Surface Structure and the Spacing Effect

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Abstract

Deficient processing theories of the spacing effect attribute poor recall of massed-repeated items to a failure to process one of the presentations fully. An implication of this approach is that anything that increases the probability that a repetition will receive full processing, or conversely, decreases the probability that the item will be recognized as a repetition, should improve memorability of the item. The present set of experiments tested this prediction by manipulating the surface structure of repeated sentences. On the basis of previous research, it was assumed that memory for surface structure of sentences decays rapidly, and hence can contribute to initial identification of repetitions only at short spacings. Since this manipulation should have hindered recognition of repetitions as repetitions, it was expected to induce full processing of massed repetitions, and thus facilitate recall of these items. This prediction was supported. When sentences were repeated verbatim (Exp. 1) or by the same speaker (Exp. 2), the typical spacing effect obtained. However, when the surface structure or speaker changed at time of repetition, massed repetitions were recalled nearly as well (Exp. 1) or as well (Exp. 2) as their spaced counterparts.

SURFACE STRUCTURE AND THE SPACING EFFECT

Although one of the best known and most researched memory phenomenon, the spacing effect has yet to be satisfactorily explained. Recent explanatory attempts have fallen into two classes. The first class includes those explanations that attribute the spacing effect to increasing independence of encoding events with increasing intervals between repetitions. The best known and widely studied of these is the encoding variability hypothesis, which attributes higher recall of spaced repetitions to a greater likelihood that a repetition will be encoded in a different subjective context at longer intervals than at shorter ones. The greater the number of retrieval routes to or encoding contexts for a given item, the greater the probability that the item will be retrieved. However plausible, this class of theories has not fared well empirically. Ross and Landauer (1978), for example, pointed out that theories in this class also predict that spacing should improve the probability of remembering at least one of two different items each studied once, a prediction not upheld by their data. Postman and Knecht (1983) tested the encoding variability hypothesis by systematically increasing the number of explicit contexts in which a to-be-remembered item was embedded. They found recall levels to be <u>lower</u> following variable than after constant encoding, leading them to conclude that multiple retrieval routes was not a sufficient condition for improved recall.

The second class of spacing-effect theories includes those that appeal to deficiency or attentuation of processing as a consequence of massing items. These theories postulate that massed repetitions receive less processing than their spaced counterparts, and that recall is a function of the amount processing an item receives. The mechanisms purported to be responsible for variations in processing are several. The robustness of the phenomenon has prompted some theorists to implicate hard-wired, neurological mechanisms, such as consolidation and habituation, as its basis (Cornell, 1980; Hintzman, 1974). Consolidation theory holds that consolidation of the second massed presentation interferes with consolidation of the first presentation, while habituation theory posits that encoding of the first presentation temporarily habituates encoding processes until a sufficient recovery period transpires. While attractive, these theories have received at best equivocal empirical support (see Hintzman, 1974 for a review). Moreover, recent evidence indicates that the spacing effect in recall memory is correlated with development, thereby introducing the awkward constraint that such neurological mechanisms must emerge with maturation, rather than being present at birth (Toppino & DiGeorge, 1983).

Other deficient processing accounts hold that subjects adopt a voluntary strategy of not attending to or processing fully massed repetitions (Rundus, 1971; Shaughnessy, Zimmerman, & Underwood, 1972; Underwood, 1969; Waugh, 1970). However, manipulations that should induce subjects to attend to massed repetitions have failed to attentuate the spacing effect (e.g., Hintzman, Summers, Eki, & Moore, 1975).

Recently, it has been suggested that accessibility of previous encodings may underlie the spacing effect (Cuddy & Jacoby, 1982; Jacoby, 1978; Rose, 1980; Rose & Rowe, 1976). The idea is that, when an item is repeated, an attempt is made to retrieve the previous encoding of that item. The accessibility of the item will vary directly with spacing between repetitions, and the less accessible an item's encoding is, the greater the likelihood that it will enjoy reinstatement of full encoding processes.

Direct support for this account has been obtained from psychophysiological response data taken during processing of items repeated at varying intervals (Magliero, 1983; Silverstein, 1977). For example, Magliero found that processing of items repeated at long intervals produced greater pupil dilation than processing of items repeated at short intervals, pupil dilation being an indicator of increased processing effort or memory load (Kahneman & Beatty, 1966).

An implication of the accessibility hypothesis is that anything that increases the probability of full encoding processes when an item is repeated should improve recall. Spacing of items is one way to increase this probability, since forgetting or fading of memory traces is greater over longer intervals. Jacoby (1978) and Cuddy and Jacoby (1982) manipulated other factors such as ease of encoding (via a problem-solving procedure), similarity of intervening material and cue effectiveness during learning, and found conditions less conducive to retrieving prior encodings of items to produce higher subsequent recall of those items. Moreover, the spacing effect was significantly attentuated under these conditions (Cuddy & Jacoby--Experiments 2 and 3). Thus, when full processing of repeated items was induced by rendering original encodings more difficult to retrieve, massed repetitions were recalled nearly as well as spaced repetitions.

While results like these are consistent with the accessibility account of spacing effects, they are not without criticism. Because subjects in these studies were required to perform extraordinary processing of repetitions (e.g., problem-solving), the relevance of these results to spacing effects found in typical list-learning studies has been questioned (Glenberg & Smith, 1981). What is required is an attenuation of spacing effects under conditions that strongly resemble typical list-learning conditions, but induce full processing of massed repetitions. This is no small task, since the work of Shaughnessy et. al. (1972) suggests that manipulating subjects' intention to encode is not sufficient to ensure full processing of critical items.

The present study addresses this issue by capitalizing on the numerous representational levels attributed to complex stimuli such as sentences. Like other linguistic units, recall of sentences shows the typical spacing effect, that is, repeated sentences tend to be better recalled if the two occurrences are separated by other sentences than if they are not (Rothkopf & Coke, 1963; Underwood, 1970). Unlike other units, however, information contained in a sentence is generally believed to be of at least two types, surface information (e.g., wording, modality, etc.) and semantic information (i.e., the sentence's meaning). Memory for these two types of information has been shown to be independent of one another, requiring separate memory representations (Begg, 1971; Kintsch, 1975), and suffering different rates of decay (Anderson & Paulson, 1977; Garrod & Trabasso, 1973; Jarvella, 1971, 1973; Sachs, 1967, Wright, 1969). Memory for surface information generally tends to be more volatile than memory for meaning. For example, Jarvella (1971) required subjects to repeat clauses of sentences that were read to them, and found that the intervention of a single clause between presentation and recall was sufficient to significantly decrease memory for surface information. Similar results have been obtained in sentence verification tasks, where savings in response latencies due to verbatim repetition of sentences disappears with the intervention of a single sentence between repetitions (Anderson & Paulson, 1977); Garrod & Trabasso, 1973).

Since the evidence suggests that only an abstract gist representation is likely to be present after the intervention of a single sentence, one would expect little difference in the memorability of sentences repeated verbatim as opposed to those repeated with changes in surface structure after a lag of one intervening item. Moreover, these items should exhibit high retention levels since they are more likely to enjoy a reinstatement of full encoding processes having suffered a delay in repetition. Massed repetitions, however, present a very different picture. Since an item's surface structure is highly likely to be present in memory when a massed repetition of that item occurs, it should contribute to the recognition of that item as a repetition, and hence facilitate retrieval of the item's prior encoding. Changing the item's surface structure, however, should hinder recognition of the item as a repetition. As a result, full encoding processes should be initiated on the item. The result of that processing should, however, yield the same gist representation. And since only this type of representation is likely to be present in memory at time of recall, the additional processing such items received should benefit recall.

The purpose of the following experiments was to test this prediction. Lists of sentences were presented to subjects in which certain items were repeated. Repetitions occurred at different lags, and the surface structure of the sentences was either repeated exactly or changed while leaving meaning intact. In Experiment 1, the wording of visually presented sentences was changed during some of the repetitions, while in Experiment 2, the speaker of aurally presented sentences sometimes changed. Both of the manipulations were expected to induce full processing of the repeated items, even at massed presentations, since such changes were expected to hinder the recognition of repetitions as repetitions. However, the final product of comprehension processes were expected to yield equivalent representations of the repeated items since the meanings of the items did not change. As a result, sentences with a change in surface structure at time of repetition were expected to be given full encoding processes regardless of the lag at which they were repeated; sentences whose surface structure remained unchanged at time of repetition, however, were expected to be given full encodings only when a lag had transpired that was sufficient to allow individuating sentence characteristics such as surface structure to fade, and hence hinder repetition recognition. As past research suggested, a single intervening item was expected to constitute a sufficient lag.

EXPERIMENT 1

In Experiment 1, sentences were repeated verbatim or with meaning-preserving changes in their wording at each of four lags. It was hypothesized that recall of massed repetitions would benefit from changes in surface form, since these items would not be recognized as repetitions until they had undergone substantial processing for meaning. The benefits of full processing was expected to appear in higher recall probability of these items when compared to recall of verbatim massed repetitions.

Method

Subjects. Sixty-four students enrolled in Introductory Psychology courses at the University of Colorado-Boulder served as subjects in the experiment as a partial requirement for course credit.

Materials and Design. Forty sentences chosen from a variety of sources and representing a variety of semantic contents were chosen as stimuli. The forty sentences were divided into two lists. Each list contained two once-presented sentences, eight twice-presented sentences, a primacy buffer (5 sentences), and a recency buffer (5 sentences). The middle part of the list was divided into two halves; within each half one position was reserved for the second occurrence of a sentence at each of four lags (0, 1, 3, and 8 intervening sentences), and one position was reserved for a once-presented sentence. Two lags in each half were further reserved for a verbatim repetition, and two for a gist repetition such that across the two halves all four lags received both a verbatim and gist repetition. A second list version was also constructed such that all verbatim repetition positions in the first version now became gist repetition positions and vice versa. Thus, any differences in recall that may have been due to more favorable positions within the list were equally distributed across the verbatim and gist repetition conditions. Finally, to control for differences in memorability among sentences, eight sentence assignment orders was used, ensuring that each sentence was tested in each repetition-type condition at each lag. Each assignment order was presented to two subjects. All subjects saw both lists, list presentation order was counterbalanced between subjects, and list version served as a between-subjects variable.

Procedure. Presentation of stimuli was controlled by a PDP-11 minicomputer. Sentences were presented on a CRT screen at a 4 sec. rate. Subjects were run in groups of two working at independent stations. They were instructed simply to read each sentence as it appeared on the screen. They were told that the lists would contain repetitions, and that the wording of some of the repetitions would change. They were also informed of the recall tests that followed the presentation of each list. Subjects were given as much time as they needed to complete their recall following each list presentation.

Results and Discussion

A sentence was scored as correctly recalled if its gist was correctly reproduced. For example, if the actual sentence seen was, "It was an hour before breakfast and the house was silent", then the following would all count as correct reproductions: "There was still an hour before breakfast, and the house was quiet."; "It was an hour before breakfast, and everything at home was quiet."; "The house was silent in the hour before breakfast". The following examples were not treated as correct reproductions: "Things were quiet while we ate breakfast"; "It was early in the morning, and everybody was still asleep."; "When I woke up before breakfast, everything was silent." The sense of the major part of each clause--"an hour before breakfast" and "the house was silent"--had to be present in the reproduction in order for it to be treated as a correct reproduction of the sentence. The mean number of sentences correctly recalled is presented in Table 1.

An analysis of variance performed on the number of sentences correctly recalled included as variables: repetition type (Verbatim and Gist), Lag (0, 1, 3, and 8 intervening sentences), presentation order (List A First or Second), presentation version (Version 1 or 2), and sentence presentation order (Orders 1 though 8), with repeated measures on the first two variables. Significant interactions were further analyzed via simple effects tests. Significant simple main effects involving more than one mean were further analyzed using Tukey's HSD test for comparisons among pairs of means.

The main effect of Lag was significant, $\underline{F}(3,96) = 21.13$, $MS\underline{e} = .448$, $\underline{p} < .001$, as was the main effect of Repetition Type, $\underline{F}(1,32) = 15.36$, $MS\underline{e} = .3438$, $p < .001$. More importantly, included in the significant results was the Repetition Type X Lag interaction, $\underline{F}(3,96) = 3.73$, $MS\underline{e} = .412$, $\underline{p} < .025$. Recall of verbatim repetitions showed a clear spacing effect, $\underline{F}(3,192) = 19.79$, $MS\underline{e} = .429$, $\underline{p} < .01$. Recall of massed repetitions was statistically inferior to recall of all spaced repetitions. (The critical range for Tukey's HSD test of pariwise comparisons was .301; comparison of recall of massed repetitions and each spaced repetition yielded differences of .641, .829, and .757 for lags 1, 3, and 8, respectively.)

Recall of gist repetitions also exhibited an effect of spacing, albeit in an attenuated form, $\underline{F}(3,192) = 5.84$, $MS\underline{e} = .429$, $\underline{p} < .01$. Massed repetitions were found to be recalled less often than repetitions at lags 1 and 8, but not at lag 3. (The differences between mean recall of massed repetitions and each spaced repetition were .375, .296, and .453, for lags 1, 3, and 8, respectively.) However, recall of massed gist repetitions was clearly superior to that of verbatim massed repetitions, $\underline{F}(1,128) = 16.71$, $MS\underline{e} = .394$, $\underline{p} < .001$, while recall of the two types of repetitions was equivalent at all other lags (all $\underline{F}$s < 1). These results indicate a clear attenuation of the spacing effect when sentences are repeated in gist only form. Moreover, they are consistent with the hypothesis that changes in surface form trigger full processing activities of items so changed, thereby enhancing their memorability.

EXPERIMENT 2

The results of Experiment 1 were consistent with deficient-processing explanations of the spacing effect. However, one argument that could be levelled against this interpretation is that changing the wording of a sentence changes the item itself. A sentence comprises both wording and meaning; a sentence whose wording is changed is simply not the same sentence, and it is therefore not clear in what sense a gist-only repetition counts as a true repetition. However, there are other forms of surface structure that may be changed that allow wording and meaning to remain untouched. For example, Geiselman and Bellezza (1976, 1977) found that subjects could reliably identify which of two speakers had spoken a given sentence from a list under both intentional and incidental learning conditions. They interpreted these results to mean that voice or speaker information is processed during sentence comprehension without requiring an allocation of processing resources beyond those used to encode linguistic aspects of the sentence. Since speaker information appears to be reliably encoded during comprehension, identification of an item as a repetition should be hampered if the speaker of the item changes at time of repetition. Therefore, it is more likely that an item changed in this way will enjoy fuller processing than an item whose speaker does not change at time of repetition, and reinstatement of comprehension processes should benefit recall of items of the former type.

The purpose of Experiment 2 was to test this prediction. Sentences were recorded on tape and presented to subjects auditorily. When a sentence was repeated, the speaker (female or male) of the sentence either changed (female to male or vice versa) or remained the same. As in Experiment 1, it was reasoned that if deficient processing of massed items does underlie the spacing effect, and if surface structure participates in the determination of item identity, and hence, determines the degree of processing a given item should receive, then retention of massed items whose surface structure is changed when repeated should exceed that of massed items that do not change. Moreover, the spacing effect itself should be attentuated by this manipulation. In effect, then, the retention curves of Experiment 2 were expected to approximate those of Experiment 1.

Method

Subjects. Sixty-four subjects enrolled in Introductory Psychology courses at the University of Colorado-Boulder served as subjects as a partial requirement for course credit. Thirty-two subjects were female and thirty-two were male.

Materials and Procedure. The materials used were the same as in Experiment 1. The two lists of sentences were combined into one, however, because pilot work indicated ceiling effects in recall of the individual lists when they were presented to subjects auditorily as opposed to visually. Thirty-two tapes were constructed, two for each of the sixteen presentation orders described in Experiment 1. For half of these tapes, the main speaker of the sentences was male, and for the remaining half the main speaker was female. Sentences were repeated either by the male speaker or by the female speaker. The difference in speakers was clearly discernible on the tapes. Subjects therefore heard thirty-two sentences in all, five primacy buffer sentences, five recency buffer sentences, four once-presented sentences, two filler sentences, and sixteen twice-presented sentences. Of the twice-presented sentences, four occurred at each of the four lags (0, 1, 3, and 8 intervening sentences). Of the four in each lag, two were repeated by the same speaker, and two were repeated by a different speaker. The various lag and repetition type conditions were equally distributed along each quarter of the list across subjects.

Subjects were run in groups of four, and were instructed as in Experiment 1. The sentences were presented on individual cassette tape recorders, and subjects listened to them over headphones. They were instructed to remove their headphones when they no longer heard sentences being presented. At that time they were given sheets of paper on which to write down the sentences they remembered.

Results and Discussion

Recall was scored as in Experiment 1; the mean numbers of correctly recalled sentences are presented in Table 2. An analysis of variance performed on the number of sentences correctly recalled included as variables: Sex of main speaker on the tape (Male or Female), sex of subject (Male or Female), list presentation version (Version 1 or 2), repetition type (Same and Different Speaker), and lag (0, 1, 3, and 8 intervening sentences), with repeated measures on the last two variables. A few of the interactions among control variables were significant, but because they were not interesting in any theoretical sense, they will not be reported here. As in Experiment 1, significant interactions were followed by simple effects tests. Significant simple main effects involving more than one mean were compared using Tukey's HSD test for comparisons among means.

The main effect of lag was significant, $F(3,168) = 6.897$ $MSe = .379$, $p < .001$, as was the main effect of repetition type, $F(1,56) = 10.154$, $MSe = .339$, $p < .001$. More importantly, however, the interaction of lag and repetition type was also significant, $F(3,168) = 2.69$, $MSe = .452$, $p < .05$. Simple effects tests were conducted on this interaction, and the results follow:

(1) When sentences were repeated by the same speaker, the typical spacing effect was found, $F(3,336) = 8.159$, $MSe = .4155$, $p < .01$. More particularly, recall of massed repetitions was found to be significantly lower than recall of sentences at each of the other three lag conditions; recall levels among the three distributed conditions were equivalent. (The required difference among the means using Tukey's test for paired comparisons was .2965. The

obtained differences were as follows: 0 vs. 1 = .375; 0 vs. 3 = .500; 0 vs. 8 = .469; 1 vs. 3 = .125; 1 vs. 8 = .094; 3 vs. 8 = .031.) These results therefore mirrored those of verbatim repetitions in Experiment 1.

(2) When sentences were repeated by a different speaker, however, the spacing effect was obliterated, $\underline{F}(3,336) = 1.06$, $MS\underline{e} = .4155$, $\underline{p} > .05$. In fact the levels of performance for all lags in this condition were nearly equivalent.

(3) Although sentences repeated by a different speaker tended to be better recalled than those repeated by the same speaker at each lag, the difference was significant only for massed repetitions (Same vs. Different Speaker at lag 0, $\underline{F}(1,224) = 7.548$, $MS\underline{e} = .870$, $\underline{p} < .01$; $\underline{F}$s at all other lags < 1.) Thus, massed repetitions benefitted most from a change in this type of surface structure.

GENERAL DISCUSSION

Deficient-processing accounts of the spacing effect attribute poor recall of massed repetitions to attenuation of processing of one of the presentations. A recent formulation (Cuddy & Jacoby, 1978) of the deficient-processing approach suggests that the likelihood of full processing for an item depends on the accessibility of previous encodings of the repeated item. If the previous encoding is readily accessible, as is the case in massed repetitions, full processing of the repetition is by-passed in favor of simple retrieval of the previous encoding. If the previous encoding is not readily accessible, as is the case in spaced repetitions, the repetition is fully processed and hence is more readily recalled.

An implication of this approach is that anything that increases the probability of a repetition receiving full processing, or conversely, decreases the probability of the item being recognized as a repetition, should improve memorability of the item. The present set of experiments tested this prediction by manipulating the surface structure of repeated sentences. On the basis of previous research, it was assumed that memory for surface structure of sentences decays rapidly, and hence can contribute to initial identification of repetitions only at short spacings. Since this manipulation should have hindered recognition of repetitions as repetitions, it was expected to induce full processing of massed repetitions, and thus facilitate recall of these items. This prediction was supported. When sentences were repeated verbatim (Exp. 1) or by the same speaker (Exp. 2), the typical spacing effect obtained. However, when the surface structure or speaker changed at time of repetition, massed repetitions were recalled nearly as well (Exp. 1) or as well (Exp. 2) as their spaced counterparts.

We claim that these results support a deficient-processing account of the spacing effect. From an encoding variability standpoint, however, one might argue that a change in surface structure represents a new context within which the gist of the sentence is embedded. The usefulness of this context at time of retrieval is doubtful, however; memory for surface structure, while often above chance (Anderson & Paulson, 1977; Sachs, 1967), is quite poor relative to memory for gist. Indeed, memory for surface structure approximates memory for gist only when it is imbued with important pragmatic information (Keenan, MacWhinney, & Mahew, 1977; Kintsch & Bates, 1977). It is therefore unlikely that surface structure can serve as a useful retrieval cue or path in recalling an item.

Finally, the implication that hindering recognition of repetitions should improve recall appears at odds with the observation that the spacing effect is found only for repetitions that are recognized at such (Crowder, 1976). Indeed, this contradiction has been cited at a criticism of studies employing homographs to test the encoding variability hypothesis (Hintzman, 1976; MacFarland, Rodes, & Frey, 1979). In these studies, two different senses or gists of the homograph are biased by presentation contexts, with the result that the spacing effect is attenuated (Madigan 1969). Hence, this manipulation depends on reduced recognizability of repetitions. Two points can be made here concerning these criticisms. First, a change in surface structure is presumed initially to hinder recognition of repetitions, but is not presumed to prevent such recognition. After processing of the item, it is assumed that subjects readily recognized having seen a sentence with the same meaning before. In fact, several subjects spontaneously indicated on their protocols that certain sentences changed wording at time of repetition.

Second, the result of homograph processing is diametrically opposed to surface structure processing. Homographs are senses or gists which share nothing more than a surface structure, i.e., a particular organization of letters. In the manipulation employed here, stiumli possess two surface structures but share a singe sense or gist. Since it is the sense or gist that is the psychologically relevant and more durable encoding, it is this sense or gist that must be repeated in order for the repetition to count as a repetition. Homograph manipulations fail in this capacity; the present manipulations do not.

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Table 1

Proportion of Sentences Whose Gist As Accurately Recalled,

Experiment 1

	Number of Intervening Sentences			
Repetition type	0	1	3	8
Verbatim	.179	.500	.594	.558
Gist	.406	.594	.554	.633

Table 2

Proportion of Sentences Whose Gist As Accurately Recalled,

Experiment 2

	Number of Intervening Sentences			
Repetition type	0	1	3	8
Same Speaker	.140	.328	.390	.375
Different Speaker	.367	.351	.446	.398