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CONTROL AND ORGANIZATION IN PRIMARY MEMORY:
EVIDENCE FROM SUFFIX EFFECTS

by

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A THESIS SUBMITTED
IN PARTIAL FULFILLMENT OF THE
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ABSTRACT

Control and Organization in Primary Memory:
Evidence from Suffix Effects

by

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This investigation is concerned with the control and organization of the "psychological present," or primary memory, and specifically with the implications of such control and organization for the suffix effect. The suffix effect arises when a nominally irrelevant speech item, or "suffix," is appended to a spoken sequence of items, and it consists of an impairment in the recall of the most recent items in the sequence, especially the last item (e.g., Crowder, 1967; Dallett, 1965). The dominant explanation of the suffix effect has been in terms of "bottom-up" masking in general (e.g., Nairne, 1990) and precategorical acoustic masking in particular (e.g., Crowder & Morton, 1969; Crowder, 1978, 1983; Greene & Crowder, 1984). The current version of this explanation is "two-component" theory, wherein the precategorical masking explanation is confined to the terminal component of the suffix effect (i.e., at the last position of the sequence), with the preterminal component being open to influences of top-down or conceptually-based interpretation and strategy (see Greene, 1992 for a review). Reported here are 12 experiments, each
of which provides evidence inconsistent with two-component theory. Experiments 1-4 failed to replicate the principal findings proffered in support of the theory; Experiments 5-11 extended some of the findings of the first four experiments by showing additional evidence of postcategorical influences on the terminal suffix effect; and Experiment 12 demonstrated a suffix effect with static visual presentation. These findings, and indeed those in the suffix effect literature in general, are interpreted along the lines of the now largely ignored perceptual grouping account proposed by Kahneman (1973; Kahneman & Henik, 1981).
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Control and Organization in Primary Memory: Evidence from Suffix Effects

The broad issue addressed in this dissertation is how the control of primary memory should be conceptualized. More particularly, it inquires about the extent to which primary memory is stimulus controlled as opposed to conceptually controlled. Or, in more contemporary terms, it asks how far primary memory is driven by "bottom-up" or relatively peripheral "structural" components of the information-processing system as opposed to "top-down" conceptually-based interpretations and strategies. The specific concern is with one source of evidence pertaining to this issue, namely the suffix effect.

The suffix effect, or stimulus suffix effect as it is sometimes called, is the impairment in recall caused by appending a nominally irrelevant speech item, or "suffix," to the end of the sequence (Crowder, 1967; Dallett, 1965). This impairment is always largest at the final position, but it typically occurs at each of the last three or so positions (Crowder, 1967, 1976; Crowder & Morton, 1969), and not infrequently it extends back even farther into the sequence (Engle, 1974, 1980; Greene 1992; Morton, Crowder, & Prussin, 1971; Nairne, 1990; Penney, 1979). The impairment has been found to be nearly as large as that caused by adding another to-be-remembered item to the list (e.g., Crowder, Experiment 3, 1967; Frick, 1988). The implication is that explicit instructions either to ignore the suffix or to treat it as a mere recall signal cannot be heeded. In most cases, the same item is used over and over as the suffix, and it never doubles as a to-be-remembered item. And, where suffix condition
varies between blocks of lists or even between subjects, the occurrence as well as the identity of the suffix is fully predictable. Even so, it seems that it cannot be ignored.

The suffix effect is perhaps most pronounced and has been most studied with a serial recall procedure, in which subjects attempt recall of the items in their order of presentation without backtracking (Crowder, 1971a; Crowder & Morton, 1969). A clear suffix effect occurs with this procedure regardless of whether responses are scored according to a "serial" criterion, whereby credit is given only for items recalled and positioned correctly, or a "free" criterion, whereby credit is given for all items recalled regardless of assigned position (Watkins & Todres, 1979). But the suffix effect is by no means limited to serial recall. Indeed, it is extraordinarily robust, having been demonstrated with an impressive variety of other procedures. Thus, the effect has also been obtained with (i) ordered recall (e.g., Engle, 1980, Experiment 3; Penney, 1979), wherein subjects may recall the items in any order they wish but credit is awarded only for items placed in their correct (original study) position, (ii) free recall (Engle, 1974; Penney, 1979; Roediger & Crowder, 1976), in which subjects are told they are free to recall the list items in any order they please, (iii) modified free recall such that the items can be recalled in any order except that the last three items must be recalled first (Manning & Turner, 1984), (iv) reverse recall, in which items are recalled in the reverse of their presentation order, beginning with the last item (Manning & Pacifici, 1983), (v) a running memory span procedure, in which subjects are given sequences of long but variable length, and have to recall the last, say,
eight items in their order of presentation after the sequence stops (Crowder & Morton, 1969), (vi) cued recall (Morton et al., 1971; Parkinson, 1978; Penney, 1979), in which at least one studied item is re-presented at test as a cue for recall of a specified item, such as the item that had followed the cue item at study, and (vii) recognition (Greene, 1988), in which list items have to be picked out from among items not on the list.

The suffix effect has been demonstrated with a variety of to-be-remembered stimuli, including digits (e.g., Dallett, 1965; Crowder, 1969), letters (e.g., Crowder, 1971a; O. C. Watkins & Watkins, 1980), syllables (Crowder 1971b, 1973; Darwin & Baddeley, 1974), words (e.g., Morton et al., 1971; Roediger & Crowder, 1976), and sentences (Balota, Cowan, & Engle, 1990). The effect also has been observed using nonverbal stimuli, such as musical notes and common environmental sounds (e.g., Greene & Samuel, 1986; Roberts, 1986; Rowe & Rowe, 1976). Nor is the suffix effect restricted to a certain vocabulary size. Thus, large suffix effects have been found regardless of whether each item occurs in no more than one list (e.g., Roediger & Crowder, 1976; Watkins & Todres, 1979) or in every list (e.g., Crowder, 1978; Elmes, 1974).

Traditionally, it has been concluded that the suffix effect is largely restricted to situations in which the suffix is presented within the first two seconds following the final list item (e.g., Crowder, 1976). However, when subjects are asked to perform a silent task that eliminates their ability to think about, or rehearse, the list items during the delay, suffix effects have been obtained with delays as long as 20 seconds (e.g., Watkins & Todres, 1980; Balota & Duchek,
Finally, suffix effects have been found using a variety of presentation rates (e.g., Balota & Engle, 1981; O. C. Watkins & Watkins, 1980; Penney, 1979).

Clearly, the suffix effect is extraordinarily robust, and equally clearly it has been the focus of extensive investigation (for reviews, see Greene, 1992; Neath, 1998). A satisfactory account of the suffix effect would, at the very least, facilitate the organization of a large and well-established literature. Such an account would also speak to the more general issues of control and organization in primary memory.

The first, and still the most influential, account of the suffix effect is the theory of precategorical acoustic storage, or PAS (Crowder & Morton, 1969; Crowder, 1978, 1983, 1986, 1993; Greene & Crowder, 1984a; Morton, Marcus, & Ottley, 1981). This is an information-processing theory with PAS conceived as a peripheral structure that retains speech in a sensory (echoic/acoustic), or relatively raw (precategorical), form for at least 2 seconds (see Figure 1). Specifically, "information stored precategorically is raw in the sense of not yet having made contact with S's overlearned linguistic repertoire," and "only material which has been categorized is available for rehearsal, association, or participation in such organizational strategies as may be available to S" (Crowder & Morton, 1969, p. 366). Moreover, PAS is "strictly limited in size, so that any new item would act to displace earlier items" (Crowder, 1976, p. 57). Thus, the primary distinction that this theory makes is between bottom-up precategorical information and top-down conceptually-based (categorical) information. Specifically, because
Figure 1. A conceptual model of the theory of precategorical acoustic storage.
the suffix effect is attributed to an overwriting principle that occurs in PAS and prior to categorization, it follows that the suffix effect should be susceptible to bottom-up physically-based influences but not to top-down conceptually-based influences. This fundamental proposition led to numerous predictions that were rigorously tested and supported in well known early work.

Thus, numerous experiments have yielded findings consistent with the assumption of PAS theory that the suffix effect is susceptible to physical manipulations that can be assumed to have their effect at the precategorical level. For example, the suffix effect is attenuated by changing for the suffix item both apparent spatial presentation location (Morton et al., 1971) and voice of presentation (Morton et al., 1971). Also, a nonspeech suffix (e.g., a buzzer) following a list of verbal items has no obvious effect (e.g., Morton et al., 1971; Crowder, 1972).

The theory of PAS has also received much support for its prediction that the suffix effect is immune to top-down conceptually-based influences. For example, according to the theory, suffix effects should not occur with purely visual presentation because iconic information is too brief to contribute to recall within a time frame typical of a suffix-effect procedure, so that recall of visual lists is an entirely postcategorical phenomenon. And although visual suffix effects have occassionally been reported (Frick & DeRose, 1986a, 1986b; Hitch, 1975), they have been small and have not always proven replicable (Greene, 1987; see also Engle, 1974). Additionally, because visual information and auditory information are assumed not to "meet" prior to the categorical level (Crowder, 1976, p. 59),
there should not be a typical suffix effect from a visual suffix on auditory list items or from an auditory suffix on visual list items (see Crowder & Morton, 1969; Crowder, 1976). By and large, these predictions have been confirmed (e.g., Morton & Holloway, 1970; see also Crowder 1976). Moreover, for all intents and purposes, bimodal presentation yields a pattern of results identical to that obtained with purely auditory lists (e.g., Crowder, 1970; see also Crowder, 1976; Greene & Crowder, 1984a; Greene, Elliott, & Smith, 1988; Nairne & Walters, 1983).

That a suffix is more or less as detrimental to list recall as is an additional list item (e.g., Crowder, 1967; see also Frick, 1988) is also consistent with the core assumption of PAS theory that the suffix has its effect at a stage of analysis beyond the reach of the subjects' intentions. Further, according to the theory of PAS, neither the conceptual (semantic) identity of the suffix per se nor the semantic relationship between the suffix and list items should influence the suffix effect, and both predictions have received support. Thus, the suffix effect on a list of digits is unaffected by whether the suffix is, for example, the word "zero," "rosy," "nought," "recall," "uh" or backward speech (e.g., Crowder & Raeburn, 1970; Morton et al., 1971), and the suffix effect for a list of items drawn from the same conceptual category (e.g., kitchen utensils or animals) is unaffected by whether the suffix is drawn from the same or a different category (e.g., Morton et al., 1971).

Clearly, the theory of precategorical acoustic storage has garnered a great deal of evidence in its support. But not all of the evidence has been supportive. Indeed, contrary evidence has forced
two substantial revisions (e.g., see Baddeley, 1990; 1997; Neath, 1998; Neath, Surprenant, & Crowder, 1993; for a full review see Greene, 1992).

The first revision came in response to findings that suffix effects could be obtained with motor or gesticular stimuli, including mouthed (e.g., Greene & Crowder, 1984a), lipread (e.g., Spoehr & Corin, 1978; Campbell & Dodd, 1980) and signed (e.g., Shand & Klima, 1981) words (for a review see Greene, 1992). The revision took the form of a somewhat broader or more abstract version of "sensory" storage (Crowder, 1983; 1986; Greene, 1992; Greene & Crowder, 1984a). The various types of gesticular stimulation in these studies are now believed to be inherently precategorical in nature and to produce their effects in PAS through a lifetime of precategorical association with speech sounds (for a review see Crowder, 1986; Greene, 1992; Greene & Crowder, 1984a). Consistent with this view is the finding that mouthed suffix effects are not obtained with deaf subjects (Engle, Cantor & Turner, 1989; see Greene, 1992).

It is important to note that even with this revision, PAS-type masking theories retain the strong prediction of no suffix effects with static visual stimuli. Because such stimuli are assumed to have no precategorical auditory (e.g., Crowder & Morton, 1969) or precategorical motoric (Greene & Crowder, 1984a) codes and a precategorical visual code, or icon, too brief to contribute to recall over the time course of suffix experiments, recall of visual items should be based entirely on postcategorical memory. As Crowder and Morton (1969, p. 369) put it, "if the Stimulus Suffix Effect depends upon the displacement of information in PAS . . . then with
visual stimulus presentation there should be no Stimulus Suffix Effect, because there should be no information in PAS" (Crowder & Morton, 1969, p. 369).

The second revision to PAS is the restriction of its domain to just the very last, or "terminal," item in the sequence (see Baddeley & Hull, 1979, p. 139; Balota & Engle, 1981; pp. 354, 356-357; Greenberg & Engle, 1983, p. 555; Greene, 1992, p. 27; Penney, 1985, p. 243). The "preterminal" component of the suffix effect is now generally regarded as susceptible to top-down conceptually-based influences, including rememberer strategy. Greene (1992) captured two-component theory as follows:

There is a growing consensus that suffix effects at earlier positions reflects the use of particular strategies by the subjects; these preterminal effects can be influenced quite easily by changing the strategy that a subject is following. In contrast, the suffix effect at the last position is not influenced by these strategic manipulations and thus seems to be telling us something about relatively fixed structures in human memory (p. 26).

The currency of this "two-component" theory is such that the author failed to find a single dissenting view among the many references to this theory (namely, Baddeley & Hull, 1979; Balota & Engle, 1981; Campbell, Garwood, & Rosen, 1988; Cowan, 1984; Engle, 1980; Greene, 1991, 1992; Greene & Crowder, 1988; Greene, Elliott, & Smith, 1988; Harris, 1989; LeCompte & Watkins, 1993; Miles, Westley, & Buller, 1995; Nairne, 1990; Neath, Surprenant, & Crowder, 1993; Penney, 1985, 1989; Penney & Godsall, 1993; Watkins & Sechler, 1989; see also Crowder, 1986; Greenberg & Engle, 1983;

Two-component theory can account for the vast majority of findings in the suffix literature. But not all. A review of the literature has uncovered three exceptions to the conclusion that the terminal suffix effect is strictly the result of a bottom-up overwriting principle in a peripheral information-processing structure.

The first exception is the finding that in certain instances the conceptual (semantic) relationship between the suffix and the terminal list item can indeed influence the magnitude of the terminal suffix effect. This evidence has taken two forms. First, Salter and Colley (1977) found that, relative to an unrelated suffix, a suffix that was a synonym of the terminal item attenuated the terminal suffix effect. Salter and Colley argued that this attenuation was not the result of subjects giving greater attention to the terminal item at the expense of other items because there was no compensatory impairment at the other positions. Rather, Salter and Colley concluded that the synonymous suffix acoustically impaired the terminal item but at the same time semantically enhanced it. The second form of evidence of conceptual influences on the suffix effect derives from a study by Ayers, Jonides, Reitman, Egan, and Howard (1979), in which context (instructions and non-critical suffixes) was designed to bias the interpretation of an ambiguous suffix. Specifically, an ambiguous nasal 'wah' sound was presented as a suffix. Some subjects were told that it was a plunger-muted trumpet note and were presented with other lists that concluded with suffixes that were clearly produced with musical instruments (e.g., a plucked
violin string). Other subjects were instructed that the ambiguous 'wah' suffix was a verbal utterance and were presented with other lists that concluded with clearly verbal suffixes (e.g., "pin"). Ayers et al. found that the exact same ambiguous (wah) suffix had little effect on the terminal list items when framed as nonverbal but a strong effect when framed as verbal.

Contrary to PAS theory in general and two-component theory in particular, the findings of Salter and Colley (1977) and Ayers et al. (1979) strongly imply that even the terminal suffix effect can be influenced by the semantic relation—as conceptualized by the subject—between the suffix and list items. But though the findings are clear, intuitively plausible, and replicable (see Miles et al., 1995; Neath et al., 1993, respectively), their strong implication of top-down influence has been resisted in favor of refinements to the PAS theory and its core principle of a passive bottom-up overwriting principle (Crowder, 1978, 1983, 1986, 1993; Greene, 1992; Greene & Crowder, 1984a; see also Nairne, 1990; Neath et al., 1993; Penney, 1985, 1989; Penney & Godsell, 1993). Thus, influential reviews of the suffix effect literature have tended either to discuss these top-down findings as anomalies amidst a host of findings that conform to overwriting theories (Greene, 1992; Penney, 1989), or suggest that they can be accommodated within an overwriting framework by adopting ad-hoc revisions (Nairne, 1990; Neath, 1998; Neath et al., 1993).

The second empirical problem for two-component theory is a recent demonstration of a visual suffix effect. According to two-component theory and its predecessors (Crowder, 1978, 1983;
Crowder & Morton, 1969; Greene & Crowder, 1984a; Greene, 1987, 1992; Penney, 1985, 1989; Penney & Godsell, 1993), as well as to certain other overwriting theories (e.g., Nairne, 1990), static visual information does not proceed through the same physically-sensitive structure or processes as the auditory/gesticular information, and does not survive in precategorical form long enough to play a role in most immediate memory procedures. Consistent with this prediction, Greene (1987) failed to obtain a visual suffix effect in any of seven experiments in which supraspan lists were shown both sequentially and simultaneously, with and without the requirement of subvocal articulation, and with a variety of presentation durations.

On the other hand, LeCompte and Watkins (1995, Experiment 5) reported a visual suffix effect using a procedure highly similar to that used by Greene (1987, Experiment 4), with supraspan lists in which items were shown simultaneously for 4 seconds. The one departure from Greene's Experiment 4 was that subjects subvocally mouthed "blah" throughout the study interval. (Although Greene required subvocal articulation during simultaneous visual presentation in his Experiments 6 and 7, total presentation duration in these experiments was a mere 1.2 seconds). Presumably, the subvocalization increased reliance on precategorical visual memory. LeCompte and Watkins also attenuated the effect of a compound (2-item) suffix by manipulating the font to increase the physical similarity of its constituent elements—thereby, presumably, decreasing the extent to which the compound suffix grouped with the list items. Statistical evaluation of this attenuation was made only for the lists as a whole, although a plot of recall as a function of
position (LeCompte & Watkins, Figure 5) shows clearly that, like the auditory suffix effect, the visual suffix effect was localized toward the end of the list. Overwriting theories in general (e.g., Crowder, 1978, 1983; Greene & Crowder, 1984a; also see Nairne, 1990) and two-component theory in particular (e.g. Greene, 1992; Penney, 1985, 1989; Penney & Godsell, 1993) fail to accommodate these findings.

The third difficulty for the assumption that the terminal suffix effect is strictly the product of a bottom-up overwriting principle was recently provided by this author’s (Bloom, 1997) failure to replicate the findings of Penney (1985). Working with auditory stimuli, Penney eliminated the preterminal but not the terminal suffix effect by varying list length and thereby rendering the end of the list unpredictable. Because predictability of list length can reasonably be assumed to influence such subject strategies as rehearsal and grouping or other forms of organization, this finding has been widely cited as providing central support for two-component theory. However, my findings were quite otherwise. Making list length unpredictable had no influence on the preterminal suffix effect and modestly enhanced the terminal suffix effect. I suggested that the discrepancy may have been due, in part at least, to a confound in Penney’s research between knowledge of list length during presentation and knowledge of list length during recall. I removed this confound by specifying list length at the time of test regardless of whether list length was known at study.

In summary, two-component theory postulates a qualitative distinction between memory for the terminal item of a short, just-
spoken sequence of items and memory for the preceding items: the 
terminal suffix effect is assumed to be affected only by bottom-up 
overwriting within a relatively peripheral structure of an 
information-processing system, whereas the preterminal suffix effect 
is assumed to be readily influenced by top-down conceptually-based 
factors including the subjects' interpretations and strategies. The 
theory's success with the vast majority of the findings in the suffix 
literature does not seem to have been noticeably compromised by 
contrary evidence. The research reported here expands this contrary 
evidence.

The Present Investigation

The research to be presented here takes the form of 12 
experiments that undermine the notion of a qualitative distinction 
between the terminal and preterminal suffix effects, mostly by 
amplifying the case for top-down conceptually-based influences on 
the terminal as well as the preterminal suffix effect (cf. Ayers et al. 
1979; Salter & Colley, 1977). The 12 experiments comprise three 
converging lines of inquiry.

Experiments 1 through 4 followed Bloom's (1997) line of inquiry 
by reexamining the influence of four additional top-down, 
conceptually-based variables—namely presentation rate, practice, 
suffix length, and suffix delay. Because the influence that these 
variables have been reported to have on the suffix effect constitute 
the empirical basis of two-component theory, the reports would 
seem worth checking. Experiments 5 through 11 essentially 
extended the line of inquiry initiated by Salter and Colley (1977) and 
Ayers et al. (1979). Specifically, Experiments 5 through 7 used a
novel procedure for seeking further evidence that the terminal suffix
effect is influenced by the subjects' conception of the (semantic)
relationship between the suffix and terminal list item, and
Experiments 8 through 11 explored whether this relation can also
modulate the effect of suffix delay. Finally, Experiment 12 showed
that the effect of separating the suffix from the list items obtained in
the auditory modality (Experiments 4 and 8) also occurs in the visual
modality.

Overview of Experiments 1 - 4

Support for two-component theory has come in the form of
evidence that five variables dissociate a conceptually-sensitive
preterminal suffix effect from a structurally-based terminal suffix
effect. These findings have been mutually reinforcing, and it is fair
to say that two-component theory is now generally accepted.
Nevertheless, a close look at the findings left me so uneasy that I
decided to see whether I could replicate them.

Bloom (1997) has already reported certain failures to replicate
the critical dissociating effect of one of the variables, namely
predictability of list length. Bloom found that, contrary to Penney
(1985) and indeed two-component theory generally, making list
length unpredictable had no discernible influence on the preterminal
suffix effect but did modestly enhance the terminal suffix effect.
This failure of replication underscores the need to reinvestigate the
effects of the remaining four variables offered in support of two-
component theory.

Such reinvestigation is further motivated by certain
shortcomings, or points of concern, in the extant evidence. One such
shortcoming shared by most extant research is that the variables in question were manipulated either between groups of subjects or across blocks of lists within subjects. The precise form of the suffix effect in each of these experiments could therefore reflect, not just the effect of the suffix on memory for the already-presented items, but also a difference in the way the list items were studied. Even the presence or absence of a suffix is more often than not varied between groups of subjects. Perhaps, therefore, subjects in the suffix group studied in a way that would minimize disruption from the suffix, and moreover perhaps their effectiveness in this regard could have varied with the strategic variable of interest and list position. If so, the existing conclusions would not apply to two-component theory and the suffix effect in the canonical sense (e.g., Engle, 1980) of the detrimental effect of a suffix on memory for already-presented items. Thus, in all of the experiments that follow, suffix condition and other variables of interest were varied unpredictably from list to list, thereby ensuring that any observed differences were attributable to the variable of interest (the variables of exception being practice, which inherently occurs across lists or blocks of lists, and presentation rate which, whether blocked or not, is predictable as soon as the second list item is presented).

The purpose of the first four experiments of this dissertation, then, was to follow Bloom's (1997) line of inquiry by addressing these methodological issues and reinvestigating the remaining four variables that have previously shown a dissociation between preterminal and terminal positions of the suffix effect. Specifically, Experiments 1 through 4 reinvestigated whether the suffix effect
was influenced by presentation rate, practice, suffix length, and suffix delay respectively.

Experiment 1

One empirical basis for the two-component theory of the suffix effect is Balota and Engle's (1981) finding that slowing the presentation rate enhanced the preterminal component of the suffix effect but did not affect the terminal component. Because rate of item presentation can plausibly be assumed to affect subject strategy, this finding has been taken as support for two-component theory.

A troubling detail of Balota and Engle's (1981) methodology is that suffix condition was varied between subjects. The precise form of the suffix effect could therefore reflect, not just the effect of the suffix on memory for the list items, but also a difference in the way the list items were studied. The purpose of Experiment 1 was to preclude such uncertainties of interpretation by varying suffix condition unpredictably from list to list. An influence of presentation rate on the preterminal component of the suffix effect and a lack of an influence on the terminal component under these conditions would strengthen Balota and Engle's support for two-component theory.

Method

Subjects. The subjects were 32 Rice University undergraduates.

Lists. The digits 0-9 were recorded on the computer in a clear male voice, and the durations of the recordings adjusted to approximately 300 ms. A separate batch of 72 9-digit lists was formed for each subject. For each list, the digits were chosen
randomly within the constraints that no digit occurred more than once, no digit was one higher or one lower in value than an immediate neighbor, and there were no runs of more than three successive odd digits or three successive even digits. Eight lists were used for practice, leaving 64 for the experiment proper. The latter were randomly assigned to four blocks of 16--one block for the 450-ms suffix condition, one block for the 900-ms suffix condition, one block for the 450-ms no-suffix condition, and one block for the 900-ms no-suffix condition. The suffix was the word "recall" spoken in the same voice as the digits and adjusted to a duration of 300 ms. For the no-suffix condition, an unfilled pause between presentation of the final digit and the appearance of the response position markers was substituted for the suffix.

**Design.** The experiment conformed to a 2 (presentation rate) x 2 (suffix condition) x 2 (preterminal and terminal positions) design with repeated measures on all three variables. Items were presented with an onset-to-onset presentation rate of either one every 450 ms or one every 900 ms. Lists were followed either by the verbal suffix "recall" or a silent interval. Presentation rate was blocked by session half, with half of the subjects receiving the lists at the rate of one item every 450 ms in the first half of the session and one item every 900 ms in the second half, and the other half of the subjects being assigned to first the 900-ms rate and then the 450-ms rate. Lists were assigned to suffix conditions at random within the constraint that each suffix condition was represented eight times within each block of 16 lists.

**Procedure.** The subjects were tested up to four at a time.
Instructions were shown on the computers and simultaneously read aloud by the Experimenter. After practicing on four lists, the subjects proceeded at their own pace, with lists being presented from their computers via headphones. They were presented with a sequence of 68 lists, with rate of presentation being switched from one item every 450 ms to one every 900 ms or vice versa midway through the sequence. The first pair of lists within each rate (i.e., Lists 1 and 2, and Lists 35 and 36) included one in the suffix condition and one in the no-suffix condition; unbeknownst to the subjects, these four lists were treated as additional practice lists and so were not scored. Lists 1 and 35 were preceded by a message on the computer screen stating that the upcoming lists would be presented “relatively rapidly” or “relatively slowly.”

The subject initiated each trial by clicking a “start” button. After a 500-ms delay, the consonants were presented via the headphones at either a 450-ms or 900-ms onset-to-onset rate. In the suffix condition, the word "recall" was spoken in rhythm with the consonants (i.e., beginning 450 or 900 ms after the onset of the last consonant), and on the next “beat” there appeared in the middle of the screen a row of eight dashes, which served as position markers for the responses. In the no-suffix condition the position markers appeared two beats (i.e., 900 or 1800 ms) after the onset of the last consonant, with the interval between the last consonant and presentation of the position markers unfilled. Once the position markers appeared, the subject attempted to type the consonants in their order of presentation, using the hyphen key for each consonant they failed to recall. For this purpose, copies of the consonants were
affixed in alphabetical order to the digit keys 1 through 0 near the
top of the keyboard, the keys having been programmed to produce
the affixed letter in size 24, Monaco font, above the position markers.
At any point during recall the last item typed could be erased by
pressing the Delete key; earlier responses could not be changed.
Subjects responded at their own rate and signaled completion of a
trial by clicking an "OK" button.

Results

Figure 2 shows the suffix and no-suffix serial position functions
for each presentation rate. Presentation rate had no discernible
influence on the preterminal suffix effect, though it did appear to
affect the terminal suffix effect.

Following Balota and Engle (1981), statistical analyses focused on
the last position and the preceding four positions. The main findings
were independent of whether the order of occurrence of the two
presentation rates was included as a variable, and in the interest of
simplicity I report only those analyses that did not include this
variable. The relevant statistical findings can be summarized thus:¹

1. With the data combined over suffix condition, mean
probability of recall over the last five positions was lower for the
450-ms rate (.44) than for the 900-ms rate (.54). This difference
almost certainly did not arise by chance, $F(1, 31) = 24.61$, $MSE = .014,$
$p = .000.$²

2. With the data combined over presentation rate, mean
probability of recall over the last five positions was lower for the
suffix condition (.42) than for the no-suffix condition (.56). This
difference, too, was highly unlikely to have arisen by chance,
Figure 2. Serial recall as a function of presentation rate, suffix condition, and position (Experiment 1).
\( F(1, 31) = 155.61, \text{MSE} = .0040, p = .000. \)

3. This suffix effect over the last five positions was almost identical for the 450-ms and 900-ms presentation rates (.15 and .14, respectively), thus precluding a Rate x Suffix Condition interaction, \( F(1, 31) = 0.15, \text{MSE} = .0055, p = .70. \)

4. The preterminal suffix effect barely differed between the 450-ms and 900-ms presentation rates (.07 vs. .08), a fact reflected in the absence of a discernible Rate x Suffix Condition interaction, \( F(1, 31) = 0.29, \text{MSE} = .0051, p = .59. \)

5. Presentation rate did, however, appear to influence the terminal suffix effect, with the effect being greater at the 450-ms rate (.45) than at the 900-ms rate (.35). This difference was reflected in a Rate x Suffix Condition interaction for the terminal position, \( F(1, 31) = 4.98, \text{MSE} = .018, p = .03. \)

6. The difference in the effect of presentation rate on the preterminal and terminal suffix effects was unlikely to have arisen by chance. Thus, for the Rate x Suffix Condition x Position interaction, \( F(1, 31) = 8.39, \text{MSE} = .0068, p = .007. \)

In contrast to Balota and Engle’s (1981) findings, Experiment 1 showed presentation rate to have a discernible influence of presentation rate on the terminal suffix effect but not on the preterminal suffix effect. If we accept Balota and Engle’s assumption that presentation rate affects subject strategy but not memory structure, these findings are entirely contrary to two-component theory.

Experiment 2

Balota and Engle’s (1981) experiment doubles as the primary
source for another empirical mooring of two-component theory, namely the finding that as subjects become practiced with the procedure, the preterminal component of the suffix effect increases but the terminal component remains unaffected. Given that practice can plausibly be assumed to affect remembering strategy, such a finding is consistent with two-component theory. However, there are three worrisome details of Balota and Engle's (1981) methodology.

First, subjects received a non-trivial number of practice lists beforehand (15 trials). It seems plausible that such a generous number of practice lists would absorb at least part of any potential effect that practice may have upon recall. Moreover, such an effect could, conceivably, interact with suffix condition, predictability of suffix condition, or list position.

Second, Balota and Engle (1981) presented 40 trials in each block (half) of the experiment. A large number of trials may partly absorb any potential effect of practice; on the other hand, a small number of trials risks instability and unfamiliarity with the task in the first block. Again, such an effect could interact with suffix condition, predictability of suffix condition, or list position.

Third, the suffix and no-suffix conditions were manipulated between subjects. Therefore, the observed form of the suffix effect could reflect, not just the effect of the suffix on memory for the already presented items, but also a difference in the way the two groups studied the list items. If so, Balota and Engle's findings would tell us little about the retrograde effect of the suffix, and so would have little if any relevance to two-component theory.

Experiment 2 was designed to address these concerns. It
involved the presentation of just four practice trials and two blocks of 28 trials (14 in each suffix condition) in the experiment proper, for a total of 56 trials.

**Method**

**Subjects.** The subjects were 32 Rice University undergraduates. None had taken part in the previous experiment.

**Lists.** The digit utterances were those used in Experiment 1. For each subject, a separate batch of 60 9-digit lists were constructed within the set of constraints adopted in Experiment 1. The digits occurred at a rate of one every 500 ms, with the suffix occurring in rhythm with the digits and thus with an onset 500 ms after onset of the last digit. Four of these lists were used to familiarize the subjects with the procedure; of these, two were followed by a suffix and two were not. The remaining lists were randomly assigned to four sets of 14, of which one set was used in the first-half no-suffix condition, one in the first-half suffix condition, one in the second-half no-suffix condition, and one in the second-half suffix condition. The suffix "recall" was also taken from Experiment 1. For the no-suffix condition the suffix was replaced by a silent pause.

**Design.** The experiment conformed to a 2 (practice) x 2 (suffix condition) x 2 (preterminal and terminal positions) design, with repeated measures on all three variables. Practice was defined in terms of location within the sequence of lists in the experiment proper—specifically, the first or second half of the sequence. Suffix condition varied randomly within the constraint that each half of the sequence included the same number (namely 14) of suffix and no-suffix lists.
Procedure. The procedure was the same as that for Experiment 1 except that (i) the experiment proper included eight fewer lists, and (ii) for all lists, items were presented at a 500-ms rate and the response position markers were presented 1000 ms after the onset of the last digit.

Results

Figure 3 shows the suffix and no-suffix serial position functions for each half of the testing session. These functions show that practice had no clear influence on the preterminal suffix effect but appeared to reduce the terminal suffix effect.

Following Balota and Engle (1981), statistical analyses were confined to the last five positions, of which the four prior to the final position were referred to as preterminal positions (or, in the context of analyses of variance, collectively as the preterminal position) and the final position as the terminal position. The relevant findings can be stated in the following points:

1. With the data combined over suffix condition, mean probability of recall over the last five positions was a little higher for the second half of the session (.52) than for the first (.49), but the difference may well have arisen by chance, $F(1, 31) = 2.43$, $MSE = .0057$, $p = .12$.

2. With the data combined over session half, mean probability of recall over the last five positions was .57 in the no-suffix condition and .43 in the suffix condition. We may be confident that this difference did not arise by chance, $F(1, 31) = 104.48$, $MSE = .0064$, $p = .000$.

3. The suffix effect over the last five positions barely changed
Figure 3: Serial Recall as a Function of Practice (Session Half), Suffix Condition, and Position (Experiment 2).
from the first half of the sequence (.15) to the second half (.14), as confirmed by the virtual absence of a Practice x Suffix Condition interaction, $F(1, 31) = 0.02, \text{MSE} = .0045, p = .90$.

4. The preterminal suffix effect was larger for the second half of the sequence (.10) than for the first (.08), but the difference was slight and, as confirmed by the Practice x Suffix Condition interaction term for the preterminal data, could well have arisen by chance, $F(1, 31) = 0.70, \text{MSE} = .0054, p = .41$.

5. The terminal suffix effect was smaller for the second half of the sequence (.31) than for the first (.41). The Practice x Suffix Condition interaction for the terminal position data indicates that this change was unlikely to have occurred by chance, $F(1, 31) = 7.83, \text{MSE} = .011, p = .009$.

6. The difference in the changes in the preterminal and terminal suffix effects from the first half of the sequence to the second was also unlikely to have arisen by chance. Thus, for the Practice x Suffix Condition x Position interaction, $F(1, 31) = 10.21, \text{MSE} = .0061, p = .003$.

These findings are inconsistent with those of Balota and Engle (1981). Whereas in Balota and Engle's experiment, practice enhanced the preterminal component of the suffix effect but left the terminal component unaffected, in the present experiment practice had no clear effect on the preterminal component but diminished the terminal component. If we accept Balota and Engle's assumption that practice affects rememberer strategy but not structure-based memory, then these findings run counter to two-component theory.
Experiment 3

Two-component theory has also drawn support from an investigation of the influence on the suffix effect of acoustic length of the suffix item. Baddeley and Hull (1979) found that, compared to a short suffix (such as "Rhyl"), a long suffix (such as "Abergavenny") gave rise to a larger preterminal suffix effect but a smaller terminal suffix effect. In what was perhaps the first statement of two-component theory, Baddeley and Hull concluded that increasing the length of the suffix served (a) to disrupt rehearsal and so speed forgetting of the preterminal items, and (b) to reduce loss of a precategorical acoustic representation of the last item (cf. Crowder & Morton, 1969).

Experiment 3 was designed to address two concerns with these conclusions. The first is that Baddeley and Hull (1979) defined the terminal suffix effect, not as the impairment in last-item recall when a suffix is appended to the list, but rather as last-item recall relative to penultimate-item recall in the same suffix condition. This definition complicates any comparison of preterminal and terminal suffix effects because it ties the latter to the former. This may be no mere quibble, for Baddeley and Hull's conclusion that last-item recall is impaired less by long suffixes than by short suffixes would almost certainly not hold were the terminal suffix effect defined in the normal way—that is, as the impairment in last-item recall when a suffix is appended to the list. The relevant data are for their Experiments 1 and 3, given in their Figure 1 and Table 6, respectively. Inspection of their Figure 1 coupled with some reasonable inferences from their statistical analyses suggest that the
difference in recall of the terminal item under the short- and long-suffix conditions may very well have arisen by chance. Their Table 6 reveals that the impairment in last-item recall was actually in the direction contrary to their conclusion, being slightly greater in the long-suffix condition than in the short-suffix condition.

The second concern is that suffix condition was varied between blocks of lists rather than unpredictably from list to list. Baddeley and Hull's (1979) findings could therefore have arisen, at least in part, from study strategies being tailored to the suffix condition rather than from the retroactive effect of the suffix. Also, blocking by suffix condition leaves open the possibility of an interaction between suffix condition and the order in which the suffix conditions occurred—a difficulty that was in fact realized in their Experiment 1. Neither of these complications would arise if suffix conditions were scrambled unpredictably in a single sequence of lists.

The purpose of Experiment 3, then, was to reevaluate the claim that lengthening the suffix enhances the preterminal suffix effect while reducing the terminal suffix effect. More particularly, it was designed to see if the claim would hold with a conventional definition of the terminal suffix effect and a procedure that precluded knowledge of suffix condition during list presentation.

Method

Subjects. The subjects were 32 Rice University undergraduates. None had taken part in either of the previous experiments.

Lists. Because this experiment involved a new suffix, all stimuli were recorded anew. Recording was in the same clear male voice used for the previous experiments. The list items were the digits 0
through 9 and the short and long suffixes were "now" and "recollection." The duration of each digit was adjusted to approximately 300 ms. The short and long suffixes were spoken in a natural way and their durations happened to be very nearly 300 ms and 600 ms, respectively.

For each subject, 60 9-digit lists were constructed in the manner described for Experiment 1, except that items were presented at a rate of one every 500 ms. Onset of the suffixes and presentation of the response position markers occurred 500 ms and 1100 ms, respectively, after onset of the last digit; note that presentation of the long suffix was completed just as the position markers appeared. For the no-suffix condition, the interval between the last digit and the appearance of the position markers was unfilled. Six lists were used for practice, leaving 54 for the experiment proper.

**Design.** The experiment conformed to a 3 (suffix condition) x 2 (preterminal and terminal positions) design, with repeated measures on both variables. Twenty lists were assigned to the short-suffix condition, 20 to the long-suffix condition, and 20 to the no-suffix condition. Ordering of the suffix conditions was according to a randomized blocks procedure, with separate randomizations for each subject.

**Procedure.** The subjects were tested up to four at a time. Instructions were both shown on the computers and read aloud by the Experimenter. There followed three practice trials, one in each suffix condition. For the remaining lists, subjects worked at their own pace, with lists being presented over headphones. The first three of these lists were also treated as practice and were not scored.
Each trial proceeded as in Experiment 2 except for the use of two fewer lists in the experiment proper and an 1100 ms interval between onset of the last digit and presentation of the response position markers.

Results

Figure 4 shows the serial position functions for the no-suffix, short-suffix, and long-suffix conditions. The principal finding was that length of suffix had little effect on either the preterminal or the terminal components of the suffix effect.

Following Baddeley and Hull (1979), the data for all positions were included in the statistical analyses. The terminal component of the suffix effect was identified with the last position, and the preterminal component with all eight preceding positions. The main findings are as follows:

1. With the data averaged across all nine positions, mean probability of recall was higher in the no-suffix condition (.62) than in either the short-suffix condition (.53), t(31) = 5.64, p = .000, or the long-suffix condition (.53), t(31) = 5.59, p = .000.

2. With the data averaged across all positions, mean probability of recall did not differ discernibly between the short-suffix and long-suffix conditions, t(31) = 0.38, p = .71.

3. At the terminal position, recall was more probable in the no-suffix condition (.85) than in either the short-suffix condition (.42), t(31) = 13.25, p = .000, or the long-suffix condition (.45), t(31) = 13.63, p = .000. More interestingly, there was little difference in last-item recall between the short-suffix and long-suffix conditions, t(31) = 0.97, p = .34.
Figure 4. Serial recall as a function of suffix condition and position (Experiment 3).
4. With the data averaged across all positions other than the last, recall was again more probable in the no-suffix condition (.62) than in either the short-suffix condition (.54), \( t(31) = 4.33, p = .000 \), or the long-suffix condition (.54), \( t(31) = 4.41, p = .000 \). More to the point, there was virtually no difference in preterminal recall between the short-suffix and long-suffix conditions, \( t(31) = 0.69, p = .50 \).

5. A 3 (suffix condition) x 2 (position) analysis of variance with repeated measures on both variables revealed an interaction between suffix condition and position that was unlikely to have arisen by chance, \( F(2, 62) = 59.81, \text{MSE} = .0098, p = .000 \). It is clear from Figure 9 that this effect was primarily the result of a larger suffix effect at the terminal position than at the preterminal position. Of more interest is the Suffix Condition x Position interaction with the analysis confined to the short-suffix and long-suffix conditions. This proved to be unimpressive, \( F(1, 31) = 1.46, \text{MSE} = .0072, p = .24 \).

These statistical observations confirm that, contrary to Baddeley and Hull's (1979) conclusion, lengthening the suffix had no discernible influence on either the preterminal or terminal components of the suffix effect. Note that the discrepancy between this conclusion and Baddeley and Hull's conclusion appears not to hinge on the definition of the terminal suffix effect, for it survives a rescoring of the data according to Baddeley and Hull's definition. Thus, the extent to which recall was more probable for the last item than for the immediately preceding item did not differ convincingly between the long-suffix condition (.19) and the short-suffix condition (.16), \( t(31) = 1.05, p = .30 \). In short, however the data are analyzed, this experiment provides no support for two-component theory.
Experiment 4

Another strand of evidence recently proffered in support of two-component theory is the effect of varying the delay between the last list item and the suffix. Penney and Godsell (1993) presented items at a rate of one every 400 ms and compared the effects of four suffix delays (400, 600, 800, and 1000 ms). They concluded that delaying the suffix increased the probability of recall for the last item but had no effect on recall of the two immediately preceding items. In keeping with two-component theory, they argued that suffix delay affected the structural component of the suffix effect but not the strategic component.

I will return to this argument in the general discussion, but here I consider two issues regarding Penney and Godsell's (1993) findings. First, I was not entirely convinced that they failed to produce any evidence at all for an effect of suffix delay on the preterminal suffix effect. Certainly they failed to find a strong effect, but a close inspection of their data reveals that probability of recall at the preterminal positions (as defined by Penney and Godsell) increased systematically across the four delay conditions in each of their two experiments. The probability of two such trends occurring by chance is only 1 in \(4!^2\), or 1 in 576. Second, an effect at the preterminal positions might have been more apparent if the suffix delay had been longer— at least relative to presentation rate (cf. Frankish & Turner, 1984). In Experiment 4, then, I compared the effect of presenting a suffix in rhythm with the list items with that of delaying it fully four "beats".
Method

Subjects. The subjects were 32 Rice University undergraduates. None had taken part in any of the previous experiments.

Lists. The digits 0-9 were recorded on the computer in a clear male voice, and their durations adjusted to approximately 300 ms. For each subject, 66 9-digit lists were constructed by randomly ordering the digits 1 to 9 within the constraints that no digit was one higher or one lower in value than an immediate neighbor and there was no case of more than three consecutive digits being either all odd or all even. The digits occurred at a rate of one every 500 ms, and so were separated by pauses of approximately 200 ms. The suffix was "zero" spoken in the same voice as the list digits. The onset of the suffix was either 500 ms or 2500 ms after the onset of the last digit, defining the immediate suffix condition and delayed suffix condition, respectively. For the no-suffix condition, the time between the last item and presentation of the response position markers was unfilled. Six lists were used for practice, and 60 for the experiment proper.

Design. The experiment conformed to a 3 (suffix condition) x 2 (preterminal and terminal positions) design, with repeated measures on both variables. The occurrence of the three suffix conditions (no-suffix, immediate-suffix, and delayed-suffix) was according to a randomized blocks procedure, with separate randomizations for each subject.

Procedure. The procedure was identical to that for Experiment 3 except that: the experiment proper included six more lists; the number of suffix-delay conditions was set at two; and the time
between onset of the last digit and presentation of response position markers was always 2800 ms (so that, in the case of the delayed suffix condition, the response position markers followed the suffix directly).

Results

Figure 5 shows the serial position function for each suffix condition. Clearly, delaying the suffix reduced the preterminal as well as the terminal component of the suffix effect.

For the statistical analyses, I followed Penney and Godsell (1993) in restricting consideration to the last three positions, of which two were characterized as the preterminal position and the last as the terminal position. The main findings are:

1. With the data averaged across the last three positions, mean probability of recall was higher in the no-suffix condition (.54) than in both the immediate-suffix condition (.28), \( t(31) = 13.07, p = .000 \), and the delayed-suffix condition (.43), \( t(31) = 5.42, p = .000 \).

2. With the data averaged across the last three positions, the immediate suffix effect was clearly larger than the delayed suffix effect, \( t(31) = 6.17, p = .000 \).

3. At the terminal position, probability of recall was .34 in the immediate suffix condition and .58 in the delayed suffix condition. The difference was unlikely to have arisen by chance, \( t(31) = 6.63, p = .000 \).

4. The effect of suffix delay was not confined to the terminal position. Thus, for the two preterminal positions, the probability of recall in the delayed suffix condition (.35) exceeded that in the immediate suffix condition (.26) to an extent unlikely to have arisen
Figure 5: Probability of Serial Recall as a Function of Suffix Delay and Position (Experiment 4).
by chance, $t(31) = 3.88, p = .001$.

5. A 3 (suffix condition) x 2 (position) analysis of variance with repeated measures on both variables revealed a convincing interaction between suffix condition and position, $F(2, 62) = 47.01$, $MSE = .0098, p = .000$. Of particular interest, in an analysis involving just the immediate-suffix and delayed-suffix data, the Delay x Position interaction was unlikely to have arisen by chance, $F(1, 31) = 15.31$, $MSE = .011, p = .000$, and showed that the difference in the immediate and delayed suffix effects was clearly greater at the terminal position (.24) than at the preterminal positions (.10). This interaction needs to be interpreted with caution, however, in that the proportional effect of delaying the suffix was greater at the preterminal positions than at the terminal position (see Figure 8). Thus, delaying the suffix reduced its effect by 67% at the preterminal positions and by 50% at the terminal position.

The results of this experiment are contrary to Penney and Godsell's (1993) conclusion that the effect of delaying the suffix is localized at the terminal position. And given their assumption that suffix delay affects the structural component of the suffix effect, they are also inconsistent with two-component theory.

Summary of Experiments 1 - 4

Two-component theory claims a qualitative distinction between a top-down conceptually-based preterminal suffix effect and a bottom-up structurally-based terminal suffix effect. The empirical support for two-component theory rests upon the findings that five variables dissociate a strategically-sensitive preterminal suffix effect and a strategically-immune terminal suffix effect. The purpose of
the first four experiments was to reconsider the case for two-component theory. Specifically, following Bloom's (1997) reexamination of the claim of a dissociative effect of list-length predictability, Experiments 1 through 4 reexamined the four remaining claimed dissociative effects (those of presentation rate, practice, suffix length, and suffix delay) as support for two-component theory. As with those of Bloom (1997), each of these experiments failed to replicate the critical dissociative effect. Specifically, suffix length was found to have no clear influence on either the terminal or preterminal suffix effect; suffix delay attenuated the terminal and preterminal suffix effects alike; and both practice and slowing presentation rate--two variables previously assumed to have top-down influences--modestly attenuated only the terminal suffix effect. As with Bloom's (1997) results, these findings consistently undermine two-component theory's distinction between a conceptually-based preterminal suffix effect and a conceptually-immune terminal suffix effect.

Overview of Experiments 5 - 11

Experiments 5 through 11 extended the examination (Ayers et al., 1979; Salter & Colley, 1977; see also Experiments 1 and 2 herein, and Bloom, 1997) of top-down, conceptually-based influences on the terminal suffix effect. Specifically, Experiments 5 through 7 examined in a novel way the effect of semantic relatedness between the suffix and list items. According to two-component theory, this relation should not influence the terminal suffix effect, for the terminal suffix effect is assumed to be a bottom-up effect and hence immune to any conceptual information. Experiments 8 through 11
used the same procedures to investigate whether such a conceptually-based manipulation modulates the effect of suffix delay.

Experiment 5

Contrary to conclusions drawn from early research (see reviews by Crowder, 1976; Greene, 1992; and Neath, 1998), it has been shown that the semantic relatedness between the suffix and the list items (Salter & Colley, 1977)--as conceptualized by the subject (Ayers et al., 1979)--can influence the magnitude of the terminal suffix effect. The "trick" appears to be the use of strong manipulations of context and semantic association between suffix and list items. Salter and Colley used suffixes that were synonyms of the terminal items and Ayers et al. used powerful contextual manipulations to bias the subjects' perception of the suffix as verbal or nonverbal.

In an attempt to amplify these findings, I combined both approaches to assess in a novel way whether the semantic relationship between the terminal item and the suffix influenced the suffix effect. As in early research (e.g., Morton et al., 1971; for a review see Crowder, 1976), an acoustically discrete suffix was used (see Frankish & Turner, 1984) but, as in the Ayers et al. and Salter and Colley studies, manipulations of context and semantic relatedness were strong. Specifically, the list items were digits and the suffixes, presented almost immediately after the terminal digit, were the words "recall" and "hundred." The idea was that subjects would presumably form a stronger semantic (conceptual) union between the terminal list item and the "hundred" suffix (e.g., ". . .
seven hundred") than between the terminal list item and the "recall" suffix (e.g., ". . . seven recall"). At issue was whether such a conceptual manipulation would influence the suffix effect in general and, contrary to two-component theory, the terminal suffix effect in particular.

Method

Subjects. The subjects were 24 Rice University undergraduates.

Lists. The to-be-remembered items were the recordings of the digits 1 through 9 used in Experiment 4. Fifty seven 9-digit lists were created, 3 for practice and 54 lists for the experiment proper. Lists were constructed by randomly ordering the digits 1 to 9 within the constraints that no digit was one higher or one lower in value than an immediate neighbor and that, across the 54 lists of the experiment proper, each digit occurred equally often (6 times) in each of the nine positions of the list. The words "hundred" and "recall" were spoken in the same voice as the digits and served as suffixes. In fact, they had been recorded at the same time as the digits. The suffixes, like the digits, were each adjusted to a duration of 300 ms.

Design. The experiment conformed to a 3 (suffix condition) x 2 (preterminal and terminal positions) design with repeated measures on both variables. The three suffix conditions (no suffix, "recall" suffix, and "hundred" suffix) were each represented 9 times in both the first 27 lists and the last 27 lists of the experiment proper, with separate randomizations for each subject. Assignment of individual lists to suffix conditions was counterbalanced across three groups of subjects so that, overall, each list served in each condition equally
often.

**Procedure.** The subjects were tested up to four at a time. Instructions were shown on the computers and simultaneously read aloud by the Experimenter. After practicing on three lists, the subjects proceeded through the lists of the experiment at their own pace, with lists being presented from their computers via headphones.

Subjects initiated each list by clicking a “start” button. After a 500-ms delay, the digits were presented via the headphones at a 900-ms onset-to-onset rate. Following the last digit, subjects heard nothing, the suffix "recall," or the suffix "hundred." The onset of the suffix followed the offset of the last digit by 17 ms. Immediately following the suffix (and hence 317 ms after offset of the last digit) subjects were presented with nine position markers. In the no-suffix condition the position markers also appeared 317 ms after the offset of the last digit, but the interval between the last digit and presentation of the position markers was unfilled. Once the position markers appeared, the subject attempted to type the digits in their order of presentation, using the hyphen key for each digit they failed to recall. The responses appeared in size 24, Monaco font above the position markers. At any point during recall the last item typed could be erased by pressing the Delete key; earlier responses could not be changed. Subjects responded at their own rate and signaled completion of a trial by clicking an "OK" button.

**Results**

Figure 6 shows the serial recall function for each suffix condition. Most importantly, the "hundred" suffix effect was smaller
Figure 6. Serial recall as a function of suffix condition and position (Experiment 5).
than the "recall" suffix effect, especially at the terminal position.

Following Penney (1985) and Bloom (1997), statistical analyses focused on the final four positions, of which the three prior to the last were referred to as preterminal positions (or collectively as the preterminal position) and the last as the terminal position. The relevant findings can be stated in five points:  

1. With the data averaged across the last four positions, mean probability of recall was higher in the no-suffix condition (.72) than in both the "recall" suffix condition (.48), $t(23) = 9.14, p = .000$, and the "hundred" suffix condition (.55), $t(23) = 7.57, p = .000$.

2. With the data averaged across the last four positions, the "hundred" suffix effect (.17) was smaller than the "recall" suffix effect (.24), $t(23) = 2.47, p = .02$.

3. For the three preterminal positions, although the "hundred" suffix effect (.14) was somewhat smaller than the "recall" suffix effect (.19), the difference was not entirely convincing, $t(23) = 1.80, p = .08$.

4. The terminal suffix effect was smaller following the "hundred" suffix (.25) than following the "recall" suffix (.39) to an extent unlikely to have arisen by chance, $t(23) = 2.96, p = .007$.

5. A 3 (suffix condition) x 2 (position) analysis of variance with repeated measures on both variables revealed a convincing interaction between suffix condition and position, $F(2, 46) = 14.88$, $MSE = 0.0079, p = .000$. Of particular interest is that the difference in the "recall" and "hundred" suffix effects was greater at the terminal position (.14) than at the preterminal positions (.05). An analysis of variance for just the "recall" and "hundred" data showed that the
difference between these suffix effects, as expressed in the Suffix \( x \) Position interaction, was unlikely to have arisen by chance, \( F(1, 23) = 7.01, \text{MSE} = 0.008, p = .01 \).

Changing the semantic identity of the suffix from "recall" to "hundred" had a less-than-convincing influence on the preterminal component of the suffix effect, but it clearly attenuated the terminal component. This finding, like those obtained by Salter and Colley (1977) and Ayers et al. (1979), suggests that the terminal suffix effect is influenced by the way subjects conceptualize the suffix in relation to the terminal list item.

Moreover, it would appear unlikely that the present findings are the result of undue attention being given to the terminal item (see Salter & Colley, 1977). Thus, assuming a limited recall capacity (e.g., Crowder, 1976), any gain in recall of the terminal item would be expected to be offset by reduced recall of the preterminal items. But as can be seen in Figure 6, the data provide little evidence for this possibility.

Experiment 6

Experiment 6 was intended as a check on the primary conclusion drawn from Experiment 5, namely that the attenuation of the terminal suffix effect when "hundred" served as the suffix was due to some sort of semantic unification of the suffix and the terminal list item. It was identical to Experiment 5 except that "hundred" and "recall" were replaced by "dredhun" and "callre." Thus the component sounds of the suffixes remained the same, and just their order was changed. According to the semantic grouping interpretation, the attenuation of the terminal suffix effect should
not extend to this experiment because both suffixes were meaningless and so should not differ in their semantic relatedness to the terminal list item.

**Method**

**Subjects.** The subjects were 24 Rice University undergraduates.

**Lists.** The digit utterances and list construction were exactly as in Experiment 5. The suffix utterances were those used in Experiment 5 except that they were spliced and reconfigured to be meaningless ("callre" and "dredhun") and therefore semantically unrelated to the digits, though containing the same acoustic information. The suffixes, like the digits, remained 300 ms in duration.

**Design.** The experiment conformed to a 3 (suffix condition) x 2 (preterminal and terminal positions) design with repeated measures on both variables. In the experiment proper, the three suffix conditions (no suffix, "callre" suffix, and "dredhun" suffix) occurred equally often and in random order in both the first 27 lists and the last 27 lists, with separate randomizations for each subject. Assignment of individual lists to suffix conditions was counterbalanced across three groups of subjects, so that, overall, each list served in each condition equally often.

**Procedure.** The procedure was identical to Experiment 5.

**Results**

Figure 7 shows the serial recall function for each suffix condition. Importantly, the "dredhun" suffix was no less detrimental to recall at the terminal position than was the "callre" suffix.

Statistical analyses focused on the final four positions, of which
Figure 7. Serial recall as a function of suffix condition and position (Experiment 6).
the three prior to the last were referred to as preterminal positions (or collectively as the preterminal position) and the last as the terminal position. The relevant findings can be stated in five points:

1. With the data averaged across the last four positions, mean probability of recall was higher in the no-suffix condition (.60) than in both the "callre" suffix condition (.43), \( t(23) = 8.21, p = .000 \), and the "dredhun" suffix condition (.40), \( t(23) = 8.76, p = .000 \).

2. With the data averaged across the last four positions, the "callre" suffix effect (.17) was, if anything, smaller than the "dredhun" suffix effect (.20), \( t(23) = 1.88, p = .07 \).

3. For the three preterminal positions, the "callre" suffix effect (.10) was somewhat smaller than the "dredhun" suffix effect (.14), \( t(23) = 2.22, p = .04 \). Even if additional research were to show this effect to be real, the fact that it is mediated almost entirely by the third and fourth positions from the end of the list, rather than the second from the end of the list, undermines its relevance to present purposes.

4. The terminal suffix effect was virtually identical in the "callre" and "dredhun" conditions (rounding to .46 in both cases), \( t(23) = 0.22, p = .83 \).

5. A 3 (suffix condition) x 2 (position) analysis of variance with repeated measures on both variables revealed a convincing interaction between suffix condition and position, \( F(2, 46) = 28.76, MSE = 0.010, p = .000 \). Although the difference in the "callre" and "dredhun" suffix effects was slightly less at the terminal position (.00) than at the preterminal positions (.04), an analysis of variance for just the "callre" and "dredhun" data showed that the difference
between these suffix effects, as expressed in the Suffix x Position interaction, was unconvincing, $F(1, 23) = 1.29$, $\text{MSE} = 0.007$, $p = .27$.

Whereas the terminal suffix effect for digit lists was smaller with a "hundred" suffix than with a "recall" suffix (Experiment 5), the terminal suffix effect was not smaller with a "dredhun" suffix than with a "callre" suffix (Experiment 6). This finding suggests that the attenuation of the terminal "hundred" suffix effect relative to the terminal "recall" suffix effect (Experiment 5) was not the result of a fortuitous difference in the acoustical components of "hundred" and "recall." By the same token, it reinforces the conclusion that, contrary to two-component theory, the terminal suffix effect is susceptible to the semantic relation (coherence) between the suffix and the last item of the list.

Experiment 7

Experiments 5 and 6 provide strong evidence that even the terminal component of the suffix effect is subject to "top-down" influences. Such evidence is contrary to the core assumption of overwriting theories in general, and of two-component theory in particular, namely that the terminal suffix is immune to conceptually-based influences. It could be countered, however, that it is not necessarily contrary to a watered-down version of such theories, whereby recall of the last few items of a list (or, in the case of two-component theory, the terminal item) is the product of postcategorical as well as precategorical memory. Given the patently obvious fact that all items are perceived directly upon presentation, they must all be subject to postcategorical processing, in which case it is not unreasonable to assume that they will endure to some extent
in a postcategorical memory (cf. Craik & Lockhart, 1972; Crowder, 1976). If this much is conceded, then the critical findings of Experiment 5 could be dismissed as a von Restorff effect. Thus, any postcategorical unification of the "hundred" suffix with the terminal item would result in a subjective terminal item that was conceptually distinct from the other list items, and perhaps could be comparatively well recalled for just this reason. In other words, two-component and other overwriting theories would apply to just the precategorical contribution to memory and thus be unaffected by any postcategorical unification of the suffix with the terminal list item.

The purpose of Experiment 7 was twofold. First, it provided an opportunity to replicate the Experiment 5 finding that promoting conceptual unity between the suffix and the terminal list item attenuates the suffix effect. Second, it provides a test of the von Restorff explanation of this finding. If the attenuation of the terminal suffix effect is due to the conceptual distinctiveness of the functional terminal item ("seven hundred," for example), then it should not occur if "hundred" followed, not just the terminal item, but every list item. Thus, in Experiment 7, a "through-list 'hundred'" condition was added to the three conditions of Experiment 5.

**Method**

**Subjects.** The subjects were 24 Rice University undergraduates.

**Lists.** The digit and suffix utterances were those used in Experiment 5. Of 76 9-digit lists that were created, four were used for practice and 72 for the experiment proper. List construction was as in Experiment 5. In the experiment proper, each digit occurred
on eight occasions in each of the nine positions.

**Design.** The experiment conformed to a 4 (suffix condition) x 2 (preterminal and terminal positions) design with repeated measures on both variables. The four suffix conditions (no suffix, "recall" suffix, "hundred" suffix, and through-list "hundred" suffix) were each represented nine times in random order in both the first 36 lists and the last 36 lists of the experiment proper, with separate randomizations for each subject. Assignment of individual lists to suffix conditions was counterbalanced across four groups of subjects so that, overall, each list served in each condition equally often.

**Procedure.** The procedure was identical to that of Experiment 5, except that, to accommodate the added (through-list "hundred" suffix) condition, the number of lists was increased by one third.

**Results**

Figure 8 shows the serial recall function for each suffix condition. Relative to the "recall" suffix, the "hundred" suffix again attenuated the detrimental effect of the suffix at the terminal position. Moreover, a similar attenuation also occurred when "hundred" followed every list item rather than just the last.

Statistical analyses focused on the final four positions, of which the three prior to the last were designated as preterminal positions (or collectively as the preterminal position) and the last as the terminal position. The relevant findings can be stated in five points:

1. With the data averaged across the last four positions, mean probability of recall was higher in the no-suffix condition (.67) than in the "recall" suffix condition (.51), $t(23) = 7.07$, $p = .000$, the "hundred" suffix condition (.53), $t(23) = 5.84$, $p = .000$, and the
Figure 8. Serial recall as a function of suffix condition and position (Experiment 7).
through-list "hundred" suffix condition (.50), $t(23) = 6.76, p = .000.$

2. With the data averaged across the last four positions, the "recall" suffix effect (.16) did not differ from the "hundred" suffix effect (.14), $t(23) = 1.60, p = .12,$ or the through-list "hundred" suffix effect (.17), $t(23) = 0.30, p = .77.$ The "hundred" suffix effect differed, albeit not entirely convincingly, from the through-list "hundred" suffix effect, $t(23) = 1.88, p = .07.$

3. For the three preterminal positions, the "recall" suffix effect (.11) did not differ from the "hundred" suffix effect (.11), $t(23) = 0.24, p = .82,$ nor did it differ convincingly from the through-list "hundred" suffix effect (.15), $t(23) = 1.68, p = .11.$ There was a suggestion of a difference between the "hundred" suffix effect and the through-list "hundred" suffix effect, $t(23) = 1.77, p = .09.$

4. At the terminal position, the "recall" suffix effect (.33) was larger than the "hundred" suffix effect (.21), $t(23) = 4.24, p = .0003,$ and the through-list "hundred" suffix effect (.23), $t(23) = 3.92, p = .0007.$ The "hundred" suffix effect was not discernibly different from the through-list "hundred" suffix effect, $t(23) = 0.79, p = .44.$

5. A $4 \times 2$ (suffix condition x position) analysis of variance with repeated measures on both variables revealed a convincing interaction between suffix condition and position, $F(3, 69) = 14.40,$ $MSE = 2.27, p = .007.$ Of particular interest are three findings. First, relative to the "recall" condition the attenuation of the suffix effect in the "hundred" condition was more pronounced at the terminal position (.12) than at the preterminal positions (.00). An analysis of variance for just the "recall" and "hundred" data showed that the difference between these suffix effects, as expressed in the Suffix $x$
Position interaction, was unlikely to have arisen by chance, $F(1, 23) = 14.44$, $\text{MSE} = .007$, $p = .001$. Second, relative to the "recall" condition the attenuation of the suffix effect in the through-list "hundred" condition was more pronounced at the terminal position (.10) than at the preterminal positions (.04). An analysis of variance for just the "recall" and the through-list "hundred" data showed that this difference, as expressed in the Suffix x Position interaction, was also unlikely to have arisen by chance, $F(1, 23) = 24.17$, $\text{MSE} = 0.006$, $p = .000$. Finally, relative to the through-list "hundred" condition, the attenuation of the suffix effect in the "hundred" condition was slightly less pronounced at the terminal position (.02) than at the preterminal positions (.04). An analysis of variance for just the through-list "hundred" and the "hundred" data showed that this difference, as expressed in the Suffix x Position interaction, could easily have arisen by chance, $F(1, 23) = 0.67$, $\text{MSE} = 0.005$, $p = .42$.

In short, the results of this experiment replicate the two critical findings of Experiment 5. First, changing the suffix from "recall" to "hundred" had no reliable influence at the preterminal positions but did attenuate the terminal suffix effect. Second, this finding appears not to be the result of subjects giving extra attention (rehearsal, etc.) to the last item at the expense of preceding items (see Salter & Colley, 1977). In fact, as can be seen in Figure 8, performance in the "hundred" condition is numerically superior to the "recall" condition at eight of the nine positions, the average probability of recall for all nine positions being .68 in the "hundred" condition and .64 in the "recall" condition.

The inclusion of a through-list "hundred" condition, in which
"hundred" occurred after all nine digits, allowed evaluation of a von Restorff interpretation of the attenuation of the terminal suffix effect in the "hundred" suffix condition. The terminal suffix effect in the through-list condition was similar to that in the "hundred" condition and smaller than that of the "recall" condition, implying that the observed influence of semantic relatedness between the terminal item and the suffix is not the result of the functional terminal list item (e.g., . . . "seven hundred") being remembered better because it is distinctive relative to the other list items. This pattern of findings is inconsistent with two-component theory but consistent with the idea that the suffix effect—even at the terminal position—is a composite of (at least) two processes that can operate antagonistically, namely bottom-up (physical) processes and top-down conceptually based processes (see Salter & Colley, 1977). Specifically, whereas increasing the (perceived) physical similarity of the suffix and list items increases their physical coherence (grouping) and thereby impairs recall (e.g., Morton et al., 1971), increasing the semantic relatedness or similarity of the suffix and list items increases their semantic coherence (grouping) and thereby improves recall (Experiments 5-7; Salter & Colley, 1977).

Experiment 8

Experiments 8 through 11 concerned the effect of delaying the suffix. Previous research has found that delaying the suffix serves to reduce the suffix effect—most notably (present Experiment 4; Crowder, 1969, 1971a; Frankish & Turner, 1984), and sometimes exclusively (Penney & Godsell, 1993), at the terminal position. This finding has been interpreted in terms of overwriting of time-
dependent precategorical information and, therefore, as consistent with two-component theory (e.g., Penney & Godsell, 1993). The results of Experiments 5 and 7 raise the intriguing possibility that this finding may not hold over all conditions. Specifically, they showed that the suffix effect, and particularly its terminal component, can be reduced when the suffix can be semantically integrated with the terminal list item to form a conceptual unit. Perhaps, therefore, the increment in the effect of a suffix when its presentation is hastened might not hold with the "hundred" suffix, for it would tend to be opposed by the effect of semantic coupling between the terminal item and an immediate suffix. The net effect of suffix delay for this kind of suffix would be the difference between two opposing effects, namely bottom-up impairment (overwriting) and top-down facilitation (integration). In short, with "hundred" rather than, say, "recall" or "zero" as the suffix, the normal attenuation of the suffix effect that is brought about by delaying the suffix would be less apparent, eliminated, or even reversed. The purpose of Experiment 8 was to explore this possibility.

Method

Subjects. The subjects were 72 Rice University undergraduates.

Lists. The to-be-remembered items and the suffix were the digit and "hundred" recordings used in Experiment 5. Fifty-four 9-digit lists were constructed in the manner described in Experiment 5.

Design. The experiment conformed to a 3 (suffix condition) x 2 (preterminal and terminal positions) design with repeated measures on both variables. For the control condition the last item of the list was followed by silence; for the immediate suffix condition,
offset of the last list item was followed by the word "hundred" with a pause of a mere 17 ms; and for the delayed suffix condition the word "hundred" followed the offset of the last list item only after a noticeable delay. Actually, the duration of this delay was varied: for half of the subjects it was 600 ms (putting the suffix in rhythm with the list items), and for the other half of the subjects it was 1500 ms. With a typical suffix (e.g., "zero"), the "delayed" suffix condition attenuates the suffix effect only when the delay exceeds the interstimulus interval of the list items; when the delay is equal to or less than the interstimulus interval, the difference in suffix effects is, at best, quite small (e.g., Frankish & Turner, 1984). Thus, it seemed reasonable to assess whether the influence of a novel "hundred" suffix would similarly depend upon the length of suffix delay such that, for example, the typical influence of delay might be more likely to attenuate or reverse with a "delayed" condition that is equal to the interstimulus interval. As it happens, the findings did not differ discernibly between the two groups of subjects, and in the interest of both brevity and clarity, the data were combined across the two groups. Assignment of individual lists to suffix condition was counterbalanced across three groups of subjects so that, overall, each list served equally often in each suffix condition.

**Procedure.** Apart from the details of suffix presentation, the procedure was the same as in Experiment 5. In all three conditions, digits were presented at a 900-ms onset-to-onset rate, and the nine position markers were presented either 900 or 1800 ms following the offset of the terminal list item, depending upon whether subjects were in the shorter (600 ms) or longer (1500 ms) delayed suffix
group. Note that, for the delayed suffix conditions, this timing ensured that onset of the position markers coincided with the offset of the delayed suffix. The order of list presentation and hence of the three conditions was separately randomized for each subject.

**Results**

Figure 9 shows the serial recall function for each suffix condition. Contrary to previous findings (e.g., Crowder, 1971a; Frankish & Turner, 1984; Penney & Godsell, 1993), delaying the suffix failed to mitigate the terminal suffix effect.

Statistical analyses focused on the final four positions, of which the three prior to the last were referred to as preterminal positions and the last as the terminal position. The relevant findings are as follows:9

1. With the data averaged across the last four positions, mean probability of recall was higher in the no-suffix condition (.63) than in both the immediate-suffix condition (.46), \( t(71) = 12.20, p = .000 \), and the delayed-suffix condition (.49), \( t(71) = 10.87, p = .000 \).

2. With the data averaged across the last four positions, the delayed suffix effect (.14) was somewhat smaller than the immediate suffix effect (.17), \( t(71) = 1.96, p = .05 \).

3. For the three preterminal positions, the effect of a delayed suffix (.11) was smaller than that of an immediate suffix (.15), \( t(71) = 2.96, p = .004 \).

4. The terminal suffix effect was virtually identical in the delayed and immediate suffix conditions (rounding to .24 in both instances), \( t(71) = 0.17, p = .87 \).

5. A 3 (suffix condition) x 2 (position) analysis of variance with
Figure 9. Serial recall as a function of suffix condition and position (Experiment 9).
repeated measures on both variables revealed a convincing interaction between suffix condition and position, $F(2, 142) = 17.91$, $\text{MSE} = 0.008$, $p = .000$. The difference between the immediate and delayed suffix effects was larger at the preterminal positions (.04) than at the terminal position (.00). An analysis of variance for just the immediate suffix and delayed suffix data showed that the difference between these suffix effects, as expressed in the Delay x Position interaction, was not entirely convincing, $F(1, 71) = 3.33$, $\text{MSE} = 0.008$, $p = .07$.

In short, this experiment showed that delaying a "hundred" suffix attenuated its effect only slightly, and more importantly such attenuation as did occur was localized at the preterminal positions. This finding is thus entirely contrary to the assumption (e.g., Penney & Godsell, 1993) that the effect of suffix delay is restricted to the terminal position, and by the same token it undermines two-component theory.

Experiment 9

The purpose of Experiment 9 was to see whether a conventional effect of suffix delay would occur with a procedure identical to that of Experiment 8 except for the substitution of a standard suffix. To the extent that the findings of Experiment 8 reflected the strong conceptual relation between the suffix and terminal list item (e.g. "seven hundred"), the findings of Experiment 9 should be different. Presumably, the effect of delay should be most pronounced at, or confined to, the terminal position (e.g., Crowder, 1971a; Frankish & Turner, 1984; Penney & Godsell, 1993)
Method

Subjects. The subjects were 33 Rice University undergraduates.

Lists. The stimuli were the recordings used in Experiment 8 with the exception that the suffix word "hundred" was replaced by "zero." The "zero" was recorded at the same time as the stimuli used in Experiment 5 (and hence Experiment 8) and, like the list items, was adjusted to a 300-ms duration.

Design and procedure. The design and procedure were as in Experiment 8 with one exception. Because, with a typical suffix (e.g., "zero"), delaying the suffix serves to attenuate its effect only when the delay exceeds the interval separating the list items (e.g., Frankish & Turner, 1984), the 1500-ms suffix delay was used in the "delayed" suffix condition for all subjects.

Results

Figure 10 shows the serial recall function for each suffix condition. Consistent with previous research (e.g., Crowder, 1971a; Frankish & Turner, 1984), delaying a "zero" suffix attenuated the suffix effect, with the attenuation being greatest at the terminal position.

Statistical analyses focused on the final four positions, of which the three prior to the last were referred to as preterminal positions (or collectively as the preterminal position) and the last as the terminal position. The relevant findings can be stated in five points:

1. With the data averaged across the last four positions, mean probability of recall was higher in the no-suffix condition (.66) than in both the immediate-suffix condition (.49), $t(32) = 9.65$, $p = .000$, and the delayed-suffix condition (.52), $t(32) = 8.03$, $p = .000$. 
Figure 10. Serial recall as a function of suffix condition and position (Experiment 9).

![Graph showing serial recall as a function of suffix condition and position.](image)
2. With the data averaged across the last four positions, the delayed suffix effect (.14) was smaller than the immediate suffix effect (.17), \( t(32) = 2.22, p = .03 \).

3. For the three preterminal positions, the delayed suffix effect (.10) was smaller than the immediate suffix effect (.12), but not convincingly so, \( t(32) = 1.13, p = .27 \).

4. The terminal suffix effect was clearly smaller in the delayed suffix condition (.24) than in the immediate suffix condition (.32), \( t(32) = 2.68, p = .01 \).

5. A 3 (suffix condition) x 2 (position) analysis of variance with repeated measures on both variables revealed a convincing interaction between suffix condition and position, \( F(2, 64) = 16.88 \), \( \text{MSE} = 0.010, p = .000 \). The difference in the delayed and immediate suffix effects was greater at the terminal position (.08) than at the preterminal positions (.02). As expressed in the Delay x Position interaction of an analysis of variance for just the immediate suffix and delayed suffix data, this difference was not entirely convincing \( F(1, 32) = 3.71, \text{MSE} = 0.009, p = .06 \). When account is taken of the prediction that the advantage of the delayed suffix effect over the immediate suffix effect would be greater--as opposed to merely different--when the suffix was delayed, it becomes a little more convincing (\( p = .03 \)).

In short, the standard finding that delaying the suffix reduces its effect at the terminal list position was replicated. Of more particular importance was the difference in the pattern of results between this experiment and Experiment 8. Whereas in Experiment 8, the effect of suffix delay, such as it was, was no greater at the terminal position
than the preterminal positions, in Experiment 9 the effect of delay increased systematically across the last four positions. As the only difference between Experiments 8 and 9 was in the nature of the suffix ("hundred" vs. "zero"), it seems likely that the effect of suffix delay in Experiment 8 was moderated by the semantic relation between the suffix and terminal list items.

Experiment 10

The elimination of the effect of suffix delay at the terminal position in Experiment 8 raises the intriguing possibility that, if the conceptual coherence between the immediate suffix and terminal list item were even stronger than in Experiment 8, the effect of suffix delay on recall of the terminal list item might even be reversed.

According to two-component theory, the terminal component of the suffix effect has a precategorical locus, and given that static visual information and auditory information do not "meet" until the categorical level (Crowder, 1976, p. 59), the auditory suffix effect should not be affected by the simultaneous presentation of static visually presented information (see Crowder & Morton, 1969; Crowder, 1976; Greene & Crowder, 1984a; Greene, 1992). And indeed, for all intents and purposes, bimodal presentation has been found to yield the same pattern of results as purely auditory presentation (e.g., Crowder, 1970; see also Crowder, 1976; Greene & Crowder, 1984a; Greene, Elliott, & Smith, 1988; Nairne & Walters, 1983).

On the other hand, the postcategorical (conceptually-based) effects obtained in Experiments 5 through 9, as well as those of certain previous studies (Ayers et al., 1979; Salter & Colley, 1977),
suggest the possibility that presenting the "hundred" suffix and list digits with concomitant visual information could further enhance the semantic relationship between the terminal item and an immediate suffix. If it is assumed that such enhanced conceptual integration would dissipate with suffix delay, the delayed suffix effect could end up larger than the immediate suffix effect. Such a finding would clearly be at variance with the notion, at the core of two-component theory, that the terminal suffix effect is solely the product of passive, time-dependent, precategorical overwriting. Experiment 10 was designed to evaluate this possibility.

Method

Subjects. The subjects were 72 Rice University undergraduates.

Lists. The stimuli were those used in Experiment 8.

Design. The design was as in Experiment 8. As before, there was no discernible difference between the data for the two subject groups (i.e., between the effects of 600- and 1500-ms suffix delays in the "delayed"-suffix condition), and only the combined data will be reported.

Procedure. The procedure was the same as in Experiment 8 with the exception that all stimuli were shown in the center of the monitor at the same time they were spoken. More precisely, the visual and auditory presentation began at the same instant, but whereas the auditory version lasted just 300 ms, the visual version lasted 650 ms. In the immediate suffix condition, the auditory characteristics of Experiment 8 were retained, with just 17 ms separating the suffix from the last item. Visually, the last item (e.g., 7) and the suffix (00) were presented simultaneously (i.e., as "700")
at the spoken onset of the last item. In the delayed suffix condition, the auditory characteristics of Experiment 8 were retained with, depending upon subject group, either a 600- or a 1500-ms interval separating the suffix from the last item. Visually, the last item (e.g., 7) and the suffix (00) were presented separately, namely at the spoken onset of the last item and the spoken onset of the suffix respectively. The visual suffix (00) was presented just to the right of where the last digit had been presented, so that the spatial relationship between the suffix and last list item was the same in the immediate and delayed suffix conditions.

Results

Figure 11 shows the serial recall function for each suffix condition. In a reversal of its characteristic attenuating influence, delaying a suffix actually enhanced the terminal suffix effect.

Statistical analyses focused on the final four positions, of which the three prior to the last were referred to as preterminal positions and the last as the terminal position. The relevant findings are as follows: 9

1. With the data averaged across the last four positions, mean probability of recall was higher in the no-suffix condition (.61) than in both the immediate-suffix condition (.48), \( t(71) = 12.25, p = .000 \), and the delayed-suffix condition (.44), \( t(35) = 12.96, p = .000 \).

2. With the data averaged across the last four positions, the delayed suffix effect (.17) was modestly larger than the immediate suffix effect (.13), \( t(71) = 2.44, p = .02 \).

3. For the three preterminal positions, the immediate (.13) and delayed (.14) suffix effects differed very little, \( t(71) = 0.70, p = .49 \).
Figure 11. Serial recall as a function of suffix condition and position (Experiment 10).
4. The terminal suffix effect was larger in the delayed suffix condition (.26) than in the immediate suffix condition (.16). The difference was unlikely to have arisen by chance, $t(71) = 4.76$, $p = .000$.

5. A 3 (suffix condition) x 2 (position) analysis of variance with repeated measures on both variables revealed a convincing interaction between suffix condition and position, $F(2, 142) = 24.23$, $\text{MSE} = 0.006$, $p = .000$. Of particular interest is that the difference in the immediate and delayed suffix effects was larger at the terminal position (.10) than at the preterminal (.01) positions. An analysis of variance for just the immediate suffix and delayed suffix data showed that the difference between these suffix effects, as expressed in the Delay x Position interaction, was unlikely to have arisen by chance, $F(1, 71) = 20.11$, $\text{MSE} = 0.008$, $p = .000$.

In summary, the use of a "hundred" suffix together with concomitant visual presentation reversed the typical effect of suffix delay (e.g., Experiments 4 and 9) such that delay increased the suffix effect, at least at the terminal position. This finding is predicted by neither bottom-up overwriting accounts of the suffix effect in general (see Crowder & Morton, 1969; Frankish & Turner, 1984), nor two-component theory in particular (e.g., Greene, 1992; Nairne, 1990; Penney & Godsell, 1993). Rather, it suggests that even the terminal suffix effect depends on the way subjects conceptualize the relation between the suffix and terminal item.

Experiment 11

Experiment 11 was intended as a check on the primary conclusion drawn from Experiment 10, namely that the reversal of
the typical effect of suffix delay was indeed due to some sort of semantic unification of the suffix and the terminal list item. There is, as it happens, an alternative explanation. Because the spoken onset of the final list item coincided with the visual onset of both the last item and the suffix in the immediate suffix condition, subjects had (a 317-ms) visual forewarning of the spoken suffix that was not available in the delayed suffix condition. It is conceivable that this forewarning enabled subjects to attend to the terminal item and ignore the suffix in a way that was not possible in the delayed suffix condition. Moreover, assuming a limited memory capacity (e.g., Crowder, 1976), this attentional deployment to the end of the list could account for the finding in Experiment 10 of modestly lower recall across the first three positions in the immediate condition (.69) compared to the delayed condition (.74), t(35) = 2.71, p = .01.

Experiment 11 was designed to evaluate this alternative interpretation of the results of Experiment 10. It was identical to Experiment 10 except for the spatial configuration of the visual component of the terminal list item and suffix. At issue was whether reconfiguring the visual aspects of the presentation of the final list digit and the suffix would affect the immediate suffix effect and thus modulate the influence of suffix delay found in Experiment 10. According to the semantic grouping interpretation, if the visual presentation of the immediate suffix and the last list item were presented in an unfamiliar and relatively meaningless spatial relation (e.g., 00 instead of 700), then the visual information would do little to promote conceptual unification of the suffix and last list item, and so the effect of suffix delay should be similar to that found
with purely auditory presentation, as in Experiment 8. In other words, it was predicted that in this experiment the effect of a suffix at the terminal position would be essentially invariant of its delay. Alternatively, if in Experiment 10 the superior recall of the terminal item in the immediate suffix condition was attributable simply to the advanced visual warning of the impending spoken suffix then, because that same advance warning is now available, a similar pattern of findings should be obtained. That is, increasing suffix delay should result in a larger terminal suffix effect, just as in Experiment 10.

Method

Subjects. The subjects were 72 Rice University undergraduates.

Lists. The stimuli were those used in Experiment 10.

Design. The design was that used in Experiment 10. Once again, there was no discernible difference between the data for the two subject groups (i.e., between the effects of 600- and 1500-ms suffix delays in the "delayed" suffix condition), and only the combined data will be reported.

Procedure. The procedure was the same as in Experiment 10 with the exception of the spatial arrangement of the visual aspects of the last item and the "hundred" suffix (00). In the immediate-suffix condition, the 00 was shown simultaneously with, but 1 cm below, the last digit (e.g., 00). In the delayed-suffix condition, the 00 was presented, depending upon subject group, either 600 or 1500 ms after termination of the last digit and in the same place as in the immediate suffix condition (i.e., 1 cm below the location of the last digit).
Results

Figure 12 shows the serial recall function for each suffix condition. As in Experiment 8, which presented a "hundred" suffix auditorally, delaying a suffix had no influence on the suffix effect at the terminal position.

Statistical analyses focused on the final four positions, of which three were referred to as preterminal positions and the last as the terminal position. The relevant findings are as follows:\textsuperscript{9}

1. With the data averaged across the last four positions, mean probability of recall was higher in the no-suffix condition (.70) than in both the immediate-suffix condition (.53), $t(71) = 12.37$, $p = .000$, and the delayed-suffix condition (.55), $t(71) = 11.32$, $p = .000$.

2. With the data averaged across the last four positions, the delayed suffix effect (.15) was somewhat smaller than the immediate suffix effect (.17), but the difference was unconvincing, $t(71) = 1.30$, $p = .20$.

3. For the three preterminal positions, although the delayed suffix effect (.12) was somewhat smaller than the immediate suffix effect (.15), the difference was suggestive but not decisive, $t(71) = 1.82$, $p = .07$.

4. The terminal suffix effect was virtually the same for the delayed suffix condition (.24) and the immediate suffix condition (.23), $t(71) = 0.42$, $p = .68$.

5. A 3 (suffix condition) x 2 (position) analysis of variance with repeated measures on both variables revealed a convincing interaction between suffix condition and position, $F(2, 142) = 20.72$, $MSE = 0.006$, $p = .000$. The difference in the immediate and delayed
Figure 12. Serial recall as a function of suffix condition and position (Experiment 1).
suffix effects depended upon position such that the immediate suffix effect was .03 larger than the delayed suffix effect at the preterminal positions but .01 smaller at the terminal position. An analysis of variance for just the immediate suffix and delayed suffix data showed that the difference between these suffix effects, as expressed in the Delay x Position interaction, was suggestive but less than convincing, $F(1, 71) = 3.48$, $\text{MSE} = 0.007$, $p = .07$.

As predicted, the effect of a suffix on recall of the last item of the list was essentially invariant of its delay. This finding parallels that of Experiment 8 in which presentation was purely auditory, and it shows that the visual information was not used to foster integration of the terminal item and immediate suffix. Thus, although the terminal suffix effect for spoken digit lists was smaller with an immediate "hundred" suffix than with a delayed "hundred" suffix when the concomitant visuo-spatial configuration of the terminal item and suffix was meaningful (Experiment 10), this was not the case when the visuo-spatial configuration was not meaningful (Experiment 11). Moreover, in the immediate suffix condition, recall of the first three items of the list was impaired relative to the delayed suffix condition regardless of whether the terminal suffix effect was (Experiment 10) or was not (Experiment 11) attenuated. Across Experiments 10 and 11, then, manipulating the meaningfulness of the visual-spatial configuration of the terminal item and suffix did influence the effect of suffix delay at the terminal position but not the effect at the first few positions. Given that the forewarning of the impending spoken suffix in the immediate suffix condition was the same for these two experiments, no support is
provided for a forewarning account of the findings of Experiment 10. Furthermore, the observed independence between the effects of suffix delay at the end and beginning of the list undermines the possibility that the apparent enhancement in recall of the first three items when the suffix is delayed was a consequence of additional attention (rehearsal, etc.) being given to the last item at the expense of preceding items (see Salter & Colley, 1977).

In short, these findings, together with those of Experiments 5 through 8, advance the case for the terminal suffix effect being susceptible to the semantic relation between the suffix and the last item of the list, and by the same token they undermine the case for two-component theory.

Summary of Experiments 5 - 11

According to two-component theory, such top-down conceptually based factors (as semantic relatedness and static visual information) should not influence the terminal suffix effect. However, Experiments 5, 6, and 7 showed that the terminal suffix effect could be reduced by using a suffix that might be expected to bond with the terminal list item to form a cohesive conceptual unit. Experiments 8 and 9 showed that delaying such a suffix did not have the usual attenuating effect. Indeed, the effect of such a suffix was little, if any, changed by delay. Presumably, delay served to weaken the conceptual bond between the suffix and the terminal list item, so offsetting the normal attenuating effect of delay. Experiment 10 extended this finding by showing that a concomitant static visual presentation of a cohesive suffix could actually reverse the normal effect of suffix delay, so that a delayed suffix had a greater
detrimental effect on recall of the terminal list item than did an immediate suffix, and Experiment 11 ruled out a potential artifactual account of this finding. Collectively, the findings of Experiments 5 to 11 reinforce those of Experiments 1 and 2 in showing that, contrary to two-component theory, even the terminal suffix effect is susceptible to top-down, conceptually-based influences.

Experiment 12

According to two-component theory, the terminal suffix effect arises from bottom-up overwriting of precategorical information in a relatively peripheral information-processing structure. This structure is generally considered to be localized in the auditory sensory channel, although certain findings have forced a modification of the theory to allow precategorical retention of dynamic, speech-related gesticular/visual information. But two-component theory and PAS theory generally hold the line there. It precludes any influence on the suffix effect of static visual information; such information is presumed to enter through a route other than the precategorical route assumed to underlie the suffix effect. And indeed, static visual analogs of standard auditory suffix procedures have typically failed to yield any semblance of the clear and selective impairment manifest in the auditory suffix effect (e.g., Greene, 1987).

On the other hand, static visual suffix effects have occasionally been found with certain variants of the standard suffix procedure. Kahneman (1973; Kahneman & Henik, 1977, 1981) found suffix effects with brief (500 ms) simultaneous presentation of six digits, the suffix being appended to the end of the list and shown at the
same time. Frick and DeRose (1986) also found suffix effects with simultaneous visual presentation. They measured memory span using a longer exposure time (number of items x 560 ms) and they required their subjects to subvocally articulate "blah" throughout the presentation interval in an attempt to make the task functionally more visual. Hitch (1975) found modest visual suffix effects with letters presented sequentially at a 500-ms rate (Experiment 1) and with digits presented sequentially at a 1-s rate (Experiment 2).

It can be argued, however, that these studies do not seriously challenge bottom-up, overwriting accounts of the suffix effect (see Crowder, 1986; Greene, 1987). First, Kahneman (1973) used such a brief presentation duration that, as some have argued, his findings may be better cast in perceptual rather than mnemonic terms. Second, as noted by some, although Frick and DeRose (1986) used a presentation duration more characteristic of auditory suffix experiments, their lists, unlike typical auditory lists, were not of predictable supraspan length. Third, Hitch (1975) presented the suffix and no suffix lists in separate blocks, thereby making the suffix predictable. Finally, Greene (1987; see also Morton & Holloway, 1970) has failed to replicate the visual suffix effects of each of these three studies.

LeCompte and Watkins (1995, Experiment 5) reported a static visual suffix effect using procedures highly similar to those used by Greene (1987, Experiment 4), namely supraspan lists that were presented visually and simultaneously for a total of 4 seconds. The one departure from Greene's experiment was that subjects subvocally mouthed "blah" during study. Although Greene reported
two additional experiments that required subvocal articulation during simultaneous visual presentation, presentation duration in those experiments was only 1.2 seconds. Following Greene, LeCompte and Watkins (1995) adopted such procedural details as presentation duration and the use of a constant supraspan list length on the basis of standard practice in the typical auditory suffix paradigm. The idea here was that, if suffix effects could be demonstrated under these conditions, they would pose a significant challenge to the PAS lineage of theories (see Crowder, 1986; Greene, 1987).

LeCompte and Watkins's (1995) procedures did indeed result in a reliable suffix effect. Moreover, increasing the similarity (by way of font) of the two elements of a compound suffix attenuated the suffix effect, presumably because the similarity between elements of a compound suffix fostered their perceptual coherence, and by the same token their perceptual dissociation from the list items. These visual effects were assessed with recall averaged across all eight list positions, but it is clear from the serial position functions (LeCompte & Watkins's Figure 5) that, as with auditory presentation, the visual suffix effect was most pronounced towards the end of the list. PAS-type overwriting theories in general (e.g., Crowder, 1978, 1983; Greene & Crowder, 1984a; also see Nairne, 1990; Penney, 1985; Penney & Godsell, 1993) and two-component theory in particular (e.g., Greene, 1992; Penney & Godsell, 1993) cannot account for such a visual suffix effect.

Experiment 12 was an attempt to replicate and extend LeCompte and Watkins's (1995) findings. If the visual suffix effect they
reported really is the same kind of phenomenon as the suffix effect observed with auditory presentation, then it should be possible to demonstrate a visual effect analogous to that of suffix delay obtained with auditory presentation. That is, a suffix which is spatially close to the terminal list item might be expected to impair recall more than one that is spatially removed from the terminal list item. The specific purpose of Experiment 12, therefore, was to replicate the finding that recall of the last few items of a visual list is impaired by a statically-presented visual suffix, and to assess whether this suffix effect would diminish by (spatially) separating the suffix from the list items.

**Method**

**Subjects.** The subjects were 30 Rice University undergraduates.

**Lists.** The to-be-remembered items were the digits 0 through 9, except for 3 which, following LeCompte and Watkins (1995) and Frick and DeRose (1986), was reserved for use as the suffix. A separate set of 63 digit lists was constructed for each subject. List construction was in accordance with the criteria specified in Experiment 1. The digits were presented in the center of the monitor in size 18 Courier font.

**Design.** The experiment conformed to a 3 (suffix condition) x 2 (preterminal and terminal positions) design with repeated measures on both variables. The to-be-remembered digits were always presented in the middle of the monitor with no spaces between them. To the right of the last (ninth) digit was a white background (control condition), the suffix "3" placed next to the terminal list item (proximal suffix condition), or the suffix "3" separated by 2 spaces
from the terminal list item (distal suffix condition).

**Procedure.** Subjects were given three practice trials, one in each suffix condition. On each of the 60 trials of the experiment proper a row of nine digits and, for some trials, a suffix was shown for 4.5 s. The order of the three suffix conditions (control, proximal, distal) was randomized separately for each subject. Subjects were instructed to ignore any concluding "3" and to recall the other 9 digits in their presentation order. Immediately following list presentation, the nine position (response) markers were shown and subjects attempted to type the nine digits in their presentation order, beginning with the first digit in the left-most space and concluding with the ninth digit in the right-most space. When satisfied, subjects clicked an "OK" button and were prompted to begin the next trial.

**Results**

Figure 13 shows the serial recall function for each suffix condition. In the proximal suffix condition, recall of the last few digits was impaired relative to the control condition. In contrast, the distal suffix had no clear effect.

Statistical analyses focused on the final four positions, of which the three prior to the last were referred to as preterminal positions and the last as the terminal position. The relevant findings are as follows:¹⁰

1. With the data averaged across the last four positions, mean probability of recall in the no-suffix condition (.48) differed from that in the proximal-suffix condition (.40), \( t(29) = 5.12, p = .000 \), but not from that in the distal-suffix condition (.50), \( t(29) = 1.50, p = .14 \).

2. With the data averaged across the last four positions, the
Figure 13. Serial recall as a function of suffix condition and position (Experiment 12).
proximal suffix effect (.08) was clearly larger than the (nonexistent) distal suffix effect (.02). The difference was almost certainly not attributable to chance, $t(29) = 7.04$, $p = .000$.

3. For the three preterminal positions, mean probability of recall was higher in the no-suffix condition (.48) than in the proximal-suffix condition (.41), $t(29) = 3.99$, $p = .000$, but not than in the distal-suffix condition (.50), $t(29) = 1.13$, $p = .27$. The proximal suffix effect (.07) was clearly larger than the distal suffix effect (.02), $t(29) = 5.79$, $p = .000$.

4. At the terminal position, probability of recall was higher in the no-suffix condition (.50) than in the proximal-suffix condition (.39), $t(29) = 4.78$, $p = .000$, but not than in the distal-suffix condition (.53), $t(29) = 1.51$, $p = .14$. The proximal suffix effect (.11) was clearly larger than the distal suffix effect (-.03), and the difference was not likely to have arisen by chance, $t(29) = 5.08$, $p = .000$.

5. A 3 (suffix condition) x 2 (position) analysis of variance with repeated measures on both variables revealed a marginal interaction between suffix condition and position, $F(2, 58) = 2.94$, $MSE = .005$, $p = .06$. The proximal suffix effect was larger at the terminal position (.11) than at the preterminal position (.07), although as shown by the Suffix x Position interaction for just the control and proximal suffix data, this difference was less than compelling, $F(1, 29) = 3.76$, $MSE = .005$, $p = .06$. Finally, there was a tendency for the effect of suffix proximity to be greater at the terminal position (.14) than at the preterminal position (.09), as shown by the Delay x Position interaction for just the proximal and distal suffix data, $F(1, 29) = 4.20$, $MSE = .007$, $p = .05$. 
In short, this experiment has demonstrated a suffix effect in the visual modality using static presentation. Moreover, it has done so with a fixed supraspan list length and a lengthy presentation duration, both of these details serving to increase the parallel with the typical auditory suffix effect (see Crowder, 1986; Greene, 1987). Additionally, this visual suffix effect was localized toward the end of the list and dissipated when the suffix was separated from the list items, paralleling the effect of temporal separation in the auditory modality. These findings are inconsistent with two-component theory (e.g., Greene, 1992), and with overwriting theories in general (e.g., Crowder, 1978, 1983; Greene & Crowder, 1984a; Nairne, 1990), because such theories assume that static visual information does not take the structural route presumed to give rise to the suffix effect (see Crowder, 1978, 1983; Greene, 1987, 1992).

General Discussion

Here I do six things: (i) summarize the findings of the 12 experiments reported here as they pertain to two-component theory, (ii) consider the implications of the replication failures, (iii) argue that the evidence that has been taken as supporting two-component theory is less conclusive than generally supposed, (iv) note mounting evidence inconsistent with two-component theory's core assumption that the terminal suffix effect is immune to conceptually-based manipulations, (v) summarize problematic aspects of the present findings as they relate to various other accounts of the suffix effect, and (vi) cast the suffix effect as the product of perceptual grouping.

Summary

Recall of the last few of a just-spoken list of items is typically
impaired if a nominally irrelevant "suffix" item is spoken directly after list presentation. According to what I have dubbed two-component theory, there is a qualitative difference between the effect on the very last item (the terminal suffix effect) and the effect on the immediately preceding items (the preterminal suffix effect). The terminal suffix effect is posited to be "structural," or fixed by the nature of the "memory system," whereas the preterminal suffix effect is regarded as mutable and readily susceptible to top-down conceptually-based influences, including the rememberer's interpretations and strategies.

The present investigation provides new evidence that undermines the qualitative distinction between the terminal and preterminal suffix effects, largely by demonstrating top-down conceptually based influences on the terminal suffix effect. The 12 experiments comprise three converging lines of evidence.

**Experiments 1-4.** Continuing Bloom's (1997) line of inquiry, Experiments 1 through 4 reevaluated four variables (presentation rate, practice, suffix length, and suffix delay) that are presumed to influence subject's strategies and, consistent with two-component theory, have been shown to selectively affect the preterminal component of the suffix effect. Experiment 1 reexamined Balota and Engle's (1981) finding that slowing presentation of the list items enhanced the preterminal suffix effect while leaving the terminal suffix effect essentially unaffected. Contrary to Balota and Engle's finding, slowing presentation had no influence on the preterminal suffix effect but did have a modest attenuating influence on the terminal suffix effect.
Experiment 2 was designed to evaluate the effect of practice. Whereas Balota and Engle (1981; see also Penney, 1985) found that practice with the task enhanced the preterminal suffix effect but had no discernible influence on the terminal suffix effect, Experiment 2 showed quite a different pattern of results: practice served to attenuate the terminal suffix effect but had no discernible influence on the preterminal suffix effect.

Experiment 3 failed to confirm Baddeley and Hull's (1979) claim that use of a long suffix rather than a short suffix serves both to increase the preterminal suffix effect and to decrease the terminal suffix effect. True to theory, Baddeley and Hull assumed that the longer suffix caused more disruption of memory strategy but less damage to structure-based memory. Experiment 3 showed no discernible effect of suffix length on either the preterminal or terminal suffix effects.

Finally, Experiment 4 was designed to follow up Penney and Godsell's (1993) finding that delaying presentation of the suffix selectively reduced the terminal suffix effect. In keeping with two-component theory, Penney and Godsell assumed that suffix delay affected the structure-based component of the suffix effect but not the strategy-based component. Experiment 4 turned out differently: Delaying the suffix sharply reduced the preterminal as well as the terminal suffix effect.

Experiments 5-11. Experiments 5 through 11 investigated the influence of another top-down conceptually based variable, namely the semantic relationship or coherence between the suffix and list items. In Experiments 5 and 7, digits were almost immediately
followed by silence, the suffix "recall," or the suffix "hundred."
Contrary to two-component theory, but consistent with certain other
findings (Ayers et al., 1979; Salter & Colley, 1977), increasing the
semantic coherence between the suffix and the list items by use of
the "hundred" suffix served to attenuate the terminal suffix effect.

Experiments 8 through 11 extended this finding by
demonstrating that the subject's conceptualization of the suffix and
list items modulates the effect of suffix delay. In particular,
Experiment 8 showed that, relative to a "recall" suffix, a "hundred"
suffix attenuated, if not eliminated, the typical influence of suffix
delay at the terminal position. And Experiment 10 demonstrated
that a "hundred" suffix together with concomitant static visual
presentation reversed the typical effect of suffix delay, such that the
terminal suffix effect increased with suffix delay.

Thus, it appears that the suffix effect can be influenced by at
least two types of postcategorical information, namely the identity of
the suffix (and its semantic relation to the last list item) and the
semantic nature of concomitant static visual information. These
results reinforce the findings of Experiments 1 and 2 in showing that
even the terminal suffix effect is susceptible to top-down
conceptually-based influences, and they thereby reinforce the case
against two-component theory.

**Experiment 12.** The susceptibility of the terminal suffix effect to
concomitant visual information is inconsistent with its interpretation
as a wholly precategorical phenomenon (see also LeCompte &
Watkins, 1995, Experiment 5). Experiment 12 extended this
argument by demonstrating a suffix effect with static visual
presentation. Interestingly, manipulation of spatial proximity influenced the visual suffix effect in just the same way as manipulation of temporal proximity influences the auditory suffix effect (e.g., Experiment 4; Crowder, 1976; Crowder, Morton, & Prussin, 1971). These findings are troublesome for auditory masking theories in general (e.g., Crowder, 1978, 1983; Greene & Crowder, 1984a) and two-component theory in particular (e.g., Greene, 1992; Penney & Godsell, 1993; see also Nairne, 1990) because static visual information is assumed neither to be processed through the same physically sensitive structure as that used for auditory/gesticular information nor to survive in precategorical form long enough to play a role in most immediate memory procedures (e.g., Crowder, 1978, 1986, 1993; Greene, 1987, 1992).

In short, the 12 experiments reported here consistently undermine the core assumption of two-component theory, namely that top-down conceptually-based factors influence the preterminal component but not the terminal component of the suffix effect. Indeed, not only did I fail to replicate certain previous findings of conceptually-based influences on the preterminal suffix effect, but such influences as did occur were largely localized at the terminal position (Experiments 1, 2, 4, 5, 7, 10, and 12).

Fidelity of Replication

Failures to replicate a behavioral finding are invariably susceptible to the charge that the referent experiments were not replicated closely enough. Certainly, no claims are made for absolute fidelity of replication in the experiments reported here. This is even true of the first four experiments, which were specifically designed
to replicate particular findings. The methodological departures of these four experiments from their respective referent experiments warrant comment. Five changes are especially worthy of mention.

First, except in Experiment 4, I used lists longer than those used in the referent experiments in order to reduce performance to an informative level. Second, in all four experiments I changed the identity of the suffix. In the case of Experiment 3, this change could be said to be a ripple effect of the difference in subject populations, for unlike their British counterparts, our subjects could be assumed to be unfamiliar with "Rhyl" and "Abergavenny." But in Experiments 1 and 2 such changes were essentially gratuitous. Third, except where manipulated as the variable of interest (i.e., in Experiments 1 and 2), presentation rate was standardized at one item every half second. Fourth, suffix condition varied unpredictably from list to list whereas in all but one of the referent experiments (Penney & Godsell, 1993, Experiment 1) suffix condition was known to the subject during list presentation. Fifth, although the preterminal suffix effects were defined as in the respective referent experiments, the terminal suffix effects were defined in the same way for all experiments, and in this respect analyses for Experiment 3 deviated from those of the referent experiment.

What is to be made of these deviations from the referent experiments? I believe that most of them did not greatly influence the findings. The suffix effect is remarkably robust with respect to subject population, suffix identity, and presentation rate, and a review of the literature suggested that, generally speaking, the same holds true for its preterminal and terminal components. Moreover,
suffix predictability appears to have little influence on the ways in which either component of the suffix effect responds to presentation rate (Experiment 1 versus Engle, 1980), practice (Experiment 2 versus Watkins & Sechler, 1989), and delay of suffix (compare Experiments 1 and 2 of Penney & Godsell, 1993).

I should concede that my case for adequate fidelity of replication is fragmentary, and that much of the evidence I have cited is descriptive and statistically inconclusive. However, the case would still be far from clinched even if the evidence were complete and statistically secure. Thus, even if I had followed the referent reports to the letter, each discrepancy in finding could have been caused by a difference in one or more points of procedure considered too minor to have been included in the descriptions of the referent experiments. A claim that my procedures adequately replicate those of the referent experiments therefore takes another form, namely that my objective was not one of replicating methodology, but rather one of replicating findings in the service of evaluating a theory. The important point here is that evaluating a theory calls for replication of only those aspects of procedure that are germane to the theory. If my failures to support two-component theory were due to an inadvertent change in some unspecified procedural detail or, for that matter, to an advertent change in suffix identity, presentation rate, or some other detail unrelated to the theory, then the theory may be said to be, at best, underspecified.

Not all of my changes were arbitrary or made merely in the interest of consistency. For example, rather than following Baddeley and Hull (1979) in defining the terminal suffix effect as level of
recall at the last position minus level of recall at the preceding position in the same suffix condition, I thought the essence of two-component theory was better captured by the more familiar definition of level of recall in the no-suffix condition at the last position minus level of recall in the suffix condition at the last position.

I also believe that in experiments designed to evaluate two-component theory, suffix condition should not be known to the subject during list presentation. Without this precaution, there is always the potential for study strategy being systematically tailored to suffix condition, in which case the observed suffix effects would be an amalgam of the effects of study strategy and of suffix presentation per se. Of course, any effect that suffix condition may have on the way the lists are studied could be held to be partly, or indeed entirely, the basis for the strategic component of preterminal recall. To my knowledge, Penney and Godsell (1993) are the only advocates of two-component theory open to such a possibility. The only other view I have found on the issue is that of Engle (1980), who took the opposite stance and regarded any potential confound between suffix condition and the way items are attended or rehearsed as a defect in design. For my part, I note that to the extent that it attributes the strategy-based component of the suffix effect to study strategies specific to suffix condition, two-component theory is limited to the suffix effect as it occurs when suffix condition is known to the subject during list presentation—typically when it is varied between blocks of trials or between subjects; it would not apply to the suffix effect as it occurs when suffix condition is
unpredictable. Limiting the theory this way would not be parsimonious, especially because the actual effect of predictability of suffix condition on either the preterminal or terminal component of the suffix effect is, at least to my knowledge, small if indeed it exists at all.

**Pillars of Two-Component Theory Reconsidered**

Even were it replicable, much of the evidence on which the case for two-component theory has been made may be less supportive of the theory than is commonly assumed. The problem is that there seems to be no basis in the theory for the details of the evidence being as they are. Why should making list length unpredictable eliminate the preterminal suffix effect rather than enlarge it? Why should practice or a slower presentation rate increase rather than decrease the preterminal suffix effect? And why should an increase in the acoustical length of the suffix decrease the terminal suffix effect while increasing the preterminal suffix effect as opposed to, say, the other way around?

In each of these cases it seems that, if forced, answers based on two-component theory would be wrong. Surely, making list length unpredictable would, if anything, compromise strategic efforts to render memory for the last few items suffix-resistant, thereby enlarging the preterminal suffix effect. Likewise, both allowing practice and slowing presentation could, if anything, be expected to aid strategic efforts to process the list items in a way that protects against the suffix, thereby attenuating the strategically-based preterminal suffix effect. Also, a delay in suffix presentation would seem to be an opportunity for rehearsal or some other strategic
process, in which case an influence might be expected on the preterminal as well as the terminal component of the suffix effect. And it seems reasonable to suppose that the primary effect of increasing the acoustical length of the suffix would be on the passive "structural" component of memory, for at the precategorical level of analysis commonly assumed to characterize such memory, a long suffix would carry more information and so, presumably, interfere more with the list items than would a short suffix (see Watkins, 1972; Watkins & Watkins, 1973).

Theorists, and perhaps information-processing theorists in particular (see Watkins, 1990), have a way of extracting nourishment from just about any pertinent finding, and clearly two-component theorists have not been wanting in this regard. Compare the account that Balota and Engle (1981) gave of their findings on the effect of presentation rate with Penney and Godsell’s (1993) account of their findings on the effects of suffix delay. Balota and Engle saw support for two-component theory in their finding that presentation rate affects just the preterminal component of the suffix effect on the grounds that varying the amount of time available per item would be expected to influence the extent to which, and perhaps even the manner in which, the subject thinks about the items. But Penney and Godsell also found support for the theory in their finding that delaying the suffix systematically increased recall at just the terminal position, arguing that delay of suffix affected the structural component of the suffix effect but not the strategical component. Thus, we are told that on the one hand time between the presentations of successive items affects preterminal recall because
time affects strategically-based recall, and that on the other hand
time between the last list item and a following suffix affects terminal
recall because time affects structurally-based recall. Had these
arguments come from the same source, a skeptic would surely be
forgiven for suspecting dubious reasoning if not sharp practice.

Malleability of the Terminal Suffix Effect

Ample converging evidence is now amassing that is contrary to
two-component theory's core assumption that the terminal suffix
effect is a product of memory "structure" and beyond the influence
of the subject's conceptions and strategies.

First, and as reviewed earlier, the terminal suffix effect depends,
under certain circumstances, on the conceptual relation between the
suffix and the last item of the list (Salter & Colley, 1977). Second, as
also noted earlier, research with certain cleverly chosen suffixes has
shown that the terminal component of the suffix effect is sharply
dependent on whether the subjects are set up to perceive the suffix
as speech or as a non-speech sound (Ayres, Jonides, Reitman, Egan, &
Howard, 1979; Neath et al., 1993; Ottley, Marcus, & Morton, 1982).
Two-component theory allows "top-down" or conceptually-based
influences on the preterminal suffix effect, but does not allow such
influences on the terminal suffix effect, for in terms of the theory it
is the stimulus as presented rather than the stimulus as perceived
that matters for the "structural" memory that underlies recall of the
last item.

Two other findings, although largely overlooked, also appear
inconsistent with the idea that subject-based strategies cannot
influence the suffix effect at the terminal position. First, Morton,
Crowder, and Prussin (1971, Experiments 8 & 10) found that if subjects are aware that a suffix will come from a direction different from that of the list items, then its effect will be lessened. Given that an effect of being able to anticipate some aspect of the procedure reflects a top-down, if not strategy-based, influence (see Engle, 1980; Penney, 1985; Penney & Godsell, 1993), the effect should, according to two-component theory, be localized at the preterminal positions. But in fact it is most pronounced at, if not restricted to, the terminal position. Second, the order in which the list items are recalled is plainly a matter of strategy—even if as guileless as following instructions—and yet it does influence the terminal suffix effect. Thus, the terminal suffix effect in particular is reduced if, instead of being recalled in their presentation order, the list items are recalled from last to first (Manning & Pacifici, 1983), or beginning with the last three (Manning & Turner, 1984), or without regard to presentation order (Roediger & Crowder, 1976).

To these examples may be added certain findings from the research I have reported here and in recent work (Bloom, 1997). In particular, two-component theory is inconsistent with my findings of: (a) a reduction in the terminal suffix effect when presentation rate was slowed (Experiment 1), when practice was allowed with the task (Experiment 2), and when the semantic relationship or coherence between the suffix and terminal list item was increased (Experiments 5 & 7); (b) an increase in the terminal suffix effect both when list length was unpredictable (Bloom, 1997, Experiment 1)\textsuperscript{12} and when list length was specified at test (Bloom, 1997, Experiment 2); (c) an attenuation, if not elimination, of the typical influence of suffix delay
at the terminal position with high semantic coherence between the suffix and terminal list item (Experiment 8); (d) a reversal of the typical influence of suffix delay on the terminal position with high semantic coherence between the suffix and terminal list item and concomitant visual presentation (Experiment 10); and (e) a suffix effect with static visual presentation (Experiment 12).

Alternative Accounts of the Suffix Effect

If the suffix effect is not well accounted for by two-component theory, then what account should be given? In this section, I briefly consider other extant theories (for reviews of these theories, see Greene, 1992; Neath, 1998).

Precategorical Acoustic Storage. Two-component theory is a variant of the theory of precategorical acoustic storage or PAS (Crowder & Morton, 1969; Crowder, 1978; Greene & Crowder, 1984a; Morton, Marcus, & Ottley, 1981; see also Nairne, 1990). Whereas two-component theory distinguishes between the preterminal and terminal component of the suffix effect, the theory of PAS in its generic form makes no such distinction. Rather, it assumes that the entire suffix effect results from precategorical overwriting in a relatively peripheral information-processing structure. PAS theory thus runs afoul of evidence presented here and elsewhere (Ayers et al., 1979; Salter & Colley, 1977) that the suffix effect is subject to top-down postcategorical influences. Also, PAS theory does not specify a mechanism that would produce a visual suffix effect of the sort demonstrated in Experiment 12.

Feature Model. The feature model (Nairne, 1990), like the theory of PAS, explains the suffix effect in terms of overwriting of
physical or "modality-dependent" (auditory) features. The overwriting of these modality-dependent features, and thus the suffix effect itself, is considered "precategorical" and to "not be under strategic control" (Nairne, 1990, pp. 252 and 259). For example, the greater the similarity between the modality-dependent features (e.g., voice) of the suffix and list items, the greater the number of features overwritten by the suffix and the larger the suffix effect. Finally, the feature model offers a two-component interpretation of the suffix effect such that, only the terminal suffix effect is the result of "modality dependent" feature overwriting. The preterminal suffix effect is presumed to have a different cause: the suffix is assumed to gain automatic access to the set of presented items and thereby increase the size of the search set and so lower recall.

The findings reported here pose two problems for this theory. First, the finding that postcategorically based, or "modality independent," factors can influence the terminal suffix effect (see also Ayers et al., 1979; Salter & Colley, 1977) is inconsistent with the feature model's precategorical "modality dependent" explanation. Second, because visual presentation is presumed to yield primarily modality independent traces (Nairne, 1990, p. 255) and because the suffix effect is presumed to arise from the overwriting of modality dependent features (within the auditory mode), the feature theory does not specify a mechanism that would produce a visual suffix effect of the sort demonstrated in Experiment 12.

**Changing-State Hypothesis.** According to the changing-state hypothesis (Campbell & Dodd, 1980; see also Campbell, Dodd & Brasher, 1983), the suffix effect occurs only with dynamic stimuli--
that is, stimuli that change or unfold over time. Campbell & Dodd (1980) argue that suffix effects "may reflect a general tendency for changing state information to be processed differently than information (usually visual) which can be resolved simultaneously. (p. 97)" Thus, according to the theory, suffix effects arise with gesticular (i.e., mouthed, lipread, and hand-signed) as well as auditory presentation, for in each case the stimuli unfold over time. However, the changing-state hypothesis cannot account for the present finding of a suffix effect being modulated by (Experiment 10), or even the sole consequence of (Experiment 12), static visual stimuli.

**Primary Linguistic Code Hypothesis.** According to the Primary Linguistic Code Hypothesis (Shand & Klima, 1981), speech (acoustical and gesticular) is the primary linguistic code and hence the way information is represented in primary memory (Conrad, 1964). In contrast, when information is presented in static visual form it has to be recoded into the primary linguistic speech-based code. The key assumption is that the suffix effect arises only when stimulus presentation occurs in the primary linguistic code and does not have to be recoded. Although this assumption has received some attention, it has never been fully articulated. This issue aside, the primary linguistic code hypothesis can account for the suffix effects obtained with speech-related codes, including speech, mouthed, and lipread presentation. And if one assumes that for native signers of American Sign Language (ASL), the primary linguistic code is ASL rather than speech, this hypothesis can also account for the demonstration of suffix effects with ASL. However, like the
changing-state hypothesis, the primary linguistic code hypothesis cannot account for the present finding of a suffix effect being modulated by (Experiment 10), or even the sole consequence of (Experiment 12), stimuli presented in a secondary code, namely static visual presentation.

Temporal Distinctiveness Account. According to temporal distinctiveness theory (Glenberg, 1987; Glenberg & Swanson, 1986), temporal information is encoded at the time of study and this encoding is more precise or finer grained both for more recent presentations (hence the recency effect) and for auditory presentation (hence the modality effect). This theory can also account for the suffix effect by assuming that the presentation of a suffix overloads the otherwise fine grained auditory temporal cues associated with the end of the list, thereby reducing the distinctiveness of the last few list items and thus their likelihood of being recalled.

This innovative theory makes a number of predictions concerning the suffix effect. One such prediction, articulated by Glenberg and Swanson (1986, p. 12), is of an interaction between familiarity with the task (operationalized as practice) and position, with familiarity affecting the preterminal component of the suffix effect more than the terminal position. Glenberg and Swanson cited the findings of Balota and Engle (1981) as consistent with this prediction. However, Experiment 2 of the present investigation (also see Watkins & Sechler, 1989, Experiment 1), showed practice to have no discernible influence on the preterminal component of the suffix effect but a modest influence on the terminal component.
Additionally, temporal-distinctiveness theory does not address visual suffix effects.

**Suffix Effect as Perceptual Grouping**

There is yet one other interpretation of the suffix effect, one that is much more compatible with the present findings. It may be referred to as the perceptual grouping hypothesis (Kahneman, 1973; Kahneman & Henik, 1977, 1981; see also Frick & DeRose, 1986a, 1986b; LeCompte & Watkins, 1995).

Kahneman and his colleagues (Kahneman, 1973; Kahneman & Henik, 1977, 1981) found visual suffix effects when a "zero" was appended to a list of briefly displayed digits, the to-be-remembered digits and the zero suffix being displayed all at the same time. When additional zeros were added to the existing single zero, thereby forming a row or column of zeros, the suffix effect was attenuated. Kahneman accounted for these findings in terms of obligatory perceptual grouping in the tradition of Gestalt principles, such as good continuation (see also Neisser, 1967; Neisser, Hoenig, & Goldstein, 1969). In essence, the suffix effect arises to the extent that a suffix is perceptually organized or grouped as another item of the to-be-remembered list.

This hypothesis can be extended to the auditory suffix effect. For example, its nominal irrelevance notwithstanding, the typical suffix is a verbal utterance spoken in the same voice as, and in rhythm with, the list items. It is therefore likely to be perceptually grouped with the list items and so impair their recall (Frankish & Turner, 1984; LeCompte & Watkins, 1995). Changes in the suffix or in the perceived relation of the suffix to the list items would, on this
mode of thinking, affect the magnitude of the suffix effect. And there is much empirical evidence consistent with this prediction, including evidence of the susceptibility of the suffix effect to manipulations of similarity (Ayers et al., 1979; Crowder, 1976; Darwin & Baddeley, 1974; Elmes, 1974; Greene, 1992; LeCompte & Watkins, 1995; Manning & Robinson, 1989; Miles, Westley & Buller, 1995; Nairne, 1990) and proximity (Crowder, 1976; Frankish, 1985; Frankish & Turner, 1984; Greene, 1992; Kahneman, 1973). Thus, presenting the suffix in a voice different from that for the list items decreases the perceptual similarity between the suffix and the list items and so attenuates the suffix effect (Morton et al., 1971). Likewise, temporally delaying the suffix and so perceptually separating it from the list items also attenuates the suffix effect (Crowder, 1969, 1971a). Additionally, presenting the suffix from an apparent (spatial) location different from that of the list items also attenuates the suffix effect (Morton, Crowder & Prussin, 1971, Experiments 8 & 10).

Although such auditory findings have traditionally been viewed as controlled by a variety of bottom-up, physical or structurally-based manipulations (e.g., Crowder, 1976; Greene, 1992; Kahneman, 1973; LeCompte & Watkins, 1995; Nairne, 1990), the present research suggests that the perceptual organization of a suffixed list may also be subject to top-down conceptually-based influences (see also Ayers et al., 1979; Salter and Colley, 1977). For example, the results of Experiments 1 and 2, as well as those of Bloom (1997), demonstrate that even the terminal portion of the suffix effect can be modestly attenuated by a slower rate of presentation, greater
practice in performing the task (see also Watkins & Sechler, 1989), and ability to predict when the list will end. It is reasonable to suppose that each of these manipulations should, if anything, facilitate subject's strategies of perceptually separating the suffix item from the list items.

Experiments 5 through 11 make the same point in the opposite way. Specifically, they show that increasing the semantic relation between the suffix and the final list item by the judicious use of context and pre-experimental association served to attenuate the terminal suffix effect (Experiments 5 & 7) and modulate the effect of suffix delay (Experiment 8). Moreover, by reinforcing this relation with the aid of concomitant visual presentation, the usual effect of suffix delay was reversed such that delaying the suffix enhanced its effect (Experiment 10). A reasonable interpretation of these findings is that such conceptually based manipulations affect the extent to which the suffix and terminal item are perceived as a coherent conceptual unit.

Finally, Experiment 12 demonstrated a purely visual suffix effect. It also showed elimination of this effect through spatial separation of the suffix and the list items. Again, it is reasonable to assume that the separation of the suffix and list items affects their perceptual integration.

To summarize, I favor interpreting the present findings in particular and those of the suffix effect literature in general in terms of perceptual grouping. Perception is acknowledged to be controlled by a combination of bottom-up structurally based and top-down conceptually based processing (e.g., Bregman, 1990; Levy & Kirsner,
1989; Long, Toppino, & Mondin, 1992; Neisser, 1967; Trehub & Trainer, 1993), and so it is not implausible to assume that the suffix effect reflects perceptual grouping that is sensitive to both bottom-up influences, such as voice, and top-down influences, such as subjects' interpretations and strategies. Moreover, specific grouping principles (e.g., similarity) that are subject to both structurally based (e.g., voice) and conceptually based (e.g., semantic relationship) influences determine the manner in which and the extent to which the list items and the suffix are perceptually grouped. The extent of the suffix effect will depend on the number of items with which the suffix is perceptually grouped. As with the recency and modality effects, the extension of the suffix effect to preterminal positions attests to the reach of structural control. It may be that this reach is coextensive with that special kind of memory James (1890) referred to as the specious present, or primary memory. In any event, although structural control may increase with recency, it is—even at the terminal position—not absolute. Thus, I regard the premise underlying two-component theory of an absolute distinction between a strategy-sensitive preterminal component and a strategy-independent terminal component as simplistic. I see the entire suffix effect as all of a piece, with its preterminal and terminal positions alike being caused by subjects' inability to perceptually segregate the suffix from the list items.

This perceptual grouping account makes contact with grouping explanations of phenomena that many theorists consider to be related to the suffix effect. In particular, a variety of bottom-up and top-down instantiations of organization, particularly the principles of
similarity and proximity, have often been pressed into service to account for standard recency effects (Frick, 1989a, 1989b; Glenberg, 1990; see also Frankish, 1985, 1989), long term-recency effects (Glenberg & Swanson, 1986; Greene & Crowder, 1984b; Neath, 1993; Neath & Crowder, 1990; Thapar & Greene, 1993; Watkins & Peynircioglu, 1983), standard modality effects (e.g., Frankish, 1985; Frick, 1989a; Glenberg, Mann, Altman, Forman & Procise, 1989; Murray et al., in press), and long-term modality effects (Glenberg, 1984; Glenberg & Swanson, 1986; Greene, 1985; Neath & Crowder, 1990; Marks & Crowder, 1997). And in a yet more expansive vein, these contemporary perspectives on grouping may be placed in the context of the prominent role that organization has long maintained in several broad areas of psychology, including perception (e.g., Boring, 1942; Koffka, 1935; Neisser, 1967), learning (e.g., Hebb, 1949; Osgood, 1949; Thorndike, 1931), and memory (e.g., Bartlett, 1932, 1995; Bower & Winzenz, 1969; Hintzman, 1986; Mandler, 1967; Miller, 1956; Raaijmakers & Shiffrin, 1981; Tulving, 1962, 1964).

Perhaps, then, it is not surprising that some theorists (e.g., Elmes, 1974; Kahneman, 1973; Frankish, 1985; Frankish & Turner, 1984; Frick & DeRose, 1986a, 1986b; LeCompte & Watkins, 1995) view the suffix effect as an expression of one of psychology's more durable themes, namely perceptual organization. Certainly, such a view will foster the integration of the suffix effect with other memory phenomena.
Footnotes

1 Points 1 - 3 are based on a Suffix Condition x Rate analysis for the last five positions. Point 4 is based on a Suffix Condition x Rate analysis for the four preterminal positions, and Point 5 on the Suffix Condition x Rate analysis for just the terminal position. Point 6 is based on a Suffix Condition x Rate x Position analysis in which the mean probability of recall for the preterminal positions was weighted the same as the probability for the terminal position. All analyses took account of the repetition of measures on all variables. Additional findings from these analyses are included in the Appendix.

2 Throughout the paper, MSE values are shown to two significant digits and p values are rounded to the number of decimal places shown.

3 Points 1 - 3 are based on a Suffix Condition x Practice analysis for the last five positions. Point 4 is based on a Suffix Condition x Practice analysis for the four preterminal positions, and Point 5 on the Suffix Condition x Practice analysis for just the terminal position. Point 6 is based on a Suffix Condition x Practice x Position analysis in which the mean probability of recall for the preterminal positions was weighted the same as the probability for the terminal position. All analyses took account of the repetition of measures on all variables. Additional findings from these analyses are included in the Appendix.

4 Point 5 is based on two analyses of variance: a Suffix Condition x Position analysis in which the preterminal and terminal positions were given equal weight; and a Suffix Condition x Position analysis
for just the short and long suffix conditions in which the preterminal and terminal positions were given equal weight. Both analyses of variance took account of the repetition of measures on the suffix and position variables. Other findings from these analyses are included in the Appendix.

5 Point 5 is based on two analyses of variance: a Suffix Condition x Position analysis in which the preterminal and terminal positions were given equal weight; and a Suffix Condition x Position analysis for just the immediate and delayed suffix conditions in which the preterminal and terminal positions were given equal weight. Both analyses of variance took account of the repetition of measures on the suffix and position variables. Other findings from these analyses are included in the Appendix.

6 Point 5 is based on two analyses of variance: a Suffix Condition x Position analysis in which the preterminal and terminal positions were given equal weight; and a Suffix Condition x Position analysis for just the "recall" and "hundred" suffix conditions in which the preterminal and terminal positions were given equal weight. Both analyses of variance took account of the repetition of measures on the suffix and position variables. Other findings from these analyses are included in the Appendix.

7 Point 5 is based on two analyses of variance: a Suffix Condition x Position analysis in which the preterminal and terminal positions were given equal weight; and a Suffix Condition x Position analysis for just the "callre" and "dredhun" suffix conditions in which the preterminal and terminal positions were given equal weight. Both analyses of variance took account of the repetition of measures on
the suffix and position variables. Other findings from these analyses are included in the Appendix.

8 Point 5 is based on four analyses of variance: a Suffix Condition x Position analysis in which the preterminal and terminal positions were given equal weight; a Suffix Condition x Position analysis for just the "recall" and "hundred" suffix conditions in which the preterminal and terminal positions were given equal weight; a Suffix Condition x Position analysis for just the "recall" and through-list "hundred" suffix conditions in which the preterminal and terminal positions were given equal weight; and a Suffix Condition x Position analysis for just the through-list "hundred" and "hundred" suffix conditions in which the preterminal and terminal positions were given equal weight. All analyses of variance took account of the repetition of measures on the suffix and position variables. Other findings from these analyses are included in the Appendix.

9 Point 5 is based on two analyses of variance: a Suffix Condition x Position analysis in which the preterminal and terminal positions were given equal weight; and a Suffix Condition x Position analysis for just the immediate and delayed suffix conditions in which the preterminal and terminal positions were given equal weight. Both analyses of variance took account of the repetition of measures on the suffix and position variables. Other findings from these analyses are included in the Appendix.

10 Point 5 is based on three analyses of variance: a Suffix Condition x Position analysis in which the preterminal and terminal positions were given equal weight; a Suffix Condition x Position analysis for just the control and proximal suffix condition in which
the preterminal and terminal positions were given equal weight; and a Suffix Condition x Position analysis for just the proximal and distal suffix conditions in which the preterminal and terminal positions were given equal weight. All analyses of variance took account of the repetition of measures on the suffix and position variables. Other findings from these analyses are included in the Appendix.

11 Conforming to the referent experiments in this regard meant that the definition of the preterminal suffix effect varied from experiment to experiment. In each case, however, I conducted tests of statistical inference based on all possible definitions of preterminal: just the penultimate position, the penultimate position and the preceding position, the penultimate position and the preceding two positions, and so on to the penultimate position and all preceding positions. As might be expected from Figures 1 - 9, these analyses showed that my main conclusions held up well across these definitions.

12 It may be that rendering list length unpredictable also affected the terminal suffix effect in Penney's (1985) study, albeit in the other direction. Thus, although Penney and others have emphasized her elimination of the preterminal suffix effect, the data given in her Table 1 also showed the terminal suffix effect to be 27% smaller in the unpredictable condition.
References


Appendix

Reported here are additional findings from the analyses of variance. In all cases, the dependent variable is the mean probability of recall for the serial positions or position specified. Thus, for effects involving position, the preterminal position was weighted the same as the terminal position, despite being based on more data.

Experiment 1

Here "preterminal" refers to Positions 5 - 8. Measures were repeated on all variables.

The 2 (suffix condition) x 2 (presentation rate) analysis for the preterminal positions revealed: For the main effect of suffix condition, $F(1, 31) = 33.70$, $MSE = .0053$, $p = .000$; and for the main effect of presentation rate, $F(1, 31) = 24.83$, $MSE = .016$, $p = .000$.

The 2 (suffix condition) x 2 (presentation rate) analysis for the terminal position revealed: For the main effect of suffix condition, $F(1, 31) = 202.32$, $MSE = .025$, $p = .000$; and for the main effect of presentation rate, $F(1, 31) = 11.11$, $MSE = .014$, $p = .002$.

The 2 (suffix condition) x 2 (presentation rate) x 2 (position) analysis revealed: For the main effect of suffix condition, $F(1, 31) = 255.68$, $MSE = .014$, $p = .000$; for the main effect of presentation rate, $F(1, 31) = 21.47$, $MSE = .025$, $p = .000$; for the main effect of position, $F(1, 31) = 66.53$, $MSE = .038$, $p = .000$; for the Suffix Condition x Rate interaction, $F(1, 31) = 2.08$, $MSE = .016$, $p = .16$; for the Suffix Condition x Position interaction, $F(1, 31) = 102.66$, $MSE = .017$, $p = .000$; and for the Rate x Position interaction, $F(1, 31) = 4.89$, $MSE = .0056$, $p = .03$. 
Experiment 2

Here "preterminal" refers to Positions 5 - 8. Measures were repeated on all variables.

The 2 (suffix condition) x 2 (practice) analysis for the preterminal positions revealed: For the main effect of suffix condition, $F(1, 31) = 32.04, \text{MSE} = .0079, p = .000$; and for the main effect of practice, $F(1, 31) = 4.14, \text{MSE} = .0064, p = .05$.

The 2 (suffix condition) x 2 (practice) analysis for the terminal position revealed: For the main effect of suffix condition, $F(1, 31) = 143.55, \text{MSE} = .030, p = .000$; and for the main effect of practice, $F(1, 31) = 0.36, \text{MSE} = .011, p = .56$.

The 2 (suffix condition) x 2 (practice) x 2 (position) analysis revealed: For the main effect of suffix condition, $F(1, 31) = 171.72, \text{MSE} = .019, p = .000$; for the main effect of practice, $F(1, 31) = 0.40, \text{MSE} = .012, p = .53$; for the main effect of position, $F(1, 31) = 81.94, \text{MSE} = .034, p = .000$; for the Suffix Condition x Practice interaction, $F(1, 31) = 2.59, \text{MSE} = .010, p = .12$; for the Suffix Condition x Position interaction, $F(1, 31) = 66.43, \text{MSE} = .019, p = .000$; and for the Practice x Position interaction, $F(1, 31) = 4.89, \text{MSE} = .0052, p = .03$.

Experiment 3

Here "preterminal" refers to Positions 1 - 8. Measures were repeated on both the suffix condition and position variables.

The 3 (suffix condition) x 2 (position) analysis revealed: For the main effect of suffix condition, $F(2, 62) = 145.32, \text{MSE} = .0087, p = .000$; and for the main effect of position, $F(1, 31) = 0.99, \text{MSE} = .028, p = .77$.

The 2 (suffix length) x 2 (position) analysis of the data for just
the short-suffix and long-suffix conditions revealed: For the main effect of suffix length, $F(1, 31) = 0.36$, $MSE = .0084$, $p = .55$; and for the main effect of position, $F(1, 31) = 9.55$, $MSE = .035$, $p = .004$.

**Experiment 4**

Here "preterminal" refers to Positions 7 and 8. Measures were repeated on both the suffix condition and position variables.

The 3 (suffix condition) x 2 (position) analysis revealed: For the main effect of suffix condition, $F(2, 62) = 96.56$, $MSE = .016$, $p = .000$; and for the main effect of position, $F(1, 31) = 115.19$, $MSE = .024$, $p = .000$.

The 2 (suffix) x 2 (position) analysis of the data for just the immediate and delayed suffix conditions revealed: For the main effect of delay, $F(1, 31) = 45.26$, $MSE = .020$, $p = .000$; and for the main effect of position, $F(1, 31) = 44.52$, $MSE = .017$, $p = .000$.

**Experiment 5**

Here "preterminal" refers to Positions 6 through 8. Measures were repeated on both the suffix condition and position variables.

The 3 (suffix condition) x 2 (position) analysis revealed: For the main effect of suffix condition, $F(2, 46) = 49.98$, $MSE = .021$, $p = .000$; and for the main effect of position, $F(1, 23) = 14.33$, $MSE = .043$, $p = .001$.

The 2 (suffix) x 2 (position) analysis of the data for just the "hundred" and "recall" suffix data revealed: For the main effect of suffix condition, $F(1, 23) = 7.78$, $MSE = .026$, $p = .01$; and for the main effect of position, $F(1, 23) = 4.86$, $MSE = .033$, $p = .038$.

**Experiment 6**

Here "preterminal" refers to Positions 6 through 8. Measures
were repeated on both the suffix condition and position variables.

The 3 (suffix condition) x 2 (position) analysis revealed: For the main effect of suffix condition, $F(2, 46) = 70.49$, $\text{MSE} = .015$, $p = .000$; and for the main effect of position, $F(1, 23) = 16.45$, $\text{MSE} = .048$, $p = .000$.

The 2 (suffix) x 2 (position) analysis of the data for just the "dredhun" and "callre" suffix data revealed: For the main effect of suffix condition, $F(1, 23) = 1.53$, $\text{MSE} = .011$, $p = .23$; and for the main effect of position, $F(1, 23) = 2.16$, $\text{MSE} = .040$, $p = .16$.

**Experiment 7**

Here "preterminal" refers to Positions 6 through 8. Measures were repeated on both the suffix condition and position variables.

The 4 (suffix condition) x 2 (position) analysis revealed: For the main effect of suffix condition, $F(3, 69) = 38.92$, $\text{MSE} = .012$, $p = .000$; and for the main effect of position, $F(1, 23) = 22.70$, $\text{MSE} = .047$, $p = .000$.

The 2 (suffix) x 2 (position) analysis of the data for just the "hundred" and "recall" suffix data revealed: For the main effect of suffix condition, $F(1, 23) = 10.51$, $\text{MSE} = .008$, $p = .004$; and for the main effect of position, $F(1, 23) = 8.61$, $\text{MSE} = .022$, $p = .007$.

The 2 (suffix) x 2 (position) analysis of the data for just the through-list "hundred" and "recall" suffix data revealed: For the main effect of suffix condition, $F(1, 23) = 1.95$, $\text{MSE} = .012$, $p = .18$; and for the main effect of position, $F(1, 23) = 13.19$, $\text{MSE} = .018$, $p = .001$.

The 2 (suffix) x 2 (position) analysis of the data for just the "hundred" and through-list "hundred" suffix data revealed: For the main effect of suffix condition, $F(1, 23) = 3.14$, $\text{MSE} = .006$, $p = .09$;
and for the main effect of position, $F(1, 23) = 21.44$, $MSE = .03$, $p = .000$.

**Experiment 8**

Here "preterminal" refers to Positions 6 through 8. Measures were repeated on both the suffix condition and position variables.

The 3 (suffix condition) x 2 (position) analysis revealed: For the main effect of suffix condition, $F(2, 142) = 102.00$, $MSE = .016$, $p = .000$; and for the main effect of position, $F(1, 71) = 148.00$, $MSE = .032$, $p = .000$.

The 2 (suffix) x 2 (position) analysis of the data for just the immediate and delayed suffix data revealed: For the main effect of suffix condition, $F(1, 71) = 0.97$, $MSE = .017$, $p = .33$; and for the main effect of position, $F(1, 71) = 88.53$, $MSE = .025$, $p = .000$.

**Experiment 9**

Here "preterminal" refers to Positions 6 through 8. Measures were repeated on both the suffix condition and position variables.

The 3 (suffix condition) x 2 (position) analysis revealed: For the main effect of suffix condition, $F(2, 64) = 72.63$, $MSE = .012$, $p = .000$; and for the main effect of position, $F(1, 32) = 35.60$, $MSE = .026$, $p = .000$.

The 2 (suffix) x 2 (position) analysis of the data for just the immediate and delayed suffix data revealed: For the main effect of suffix condition, $F(1, 32) = 7.47$, $MSE = .011$, $p = .01$; and for the main effect of position, $F(1, 32) = 7.76$, $MSE = .028$, $p = .009$.

**Experiment 10**

Here "preterminal" refers to Positions 6 through 8. Measures were repeated on both the suffix condition and position variables.
The 3 (suffix condition) x 2 (position) analysis revealed: For the main effect of suffix condition, $F(2, 142) = 118.00$, $MSE = .013$, $p = .000$; and for the main effect of position, $F(1, 71) = 173.00$, $MSE = .047$, $p = .000$.

The 2 (suffix) x 2 (position) analysis of the data for just the immediate and delayed suffix data revealed: For the main effect of suffix condition, $F(1, 71) = 14.12$, $MSE = .016$, $p = .000$; and for the main effect of position, $F(1, 71) = 128.00$, $MSE = .035$, $p = .000$.

Experiment 11

Here "preterminal" refers to Positions 6 through 8. Measures were repeated on both the suffix condition and position variables.

The 3 (suffix condition) x 2 (position) analysis revealed: For the main effect of suffix condition, $F(2, 142) = 113.00$, $MSE = .015$, $p = .000$; and for the main effect of position, $F(1, 71) = 85.30$, $MSE = .039$, $p = .000$.

The 2 (suffix) x 2 (position) analysis of the data for just the immediate and delayed suffix data revealed: For the main effect of suffix condition, $F(1, 71) = 0.41$, $MSE = .016$, $p = .52$; and for the main effect of position, $F(1, 71) = 51.25$, $MSE = .029$, $p = .000$.

Experiment 12

Here "preterminal" refers to Positions 6 through 8. Measures were repeated on both the suffix condition and position variables.

The 3 (suffix condition) x 2 (position) analysis revealed: For the main effect of suffix condition, $F(2, 58) = 27.26$, $MSE = .008$, $p = .000$; and for the main effect of position, $F(1, 29) = 0.35$, $MSE = .024$, $p = .562$.

The 2 (suffix) x 2 (position) analysis of the data for just the
control and proximal suffix data revealed: For the main effect of suffix condition, $F(1, 29) = 30.24$, $MSE = .008$, $p = .000$; and for the main effect of position, $F(1, 29) = 0.002$, $MSE = .018$, $p = .964$.

The 2 (suffix) x 2 (position) analysis of the data for just the proximal and distal suffix data revealed: For the main effect of suffix condition, $F(1, 29) = 44.47$, $MSE = .009$, $p = .000$; and for the main effect of position, $F(1, 29) = 0.11$, $MSE = .017$, $p = .746$. 