The one use of rehearsal over which Watkins and Peynircioglu equivocated was the hypothesis that rehearsal produces the primacy effect of the serial position function. This possibility is the focal issue of this article.

A major impetus for the experiments of this article came from a series of experiments, some involving animals, where rehearsal's role in producing the primacy effect seemed unlikely (Santiago & Wright, 1984; Wright, Santiago, & Sands, 1984; Wright, Santiago, Sands, Kendrick, & Cook, 1985). Pigeons, monkeys, and humans were studied in similar experiments, where the retention interval between a four-item memory list and a single probe item was varied. Similar changes in serial position functions were shown for the three species. When there was no retention interval, all three species showed only recency effects in their serial position functions. For intermediate retention intervals, prominent primacy effects appeared, producing U-shaped serial position functions, and for long retention intervals, only primacy effect remained. All three species showed these same serial position function changes, but at different rates of change. These changes in the serial position function do not seem amenable to a rehearsal interpretation. First, such an explanation would require that pigeons and monkeys rehearse the memory items. This is an issue that has been pursued elsewhere, producing little or no evidence that monkeys rehearse (Cook, Wright, & Sands, 1990; Roberts & Kraemer, 1984). Second, if humans were to rehearse items during the retention interval, then to accomplish this rehearsal they must be able to retrieve these items from memory. But if they could have retrieved them from memory, then this retrieval should have provided the basis for the subjects to make correct responses even at the very short retention intervals. However, their zero-retention inter-

## Stimuli

In the first phase of Experiment 1, we used as stimuli 32 full-color travel slide pictures including landscapes, flowers, people, fruits, animals, toys, keys, watches, trees, boats, and cars. These items were the same stimuli and sequences that were used to test monkeys in a similar ISI experiment (Cook et al., 1990). Stimuli used in the second phase were 32 full-color kaleidoscope pattern pictures.<sup>2</sup> We selected the stimuli within each phase to be as distinct from one another as possible in order to minimize confusions and proactive interference.

## Procedure

Trials began with a ready signal, a clicker (5-Hz square wave). Subjects were instructed to push down on the three-position level to begin presentation of list items. List items appeared on the top rear-projection screen for 0.08 s each, with the ISI interval between them manipulated as a parameter of the experiment. One second after presentation of the sixth (and last) list item, a probe test item appeared on the bottom screen. Subjects were instructed to move the lever right or left to make a choice response when the probe item appeared: If the probe item was the same as one of the list items (Same trials), they should move the lever to the right; if the probe item was different from all of the list items (Different trials), they should move the lever to the left. Correct responses were followed by a reinforcement tone (500 Hz). Incorrect responses, or 2 s with no response (aborts), were followed by a 5-s dark time-out. Correct responses and time-outs were followed by 4-s intertrial intervals.

The order in which the stimuli were presented was fixed for a given sequence due to the pictures having been photographed onto movie film. Six 32-trial sequences were photographed with the 32 travel slides, and six 32-trial sequences were photographed with the 32 kaleidoscope stimuli. The order of stimuli in each sequence was pseudorandomly determined by a computer program that equated the number of times each stimulus appeared, the number of Same and Different trials, and the serial positions tested to the degree that was possible within each 32-trial sequence. Because there were 16 Same trials within each 32-trial block, serial positions could not be precisely equated, but they were equated (for each subject) within each day and across days for the three ISIs separately. Furthermore, in order to minimize proactive interference (cf. Wright, Urcuioli, & Sands, 1986), we ensured that probe items tested on Different trials did not appear during the preceding two trials.

Subjects were tested daily for a 32-trial block at each of the three ISIs (0.08 s, 1 s, and 4 s). The order of ISI interval testing varied across subjects and across days. In the first test phase, subjects were tested with pictures of travel slides for 2 days. Each subject was tested on all six of the travel-slide sequences, but in different orders and associated with different ISIs. In the second test phase, subjects were tested with pictures of kaleidoscope patterns for 3 days. During the first 2 days of kaleidoscope testing, each subject was tested on all six sequences with order and ISI varied across subjects. During the third day, three sequences were repeated, but these sequences varied across subjects and were associated with different ISIs than during initial presentations. Testing order and sequences were counterbalanced across subjects to the degree allowed by the procedure.

## Results

### ISI Functions

Figure 1 shows the ISI functions for travel slide pictures and kaleidoscope pattern pictures. The travel slide ISI func-

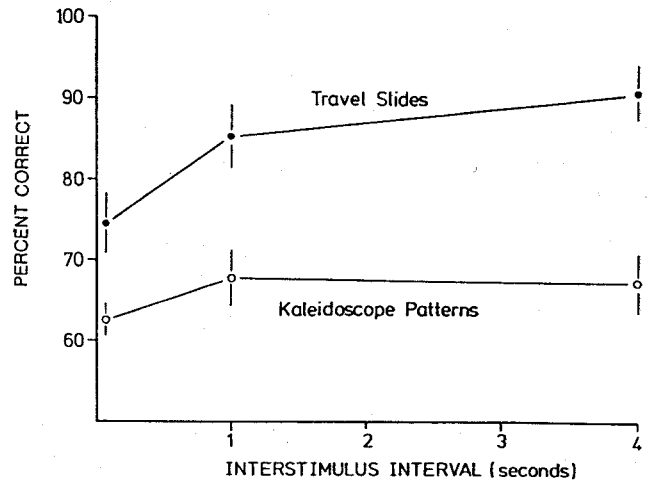


Figure 1. Performance as a function interstimulus interval (ISI) with lists of six travel slide pictures and six kaleidoscope pattern pictures. List items were presented for 0.08 s, with different ISIs between items. Error bars are standard errors of the mean.

tion shows a 16%-accuracy increase across the ISIs tested, whereas the kaleidoscope ISI function shows less than a 5% increase and does not rise above 68% accuracy. A 2 (condition: travel slides vs. kaleidoscopes)  $\times$  3 (ISI)  $\times$  9 (subjects) analysis of variance (ANOVA; with test sessions as replications) showed a significant condition effect,  $F(1, 78) = 139, p < .0001$ , a significant ISI effect,  $F(2, 78) = 14.4, p < .0001$ , and a significant Condition  $\times$  ISI interaction reflecting the different slopes of the two functions,  $F(2, 78) = 5.41, p < .01$ .<sup>3</sup> Separate 3 (ISI)  $\times$  9 (subjects) ANOVAs conducted on results from the individual conditions (with test days as the replication) showed a significant ISI effect for travel slide pictures,  $F(2, 27) = 23.3, p < .0001$ , but not for kaleidoscope pattern pictures,  $F(2, 51) = 2.2, p > .1$ . Thus, although the function for kaleidoscope stimuli shows a slight increase of almost 5% over the range of ISIs tested, this increase was not statistically significant, indicating little or no rehearsal.

### Tests for Daily Trends

A 3 (ISI)  $\times$  3 (test days) ANOVA (with subjects as the replication) showed that there were no significant performance changes across days with kaleidoscope pictures,  $F(2, 69) = 0.38, p > .65$ . Across the 3 days, performance in the 0.08-s condition was 59.5%, 55.8%, and 64.5%; in the 1-s condition it was 67.6%, 67.4%, and 67.0%; and in the 4-s condition it was 65.0%, 69.7%, and 66.7%.

<sup>2</sup> An example of a kaleidoscope pattern can be found on the cover of *Science*, July 19, 1985.

<sup>3</sup> The *dfs* of Experiment 1 result from two sessions having been conducted with travel slide pictures, three sessions with kaleidoscope pictures, and the loss (computer error) of one session's data (second session) from 1 subject on the kaleidoscope test.

### Serial Position Functions

Performances at the different serial positions are shown in Table 1. Performances for travel slide pictures tend not to vary systematically with serial position, possibly due to the overall high performance level (ceiling effect) with these stimuli. Performances for kaleidoscope stimuli generally increase with serial position. Statistical analysis using linear and quadratic orthogonal polynomials (Keppel, 1973) showed no trends for travel slides but showed significant linear trends,  $F(1, 48) > 10.4$ ,  $p < .01$ , for kaleidoscope stimuli at each ISI.

### Discussion

Travel slide pictures and the procedures used in Experiment 1 produced a robust ISI effect similar to that of Intraub (1980), despite considerable methodological differences between the experiments, including shorter list lengths, more lists, and only one recognition test per list in the experiment of this article. Kaleidoscope stimuli, by contrast, produced only a slight and nonsignificant performance rise with increasing ISI.

A logical question is why did the kaleidoscope stimuli not produce an ISI effect like the travel slide stimuli? Maybe subjects had difficulty rehearsing kaleidoscope stimuli, possibly because they had no verbal labels for the stimuli (cf. Potter & Levy, 1969). There have been some attempts by researchers to remove the verbal-labeling component in order to eliminate the ISI effect by requiring difficult within-category discriminations (e.g., Graefe & Watkins, 1980; Read, 1979; Weaver, 1974; Weaver & Stanny, 1978) or using pseudorandom, line-segment patterns (Bird & Cook, 1979; Lichtenstein & Keren, 1979). These attempts have not been successful, with one possible exception, where extremely short lists were used (Bird & Cook, 1979). Perhaps kaleidoscope stimuli are a good choice of stimuli when one wants to remove the verbal labeling component and prevent rehearsal. In Experiment 2

Table 1  
Serial Position Performance in Percent Correct for Tests in Experiment 1 with Travel Slide or Kaleidoscope Stimuli

ISI	Serial position						Different trials
	1	2	3	4	5	6	
Travel slide stimuli							
0.08	72.0	42.0	70.0	63.0	65.7	83.3	82.7
SEM	13.7	4.9	11.4	7.2	10.4	7.5	3.8
1.0	81.6	71.3	79.5	85.5	63.4	80.7	89.6
SEM	9.9	10.7	8.4	6.6	10.8	6.7	2.7
4.0	75.5	67.8	81.5	86.8	72.7	90.7	97.3
SEM	10.7	8.3	9.9	10.4	10.1	6.3	1.0
Kaleidoscope stimuli							
0.08	34.8	56.1	47.1	39.8	40.7	86.7	73.5
SEM	5.7	9.0	8.6	9.7	6.3	5.2	4.4
1.0	30.5	60.5	60.1	55.6	67.6	87.0	74.1
SEM	4.6	9.8	5.8	9.5	7.4	6.6	4.1
4.0	30.1	60.8	49.8	58.7	83.3	83.2	79.7
SEM	2.8	7.3	9.5	10.3	6.2	7.4	3.3

Note. ISI = interstimulus interval; SEM = standard error of the mean.

we trained the subjects to verbally label the stimuli before memory testing in order to determine whether or not a significant ISI effect would emerge thus indicating rehearsal.

### Experiment 2

The impression that most people have when first shown kaleidoscope stimuli is that the stimuli are attractive, colorful, and distinctive, but their image quickly fades. Experiment 2 was designed to explore the hypothesis that the lack of a significant ISI effect for kaleidoscope stimuli might be due to the subjects' inability to label the stimuli, thereby resulting in an inability to rehearse these stimuli. To this end, we first trained a group of subjects to name each kaleidoscope pattern before testing their memory for lists of them. To control for additional stimulus exposure necessary for the name training, we also exposed subjects from a control group to the stimuli, but this group was kept occupied so that they would not have an opportunity to attach their own names to the stimuli.

### Method

#### Subjects

Twenty adult subjects, over 21 years old, were recruited from the Texas Medical Center by bulletin-board advertisements. Subjects were reimbursed for their time. None had previous experience in these or related memory experiments.

#### Apparatus

The apparatus was identical to that of Experiment 1.

#### Stimuli

The stimuli were 32 kaleidoscope patterns, similar to those used in Experiment 1. With some imagination, the patterns could be seen to suggest certain objects. It was thought that these suggestive appearances might facilitate learning names for the 32 kaleidoscope patterns.<sup>4</sup>

#### Procedure: Naming Experimental Group

*Name training.* This group of 10 subjects learned the names for the kaleidoscope stimuli through 11 presentations of the stimulus set. Two daily sessions plus the first portion of a third daily session were devoted to this training. During presentation of the first set, each stimulus was presented for 9 s, and the experimenter pointed to descriptive features of the kaleidoscope pattern from which the name was derived. On subsequent presentations, the stimuli were presented for 5 s. Subjects were instructed to respond with the name of the kaleidoscope picture during the first 4 s. Correct responses were acknowledged by the experimenter. If subjects did not respond or if

<sup>4</sup> The names of the kaleidoscope patterns were Arrows, Bats, Bears, Brussels sprout, Bugs, Butterflies, Cactus, Cats, Elvis, Flower, Forks, Hands (across America), Ice cream, Jester, Lagoon, Macaroni (and cheese), Origami, Pagoda, Paper clips, Pin cushion, Pizza, Poinsettia, Poker, Pollen, Radishes, Roses, Salad, Shishkebab, Sphincter, Star Wars, Sumo (wrestler), and Window.

they responded with an incorrect name, the experimenter said the correct name during the final second of the stimulus presentation.

The 32 kaleidoscope stimuli were presented in randomized blocks, and the order of presentation varied for each of the 11 blocks. Five blocks were presented in each of the first two daily sessions, and the final block was presented at the beginning of the third daily session immediately preceding memory testing. In order to progress to the memory testing phase, subjects had to make no more than one incorrect response in the last two blocks of name training. Ten out of 11 trained subjects met this criterion.

*List-memory testing.* Subjects were tested for three daily sessions in the list-memory procedure. Each daily session consisted of three, 32-trial blocks with ISI (0.08 s, 1 s, and 4 s) constant within each block, and with a different ISI order tested each day. The list and probe sequences were composed in the same manner as in Experiment 1. Testing procedures were nearly identical to those of Experiment 1, with a few exceptions: (a) In order to ensure that the subjects understood the procedure and appropriate lever movements, we conducted six warm-up trials with two trials, one Same and one Different trial, determined pseudorandomly, at each ISI; (b) the (same) experimenter was present in the room with each subject but was largely concealed behind the plywood panel containing the stimulus screens; (c) at the conclusion of each of the three list-memory test sessions, the experimenter interviewed each subject as to his or her method, approach, and strategy that they used to perform the memory task; and (d) at the conclusion of the experiment, a 32-trial test was conducted, similar to the previous tests, but where each item was presented for 4 s with a 0.08-s ISI. This last test was conducted to see how performance might change when the memory items were in view for 4 s rather than possibly rehearsed during a 4-s ISI.

#### *Procedure: Color-Ranking Control Group*

*Stimulus exposure.* The rationale for using the color-ranking task was to focus the subjects' attention on each stimulus, like that of the experimental group, while at the same time engaging them so that they would have little opportunity to attach spontaneously their own verbal labels to the stimuli. Subjects were instructed to rank order the dominance of color using the color names: red, yellow, green, and blue. For example, the first color name given should be the most dominant color in the picture, the next color name should be the next most dominant color, and so on, with the fourth color being the least dominant. To further ensure that subjects would be occupied by the task, we instructed subjects to reverse their rank ordering every eight trials and, for example, begin with the least dominant color. The starting order (most/least dominant) varied pseudorandomly across blocks, sessions, and subjects. Exposure to the stimuli in terms of order, sequence, daily blocks, and duration was identical to the naming experimental group.

*List-memory testing.* The procedure for list-memory testing was identical to that for the naming experimental group, including testing sequences and stimuli, the experimenter present in the room, six warm-up trials, the 4-s viewing time test at the conclusion of the experiment, strategy interviews after each daily memory test session, and the instructions read at the beginning of memory testing. Neither the names for the kaleidoscope pictures nor their color rankings were mentioned to subjects in either group during list-memory testing.

*Name testing.* At the end of the experiment, when all memory testing was completed, we tested subjects in the color-ranking group for names or labels that they may have given the kaleidoscope pictures (despite attempts to prevent such labeling). We showed subjects the items one at a time, as in the color-ranking phase, and asked them to report any names or labels that they had regularly attached to the kaleidoscope pictures. The subjects were not time-limited in their

responses, but they were instructed not to make up names and to report only names they had actually used during memory testing. In order to provide a measure of reliability to these verbal reports, we showed the list of 32 pictures twice (in different randomized orders) and scored only identical labels as bonafide labels.

## *Results*

Result from the two groups are presented in five sections: ISI Functions, Acquisition Effects, Serial Position Functions, Control Group Naming Test, and Strategy Interviews.

### *ISI Functions*

Figure 2 shows ISI functions. The ISI function for the naming group shows a 20%-accuracy increase across the range of ISIs, whereas the color-ranking group shows less than an 8%-increase across this range. A 2 (group: naming vs. color ranking)  $\times$  3 (ISI)  $\times$  10 (subjects) ANOVA (with test sessions as replication) showed a significant group effect,  $F(1, 120) = 130, p < .0001$ , a significant ISI effect,  $F(2, 120) = 43.5, p < .0001$ , and also a significant Group  $\times$  ISI interaction reflecting the different slopes of the two functions,  $F(2, 120) = 5.41, p < .0001$ . Additional 3 (ISI)  $\times$  10 (subjects) ANOVAs conducted on the groups separately (with test days as the replication) showed significant ISI effects for both the naming group,  $F(2, 60) = 38.9, p < .0001$ , and the color-ranking group,  $F(2, 60) = 8.0, p < .01$ .

Figure 2 (right-hand side) shows performance when the kaleidoscope pictures were displayed for 4 s (at 0.08-s ISI). For both groups, performance with the 4-s viewing time is about 10% more accurate than with 0.08-s viewing time and 4-s ISI. This 10%-accuracy increase is somewhat greater than that shown by Intraub (1980), but may be due, in part, to this test being conducted at the completion of the other memory tests when the subjects had become proficient in remembering kaleidoscope stimuli.

### *Acquisition Effects*

The naming group showed a somewhat greater performance increase over the 3 test days than did the color-ranking group, but both groups showed at least marginally significant acquisition effects as shown in Table 2.

### *Serial Position Functions*

The serial position functions for the two groups are shown in Figure 3. Both groups showed U-shaped serial position functions. The main difference between the groups was a higher overall level for the naming experimental group. Trend analyses using linear and quadratic orthogonal polynomials (Keppel, 1973) are shown in Table 3. These analyses show that there were significant differences across serial positions for each function and that there was a significant quadratic component to each function, confirming that they were U-shaped with primacy and recency effects.

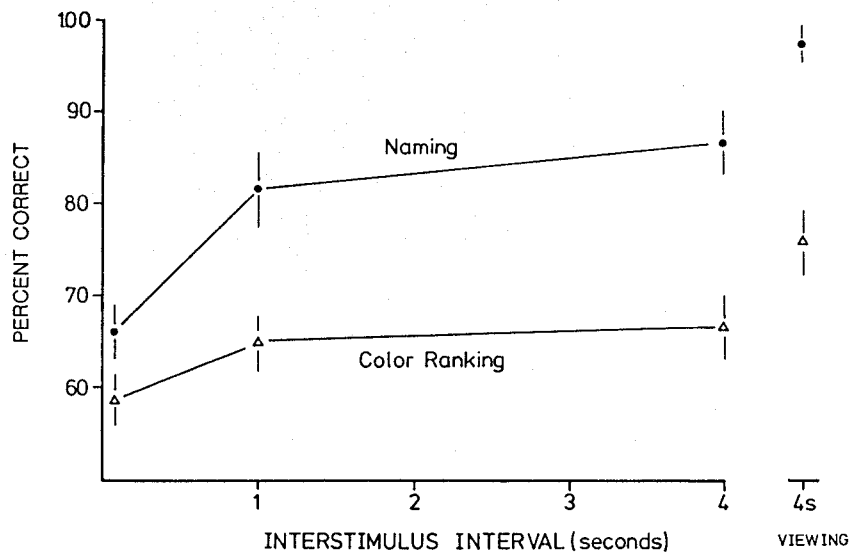


Figure 2. Performance as a function of interstimulus interval (ISI) for two groups where, prior to memory testing, the naming group learned names for the 32 kaleidoscope stimuli and the color-ranking group rated their colors. The 4-s viewing condition shows performance in which the stimuli were presented for 4 s with a 0.08-s ISI. Error bars are standard errors of the mean.

### Control Group Naming Test

The results from the naming test showed that some subjects in the color-ranking control group had named most of the stimuli, whereas others had named none of the stimuli. In increasing number, the numbers of names were 0, 0, 2, 10, 10, 25, 27, 27, 28, and 32, with a mean of 16.1 names. A logical question is whether or not subjects of this control group, which learned the most names, also produced the greatest ISI effects. To answer this question, we computed slopes of the ISI functions (linear regression on each set of three points) for individual subjects and correlated these with the number of names learned. If more names produced greater ISI effects, then there should be a strong positive correlation between slope and number of names. The correlation, however, was only .06,  $t(8) = 0.17$ ,  $p > .8$ . This means that although control subjects had labels for some, and occasionally even many, of the stimuli, labels were in themselves

insufficient to produce an ISI effect. As presented in the next section (and more fully in the *Discussion* Section of Experiment 3), what appears sufficient to produce an ISI effect is a strategy for using these labels as well as the labels themselves.

### Strategy Interviews

Interviews at the completion of each daily session revealed that 8 out of 10 subjects of the experimental group reported performing the task by building a list or chain of labels and adding the newest label to the end of the chain. As an example, consider a six-item list, in which the names that the subjects had learned for these items were BATS, CATS, BUGS, BEARS, SUMO, POKER. When the second item appeared, these subjects said to themselves BATS-CATS. When the third item appeared, they said BATS-CATS-BUGS. When the fourth item appeared, they said BATS-CATS-BUGS-BEARS. We refer to this strategy as a *chaining strategy*. Most subjects used the chaining strategy only for the first four list items and then repeated the name of the current or last presented item.

The 2 subjects of the experimental group who did not use a chaining strategy reported repeating only the name of the current list item as time permitted. This strategy is referred to as a *repeating strategy*. When the subjects' performance was grouped according to the strategy they used, the subjects using the chaining strategy performed better (68.2%, 84.2%, and 88.2%) than the subjects using the repeating strategy (57.0%, 69.9%, and 78.8%, for the three ISI intervals respectively).

One subject of the color-ranking control group reported using the chaining strategy, 5 subjects reported using the repeating strategy, and 4 subjects reported staring at the items without using any rehearsal (chaining/repeating) strategy. This last strategy will be referred to as a *sensory strategy*.

Table 2  
Acquisition in Percent Correct Over 3 Test Days for the Two Groups of Experiment 2

Group/day	Interstimulus interval			<i>M</i>	<i>F</i> ( <i>df</i> = 2, 81)
	0.08 s	1 s	4 s		
Naming					
Day 1	67.4	76.5	79.9	74.6	
Day 2	62.5	83.2	88.0	77.9	
Day 3	68.1	81.4	86.3	78.6	3.19**
Color-ranking					
Day 1	56.3	64.2	62.3	60.9	
Day 2	59.4	61.9	67.9	63.1	
Day 3	60.2	67.7	68.9	65.6	1.80*

Note. \*  $p < .1$ ; \*\*  $p < .05$ .

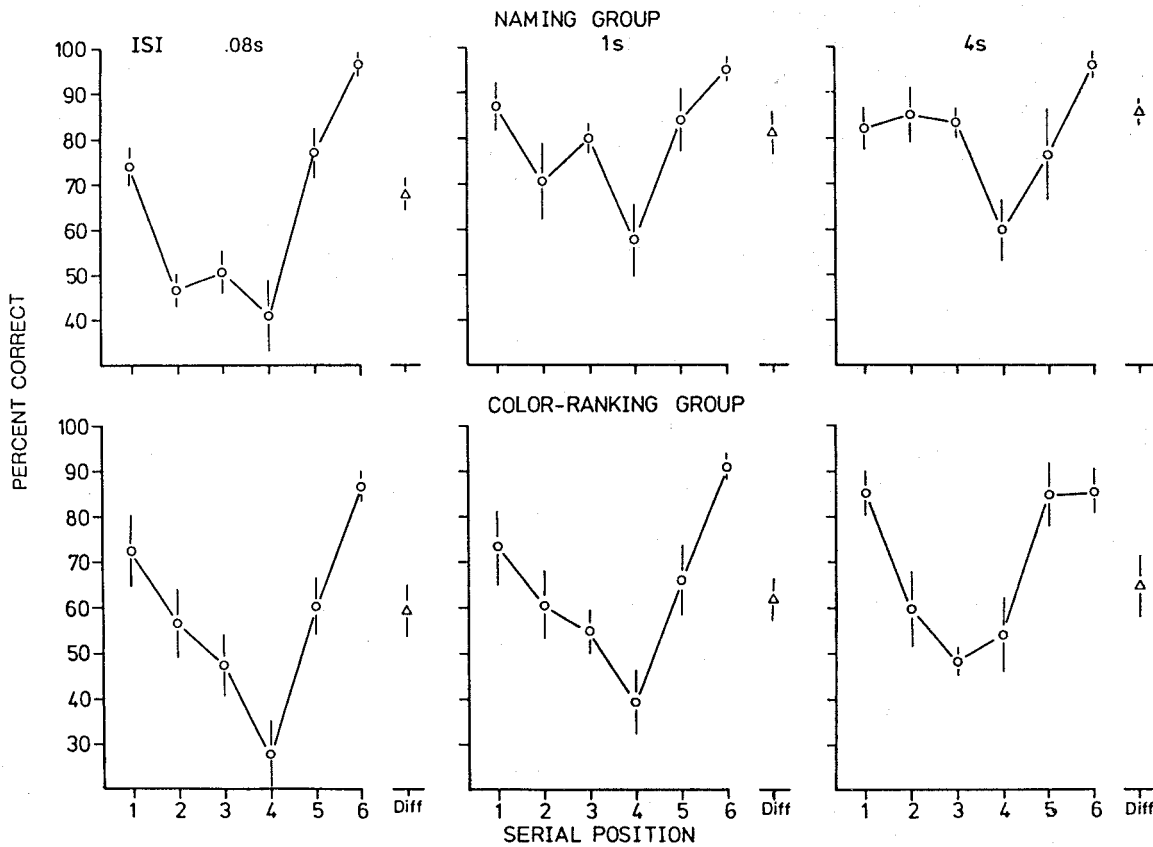


Figure 3. Performance as a function of serial position for the three interstimulus intervals, where position 1 was the first item presented. The "Diff" condition (triangles) shows performance on Different trials in which the test item did not match any list item. Error bars are standard errors of the mean.

Indeed, by and large, these sensory strategy subjects did not have any names to use. They had, on the average, names for only 3 of the 32 stimuli. When performance was grouped according to strategy, performance did generally vary with the number of names. For the chaining, repeating, and sensory strategies, the number of names were 28, 24.2, and 3, respectively, and performance was best for the chaining group (60.7%, 67.7%, and 77.8%), intermediate for the repeating

group (58.4%, 68.4%, and 66.8%), and worst for the sensory group (58.5%, 59.3%, and 63.1%) for the three ISIs respectively.

Results from the subjects' interviews indicated that there may also be somewhat of a gradual acquisition process associated with these rehearsal strategies and that a similar acquisition process may be going on with the subjects of the control group. In the experimental group, 4 subjects who originally began with the sensory strategy progressed to the repeating strategy, and 2 of these subjects further progressed to the chaining strategy. (The sensory strategy is considered to be the default strategy and probably does not have to be learned in this testing situation.) Another subject of this group began with the repeating strategy and progressed to the chaining strategy. In the color-ranking control group, 3 subjects who began with the sensory strategy progressed to the repeating strategy.

Discussion

Teaching subjects names for the kaleidoscope pictures (experimental group) produced a 20.3%-ISI effect compared with only a 4.4%-ISI effect for those subjects of Experiment 1 who had no names for the kaleidoscope stimuli. The color-ranking

Table 3  
Trend Analyses: Serial Position Functions of Experiment 2

Group/ISI	Overall	Quadratic	Linear
	F (df= 5, 54)	F (df= 1, 54)	F (df= 1, 54)
Naming			
0.08 s	17.73***	59.22***	20.47***
1 s	5.11**	14.46***	2.53
4 s	4.52*	9.92*	0.14
Color-ranking			
0.08 s	9.75***	40.28***	1.31
1 s	8.17***	32.04***	3.07
4 s	7.80***	29.19***	2.07

Note. ISI = interstimulus interval. \*p < .01; \*\*p < .001; \*\*\*p < .0001.

control group, which had also been exposed to the stimuli before memory testing, showed only a 7.7%-ISI effect. It was surprising to find that the number of names in itself was uncorrelated with the magnitude of the ISI effect. This finding may help explain why naming sometimes results in better memory performance (e.g., Bahrck & Boucher, 1968), but does not at other times (e.g., Intraub, 1979). Analyses according to the way in which these names were (or were not) used helped to explain the results. The chaining rehearsal strategy proved to be the most effective strategy for using the names, the repeating rehearsal strategy was next in effectiveness, and the sensory strategy of just staring at the items was the least effective strategy.

The acquisition effects associated with improved ISI performance over the 3 test days and the acquisition effects associated with more effective rehearsal strategies indicate that both groups were becoming more effective in performing the task. The control subjects may have just been further behind the experimental subjects in their acquisition process. The control subjects, of course, first had to learn their own names for the items, and then learn how to effectively use these names through either a repeating or a chaining rehearsal strategy. This acquisition process may have been responsible for the small but significant ISI effect produced by the color-ranking control group. The purpose of Experiment 3 was to interfere further with this acquisition process. In one case the subjects were kept occupied during the ISIs of memory testing phase of the experiment as well as during their preliminary exposure phase.

### Experiment 3

The rationale of Experiment 3 was to explore two methods of interfering with the acquisition of subject-generated labels by control subjects. One method was to extend the requirement of color-ranking responses from the exposure phase to include the memory-testing phase as well. By this means, the color-ranking control subjects might have less opportunity to develop their own labels during memory testing. Another method was to instruct subjects to stare "blankly" at the memory items as they were presented, to discount motivation for rehearsal during list presentation, and to eliminate the exposure phase, thereby eliminating some opportunity for the development of names.

#### *Method*

##### *Subjects*

There were 10 adult subjects in each of three groups. They had no previous experience in memory experiments and were recruited in the same way as described in Experiment 2.

##### *Apparatus*

The apparatus was the same as that of Experiments 1 and 2.

##### *Procedure: Naming Experimental Group*

In order to provide a proper comparison for the color-ranking control group, we asked subjects in the naming experimental group to verbalize names of the items during the memory test. These overt verbalizations provided an objective recording of rehearsals by this group (cf. Dark & Loftus, 1976; Modigliani & Hedges, 1987; Rundus, 1971; Rundus & Atkinson, 1970). The procedure for learning names for the 32 kaleidoscope pictures was identical to that described for the naming experimental group in Experiment 2. The kaleidoscope pictures and names were the same as in Experiment 2. The list-memory testing procedure also was identical, except that subjects were required to verbalize the names of the kaleidoscope pictures as the list items were presented.

Before the memory testing, we instructed subjects to verbalize not only the name of the current list item, but also, if they desired, to repeat names of items that had been presented earlier in the list. We suggested that they might want to change their approach depending upon the speed of the list presentation. The rationale for suggesting different rehearsal strategies for the names of the kaleidoscope pictures was to encourage the subjects to use a strategy they might normally adopt if not required to verbalize.

##### *Procedure: Color-Ranking Control Group*

The exposure training for this group was identical to that described for the color-ranking control group of Experiment 2. The list-memory test procedures also were identical to those described in Experiment 2, except that the subjects were instructed to give the color name of the single most dominant color (or least-dominant color) of each kaleidoscope list picture during the ISI of the memory test. To make the strategy options as similar as possible to those suggested to the experimental group, we mentioned in the instructions that they might want to repeat color names of the most dominant color of previous list items and that they might want to change their approach depending on the speed of the list presentation.

##### *Procedure: Sensory Control Group*

There was no exposure training for the sensory control group. They were instructed as were other groups about the basic procedure and were also told,

What we would like for you to do is to simply stare at the pattern and let it wash over you throughout its presentation. As the list is being presented, do not concern yourself that there is a test at the end; make it strictly a sensory experience. When the test does appear just do your best at that time.

They were given six warm-up trials (one Same and one Different trial at each of the three ISIs), three daily list-memory test sessions with a 32-trial block at each ISI, a test toward the end of the experiment with a 4-s viewing time and 0.08-s ISI, and, finally, two blocks of the 32 stimuli, where subjects verbally gave names or labels that they had attached to any of the stimuli. We did not interview these subjects after each session about their memory strategies because we felt that such questions might suggest that we did not fully expect them to obey instructions to blankly stare at the memory items.

#### *Results*

The results are presented in the same format used in Experiment 2: ISI Functions, Acquisition Effects, Serial Position

Functions, Control Group Naming Test, and Strategy Interviews.

### ISI Functions

Figure 4 shows ISI functions for the naming-aloud group and both control groups. The function for the naming-aloud group shows more than a 16%-accuracy increase across the range of ISIs tested, whereas the control groups show less than a 6%-increase across the same range. A 3 (groups)  $\times$  3 (ISI)  $\times$  10 (subjects) ANOVA (with test sessions as replications) showed a significant group effect,  $F(2, 180) = 36.9, p < .0001$ , a significant ISI effect,  $F(2, 180) = 21.9, p < .0001$ , and a significant Group  $\times$  ISI interaction reflecting the different slopes of the three functions,  $F(4, 180) = 4.7, p < .01$ . Pairwise comparisons of the three experimental groups revealed significant interactions (and significant main effects,  $dfs = 1, 120$ ;  $ps < .001$ ) between the naming-aloud group and each control group, reflecting the naming-aloud group's steeper ISI function slope:  $F(2, 120) = 8.6, p < .0001$ , for the color-ranking group; and  $F(2, 120) = 5.8, p < .01$ , for the sensory group. There was, however, no significant interaction between control groups reflecting their similar slopes,  $F(2, 120) = 0.14, p > .8$ . Evaluation of the individual ISI functions revealed a nonsignificant ISI effect for the color-ranking control group,  $F(2, 60) = 1.7, p > .15$ , a marginally significant ISI effect for the sensory control group,  $F(2, 60) = 2.67, p = .074$ , and a highly significant ISI effect for the naming-aloud experimental group,  $F(2, 60) = 28.3, p < .0001$ .

Performance with 4-s viewing time and 0.08-s ISI is shown by the three points on the right-hand side of Figure 4. For each group, performance was somewhat more accurate than with 0.08-s viewing time and 4-s ISI, but a portion of this better performance with a 4-s viewing time may be attributable to this test being conducted at the completion of the experiment, when the subjects were most proficient in the task.

### Acquisition Effects

Table 4 shows acquisition effects for the three groups. All groups show an acquisition effect of improved performance over the 3 test days. The magnitude of the acquisition effect for the naming group is somewhat smaller than it was for the naming group in Experiment 2, and somewhat smaller than that shown for the sensory or color-ranking control groups.

### Serial Position Functions

Serial position functions for the naming-aloud experimental group and two control groups are shown in Figure 5. All groups show U-shaped serial position functions, with higher overall performance level reflecting the naming group's better overall accuracy in the task. Table 5 shows trend analyses, using linear and quadratic orthogonal polynomials (Keppel, 1973). There were significant serial position differences and significant quadratic components for each function, confirming that they were U-shaped with primacy and recency effects.

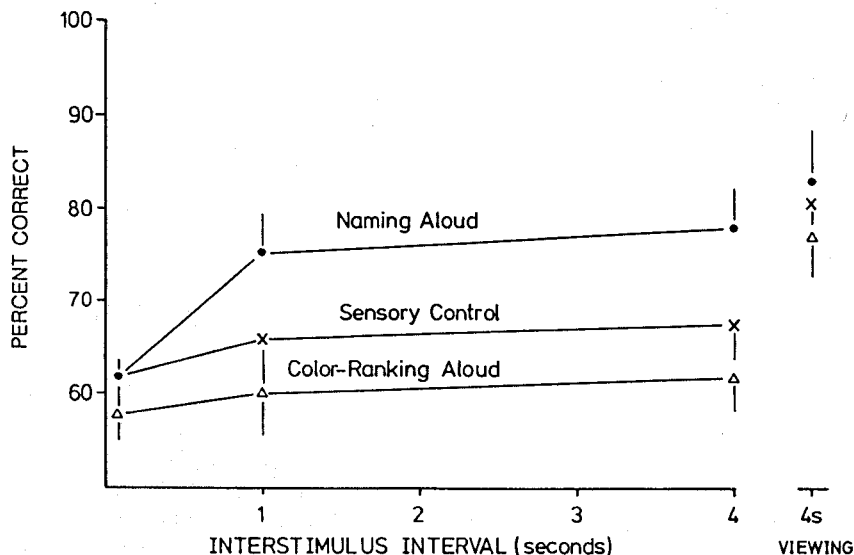


Figure 4. Performance as a function of interstimulus interval (ISI). The naming-aloud group learned names for the kaleidoscope stimuli and said these names aloud during memory testing. The color-ranking aloud group rated colors of the stimuli during memory testing as well as during a prior exposure phase. The sensory control group "blankly" stared at the list stimuli. The 4-s viewing condition shows performance in which the stimuli were presented for 4 s with a 0.08-s ISI. Error bars are standard errors of the mean.

Table 4  
Acquisition in Percent Correct Over 3 Test Days for the  
Three Groups of Experiment 3

Group/day	Interstimulus interval			<i>M</i>	<i>F</i> ( <i>df</i> = 2, 81)
	0.08 s	1 s	4 s		
Naming-aloud					
Day 1	61.6	65.4	75.9	67.6	
Day 2	61.5	80.7	76.2	72.8	
Day 3	62.0	79.2	81.7	74.3	2.88*
Color-ranking					
Day 1	53.4	56.4	61.0	56.9	
Day 2	59.3	55.6	60.4	58.4	
Day 3	60.4	67.9	64.2	64.2	3.61**
Sensory					
Day 1	56.2	58.6	67.5	60.8	
Day 2	62.0	67.4	67.3	65.6	
Day 3	67.4	71.1	68.0	68.8	4.02**

Note.  $p < .1$ ; \*\*  $p < .05$ .

### Control Groups Naming Tests

As was done in Experiment 2, we tested subjects in the control groups for names or labels they might have attached to the kaleidoscope stimuli. For the color-ranking aloud control group, the number of names, in increasing order, were 0, 2, 8, 10, 16, 18, 20, 23, 30, and 32, with a mean of 15.9 names. Correlation of name number with slope (ISI function) was .29, but was not significant,  $t(8) = 0.85$ ,  $p > .4$ . For the sensory control group, the number of names, in increasing order, were 0, 4, 7, 8, 10, 12, 14, 14, 20, 24, with a mean of 11.3 names. Correlation of name number with slope (ISI function) was .49, but also was not significant,  $t(8) = 1.57$ ,  $p > .1$ .

The correlation (.49) for the sensory control group, although not significant, was, however, considerably larger than for either color-ranking control group of Experiment 2 or 3. It may be of some interest that there was a slight inverse relation between name number and correlation. For the color-ranking group, color-ranking aloud group, and sensory group, mean names declined (16.1, 15.9, and 11.3), whereas correlations between the number of names and ISI function slopes rose (.06, .29, and .49). This inverse relation could be due to more rapid acquisition of one of the rehearsal strategies when fewer labels were involved.

### Strategy Interviews

Interviews and verbalizations (during the memory test) of the naming-aloud subjects revealed that only 3 of the 10 subjects developed and used the chaining strategy. These 3 subjects did, however, perform better at the three ISIs (62.6%, 82.2%, and 87.0%) than did the other 7 subjects (61.3%, 72.1%, and 74.0%) who used the strategy of repeating the name of the just-presented list item during each ISI.

Four color-ranking aloud subjects reported using a repeating strategy. These 4 subjects had names for an average of 24.5 of the 32 stimuli, and their performance at the three ISIs was 61.5%, 64.4%, and 65.1%. The other 6 subjects reported using a sensory strategy of staring at the items as they were

presented. These 6 subjects had names for an average of 10.2 of the 32 stimuli, and their performance at the three ISIs was 55.3%, 57.2%, and 59.8%. In comparison to the repeating strategy subjects, the sensory strategy subjects developed fewer names and performed more poorly, thus corroborating the similar finding from the control group in Experiment 2.

As was found in Experiment 2, there was some evidence of acquisition to more efficient rehearsal strategies. In the naming-aloud experimental group, 2 subjects who began with the sensory strategy progressed to the repeating strategy and one of these subjects progressed to the chaining strategy. In the color-ranking aloud control group, 3 subjects began with the sensory strategy and progressed to the repeating strategy (making a total of 4 repeating-strategy subjects).

### Discussion

#### Comparison of ISI Functions and Acquisition Processes

The procedure of requiring control subjects to rank colors during memory tests did somewhat diminish the ISI effect—which was 4.1%, down from 7.7% in Experiment 2—for the color-ranking control group. The greatest effect was a general lowering of the functions for both the naming and color-ranking groups. Comparing analogous groups in Experiments 2 and 3, 2 (experiment)  $\times$  3 (ISI)  $\times$  10 (subjects) ANOVAs (with sessions as the replication) showed significant effects of experiment for the naming group,  $F(1, 120) = 21.72$ ,  $p < .0001$ , and the color-ranking group,  $F(1, 120) = 7.29$ ,  $p < .01$ , but no Experiment  $\times$  ISI interactions:  $F(2, 120) = 0.80$ ,  $p > .5$ , for naming groups; and  $F(2, 120) = 0.97$ ,  $p > .6$ , for color-ranking groups. Perhaps the output interference from the vocalizations lowered the functions, which makes sense when we consider the position of the sensory group's ISI function. The sensory group performed at a somewhat higher performance level than the color-ranking aloud group, even though these subjects had no preexposure to the stimuli. They had no output interference.

#### Comparison of Serial Position Functions

Comparing the serial position functions of the three experiments reveals that the serial position functions with kaleidoscope stimuli were U-shaped with primacy and recency effects from Experiments 2 and 3, but not from Experiment 1. The major difference between the functions from Experiment 1 and those from Experiments 2 and 3 was the lower performance at the first serial position from Experiment 1. The sensory control group of Experiment 3 probably provides the best comparison because, like the test in Experiment 1, this group had no pretest exposure to kaleidoscope stimuli. A major difference between these two groups was that, prior to the test in Experiment 1, the subjects had experienced three daily sessions with travel slide pictures. Perhaps the strategy that the subjects found effective with the travel slides in Experiment 1 influenced and shaped their strategy to remember kaleidoscope stimuli, and, furthermore, perhaps this strat-

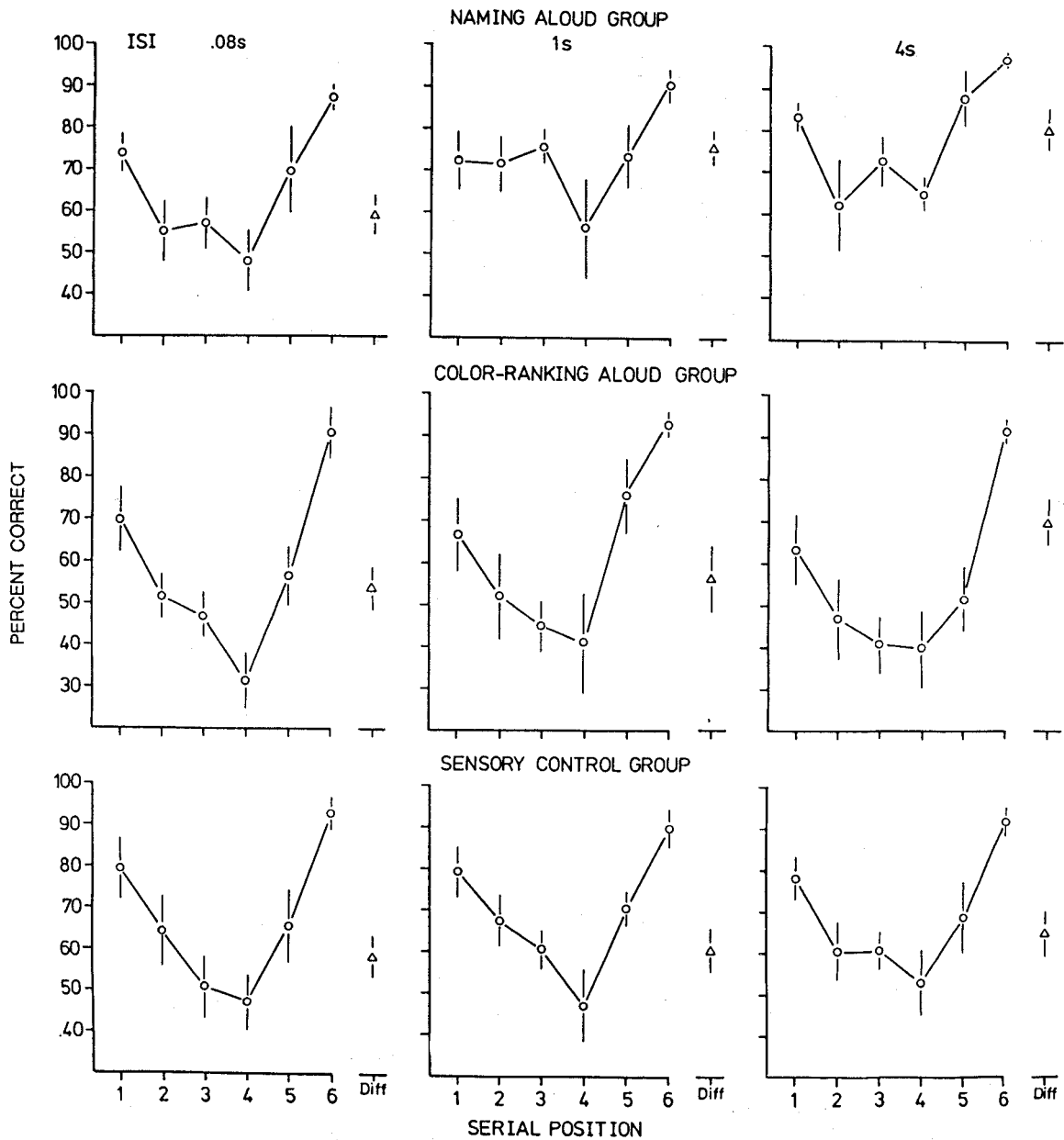


Figure 5. Performance as a function of serial position for the three interstimulus intervals, where position 1 was the first item presented. The "Diff" condition (triangles) shows performance on trials in which the test item did not match any list item. Error bars are standard errors of the mean.

egy was different from the one that the subjects developed who experienced no travel slide testing. In any case, it seems possible that not only can particular items (e.g., words, travel slides, and kaleidoscope patterns) influence the rehearsal strategy, but prior training (strategy priming) also may play a role.

*Comparison of Strategies and Subject Separation by Strategy*

A comparison of reported strategies across Experiments 2 and 3 reveals that there were a total of 12 chaining strategy

subjects, 18 repeating strategy subjects, and 10 sensory strategy subjects from the two naming groups and the two color-ranking groups. Performances of these subjects were recombined according to the strategy that each used and is shown in Figure 6.

There were considerable performance differences among these strategy groups, and mean performance was 78.6% for the chaining strategy group, 66.6% for the repeating strategy group, and 58.5% for the sensory strategy group. Statistical tests consisting of 3 (strategy group) × 3 (ISI) ANOVAs (with subjects as the replication) are shown in Table 6. There were

Table 5  
Trend Analyses: Serial Position Functions of Experiment 3

Group/ISI	Overall F(5, 54)	Quadratic F(1, 54)	Linear F(1, 54)
Naming aloud			
0.08 s	4.90***	19.60****	3.42
1 s	3.63**	7.10**	0.26
4 s	5.12***	12.85****	7.76**
Color-ranking aloud			
0.08 s	11.36****	47.20****	4.15*
1 s	6.20****	19.40****	8.90**
4 s	6.80****	26.32****	6.14*
Sensory control			
0.08 s	5.64****	26.41****	0.87
1 s	6.77****	28.25****	1.05
4 s	5.59****	23.29****	0.09

Note. ISI = interstimulus interval. \*  $p < .05$ . \*\*  $p < .01$ . \*\*\*  $p < .001$ . \*\*\*\*  $p < .0001$ .

differences among all groups, and the interaction effects show that the slope of the ISI function for the chaining strategy group was significantly different from both the repeating and sensory strategy groups. The one-way ANOVAs at the bottom of Table 6 show a significant ISI effect for both the chaining and repeating strategy groups, but not for the sensory strategy group. Thus, the sensory strategy group's ISI function can be considered flat.

Notwithstanding the nearly flat ISI function, the sensory strategy group did produce U-shaped serial position functions as shown in Figure 7. Figure 7 shows the serial position functions, Different trial performance, and standard errors of the mean for the three strategy groups at each of the three ISIs. Trend analyses using quadratic orthogonal polynomials as tests for the U shape of the functions (Keppel, 1973) showed significant quadratic components for all strategy groups at all

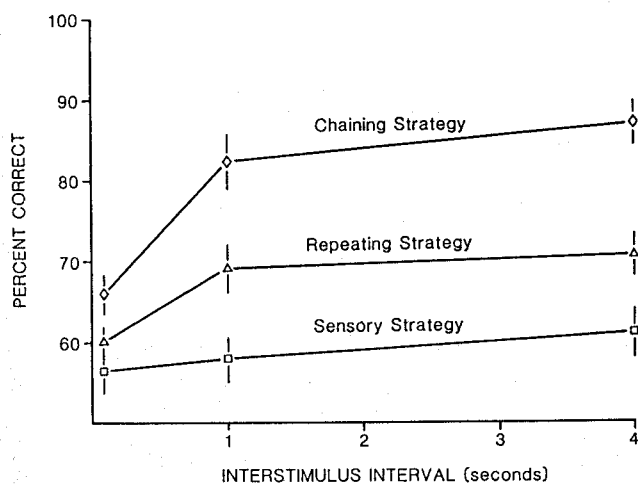


Figure 6. Performance as a function of interstimulus intervals for subjects regrouped according to rehearsal strategy. The chaining strategy group repeated names of prior items before adding the current name. The repeating strategy group repeated the name of the current list item. The sensory strategy group relied on their visual sensory experience. Error bars are standard errors of the mean.

Table 6  
ANOVAs for Subjects of Experiments 2 and 3 Separated According to Memory Strategy: Chaining (C), Repeating (R), or Sensory (S)

Strategy groups	ANOVA effects					
	Group		ISI		Interaction	
	df	F	df	F	df	F
Three groups	2, 111	56.3****	2, 111	26.7****	4, 111	3.9**
C vs. R	1, 84	46.1****	2, 84	27.3****	2, 84	3.1*
C vs. S	1, 60	142.9****	2, 60	23.0****	2, 60	9.7***
R vs. S	1, 78	19.5****	2, 78	8.3****	2, 78	1.6
C			2, 33	28.6****		
R			2, 51	7.5**		
S			2, 27	1.3#		

Note. ISI = interstimulus interval. \*  $p < .05$ . \*\*  $p < .01$ . \*\*\*  $p < .001$ . \*\*\*\*  $p < .0001$ . #  $p > .25$ .

ISIs: for the sensory and repeating strategy groups,  $F_s > 29.5$ , and  $p_s < .0001$ ; for the chaining strategy group,  $F_s > 9.5$ , and  $p_s < .01$ . These ISI functions and serial position functions for the different strategy groups reinforce previous indications in this article that the primacy effect is independent of any ISI effect or any rehearsal strategy.

## General Discussion

### Memory Strategies and ISI Effects

The results from the experiments of this article form a fairly coherent picture of some of the learning and memory processes involved when subjects are required to remember pictures that are unfamiliar and difficult to label. When first confronted with the task of remembering kaleidoscope pictures, without prior exposure to them (Experiment 1), subjects showed little or no ISI effect. These same subjects, however, had shown a steeply rising ISI function (a prominent ISI effect) in a test with travel slide pictures completed just before the test with kaleidoscope pictures.

Experiments 2 and 3 showed that training the subjects to name the kaleidoscope pictures produced much more robust ISI effects than simply exposing subjects to the stimuli. Verbalizations in Experiment 3 of either stimulus names or color rankings during the ISI diminished the ISI effects shown by similar groups in Experiment 2. Categorization of subjects by memory strategy showed a statistically flat ISI function for those who attended only to the sensory aspects of the stimuli and did not label the stimuli. Subjects who did develop and use labels for the stimuli used either a repeating rehearsal strategy of repeating the name of the current list item or a chaining rehearsal strategy of adding the current item to a name chain of the already presented items. The chaining strategy produced a more steeply rising ISI function than did the repeating strategy. Thus, the strategies in descending order of effectiveness were chaining, repeating, and sensory.

It may be of some interest that strategy advantages are apparent at the fastest presentation rate as well as the slowest presentation rate. In the fast condition, the six-item list is

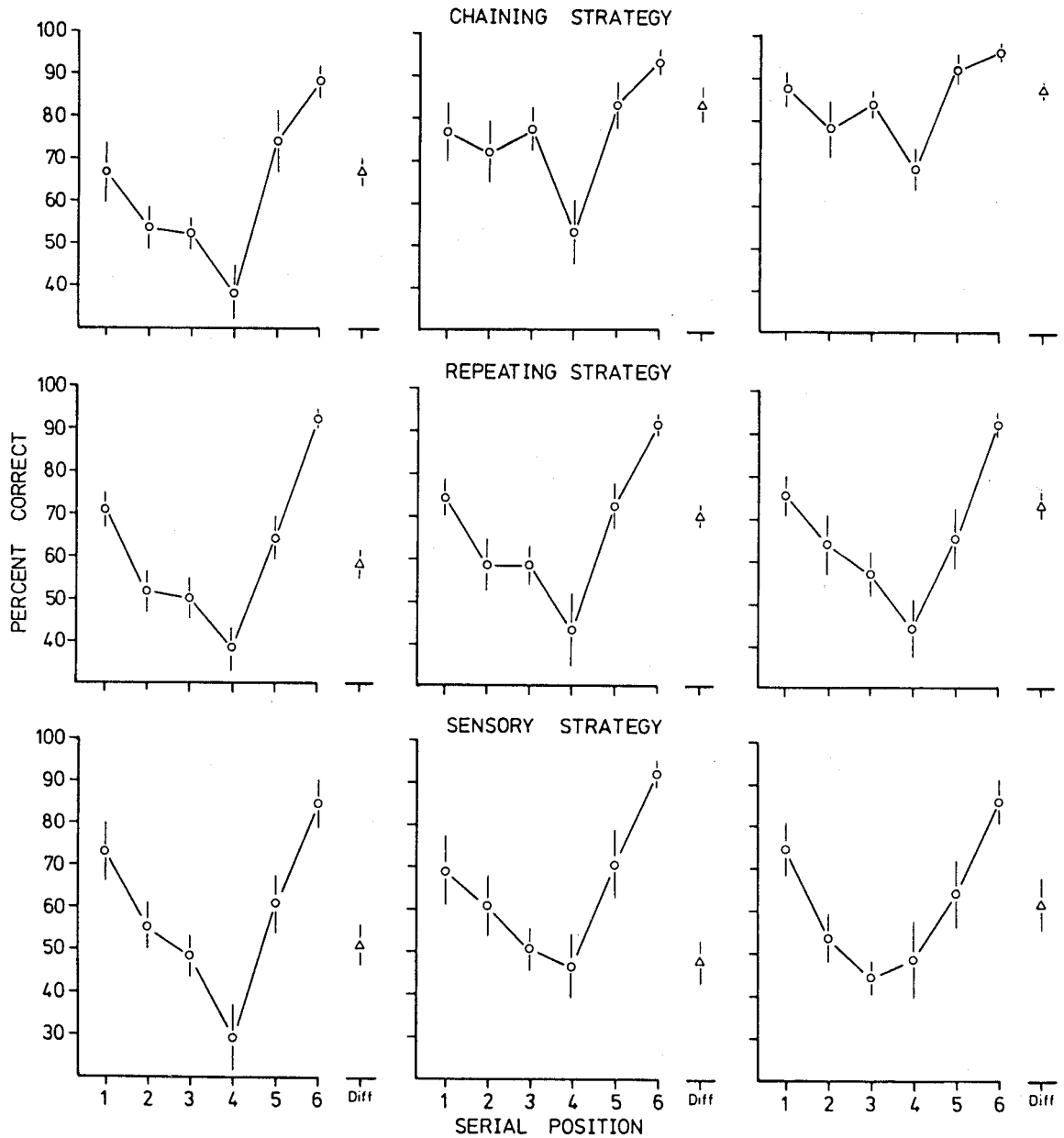


Figure 7. Performance as a function of serial position for the three strategy groups of Figure 6 at the three interstimulus intervals. Position 1 was the first item presented. The "Diff" condition (triangles) shows performance on trials in which the test item did not match any list item. Error bars are standard errors of the mean.

finished in 0.88 s—less than 1 s. No subject reported that they could use their chaining strategy at this fast rate, yet the chaining strategy subjects performed better than the repeating strategy subjects, and the repeating strategy subjects performed better than the sensory strategy subjects at this rate. Perhaps, additional rehearsals produced by the chaining strategy and, to a somewhat lesser degree, the repeating strategy at the slower presentation rates increased familiarity with the stimuli, so that fragments of the pictures might have been more identifiable. One has a definite sense of kaleidoscope fragments in this fast presentation condition.

Although the repeating strategy could be classified as a rehearsal strategy, it is distinct from the chaining strategy, in which rehearsals are distributed across several ISIs. Distributed rehearsals have been shown to be correlated with better memory than repetitive rehearsals (e.g., Modigliani & Hedges, 1987) in the same way that distributed repetitions (the spacing effect) enhances memory (e.g., Melton, 1967).

Results from the experiments presented in this article add to the growing literature of findings that the ISI procedure does reflect rehearsal and that the magnitude of the ISI effect is a good index of amount and type of rehearsal. These

experiments also show that kaleidoscope stimuli are useful in the study of rehearsal and rehearsal strategies. It seems that subjects are initially ill-equipped to rehearse kaleidoscope stimuli visually or verbally, although visual rehearsal is apparently possible with other kinds of visual stimuli (Watkins, Peynirciglu, & Brems, 1984). Furthermore, acquisition of these naming and rehearsal strategies appears to be sufficiently slowed by the use of kaleidoscope stimuli so that some study of the acquisition processes themselves is possible.

### *Rehearsal and the Primacy Effect of the Serial Position Function*

The chaining strategy was limited primarily to the first four list items. There has been some evidence and speculation about specific strategies at the beginning of lists (e.g., Modigliani & Hedges, 1987; Rundus, 1971; Watkins, 1985; Watkins & Graefe, 1981). In one example, Modigliani and Hedges (1987) required overt rehearsals from their subjects and found (through post hoc correlational analyses) that the beneficial effects of distributed rehearsal (the chaining strategy reported in this article is a form of distributed rehearsal) were in the primacy portion of the serial position function. Modigliani and Hedges proposed that rehearsal moved these items forward in time, maintained them in primary memory, and thus produced the primacy effect. Notwithstanding this and other correlational evidence (e.g., Rundus, 1971; Rundus & Atkinson, 1970) that may implicate rehearsal, correlations in themselves cannot identify the causative factor. However, examples in which the two processes (rehearsal and the primacy effect) are not present together have somewhat more definitive implications. When primacy effects occur in the absence of rehearsal, as were shown in this article, then this is definitive evidence that rehearsal cannot be a general cause of the primacy effect. The most prominent primacy effects were produced by groups showing either very little ISI effect (color-ranking control groups of Experiments 2 and 3) or no ISI effects (sensory strategy group, Figures 6 and 7).

Additional evidence addressing the issue of rehearsal and the primacy effect comes from a previous test of human subjects with kaleidoscope stimuli (Wright et al., 1985). At moderate retention intervals of 10 s and 25 s, the serial position functions were U-shaped, with well-developed primacy effects. At the longest retention interval, 100 s, the primacy effect remained after the recency effect had dissipated. In that list-memory experiment, the subjects were confronted with kaleidoscope stimuli for the first time. Thus, they were most similar to the subjects tested with kaleidoscope stimuli in Experiment 1 and those of the sensory control group of Experiment 3. Because of the similarity of the testing conditions in the Wright et al. (1985) study to the experiments reported in this article, it is unlikely that the human subjects in the Wright et al. (1985) study used any rehearsal strategy with the kaleidoscope stimuli. Additional evidence against the possibility that those subjects could have labeled and rehearsed the kaleidoscope stimuli is that the stimuli were frequently changed, and the subjects never saw the same stimuli more than twice, and never in successive 20-trial blocks. Thus, the dual requirements of learning names and

using some rehearsal strategy seem remote. Indeed, it is difficult to conceptualize how rehearsal (even if possible) could have played a role in producing the primacy effect in that experiment. List presentations were identical in all conditions with equal viewing times and ISIs. Only the retention interval differed. Differential rehearsal during the retention interval is not a plausible explanation, because in order to rehearse them, the items have to be retrieved from memory. If they can be retrieved from memory, then this retrieval should have provided the basis for the correct responses even at the very short retention intervals. But performance for the first list items, when tested immediately (zero retention interval), was close to chance performance. Despite the apparent lack of rehearsing, those subjects in the Wright et al. (1985) study did show prominent primacy effects developing as the retention interval increased, providing further evidence that rehearsal is not a necessary prerequisite for primacy effects.

The results of the Wright et al. (1985) study also provide difficulties for the end-point distinctiveness hypothesis of the primacy effect (e.g., Bower, 1971; Ebenholtz, 1972). Because the lists were presented identically and the intertrial intervals were the same, the distinctiveness of the beginning of each list should have been similar. But there were no primacy effects at short retention intervals, and they only appeared at longer retention intervals.

In the Wright et al. (1985) study, monkeys and pigeons were tested in addition to humans. Using procedures similar to those used with humans, the researchers found that both animal species showed prominent primacy effects and that the serial position functions showed the same general changes as did those for humans. It is unlikely that either animal species labeled/named the items or engaged in anything akin to the rehearsal strategies shown for human subjects in this article. Recently, monkeys have been tested in ISI experiments similar to those for humans reported in this article (Cook et al., 1990). There were no ISI effects for monkeys, and hence no evidence of rehearsal. Indeed, in some cases, the ISI function showed a decrease (rather than increase) with increasing ISI. These animal memory experiments provide additional converging evidence that rehearsal is not necessary to produce a primacy effect.

### *The Serial Position Function and Separation of Memory Processes*

There is considerable evidence indicating the existence of two (or possibly more) different human memory processes. One process seems to be associated with primary memory or items comprising the recency effect, and the other process seems to be associated with secondary memory or items comprising the prerecency portion of the serial position function, including the primacy effect (e.g., Crowder, 1976; Glanzer, 1972; Tulving, 1985). Interest in process separation appears to be growing (e.g., Squire, 1986, 1987; Tulving, 1987; Weiskrantz, 1987). Certain variables selectively affect primary memory and the recency effect: moderate to long retention delays (e.g., Gardiner, Thompson, & Maskarinec, 1974; Glanzer & Cunitz, 1966; Postman & Phillips, 1965; Roediger & Crowder, 1975; Wright et al., 1985) auditory versus visual

modality of stimulus presentation (e.g., Crowder, 1986; Crowder & Morton, 1969; Murdock, 1967), and knowledge about the end of the list (Watkins & Watkins, 1974). Other variables selectively affect secondary memory and the primacy effect: alcohol intoxication (Jones, 1973), fast presentation rates (Glanzer & Cunitz, 1966), low word frequency (Sumbly, 1963), long list lengths (Murdock, 1962), mental retardation (Belmont & Butterfield, 1971), and very short retention delays in single-item recognition tasks (Wright et al., 1985). Neuropsychological evidence also supports this functional dissociation. Specific areas of the brain have been shown to be associated with primary memory and the recency effect (Warrington & Shallice, 1984; Warrington, Logue, & Pratt, 1971; Saffran & Marin, 1975; Weiskrantz, 1987), and certain types of amnesia selectively affect secondary memory and the primacy effect (Baddeley & Warrington, 1970).

Animals likewise apparently have dual memory processes as shown by U-shaped serial position functions for apes (Buchanan, Gill, & Braggio, 1981), monkeys (Roberts & Kraemer, 1981; Sands & Wright 1980a, 1980b; Wright et al., 1984, Wright et al., 1985), pigeons (Santiago & Wright, 1984; Wright et al., 1985), and rats (Bolhuis and van Kampen, 1988; Kesner & Novak, 1982); selective removal of the primacy effect (long-term component) by hippocampal lesions (Kesner, 1985; Kesner & Novak, 1982); differential effects of retention interval manipulations on primacy and recency effects that are qualitatively similar in pigeons, monkeys, and humans (Wright et al., 1985; see also Tulving, 1987); and a similar secondary-memory locus for build up and release from proactive interference effects for rhesus monkeys (Jitsumori, Wright, & Shyan, 1989) as for humans ( Craik & Birtwistle, 1971; Stern, 1985; Wickens, Moody, & Dow, 1981).

### Concluding Remarks

Although there are probably links between these two memory systems, rehearsal does not appear to be the primary link between them, as was hypothesized by Atkinson and Shiffrin (1968) and Waugh and Norman (1965). This is not to say that rehearsal does not improve memory, because clearly it does, as shown in Experiments 2 and 3 of this article. But, if rehearsal was the sole cause of the primacy effect, then the control subjects' serial position functions should have shown little or no primacy effects, the animal (nonhuman) subjects of the Wright et al. (1985) experiment should not have developed primacy effects, and the human subjects tested with kaleidoscope pictures in the Wright et al. (1985) experiment should not have developed primacy effects. Clearly, there is mounting evidence that rehearsal cannot be the only mechanism responsible for the primacy effect. Neither, however, does the extensive research on this topic converge on any other alternative. Considering that efforts for a century have been directed toward identifying the cause of the primacy effect, perhaps viewing this effect as resulting from multiple causes will prove more profitable.

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