The results of three experiments provide converging evidence for the conclusions that hypermnesia (increased recall with repeated testing) does not depend on encoding of material in an imaginal format, but is related to the level of recall across conditions within an experiment. In Experiment 1 subjects performed orthographic, phonological, or semantic operations on words and then recalled them on three successive free recall tests. Orienting tasks affected the level of recall (semantic > phonological > orthographic), and the level of recall was correlated with hypermnesia. In Experiment 2 subjects studied nonsense syllables presented either once or three times and were then given three tests. Recall improved across tests, and the improvement was reliably greater for items studied three times. In both Experiments 1 and 2 subjects who received three tests recalled no more total items than did subjects given a single long test of equivalent duration. In Experiment 3 subjects repeatedly recalled instances of categories from semantic memory. Hypermnesia was observed and was again related to level of recall. The results help delineate the necessary and sufficient conditions for observing hypermnesia on repeated tests, and are in general agreement with the account of the phenomenon provided by J. G. W. Raaijmakers and R. M. Shiffrin's (In The psychology of learning and motivation: Advances in research and theory. New York: Academic Press, 1980. Vol. 14.) SAM model.

When people are given a list of words to remember and are then given repeated free recall tests, they typically recall items on the later tests that had been forgotten on previous tests (e.g., Tulving, 1967). However, the total number of items recalled on later tests in such studies typically does not increase over the level of the earlier tests, since item recovery is offset by the forgetting of items previously recalled (e.g., Birnbaum & Eichner, 1971; Donaldson, 1971; Tulving, 1967). However, several reports from early in this century provide suggestive evidence that total recall will sometimes improve across repeated tests.

Nicolai (1922; cited in Tulving, 1968) showed subjects a simultaneous display of ten small objects and then gave them two free recall tests. One was given immediately after presentation and the second was given at intervals varying up to 96 hours. In all cases the number of objects recalled was greater on the second test than on the first, with the largest difference occurring in the group that was tested 96 hours later. Those subjects recalled an average of 7.4 objects on the first test and 9.4 objects on the second. Similarly, Ballard (1913) observed improvements in recall across repeated tests when he tested children on passages of poetry, and Brown (1923) found improved recall on a second test both for lists of words and recall of the states of the United States. Ballard (1913) christened this phenomenon reminiscence, and it attracted some experimental interest over the years. Unfortunately, these early results were not replicated with great success (Ammons & Irion, 1954; Buxton, 1943; McGeoch & Irion,
1954, Chap. 5), and interest in the topic of increases in total recall across repeated tests languished.

In recent years interest in this problem has been rejuvenated by Erdelyi and his associates in an important series of studies that reveal reliable increases in recall of certain types of material across successive tests. Erdelyi and Becker (1974, Experiment 1) presented subjects with a series of 80 items to be remembered, 40 concrete nouns and 40 pictures that could be easily named. Subjects were allowed three successive 7-minute recall tests. (Pictures were recalled by writing down the name of the pictured object.) The basic finding was that recall of pictures increased across successive tests while recall of words remained at about the same level. This incremental recall of pictures was referred to as hypermnesia, to indicate a contrast with amnesia or forgetting. This hypermnesia effect is taken by Erdelyi and his associates to be counterintuitive, since it seemingly demonstrates an actual improvement in recall with the passage of time since original learning. Such an outcome seems to fly in the face of the normal forgetting functions obtained since the time of Ebbinghaus and thus has been viewed as of considerable theoretical importance (Erdelyi & Becker, 1974; Erdelyi, Finkelstein, Herrell, Miller, & Thomas, 1976). The basic finding of hypermnesia for pictures, unlike the early reports of improvements on successive recall tests, is readily replicable (e.g., Erdelyi et al., 1976; Madigan, 1976; Yarmey, 1976).

Studies by Roediger and Payne (1982) and Roediger and Thorpe (1978) place some constraints on the interpretation of hypermnesia. Roediger and Payne (1982) asked whether hypermnesia occurred because of some growth in the availability or accessibility of memory traces over time in absence of repeated testing, or whether the improvement in recall on later tests was due to practice or time spent recalling in the earlier tests. They presented a series of pictures to three groups of subjects who received three tests on the lists. However, the first recall test was delayed for varying periods of time for the different groups by having subjects read a passage following list presentation. With this design the effects of number of tests and increasing delay, which are confounded in the normal testing procedure, can be disentangled. The results showed clearly that improvements in recall in the multiple test situation depend on repeated testing and not on some increasing trace strength correlated with the passage of time. Delay in recall of the pictures filled with reading had no positive effect on recall, though there was no forgetting, either. However, after constant delays across conditions, recall was directly related to the number of prior tests people had been given. Thus hypermnesia in the multiple test situation is produced by prior tests benefiting performance on later ones.

Roediger and Thorpe (1978) asked whether the repeated testing in the typical hypermnesia experiment allows for better recall than simply testing subjects once, but equating the total time spent trying to recall the material. They gave people lists of pictures or words to remember and then tested recall either by giving subjects three successive 7-minute recall tests or one 21-minute test. In Experiment 1 they found hypermnesia for both pictures and words, although the effect was greater for pictures. More importantly, they found that for both pictures and words there was no difference in the total number of different items recalled between subjects given three successive 7-minute recall tests or one 21-minute test. In Experiment 1 they found hypermnesia for both pictures and words, although the effect was greater for pictures. More importantly, they found that for both pictures and words there was no difference in the total number of different items recalled between subjects given three successive tests and those given a single long test of equivalent duration. This outcome was also obtained in a second experiment with concrete and abstract words as the to-be-remembered stimuli. Since the usual procedure of multiple recall tests as employed in hypermnesia experiments does not allow recall of more items than when people are given an equivalent period of recall time, hypermnesia may result simply from subjects being provided additional recall time on repeated tests.
An interesting unanswered question about hypermnesia is that of the necessary and sufficient conditions for producing it. Many researchers have not found hypermnesia for word lists, although they generally have no trouble finding the effect with pictures (Erdelyi & Becker, 1974; Madigan, 1976; Popkin & Small, 1979; Yarmey, 1976). Erdelyi and Becker (1974) originally made the plausible suggestion that an imaginal coding format is somehow responsible for the improved recall of pictures across repeated tests. This would explain why hypermnesia occurs for pictures but not words, under the assumption that subjects do not typically resort to imaginal coding of words unless given special instructions.

The imagery hypothesis also has the merit of potentially explaining the inconsistent effect of multiple recall tests in producing hypermnesia (e.g., Buxton, 1943; Tulving, 1967). Positive results in the earlier experiments may have come from use of objects (Nicolai, 1922) or poetry that was easily imageable (Ballard, 1913). Most experiments not finding evidence of hypermnesia used verbal materials (word lists) as the to-be-remembered material (e.g., Tulving, 1967), and such stimuli are unlikely to be represented in an imaginal format. Further evidence implicating imagery in producing hypermnesia comes from research by Erdelyi et al. (1976) in which hypermnesia for words was found when subjects were instructed to form images of the words' referents during study. Since hypermnesia is often found with repeated testing of objects, pictures, poetry, and imaged words—but not for word lists without special learning instructions—imaginal coding is a likely candidate as the necessary condition for obtaining the effect.

Erdelyi and Kleinbard (1978) have recently suggested that the verbal learning tradition begun by Ebbinghaus' (1885/1913) research on memory for nonsense syllables "... may have been responsible for some major distortions in memory research" (p. 286). In particular, since one does not find hypermnesia with words presented singly, it is even less likely that one would find the phenomenon with nonsense syllables, the customary material of many of the early memory experiments. "The almost universal—but unquestioned—shift from methodologically unwieldy poetry, Ballard's usual stimulus, to the controllable 'scientific' stimulus of Ebbinghaus, the nonsense syllable, may have erroneously undermined a seminal discovery in memory" (Erdelyi & Kleinbard, 1978, p. 276).

While the imagery hypothesis accounts well for much of the research showing improved performance with repeated tests, some recent results do not fit in too well with the notion that imaginal coding is the critical variable. Erdelyi, Buschke, and Finkelstein (1977) showed hypermnesia for a list of words that were not actually presented, but which were generated in response to simple questions ("What does a baseball player hit the ball with?"). While subjects may have formed images of the words in answering the questions, there was no requirement to. In other experiments Buschke (1973, 1974) has reported impressive amounts of item recovery across repeated memory tests. Although his experiments are not directly comparable to the hypermnesia experiments, they provide evidence that item recovery across tests occurs with words as well as pictures.

Roediger and Thorpe (1978) found hypermnesia for word lists in two experiments. In Experiment 1 subjects were given concrete words with no special instructions on how to process the stimuli (unlike the Erdelyi et al., 1976, experiment), but the subjects were drawn from a pool of University of Toronto students who had participated in numerous memory experiments and thus might well have been expected to employ complex encoding strategies, including the use of mental imagery. In Experiment 2 experimentally naive subjects were given either abstract or concrete nouns and were instructed, in a between-
subjects manipulation, to encode the words either by using mental imagery or by thinking about the meaning of the words, such as by thinking of associates of the to-be-remembered words. Hypermnesia occurred for both high and low imagery words, but was greater for the former. More important, there was no interaction between the increase in recall across tests and the type of encoding subjects were supposed to be using; the hypermnesia was as great for subjects given the semantic encoding instruction as for the ones given the imagery instruction.

Belmore (1981) has also shown hypermnesia in conditions of two experiments in which imagery seems unlikely to have played a role. In Experiment 1 subjects studied words under instructions to form images or sentences using the word or its referent, while in a third condition people were told to repeat the word. Hypermnesia was found for both the sentence and imagery encoding conditions, but not for the repetition condition. In Experiment 2 subjects made judgments about each word as it was presented as to whether (a) it had more than five letters, (b) it would fit inside a grocery cart, or (c) it represented a living thing. Only the size judgment (b) was thought to involve formation of an image. Reliable hypermnesia was found only in the condition in which subjects made the living/nonliving decision about the words. Belmore (1981) concluded that hypermnesia could be induced by either imaginal coding operations or ones involving semantic elaboration, a conclusion that could apply equally well to the results of Erdelyi et al. (1977) and Roediger and Thorpe (1978). However, in Experiment 3 Belmore (1981) did not find hypermnesia related to orienting tasks promoting either good or poor recall (pleasantness ratings and counting syllables or letters, respectively). In Experiment 4 Belmore found modest increases in recall across tests that, she concluded, were related to meaningful processing and not to imaginal coding. (Experiment 1 in the present series is also directed at determining the effects of different orienting tasks on recall).

One reasonable conclusion that may be drawn from a good deal of the literature, then, is that any variable that produces greater levels or depths of processing—whether it be imaginal encoding, semantic encoding, or what have you—leads to greater hypermnesia. Put more simply, it may be that hypermnesia is related to level of recall, which is in fact the proposition receiving support in the present experiments. We argue that hypermnesia will be correlated with level of recall under a variety of experimental conditions, so long as ceiling effects are not a problem. Of course, coding processes and level of recall are normally correlated in episodic free recall experiments, but in Experiment 3 we try to show that in some sense level of recall is the more fundamental variable.

Before considering our new evidence indicating a relation between level of recall and hypermnesia, we would like to develop a rationale for supposing that recall levels and hypermnesia should be related. A basic assumption we make is that the hypermnesia obtained in the multiple test situation is predictable from the levels of item recovery in situations employing a single test of great duration, since no difference in the number of items recalled is observed when these situations are compared (Roediger & Thorpe, 1978). (Such comparisons between cumulative recall curves are portrayed in Figures 4 and 7 of the present paper.) From previous research we know that cumulative free recall curves are reasonably well described by the exponential equation

\[ n(t) = n(\infty) (1 - e^{-\lambda t}), \]

where \( n(t) \) represents the number of items that have been recalled by time \( t \), \( n(\infty) \) is the asymptote of the function (the lower bound estimate of the number of items accessible), \( e \) is the base of the natural logarithm, and \( \lambda \) is the rate of approaching the asymptote.
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(Bousfield & Sedgewick, 1944; Indow & Togano, 1970; Roediger, Stellon, & Tulving, 1977). (Grunewald and Lockhead (1980) have reported that a hyperbolic equation provides a slightly better fit for free recall of category items from semantic memory. We illustrate our logic here with the exponential, though the point we are making in no way depends on this.)

One interesting fact that has emerged from previous research with free recall in both episodic and semantic memory situations is that the asymptotic level of recall, \( n(\infty) \), and the rate of approaching that asymptote, \( \lambda \), are negatively correlated. The greater is the overall level of recall, the slower the rate of approaching the asymptote. The hypothetical curves in Figure 1 portray this relation. They may be thought of as cumulative recall curves comparing recall under some control condition (lower curve) to that under some experimental condition (upper curve) in which performance is improved. In this illustrative example, when \( n(\infty) \) is doubled, \( \lambda \) is halved. This relation indicates that if some variable increases the asymptotic level of recall in an experimental relative to a control condition, after some constant amount of recall time (\( t \)) subjects in the control condition will have recalled proportionately more of the total items that they will recall than will have subjects in the experimental condition.

Turning to the multiple test situation, we can think of recall on the first of several tests as recall after a constant period of time for the two conditions (experimental and control) that differ in levels of recall. However, subjects in the control condition with lower recall have recalled proportionately more items (relative to asymptotic recall) after the first period than have subjects in the experimental condition. Thus recall in the control condition does not have the same potential for growth on later tests as does recall in the experimental condition. Subjects in a condition in which overall recall is low (relative to some other condition) will show less improvement on repeated tests, since after a single test they are closer to the functional ceiling of the cumulative recall function, \( n(\infty) \). The general conclusion, then, is that whatever variable increases the level of recall should also lead to greater levels of hypermnesia, assuming that true ceiling effects are not a factor in the conditions with the greatest levels of recall. Differences in hypermnesia across conditions may then be predictable from a comparison of asymptotic recall levels.

By this reasoning improved recall should lead to greater hypermnesia, whatever the variables that lead to the increased recall (imagery, semantic elaboration, and so forth). Of course, the foregoing analysis oversimplifies matters somewhat by arguing that repeated tests and single tests of equivalent total duration can be treated as the same, because in repeated tests there is the possibility of forgetting between tests. Differential intertest forgetting between conditions is not taken into consideration in this account.

As previously described, several experiments have revealed a correlation between variables that affect overall level of recall and hypermnesia (e.g., Belmore, 1981, Experiments 1 and 2; Erdelyi & Becker 1974; Erdelyi et al., 1976; Roediger & Thorpe,
 ROEDIGER ET AL.  
1978). (Some recently reported exceptions are taken up in the General Discussion). Erdelyi et al. (1976) reported internal analyses of their experiments which, taken at face value, argue against a relation between recall levels and hypermnesia. Within separate experimental conditions, they correlated recall of subjects on a first test with gains between the first and third test in order to see if gains were significantly related to initial recall levels. Across three conditions they reported quite low and nonsignificant positive correlations in two cases and a negative correlation in the third. Unfortunately, possible regression artifacts in item fluctuation between tests make such analyses difficult to interpret. (Subjects with high first test recall may regress towards the group mean, and conversely for subjects with poor initial recall.) Nonetheless, these internal analyses indicate that it is not a foregone conclusion that level of recall and hypermnesia are related.

The primary purpose of the experiments reported here was to test the hypothesis that hypermnesia is related to level of recall. A secondary purpose was to show that factors unrelated to imaginal coding of stimuli could produce hypermnesia. To these ends, levels of recall were varied in three experiments in ways thought unrelated to imaginal coding, and the effects of these manipulations on multiple recall tests were observed. In Experiment 1 subjects were induced to encode words by paying attention to orthographic, phonemic, or semantic features of the words in the levels of processing paradigm studied by Craik and Tulving (1975). In Experiment 2 subjects recalled nonsense syllables repeatedly after having them presented once or three times. In Experiment 3 subjects repeatedly recalled information about different sized categories from semantic memory.

EXPERIMENT 1

Subjects saw a list of 60 words and were asked to answer a question about each word. For 20 words the question asked whether the word contained a particular letter, for 20 others the question asked whether or not the word rhymed with another word, and for the remaining 20 the question asked whether or not the word was a member of a category. Following list presentation, one group of subjects was given three successive 7-minute free recall tests on the words while another group was given one 21-minute test. We expected hypermnesia in recall of words, but also expected that it would increase with the level of processing of the studied words. We also expected, in line with previous results (Roediger & Thorpe, 1978), that the total number of different words recalled would be no greater for subjects given the usual hypermnesia manipulation of three successive recall tests than for those provided a single test of equivalent duration.

Method

Subjects. The 60 subjects were University of Toronto undergraduates who were paid for their participation. They were usually tested in small groups, although several were tested individually.

Design. A 2 × 3 × 2 mixed design was employed. The between-subjects factor was the type of recall test. Subjects were tested with either three successive 7-minute recall periods or one 21-minute period. The other factors were varied within-subjects. While studying the list words, subjects performed one of three types of orienting task on each word. Subjects either answered a question about the category to which a word belonged (semantic task), whether it rhymed with another word (rhyme task), or whether or not it contained a particular letter (letter task). The final factor was whether or not the answer to the question was yes or no. In summary, there were two types of recall test, three types of processing, and two types of response to the processing question.

Procedure. At the beginning of the experiment subjects were instructed that they would see a list of 60 words and would be
asked to recall the words later. They were also told that when each word appeared they were to answer the corresponding question about it on a sheet in front of them. The questions were numbered 1–60 and they were told to answer each question yes or no. The nature of the questions was explained and examples of the three types were given.

The 60 words were presented by slide projector at the rate of 10 seconds per word. The words were all concrete nouns. Some examples are child, lake, jail, boulder, diamond, church, and typhoon. In the letter condition subjects were asked whether or not the word contained a particular letter, in the rhyme condition they were asked whether or not it rhymed with a particular word, and in the semantic condition they were asked whether or not the word fit into a particular category. There were 20 words in each of the three conditions with the correct answer being yes to 10 of the words and no to the other 10. There were six different question forms distributed across subjects in order to counterbalance words against the six encoding conditions. Subjects always saw the 60 words in the same order, but depending on their form they were answering different questions about the words. In each successive group of six words each encoding condition was represented once. Five subjects in both the recall test conditions (one test or three tests) received one of the six forms.

Following presentation of the list there was a 60-second interpolated activity designed to minimize short term memory effects. Subjects were asked to recall as many Ontario towns and cities as they could for this period. After the interpolated task subjects were asked to recall as many of the list words as possible in any order. They had been instructed that they should write the words in columns down their recall sheets and that after every minute they would be instructed to draw a line after the last word they had written. At appropriate intervals the experimenter said "Draw line 1, draw line 2," and so on. Subjects were also asked to number the lines.

Instructions to recall the words were prefaced by remarks informing subjects that they would have a long time for recall and that they might feel as though they had finished long before the recall period was up. They were told that they should keep trying throughout the recall period, and that it had been shown in other experiments that if they did keep trying they would be able to recall many more words than they might have thought possible. Subjects who were to be tested three times were instructed to stop recall after the 7th minute and their recall sheets were collected. (Up to this point the two recall groups were treated identically.) These subjects were given a break of 1 minute during which they were instructed that they would now be asked to recall the list a second time and that they should try to recall both words they had previously recalled as well as new words. They were encouraged to try to improve their performance over the first test. After the second 7-minute test subjects were stopped, given similar instructions with the added information that this would now be the last test, and then given the third 7-minute test. Subjects who were given one 21-minute test were stopped after 7 and 14 minutes and given a brief instruction encouraging them to keep trying.

Results and Discussion

The results for subjects given three successive tests are shown in Figure 2, with recall scores broken down by the type of orienting task performed during study, but combined across the yes/no variable. Replicating the findings of Craik and Tulving (1975) and others, we found that the nature of the orienting task had a reliable effect on recall with recall best in the semantic condition and worst in the orthographic condition, $F(2, 58) = 14.54, MS_e = 8.75$. (All effects are reliable at the .05 level of confidence unless otherwise specified.) Recall also increased reliably across the three
tests, indicating that hypermnesia was obtained, $F(2, 58) = 40.41, MS_e = .34$. The other primary variable—whether the question was answered with a yes or no—also had a reliable effect, with yes responses producing better performance than no responses, $F(1, 29) = 30.89, MS_e = 1.86$. This effect is not portrayed in Figure 2, as the yes/no effect did not interact with any of the other variables.

The result of primary interest is the interaction between the type of orienting task and the number of tests. This interaction proved reliable, indicating that orienting task not only increased recall, but also increased the amount of hypermnesia obtained, $F(4, 116) = 5.32, MS_e = .36$. As is evident from Figure 2, the growth of recall across tests was greatest for the semantic orienting condition, smaller for the phonemic condition, and least for the orthographic condition. Thus hypermnesia was produced in this experiment without encouraging subjects to use imaginal coding and was positively related to the level of recall.

Presented in Figure 3 are the cumulative recall curves for items recalled across the three tests in each of the orienting task conditions. The results presented in Figure 2 were those after 7 minutes of recall. From Figure 3 it can be seen that the pattern represented in Figure 2 is maintained throughout the recall period. As reported in earlier studies (Roediger & Thorpe, 1978; Roediger & Payne, 1982), the increased recall on successive tests is somewhat greater at intermediate levels of recall time relative to the entire 7-minute period. Statistical analyses performed on recall after 3 minutes confirmed the trends shown after 7 minutes. Besides reliable main effects of number of tests, type of orienting task, and yes/no answers, the Orienting Task x Test interaction that is of particular interest here also proved reliable, $F(4, 116) = 6.67, MS_e = .67$. Thus the interaction between level of recall as induced by different orienting tasks and hypermnesia held throughout the recall period.

Shown in Figure 4 is a comparison of the cumulative recall curves for subjects given three 7-minute tests to those given a single 21-minute test. Subjects given three tests were scored for these purposes only on the unique items they recalled. That is, they were given credit the first time they recalled
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FIG. 4. Mean cumulative recall curves across the entire 21-minute test period for words studied under the three different encoding conditions of Experiment 1. Subjects received either three 7-minute tests or one 21-minute test.

an item and then repetitions of the item in later tests were not counted. As can be seen in Figure 4, there is no difference between the two types of recall tests in terms of the total number of words recalled for any of the three orienting tasks. The slight advantage of subjects receiving three tests in the rhyme and semantic orienting task conditions was not reliable at any point. (This slight difference is already seen at 7 minutes, at which point the subjects had been treated identically).

Roediger and Thorpe (1978) also found that recall on three successive tests did not differ from that on a single 21-minute test in two experiments and concluded that hypermnesia across successive tests can be attributed to increased recall time provided by the later tests. Since cumulative recall curves are so similar for subjects receiving three and one test, it may be concluded that retrieval processes in the two cases are also similar. That is, subjects receiving a single test are probably repeatedly calling to mind the items across the recall period as are subjects given three tests, but in the former case there is no overt recall.

The finding that improvements in recall over long periods are correlated with the type of orienting activity can be interpreted within the levels of processing framework (Craik & Tulving, 1975). Semantic processing may provide a richer encoding that permits retrieval by more varied means, relative to shallow levels of processing. The continuing recall of semantically coded items may reflect the use of these varied means of retrieval.

EXPERIMENT 2

In line with the reasoning provided in the Introduction, the results of the first experiment showed that hypermnesia was related to the level of recall as induced by different orienting tasks. The greatest improvement occurred on items presented in the semantic orienting condition. It is possible that in performing this sort of orienting task subjects employed an imaginal code. We consider this unlikely, since there was no in-
struction to do so, but cannot rule out the possibility.

Experiment 2 was conducted in order to provide further converging evidence that hypermnesia was related to level of recall in the absence of imaginal coding. Erdelyi and Kleinbard (1978) have argued that the phenomenon of reminiscence or hypermnesia, originally discovered by Ballard (1913), was not replicated by later researchers because they used materials such as words and nonsense syllables that are more difficult to image than Ballard's poetic material. We decided to use nonsense syllables as our materials in Experiment 2 since they should be the type of material least likely to permit imaginal coding. Level of recall between two conditions was varied by presenting a list of nonsense syllables to subjects either once or three times. After presentation, different groups of subjects recalled the items during three successive 7-minute tests or during a single 21-minute test.

Surprisingly few data bear on the question of how number of repetitions affects free recall across repeated tests. One relevant study is that of Tulving (1967, Experiment 2). In one condition of that experiment subjects were given one to six presentation trials of a 36-word list and each presentation was followed by three recall tests. Subjects were tested with oral recall during a 36-second period. Tulving referred to each period of study and test as a cycle. Presented in Figure 5 is cumulative recall of items across the three tests as a function of the number of repetitions of the material (cycles), ignoring forgetting between tests. That is, the new items correctly recalled on the second test were added to those recalled on the first test, and so on for the third test. (Since the tests were so short, intertrial forgetting was quite high. In ignoring these "forgotten" items we may assume that once recalled, subjects would be likely to recall them again given enough time, as shown by Buschke (1974).) As can be seen in Figure 5, Tulving's (1967) data do seem to show an interaction between number of presentations (cycles) and increases in recall across tests. On the other hand, Madigan (1976, Experiment 1) found no greater item recovery from presenting pictures twice rather than once on two successive tests. Experiment 2 was designed to gather further evidence about the effect of repetitions on recall across repeated tests.

Experiment 2 thus constitutes a relatively rare sort of experiment—a free recall test of nonsense syllables. As Tulving (1968) has pointed out, one reason for the unpopularity of free recall in studies of memory early in this century was that Ebbinghaus (1902) argued against the method on the grounds that it was of limited usefulness and was less sensitive than his own savings measure of retention. Certainly free recall with nonsense materials does pose methodological problems, in particular the problem of intrusions. In free recall tests of unrelated words, extralist intrusions are rare, but in recall of nonsense syllables, where it is not possible to easily distinguish misspellings from intrusions, the rate is much higher. We used a strict criterion in scoring recall such that a syllable had to be perfectly recalled to be counted correct.
Method

Design and subjects. The design was 2 x 2, employing four independent groups of subjects. The factors were the number of presentations of the nonsense syllable (1 or 3) and the form of test (3 tests or 1 test). Two of the four groups were presented the items a single time before recall, whereas the other groups received three presentations. One group from each presentation condition was then tested with three successive 7-minute recall tests, while the other group was tested with a single 21-minute test. The subjects were 140 Purdue undergraduates with 35 assigned to each of the four groups. Most participated in partial fulfillment of an introductory psychology course requirement, but 15% participated for payment. The paid subjects were equally distributed across conditions.

Materials. Fifty 3-letter consonant–vowel–consonant nonsense syllables were selected and typed on slides in lower case letters. The items met the criteria of being pronounceable and of low associativity, as determined by Noble's (1961) norms. Examples of the items include bis, fik, mez, naf, and wub. Efforts were made to employ as many different initial letters as possible and not use similar items.

Procedure. Subjects were tested in small groups. They were told that they would see a list of 50 nonsense words either once or three times and that they would be asked to recall the words after hearing some further recall instructions. The items were presented at a 5-second rate.

After the items were presented subjects received further instructions on how to recall them. These were designed, in part, to reduce recency effects. Subjects were told to recall the items in any order in columns on their recall sheets, and to draw a line under the last item recalled when so instructed. They were encouraged to keep trying throughout the recall period, and were cautioned not to guess wildly, but to write down only those items they were reasonably sure occurred on the list. These instructions took about 2 minutes and then subjects commenced recall. Other testing procedures were the same as in Experiment 1.

Results and Discussion

Presented in Table 1 are the mean recall scores in both presentation conditions for those subjects who received three tests. Recall did improve slightly but reliably across the three tests, $F(2, 136)= 12.61$, $MS_e =1.89$, indicating that hypermnesia can be found even with the lowly nonsense syllable. A Newman–Keuls test revealed that the increase in recall between the first and third test was reliable only in the condition in which items were presented three times. Presented in Figure 6 are the cumulative recall curves for the three tests for subjects who received three presentations of the list. The results show that the improvement was largely due to performance on the third test.

As expected, recall was also much greater when the items were presented three times rather than only once. The level of recall roughly doubled in the former condition (see Table 1), which proved highly reliable, $F(1, 68)= 60.97$, $MS_e = 68.87$. Of more interest is the interaction between level of recall and the number of recall tests. Although not overly impressive, the interaction is reliable, $F(2, 136)= 3.90$, $MS_e = 1.89$, indicating that the improvement in recall across the three tests was greater when the material was presented three times rather than only once. Thus the two

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<td><strong>Mean Number of Nonsense Syllables Recalled in the Three Tests When Scored at the End of 7-min Tests</strong></td>
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main purposes of the second experiment were accomplished—showing that hypermnesia could be obtained with nonsense syllables, and that the effect would increase with level of recall.

A strict criterion was used in scoring recall such that subjects were given credit for recalling a syllable only if all three letters were given in their correct order. Thus it is likely that some (and perhaps most) of the items scored as intrusions were actually partially correct items. Across the three tests, 8.69 “intrusions” occurred for subjects presented the items three times, whereas 7.95 occurred in the single presentation condition. Thus there was surprisingly little difference in intrusion rates.

A final point of interest is the comparison between subjects who were given three successive tests to those given a single long test when they were scored on the number of unique items recalled. Presented in Figure 7 are the cumulative recall curves for subjects in all four conditions across the 21-minute period. The results there show (and statistical analyses confirm) that there was no reliable difference between subjects given one test and those given three in either presentation condition. The slight advantage after 21 minutes for subjects receiving three tests in the condition in which they saw the list three times was not reliable; also, a similar advantage occurred early in the recall period (e.g., 3–4 minutes) before subjects were treated differentially. Thus the present results agree with those of the first experiment and others (Madigan & Lawrence, 1980; Roediger & Thorpe, 1978) in showing that three successive recall tests permit no greater recall than an equivalent amount of time consumed by a single extended test.

**EXPERIMENT 3**

The results of the first two experiments, together with other work (Belmore, 1981; Erdelyi et al., 1977; Roediger & Thorpe, 1978, Experiment 2), rule out the contention that imaginal coding is a critical determinant of improved recall across repeated tests (hypermnesia). As argued in the Introduction, it seems likely that whatever variables increase retention will also increase hypermnesia, up to levels of recall that approach perfect performance. On the other hand, it may be argued that improve-
ments in recall across repeated tests, while not related specifically to imagery, may result from all sorts of beneficial encoding activities (deep, elaborate, distinctive, broad, or whatever encoding operations). It is certainly the case that in episodic free recall experiments level of performance is generally related to the nature of encoding activities performed by the subjects, so that the two are naturally confounded. The results of Experiment 1 also directly support the notion that type of encoding operation determines the level of hypermnesia obtained; semantic orienting tasks provided for greater improvements in recall across tests than did phonological or orthographic orienting tasks. Similarly, in Experiment 2 it may be assumed that subjects who studied the nonsense syllables three times had encoded them more elaborately than those given only one shot at them.

Within the domain of episodic recall there is no obvious way to disentangle the natural correlation between the nature of coding activities and level of free recall to see which determines hypermnesia. However, this is possible by turning to semantic memory tasks, such as having subjects recall repeatedly as many items as possible from categories of different size. Since the material was learned long ago, there is no necessary reason to think that coding differences underlie the differences in level of recall. However, variations in level of recall can be obtained by choosing categories with differing numbers of exemplars. Thus in Experiment 3 different groups of subjects were given three successive tests in recalling as many items as possible from categories varying in size (as determined from the Battig and Montague (1969) norms): Presidents, Birds, and Sports. We expected (a) to find hypermnesia in successive recall of categories from semantic memory, for reasons described below, and (b) that the hypermnesia would be related to level of recall, without the attendant variations in types of encoding found in episodic free recall experiments.

The finding of hypermnesia in a semantic memory task has interesting implications in its own right. Roediger and Payne (1982) contrasted two possible reasons for the occurrence of hypermnesia. One is that some underlying change occurs in the memory trace over time (consolidation) that makes information more accessible on a delayed than an immediate test. Evidence reported by Shapiro and Erdelyi (1974) can be interpreted as supporting this position. On the other hand, improved recall on later as contrasted with earlier tests may be due to
some aspect of repeated testing, such as increased time provided by successive tests. This view was supported by the Roediger and Payne (1982) study, which showed that delay of recall had no effect on recall of pictures, but that after constant delays subjects recalled the items better with increasing numbers of prior tests. Thus improvements in recall were related to repeated testing, but not to the passage of time per se. Apparently such repeated testing is crucial to obtaining hypermnesia, if for no other reason than providing additional recall time.

If hypermnesia results from repeated testing rather than consolidation, it should be obtained even with testing of non-presented material in Experiment 3. Brown (1923) has previously reported evidence suggesting hypermnesia in semantic memory retrieval, an observation confirmed by Buschke (1975) and Lazar and Buschke (1972). It is most unlikely that the underlying traces of category items would be changing over the course of the experiment in absence of the testing procedure. In addition, in Experiment 3 we can ask whether the practice involved in boosting recall is general practice in recalling items from categories or is specific to the particular categories tested. To this end we employed a control condition in which subjects recalled items from semantic memory three successive times, but in this case they recalled different categories on each test (cf. Lazar & Buschke, 1972). Thus, assuming hypermnesia were to be obtained, we can determine whether it is due to general practice in retrieving items from semantic memory, or to specific practice in retrieving a particular set of items, or to both factors.

Method

Design and subjects. Subjects were tested in either Same Category conditions or Different Category conditions. In the former, subjects were given three successive tests in recalling as many instances as possible from one category (Presidents, Birds, or Sports). In the Different Category condition subjects were given three tests, but were tested once on each of the three categories in a counterbalanced order. Sixty Purdue undergraduates participated in each condition. In the Same Category condition 20 subjects were tested with each of the three categories. Subjects served in partial fulfillment of a course requirement.

Materials and scoring. Three categories were selected from the Battig and Montague (1969) norms that provided differences in levels of recall when pretested. The categories were Presidents, Birds, and Sports. In addition, we selected a large set of items from those listed in the norms to serve as critical items. Subjects were only scored on the set of critical items with all other items counted as incorrect. There were two reasons for selecting a set of critical items on which to score subjects. First, we wanted to hold constant the scoring criteria across the three tests so that any improvement on later tests would not be due to subjects simply becoming more lax about what they considered a member of the category, e.g., citing thrush as a bird on the first test and then on later tests listing a number of different types of thrushes as separate items. This criterion problem is not entirely overcome by scoring subjects on a constant set of items, but it is preferable to the alternative of counting any response as correct. Second, by providing a fixed set of critical items we could minimize the variability that might occur from testing a few subjects with special knowledge, such as an ornithology student who might know hundreds of bird names. Thus subjects were scored on 39 Presidents (Carter was President during the experiment), 75 Birds, and 96 Sports. Obviously there is not much of a criterion problem with the category of Presidents.

Procedure. Subjects were told that they were to retrieve information from well learned categories for a long period of time. They were given a sheet with a category name at the top of the sheet and told to give
as many instances as they could think of during the 10-minute interval provided. The experimenter illustrated the procedure with reference to states of the U.S. as an example. Subjects were also told to draw a line under the last item recalled when so instructed, and to keep trying throughout the recall period.

After the first test was finished, subjects were given a second sheet and told again to recall as many instances from the specified category as possible. For subjects in the Same Category condition, the category name given was the same as on the first test, while those in the Different Category condition received a new category name on each test. Subjects were not instructed about whether the category would stay the same or change during the initial instructions, so the beginning of the second test provided the first differential treatment between conditions. The second test was conducted in the same manner as the first. After the second test subjects were given a new sheet and told that this would be their final test. In each test subjects received 10 minutes for recall.

Results and Discussion

Presented in Figure 8 are the mean number of items recalled during the three tests for subjects in the Same Category conditions. The level of recall did differ for the three categories, as expected, $F(2, 57) = 37.47, MS_e = 118.33$. More importantly, recall increased reliably across the tests, $F(2, 114) = 60.45, MS_e = 5.08$, confirming that hypermnesia can be demonstrated in a semantic memory task. Also, as in the previous two experiments, hypermnesia was related to the level of recall, since the interaction between category and tests was reliable, $F(4, 114) = 9.39, MS_e = 5.08$. As can be seen in Figure 8, increased recall across tests was greatest for sports and least for presidents, with birds falling in between.

The occurrence of hypermnesia in a semantic memory task argues strongly against the idea that the phenomenon is due to some autonomous change in the memory trace in other situations, in agreement with the findings of Roediger and Payne (1982). There also is no need to appeal to imaginal coding as producing the phenomenon in the present case. Rather, hypermnesia was shown again to be determined by the overall level of recall.

Presented in Figure 9 are the cumulative recall functions for subjects who recalled sports and presidents on the three tests. (Performance for subjects who recalled birds is quite similar to the data presented, though intermediate in value.) The advantage in recall on the second and third tests develops within the first 2–3 minutes of the recall period and then is maintained throughout. Once again, it is obvious that the hypermnesia was greater for sports than for presidents, though even in the latter case there was reliable improvement across the three tests. Comparing recall on test 3 to that on test 1 for the subjects recalling presidents, 15 out of 16 nontied subjects showed greater recall on test 3 than on test 1, $p < .001$ by a sign test. The increase between test 1 and 3 was also reliable for subjects who recalled birds and sports.

Presented in Figure 10 is the mean number of items recalled across the 30-minute period by subjects recalling the three different categories. Repetitions of
items on later tests were not counted here, so that the results in Figure 10 reflect recall of new items across the tests. Although a control condition was not included in which subjects were simply given a 30-minute period for recalling items, generalizing from the first two experiments and Experiments 1 and 2 of Roediger and Thorpe (1978), one can assume that the same pattern of cumulative recall would have been obtained. In line with earlier results (e.g., Bousfield & Sedgewick, 1944; Grunewald & Lockhead, 1980), we find recall of large categories continuing even after extended periods of time. Only subjects recalling presidents seemed to have exhausted their resources, though in fact they recalled only about half the presidents and presumably knew many others.

Another issue addressed in Experiment 3 was whether the hypothesized improvement across the three tests was due to general practice in successive recall of categories from semantic memory, or whether specific practice in recalling a particular category was necessary. Different Category subjects recalled three categories for 10 minutes each, but they recalled three different categories. If their recall improves across the three successive tests in the same manner as does that of Same Category subjects, then one could conclude that the hypermnesia reflected general practice in retrieving sets of information from semantic memory. If performance of Different Category subjects did not improve as did that of Same Category subjects, then specific practice (or extra time) in retrieving categories would be implicated. Combining across the three categories for the Same Category subjects, mean recall across the three tests was 25.50, 28.17, and 30.00 items recalled. Comparable means for the first, second, and third tests for the Different Category subjects were 26.80, 26.65, and 28.13. There was no reliable effect of number of tests in the Different Category condition, $F(2, 171) < 1$, $MSe = 40.94$, despite the fact that performance improved slightly between the second and third tests. Of course, the effect of category was reliable, $F(2, 171) = 84.98$, $MSe = 40.94$, but there was no evidence of a category x type of test interaction, $F(4, 171) = 1.32$, $MSe = 40.94$. The most likely conclusion is that
performance in the Different Category condition was unaffected by the number of tests (cf. Lazar & Bushke, 1972). However, even assuming that the slight increase on the third test is a real one, the improvement across the three tests was much greater for Same Category test conditions. Taking the difference between the third test and the first test as an index of the improvement, subjects in the Same Category conditions recalled about 4.50 more words on test 3 while Different Category subjects recalled 1.33 words more. Thus it appears that the greater part of the improvement in the Same Category condition across tests was due to specific practice or extra time in recalling particular categories, rather than general practice in recalling information from semantic memory.

General Discussion

The main findings of the present research were that (a) hypermnesia was found with words encoded in different ways, with nonsense syllables, and with instances of semantic categories, (b) level of recall was correlated with hypermnesia in each case, and (c) in the experiments with words and nonsense syllables people recalled no more items when given three 7-minute tests than when given a single 21-minute test. This last finding confirms observations of Roediger and Thorpe (1978) and supports the notion that the improved recall across repeated tests results from providing subjects with extended recall time.

The two goals of the present research were to determine whether or not imagery was a critical factor in producing hypermnesia, and whether hypermnesia might be related to the level of recall in experimental situations. Regarding the first goal, it seems safe to conclude on the basis of this evidence and that of others (Belmore, 1981) that hypermnesia does not depend on an imaginal code. The very concept of imaginal codes has come under searching examination in recent years, with some arguing that even pictorial stimuli may be represented in an abstract, propositional code (e.g., Anderson, 1978). However, accepting the assumption that pictures and words presented with imagery instructions are coded in terms of a qualitatively distinct imaginal format (Paivio, 1971), use of such a code was discouraged in the conditions of the present experiments. Hypermnesia was found with words following phonemic and semantic orienting tasks, for nonsense syllables presented three times, and for items recalled from semantic categories (presidents, birds, sports). Although it is possible to concoct a story of how an imaginal code may possibly underlie recall in one or two of these situations (for example, recall of presidents), the more parsimonious conclusion is that hypermnesia can be produced without an imaginal code. Invoking imagery to explain the increases in recall found in the current experiments and those of Belmore (1981, Experiments 1 and 2) would stretch the concept so as to make it virtually meaningless.

With regard to the second goal, the relation between recall level and hypermnesia, the results are also clear, at least from the present research: hypermnesia was related to level of recall in all three experiments. In each case a reliable interaction was obtained between level of recall and improvements in recall across the three tests, in line with the reasoning in the Introduction. The contention is that hypermnesia is predictable from asymptotic levels of recall and the fact that the asymptote and rate of approaching it are negatively correlated.

The argument can be illustrated again briefly with regard to Experiment 3, though the same point can be made for the data from all three experiments. An examination of Figure 10 shows that recall of presidents is closer to its asymptotic level after 10 minutes (the end of the first test) than is recall of birds, which in turn is closer to asymptote after 10 minutes than is recall of sports. In fact, after 10 minutes subjects recalling presidents recalled 88% of the total...
number of presidents they were to recall, while the comparable figures for subjects recalling birds and sports were 79% and 69%, respectively. Thus in the cases of poorer performance, subjects will have come closer to exhausting recall during the first test and thus will have less opportunity to exhibit improvements on later tests. Of course, if several short tests (2–3 minutes) were used for presidents, so that recall was not near the asymptote after the first test, greater increases across tests (hypermnesia) might be expected.

This analysis is, of course, merely descriptive in that it does not explain what produces better recall in some situations than in others, why asymptotic levels of recall and rates of approaching these levels are negatively correlated, and why subjects cannot free recall as much as they can be shown to know about the material when tested in other ways, such as cued recall. Nonetheless, the descriptive hypothesis that hypermnesia is related to level of recall may be tentatively advanced, even if other, more fundamental questions, remain unanswered.

This hypothesis must remain tentative because the evidence to date does not entirely support it. As discussed previously, several earlier studies have revealed a correlation between level of recall and hypermnesia (e.g., Belmore, 1981, Experiments 1 and 2; Erdelyi & Becker, 1974; Erdelyi et al., 1976; Roediger & Thorpe, 1978). Also Paris (1978) found better performance by sixth graders than second graders in recall of a categorized list across three tests, and reported a reliable interaction such that hypermnesia was found only for sixth graders. However, clear failures to find such outcomes also exist. Yarmey (1976) presented subjects pictures, concrete nouns, or abstract nouns and tested them three times. He obtained hypermnesia in recall of pictures, but not abstract or concrete nouns, despite the fact that there was a substantial difference in the level of word recall favoring the concrete nouns. (Popkin and Small (1979) have reported hypermnesia for concrete but not abstract words under imagery instructions, and in this instance hypermnesia was correlated with level of recall.) Another clear failure to find hypermnesia related to level of recall was reported by Madigan and Lawrence (1980, Experiment 1), who presented subjects with 25 photographs or line drawings of objects, or words referring to them. Although photos were better recalled than line drawings, which were in turn better recalled than words, there was no interaction between recall level and hypermnesia. In fact, Madigan and Lawrence (1980, Experiment 1) did not find hypermnesia for line drawings, which is the usual stimulus material in the “picture” presentations of other studies (e.g., Erdelyi & Becker, 1974). The reasons for these and other (e.g., Belmore, 1981, Experiments 3 and 4; Erdelyi et al., 1977; Madigan 1976) inconsistent findings regarding hypermnesia and recall level are unclear, but at least they suggest that the effect may not be entirely accounted for in terms of the single factor of recall level.

Turning to a theoretical explication of hypermnesia, Erdelyi and his colleagues have focused on explaining why recall improves across successive tests in their experiments (e.g., Erdelyi et al., 1976; Erdelyi & Kleinbard, 1978), whereas many other studies have shown forgetting rather than improvements with delays since presentation. They have referred to the phenomenon of hypermnesia as “negative forgetting” (Erdelyi et al., 1976) or “unforgetting” (Erdelyi & Stein, 1981). The present experiments and the previous ones in this series (Roediger & Payne, 1982; Roediger & Thorpe, 1978) lead us to conceive the problem in a different way. Unlike forgetting studies, the hypermnesia experiment employs multiple tests of the same information. The improvements in recall are due to the cumulative effects of testing (Roediger & Payne, 1982), and increases on later tests may be due to their providing
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subjects additional recall time (Roediger & Thorpe, 1978). If hypermnesia is conceived as improved recall with extended recall time, as the results of Experiment 1 and 2 and those of Roediger and Thorpe (1978) would lead us to conclude, then virtually any theory of recall could account for the effect. Whatever processes are postulated to produce recall in the first place can simply be assumed to continue with consistently diminishing returns.

The interesting and surprising result from the hypermnesia research, by this view, is the fact that people will continue to free recall items for so long when given extended time and motivation to keep trying. The emphasis should perhaps be shifted from studying improvements of entire lists over successive tests to the increasing recall of individual items over time. In all studies reporting cumulative recall, people have been found to recall new items on later tests that were not recalled on earlier ones. That is true when either pictures or words are the studied materials, and even in cases in which hypermnesia (defined as improved recall of the entire set of material over tests) was not found (e.g., Tulving, 1967; Bermore, 1981, Experiment 3). The most striking report to date is that of Erdelyi and Kleinbard (1978), who found steady recovery of pictures and words over the period of a week when people (albeit, only three) were tested three times a day. They reported hypermnesia for pictures but not words, which they took to be the fact of theoretical interest. However, even for words there was a great amount of recovery of individual items (their Figure 4); subjects recalled about 25 of the 60 words on the first test, and then recalled about 15 of the remaining 35 at some point during the next week. The lack of hypermnesia for words was due to offsetting intertest forgetting, but the interesting fact remains that strong item recoveries occur for words as well as pictures. The recoveries are stronger for pictures than words in the Erdelyi and Kleinbard (1978) studies and elsewhere, but the important theoretical issue is to explain why subjects keep recovering items—words or pictures—over such long periods.

Roediger and Thorpe (1978) sought an explanation in terms of subjective retrieval cues. Since many studies have shown that presentation of overt retrieval cues can greatly increase recall when free recall attempts have failed (e.g., Tulving & Pearlstone, 1966), perhaps it is the case that increments in recall with long tests result from subjects cuing themselves in some way. The underlying assumption is that all recall is in response to cues, whether they be overt cues as in the cases of recognition and cued recall or the invisible cues of free recall in the subject's mind (Tulving, 1974). This speculative notion receives some weak support from the introspections of Erdelyi and Kleinbard's (1978) subjects, whose recall improved greatly across days. Subjects reported that one frequent source of additional recall was seeing a list object in their environment during the day and then reporting it on the next test. Subjects in the more typical situation may similarly retrieve items, but through self-generated rather than overtly observed cues.

These speculations regarding hypermnesia in terms of subjective retrieval cues are admittedly difficult to put to empirical test. However, such ideas may be objectified somewhat through Raaijmakers and Shiffrin's (1980) SAM model of probabilistic memory search. Although a thorough discussion of this complex model is outside the scope of this paper, the model does simulate well the basic findings of hypermnesia experiments. The model has some ten parameters, but only two are responsible for hypermnesia. These are the processes of incrementing and of fluctuation in the cue set. Incrementing refers to a process of increased strength that is postulated to accrue to the traces of items when they are recalled. Thus already recalled items will tend to be well recalled on future attempts, a fact in agreement with a good deal of data. (Others have also mentioned
this strengthening aspect of recall as potentially important to hypermnnesia, e.g., Erdeyi and Becker (1974). The second factor, fluctuation of the cue set, refers to a process similar to the notion of subjective retrieval cues advanced above. Recall within the model is cue dependent and guided by items in the cue set, which may be thought of as those items in the retrieval environment at a particular point in time. Within SAM, the cue set for free recall may contain contextual information, information about category relations in the to-be-remembered set, or, most importantly, information about previously retrieved items. The cue set is constantly changing as a person recalls information, and thus new information may be recalled in response to these hidden cue changes as subjects expend additional time and effort on recall. In simulations, changes in either the incrementing or cue set parameters is sufficient to simulate the basic data, but elimination of both parameters from the model causes it to fail. Although these ideas are in general accord with the basic phenomena of hypermnnesia, they are probably not demanded by existing data. The model can also account for hypermnnesia being related to level of recall, but only by ad hoc changes of parameter values. Nevertheless, the formalization of the incrementing and subjective retrieval cue notions within the model may produce new ways to test these ideas.

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