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On recency and echoic memory

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In short-term memory, the tendency for the last few (recency) items from a verbal sequence to be increasingly well recalled is more pronounced if the items are spoken rather than written. This auditory recency advantage has been quite generally attributed to echoic memory, on the grounds that in the auditory, but not the visual, mode, sensory memory persists just long enough to supplement recall of the most recent items. This view no longer seems tenable. There are now several studies showing that an auditory recency advantage occurs not only in long-term memory, but under conditions in which it cannot possibly be attributed to echoic memory. Also, similar recency phenomena have been discovered in short-term memory when the items are lip-read, or presented in sign-language, rather than heard.

This article provides a partial review of these studies, taking a broad theoretical position from which these particular recency phenomena are approached as possible exceptions to a general theory according to which recency is due to temporal distinctiveness. Much of the fresh evidence reviewed is of a somewhat preliminary nature and it is as yet unexplained by any theory of memory. The need for additional, converging experimental tests is obvious; so too is the need for further theoretical development. Several alternative theoretical resolutions are mentioned, including the possibility that enhanced recency may reflect movement, from sequentially occurring stimulus features, and the suggestion that it may be associated with the primary linguistic mode of the individuals concerned. But special weight is attached to the conjecture that all these recency phenomena might be accounted for in terms of distinctiveness or discriminability. On this view, the enhanced recency effects observed with certain modes, including the auditory mode, are attributed to items possessing greater temporal discriminability in those modes.

Introduction

There is little doubt that recency was of fundamental importance to the now largely abandoned view that memory is divisible into two simple components, a short-term and a long-term store (see, for example, Crowder 1976). This importance stemmed from two facts. Recency was shown to be quite unaffected by a number of variables influencing the recall of pre-recency items, and learning generally; recency was also shown to be essentially eliminated when individuals were given some distractor task, such as a counting task, at the end of the sequence to be recalled, and before being allowed to recall. Thus recency was identified with additional information from a highly accessible but limited capacity short-term store, the contents of which were readily displaced by subsequent distractor items.

The abandonment of the simple two-store theory of memory was followed fairly directly by the emergence of a general processing approach to memory, stemming from the framework provided by levels-of-processing ideas (see, for example, Cermak & Craik (eds) 1979; Craik 1981; Craik & Lockhart 1972; Craik, this symposium), and by the development of the concept

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of working memory (see, for example, Baddeley 1978; Baddeley & Hitch 1974; Hitch 1980; Baddeley, this symposium). These two different theories are of interest not just because they bid to supersede two-store theory but also because they represent rather different sorts of theory. Working memory theory seems committed to specifying, quite precisely, subcomponents of the memory system and the relations among them, and so in this sense seems closer to two-store theory. Levels-of-processing ideas involve a search for broad generalizations and an attempt to establish a few basic principles of memory.

There has been some debate in the field about the relative merits of each sort of approach (see, for example, Baddeley 1978; Lockhart & Craik 1978). But lately the value of different kinds of theory, ranging from the most precise and detailed to the very general, seems to have become more widely acknowledged (see, for example, Baddeley 1982; Lockhart 1982). There is a growing recognition that, among much else, different sorts of theory differ in their objectives, and that perhaps the time is past for arguing that one sort of theory is, in any absolute sense, preferable to another. If the goal is to provide a precise and detailed account that encompasses fine-grained functional distinctions, then an analysis that specifies a variety of complex subcomponents and their interrelations seems inescapable. Theorizing of the less precise and more general sort comes into its own if the objective is simply to capture rather broad functional similarities, and so to integrate a variety of seemingly quite diverse phenomena within a common explanatory framework.

Far from being of fundamental importance for levels-of-processing and working-memory theories, recency turned out to be quite peripheral with respect to both. It has not been implicated, for example, in any of the evidence critical to the concept of working memory, including notably that concerning speech coding and the postulated articulatory loop (see, for example, Hitch 1980). And rather than being identified with any particular subcomponent of memory, the consensus now is that recency may be explained by the general principle of temporal distinctiveness (see, for example, Baddeley & Hitch 1977; Crowder 1976, 1982; Glenberg *et al.* 1980; Hitch, 1980).

One of the findings that proved most difficult for the earlier, two-store theory, and that also gave rise to an explanation of recency based on temporal distinctiveness, was the discovery of recency in a long-term memory task that requires the individual to engage in a lengthy period of arithmetic distractor activity before and after the occurrence of every item in the sequence to be recalled (Bjork & Whitten 1974; Tzeng 1973), the same task known to eliminate recency when required only after the final item in the sequence. This surprising 'reappearance' of recency when similar distractor activity is interspersed throughout the sequence refutes the short-term store account of recency. But, as Bjork & Whitten (1974) proposed, it is consistent with the possibility that recency depends on temporal distinctiveness. More specifically, the suggestion was that recency here might depend on a backward scanning retrieval strategy that utilized ordinal retrieval cues (see also Baddeley & Hitch 1977). Although such cues would normally be particularly distinctive for items at the end of the sequence, the degree of temporal distinctiveness was assumed to depend on the relative temporal interval between each item to be recalled, and the time elapsing between the last item and recall. These *relative* temporal intervals are similar in an immediate recall test and when a regular period of distractor activity is interspersed throughout the sequence to be recalled. In both situations there is a recency effect. When distractor activity takes place only in an interval between the sequence and the test, however, those temporal intervals are dissimilar, and a backward scanning retrieval

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strategy cannot be so effectively applied because recency items are then no longer so well ordered in time.

These ideas have been confirmed by later experiments in which the temporal intervals have been varied appropriately (see, for example, Glenberg *et al.* 1980). There is additional evidence, too, supporting a temporal explanation. For example, Bartlett & Tulving (1974; see also Tulving 1970) showed that recency in immediate recall was enhanced when items were recalled from a temporal cue rather than from a semantic cue, although the items recalled from semantic cues were more likely to be recalled again in a later test. Also, in a procedure whereby temporal order recall can be independently compared with spatial order recall, Healy (1975) has observed strong serial position effects only in the temporal order task. Thus there are several sets of findings that converge on an explanation in terms of temporal distinctiveness.

Not only does the principle of temporal distinctiveness, in combination with backward scanning retrieval, provide an elegant resolution of the initially surprising dependence of recency on the distribution of distractor activity within a complete presentation sequence, it also accounts for other recency effects in long-term memory. For example, recency has been found when American students were asked to recall the names of U.S. presidents (Roediger & Crowder 1976*a*), and when members of a rugby team were asked to recall the names of the teams they had played in the current season (Baddeley & Hitch 1977). So this explanation of recency has considerable generality. It should be emphasized that no specific mechanism is entailed, just the idea that recency items tend to be more distinctive along a temporal dimension, and that because of this, a backward scanning retrieval strategy may sometimes be particularly effective. It should be noted, however, that although such a retrieval strategy is only applicable when order of recall is unconstrained, temporal distinctiveness applies equally when order of recall is prescribed. Indeed, the idea of applying the concept of distinctiveness or discriminability to serial position effects was proposed originally for ordered recall tasks (see, for example, Crossman 1955; Murdock 1960).

The fact that recency recall in short-term memory is normally greater if items from the sequence to be recalled are spoken, rather than written, seems to constitute an exception to the temporal principle just outlined. Indeed it was perceived to be similarly problematic for the two-store theory account of recency. Instead, this auditory recency advantage has been generally attributed to echoic memory, on the grounds that in the auditory case, unlike the visual, sensory information persists just long enough to supplement recall. This general view was first put forward in detail by Crowder & Morton (1969) in a theory that has inspired a great deal of subsequent research. Crowder himself has provided a number of reviews (see, for example, Crowder 1978*a*, *b*, *c*, 1980; also this symposium). Much of this research has been confined to one particular experimental procedure, and it has almost all concerned elaborations of, or points of difference from, the Crowder–Morton theory (see, for example, Crowder 1978*c*; Watkins & Watkins 1980*a*). Our concern here, however, is not with any such particular theoretical question but with the more fundamental theory that echoic memory does contribute to recall.

Rather than attempting a full summary of all the evidence supporting an echoic memory account of the auditory recency advantage, it is sufficient here merely to summarize some of the main points. Consistent with an auditory sensory memory account, the auditory advantage is typically restricted to recency items and it is specifically vulnerable to subsequent distractor items presented in the auditory mode. Such distractors usually eliminate the advantage, and

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distractor mode appears to have little influence on visual recency. Furthermore, both this selective interference effect and the auditory recency advantage are attenuated when all the items possess a high degree of phonological similarity. This converging evidence clearly fits well with echoic memory theory, even if the theory does not provide an altogether satisfactory explanation of it. Lastly, there is further converging evidence from studies showing that the selective interference effect upon auditory recency depends also on the physical discriminability of distractors and items to be recalled. The interference is reduced, for example, if distractor items and items to be recalled are spoken by different voices, or by the same voice but from a different apparent location (Morton *et al.* 1971).

An auditory recency advantage occurs naturally both when recall order is prescribed and under 'free' recall conditions, and it would seem not only parsimonious but plausible to suppose that if echoic memory contributes to recall, it does so irrespective of these task differences. Although many theorists have accepted this without question (see, for example, Broadbent *et al.* 1978; Engle *et al.* 1980; Watkins & Watkins 1980*a*), others have not (see, for example, Morton *et al.* 1981), and so it is necessary to consider this issue a little more thoroughly. It is the free recall procedure that, for obvious reasons, has been used in studying strategic factors and, in keeping with the retrieval strategy notion discussed earlier, there is evidence in free recall that more pronounced recency is associated with practice (Maskarinec & Brown 1974) and with the early recall of recency items: there may be recency even when a distractor task is interpolated between the end of the sequence and recall, provided that recency items are recalled first (Dalezman 1976). But although the auditory recency advantage in free recall is sometimes found to be correlated with order of recall differences, there is also evidence indicating that the free recall effect is not merely the result of such strategic factors (see, for example, Broadbent *et al.* 1978; Nilsson *et al.* 1979; see also Engle *et al.* 1980).

In the serial (forward-ordered) recall procedure, recency tends to be much lower, especially with written input; the auditory recency advantage is more pronounced, and tends to be more sharply restricted to the last one or two items. Following Crowder & Morton (1969), it is this procedure that has been more widely used to study auditory recency and, moreover, it is the auditory 'suffix' interference effect that has been studied most intensively, rather than the auditory recency advantage. (The suffix is a single, redundant distractor item appended to the end of the sequence, such as a zero following a sequence of numbers.) And, after earlier evidence that interference from cross-modal suffix items with spoken and written input may occur but apparently affects all items in the sequence equally (see, for example, Morton & Holloway 1970), later suffix studies have tended, almost exclusively, to include only auditory items. But despite the somewhat indirect link between studies of the auditory suffix effect and the auditory recency advantage, the auditory advantage is critical to the theory, because the theory postulates an additional source of information that is available in the auditory, but not the visual mode (see also Watkins & Watkins 1980*a*). The selective interference effect is critical to the assumption that this additional information originates in echoic memory; but a suffix effect, alone, can be readily explained in other ways: in terms of attention, perhaps, or discriminability (see, for example, Kahneman 1973; Craik 1979).

Importantly, in addition to the phenomenal generality of the auditory recency advantage across free and serial recall procedures, the suffix effect has been generalized to free recall too (Roediger & Crowder 1976*b*; but see also Engle 1974). And other free recall studies have shown that a more protracted, auditory distractor task produces a similar, selective interference effect

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on the auditory recency advantage (Broadbent *et al.* 1978; Gardiner *et al.* 1974; Martin & Jones 1979). Moreover, there is also evidence that in free recall, as in serial recall, the auditory recency advantage is vulnerable to high phonological similarity among all the items in the sequence (Watkins *et al.* 1974). Thus not only does it seem reasonable to suppose that echoic memory gives rise to the auditory recency advantage in each of these recall procedures, there is converging evidence to support this position.

Refutations

Much of the evidence reviewed in this section of the article seems contrary to or is otherwise not accommodated by the theory that echoic memory gives rise to the auditory recency advantage. Some of this evidence concerns the discovery of an auditory recency advantage under longer-term conditions where it cannot possibly be attributed to echoic memory – although there are now some further experimental results that appear to strengthen the case for arguing that this effect is separable from the auditory recency advantage found in immediate recall. There are also recent immediate recall studies of lip-reading, silent 'mouthing' by the memorizer, and sign language, all of which demonstrate recency phenomena resembling those characteristic of spoken, not written, visual input.

Auditory recency in longer-term recall

The long-term memory distractor paradigm of Bjork & Whitten (1974) and Tzeng (1973) typically involves the subject in a lengthy, vocalized counting task interspersed throughout the presentation of the sequence to be recalled. It is hard to imagine conditions that could be more inimical to any manifestation of echoic memory, but a study by Gardiner & Gregg (1979) showed that there is an auditory recency advantage under these conditions, as well as a recency effect. Not having predicted this auditory recency advantage, the Gardiner & Gregg study went on to test its robustness in a series of experiments, and to show that the effect could be obtained in a variety of circumstances. For example, the effect was observed even when the period of counting after the last item in the sequence went on for as long as 30 s. It also occurred when the length of the sequence was varied in such a way that subjects could not anticipate which items were recency ones. And it occurred, too, when rather than hearing the items to be remembered in the sequence spoken by the experimenter, those items, like the distractor items, were presented in written form for vocalization by the subject. In later experiments we have replicated the effect when all items were spoken by the experimenter (for example Gardiner *et al.* 1983*a*).

Gardiner & Gregg (1979 concluded that an auditory recency advantage occurring under those conditions could not possibly originate in echoic memory. Instead we speculated that perhaps temporal discriminability might be enhanced in the auditory mode, and that of course if that were so, the auditory advantage might be explained in much the same way as recency itself: a backward scanning retrieval strategy would simply be more effective in the auditory case. This conjecture will be discussed again later. As we also pointed out, further evidence on the relation between that auditory advantage and the more familiar immediate-recall effect would be useful. In subsequent work, taking a more empirical than theoretical tack, we have sought additional evidence about how the auditory recency advantage in this distractor procedure responds to other variables that are known to have some influence on the effect in

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immediate recall. Apart from distractor mode, there are only two other such variables whose influence seems firmly established: phonological similarity, and order of recall instructions.

As mentioned earlier, the auditory recency advantage in immediate recall is sharply reduced by high phonological similarity among the items to be recalled (see, for example, Crowder 1971; Gathercole *et al.* 1982; Watkins *et al.* 1974). In a forthcoming study (Gregg & Gardiner 1984) we have shown that the auditory recency advantage obtained when each item to be recalled is embedded in a stream of subject-vocalized counting does not conform with that empirical generalization: under those conditions, at least, the effect was found to be quite uninfluenced by phonological similarity. There are also three immediate recall studies all showing that instructions to start recall with items from the beginning of the sequence generally reduce recency recall but greatly enhance the auditory recency advantage (Craik 1969*a*; Madigan 1971; Nilsson *et al.* 1979). In another study, we have described an experiment showing that in that respect, too, the auditory recency advantage in longer-term recall does not conform with that in immediate recall (Gardiner *et al.* 1983*a*). Although recency recall was generally reduced by instructions to start recall with items from the beginning of the sequence (as also occurs in immediate recall) the auditory recency advantage was not enhanced. Incidentally, analysis of actual order of recall data indicates that neither of the two experimental results just described could be attributed to discrepancies in recall order. Moreover, the latter result, supported by other unpublished evidence, indicates that in this procedure, too, the auditory recency advantage does not depend causally on the use of a backward scanning retrieval strategy.

Thus although this longer-term auditory recency advantage remains unexplained, there are now some additional grounds that appear to strengthen the case for separating it from the apparently echoic effect in immediate recall. However, the argument would be a non-theoretical one based on whether an effect in one situation conforms with an empirical generalization that appears to hold good in another situation. Neither the influence of phonological similarity nor that of order of recall instructions is firmly rooted in echoic memory theory, and it is possible that the observed dissociation of effects produced by those factors may be anomalies that can be explained in ways that have no bearing on echoic memory. For example, some recent studies indicate that it may not necessarily be the acoustic properties of the phonologically similar items that are critical, but rather their temporal correlates (Healy 1975; see also Drewnowski 1980*a*). The interpretation of the effect of phonological similarity is also complicated by the fact that it does not just affect recency: it influences pre-recency recall as well. As for the enhanced auditory recency advantage observed when immediate recall starts with items from the beginning, rather than the end of the sequence, this might well reflect a ceiling effect. We have other evidence showing that quite a large auditory recency advantage occurs with backward order recall when steps are taken to reduce the overall level of recency recall (Gardiner *et al.* 1983*b*). So although these additional dissociations between the auditory advantage in longer-term and in short-term recall may appear to strengthen the grounds for proposing quite separate accounts of the two effects, this is not really compelling because they can be explained in ways that do not require such a separation to be made.

The evidence reviewed so far in this section of the article is relevant to another set of findings in longer-term recall, and to an echoic memory theory that is perhaps the one differing most markedly from the original Crowder–Morton theory. It had originally been assumed that echoic information persists for only a very few seconds and therefore aids recall indirectly, rather than

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directly, after having been transferred first into some more durable, modality-free form. This assumption stemmed partly from evidence that the auditory suffix effect in serial recall was greatly attenuated if the onset of the suffix was delayed by more than about 2 s or so; this evidence was taken to mean that echoic information either dissipated, or could only be used, within that brief period (see, for example, Crowder 1969; see also Routh & Mayes 1974; Penney 1979).

An auditory recency advantage, however, has been known for some time to exist after much longer delays, but these delays were either unfilled or at least involved no auditory interference (see, for example, Craik 1969*b*; see also Watkins *et al.* 1973). This fact does not in itself contradict the theory. Rather, the theory predicts that the effect will then no longer be susceptible to distractor mode, in the way that it is when distractors occur just at the end of the sequence. But Watkins & Watkins (1980*a*) and Watkins & Todres (1980) have tested and disproved this prediction. In one experiment, for example, Watkins & Watkins demonstrated that the auditory recency advantage in serial recall was sharply reduced by spoken compared with written distractors when presented after a 15 s unfilled delay following the end of the sequence; incidentally, Gathercole *et al.* (1983) have obtained a similar result in the free recall procedure. Watkins & Watkins's results led them to reject the Crowder–Morton theory and to propose instead that echoic information may persist over relatively lengthy time intervals, and may hence be used directly to aid recall. Broadbent (see, for example, Broadbent 1981; Broadbent *et al.* 1978, 1980) has put forward a similar view, although he conceives of auditory information in sensory registers, whereas in the Watkins & Watkins theory this is not so, and a more phenomenal approach to echoic memory is taken.

Watkins & Todres (1980) have provided some evidence on the question of why, if echoic memory persisted more indefinitely, earlier studies of the suffix effect had found the effect to be attenuated with much shorter delays. They showed that, as the delay before the onset of the suffix increased, recency in the suffix condition improved, whereas recency in the control (no suffix) condition remained unchanged. They then showed that this improvement in recency in the suffix condition could be prevented by silent, distractor activity, and that a suffix effect could then be obtained after as long as 20 s. It seemed as though echoic information was transformed, during the delay, into some suffix-resistant, and therefore presumably non-echoic, form.

These findings, as well as others, including certain effects of grouping by modality (see, for example, Broadbent *et al.* 1980), indeed constitute persuasive evidence for long-term echoic persistence. But in contrast with the situation in short-term recall, there is a dearth of converging evidence. Indeed, further clarification of the relation between each of the different longer-term effects reviewed here and the short-term recall effects is clearly a matter of some priority. For the moment, there are two broad conclusions that can be drawn from these longer-term recall studies. First, none of the longer-term effects can be explained by the theory that an auditory recency advantage arises from a short-lived auditory sensory memory. Second, the effect in the continual distractor procedure is not consistent even with the idea that some more durable echoic memory aids recall. Thus, at least in so far as any claim is made to a general explanation of the auditory recency advantage, echoic memory interpretations are falsified.

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Recency with lip-reading and with sign language

There are two original studies of the effects of silent, lip-read input on recency, both immediate serial recall studies. In the first, by Spoehr & Corin (1978), it was shown that a silent, lip-read suffix produced a suffix effect on auditory recency that was indistinguishable from the effect of a spoken suffix. Campbell & Dodd (1980) demonstrated that a spoken suffix caused a suffix effect if the items to be recalled were silently lip-read; in addition, they showed that there was a lip-read recency advantage when a lip-read sequence was compared with a visual, written one, although lip-reading also led to an overall decrement in recall. Like the finding that auditory interference does not prevent the occurrence of an auditory recency advantage in the long-term recall distractor procedure, these lip-reading findings, too, break the theoretically crucial link between auditory recency and distractor mode, although of course they do so in a very different way.

Campbell & Dodd's (1980) data indicate that lip-reading may, at least on occasion, entail greater task difficulty. Also, it has long been known that suffix effects are not restricted to the auditory mode: a suffix effect occurs with tactile stimuli, for example (Watkins & Watkins 1974), and even with written input (Hitch 1975; Kahneman 1973). So it is possible that lip-read distraction might also interfere with recency in a written sequence, or sometimes interfere with overall recall (cf. Morton & Holloway 1970). Gardiner *et al.* (1983*b*) followed up Spoehr & Corin's (1978) initial observation to provide further evidence on these points. In our study, sequences were presented in written form, as well as being spoken, and a distractor task, interpolated between the end of the sequence and recall, entailed lip-reading a series of digits or reading them from cards. The results showed that lip-reading did indeed markedly interfere just with auditory recency. This study also tested the procedural generality of the Spoehr & Corin result, because free recall and backward serial recall tests were used: thus lip-reading interferes strongly with auditory recency in forward serial recall, in backward serial recall, and in free recall.

Nairne & Crowder (1982) have investigated the influence of the suffix on auditory recency in immediate serial recall when the suffix is silently mouthed by the subject, rather than lip-read. More specifically, all items in this experiment were presented in written form; subjects vocalized the items in the sequence to be recalled and then, in two of the suffix conditions either vocalized or silently mouthed the suffix. Both types of suffix caused a suffix effect, but, in contrast with the Spoehr & Corin (1978) result, Nairne & Crowder found a greater suffix effect when the suffix was spoken. It would however, seem somewhat premature to argue that the greater interference observed with the spoken suffix requires the assumption of a specific acoustic memory component. Also, although there is evidence that subject and experimenter vocalization are equivalent with respect to auditory recency (see, for example, Crowder 1970; Gathercole *et al.* 1982), little evidence is available about equivalence between silent mouthing by the subject and silent lip-read input from experimenter mouthing. Conceivably, this might turn out to bear on the discrepancy between the Spoehr & Corin result and the Nairne & Crowder result.

These lip-reading data pose the most direct challenge to the theory that echoic memory gives rise to the auditory recency advantage, especially where, as has generally been the case, it has been conceived in terms of auditory sensory memory. It seems likely that these findings will lead to quite an intensive research effort. In one recent conference paper, for example, Engle *et al.* (1982) have apparently demonstrated that congenitally and profoundly deaf subjects

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exhibit an auditory recency advantage when subject-vocalization is compared with written input. In another, Nairne & Walter (1982) have reported a suffix effect when the suffix and the items in the sequence to be recalled are silently mouthed by the subjects, as well as a recency advantage when a written input sequence is silently mouthed rather than merely read. All these findings, too, are unexplained. One possible theoretical resolution, proposed by Crowder (this symposium), hinges upon evidence that there is an intimate perceptual relationship between heard and lip-read speech (see, for example, Macdonald & McGurk 1978). Evidence for this relationship, however, appears to obtain only for a few, particular phonemes. Moreover this possible resolution applies only to a small subset of all the data now available on modality-related differences in recency recall. The grounds for maintaining that at least in some situations, if not in others, an auditory recency advantage reflects, if only in part, an auditory sensory memory component, seem far from compelling.

At the time of writing, only one study of recency differences involving sign language has been published. This is an immediate free recall study in which the subjects were congenitally and profoundly deaf signers of American sign language (Shand & Klima 1981). In this study, it was shown that there was a sign-language recency advantage when signed input was compared with written input. It was also shown that there was a suffix effect when a sequence of items presented in sign language was followed by a suffix sign, both when all items were presented as moving signs and when they were all presented in pictorial form. Thus sign language too gives rise to recency phenomena resembling those obtained with heard or lip-read speech, at least with deaf subjects for whom it is the primary means of interpersonal communication.

Campbell & Dodd (1980), following an earlier suggestion (see, for example, Darwin & Baddeley 1974), had hypothesized that there may be a general tendency for items whose features occur sequentially to be encoded differently, in a way that produces a recency advantage. Shand & Klima rejected this movement hypothesis on the basis of their also finding a suffix effect with pictorial representations of signs. But this is not a very strong basis on which to reject the hypothesis (see also Campbell *et al.* 1983; Gardiner *et al.* 1983*b*). One of several reasons for caution is that although pictorial representations of sign stimuli are static in a nominal sense, none the less it is obvious from Shand & Klima's illustrations of these stimuli that sequential relations among their different aspects have to be encoded. Another is that, unlike moving signs, pictorial ones may not necessarily be associated with any recency advantage in comparison with the equivalent, written stimuli. As mentioned earlier, not all previously known suffix effects have been linked to recency differences that arise from a comparison between input modalities. It is only, as with echoic memory theory, where the appropriate modality-specific interference effect is taken in conjunction with a modality advantage in recency, that there is really a strong basis for postulating some quite separate, additional source of information.

Shand & Klima (1981) themselves proposed a primary linguistic-coding hypothesis to account for the various enhanced recency and related suffix effects observed with spoken, lip-read and sign-language input. The idea here is that written language is a more derived or secondary form of language and that these recency phenomena may in part reflect the fact that the modes involved map more directly onto the 'primary linguistic code' of the individuals concerned.

These two hypotheses are discussed briefly again in the next section, and the review of the two sets of studies, those of longer-term recall and those of immediate recall, is now completed.

There is obviously a need for more evidence on the relation between all these recency

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phenomena, and their full theoretical implications have yet to be determined. But so far as echoic memory theory is concerned, it may be concluded that not only is the theory clearly incapable of providing any general account of the auditory recency advantage, its account is falsified even in the rather narrow set of experimental procedures that directly gave rise to it. And, as it seemed to be also with the simple two-store theory of memory, it is perhaps not so much that any single finding has proved decisive, but rather that an accumulating body of contrary or otherwise problematic evidence has reached some ill-defined but critical mass.

Conjectures

Although it is reasonable to suspect that at least some of the resemblances among the various recency phenomena under review may turn out to prove somewhat superficial, it also seems unlikely that these phenomena are entirely unrelated. In keeping with a broad theoretical approach, this section briefly discusses three theoretical possibilities of a quite general kind.

In essence, echoic memory theory assumed a fundamental discontinuity between the recency effect itself and the auditory recency advantage. This discontinuity view seems to be retained both in the movement hypothesis (Campbell & Dodd 1980; Campbell *et al.* 1983) and in the primary-linguistic coding hypothesis (Shand & Klima 1981). Recency with written input, where item presentation is instantaneous and not in a primary input mode, has to be attributed to some other factor. Also, neither hypothesis provides any explanation of why the phenomena of interest are pinned to recency; echoic memory theory gave a very credible explanation of this. However, Campbell *et al.* (1983) have adopted a sensory-overwriting theory of recency in the visual mode proposed by Broadbent & Broadbent (1981). This theory assumes that sensory information gives rise to recency in the visual mode, too, and may continue to be retained unless overwritten by later items that possess similar physical features. By this conjunction of ideas, recency phenomena associated with moving features can be partly explained. But the sensory-overwriting theory of visual recency seems largely based on some effect of similarity on recency (see Broadbent & Broadbent 1981), and such evidence does not seem to provide strong grounds for a sensory memory interpretation. This theory also lacks any converging evidence of the sort that contributed so much to the strength of the echoic memory theory. Moreover, even on this view, nothing is said about why moving features should yield greater recency than still features.

The idea that the input mode involved in a person's first and principal means of interpersonal communication is a primary mode seems another interesting possibility. But it is hard to conceive of any relation between primary linguistic coding and recency. Although Shand & Klima (1981) did not specify any code, most of the evidence for phonological coding and for echoic memory theory is quite distinct (see Crowder 1978*b*, 1982). There is also evidence of an analogous 'cherological' code for the position, configuration and movement of signs in sign language in the congenitally deaf, but there is no evidence that recency in particular is implicated (Shand 1982). Campbell *et al.* (1983) discuss some additional aspects of this hypothesis, as well as of the movement hypothesis, and demonstrate that moving signs may produce more recency even when newly learnt by normal hearing individuals.

The third theoretical possibility is preferred, on the present view, and it is the most general. It implies much more continuity between all recency phenomena. Also, as shall shortly be suggested, it leads to a reconsideration of whether localization of the phenomena over recency positions has quite the theoretical significance that may have been thought.

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The mere occurrence of an auditory recency advantage in the long-term memory distractor task demonstrates a strong and previously unsuspected association between the auditory advantage and recency itself. It was this finding that had led Gardiner & Gregg (1979) to speculate that the auditory recency advantage might simply reflect enhanced temporal discriminability in the auditory mode. If this were so, then temporal distinctiveness could provide an interpretation of the auditory recency advantage, as well as of recency. Thus the third possibility is that the distinctiveness principle might tie all recency phenomena together with a common explanatory framework. This conjecture is not altogether unrelated to the two hypotheses just discussed. It implies that the auditory mode and the other modes that give rise to more pronounced recency are in a sense primary, but in the sense that items in those modes are temporally more discriminable. Also, it is possible to suppose that enhanced temporal discriminability is a consequence of movement among stimulus features, or perhaps just more protracted item encoding; but such suppositions are not an integral part of this theoretical alternative.

For the distinctiveness principle to be useful in this theoretical context, evidence that relates modality differences to temporal factors would be needed, and evidence that those modes that give rise to a recency advantage are indeed more specialized for temporal processing would be especially important. Also, some satisfactory resolution of known dissociations between recency itself, and the auditory recency advantage, would have to be achieved. Some ways of possibly resolving the apparent dissociations between recency and the auditory recency advantage that result from the effects of phonological similarity and order of recall instructions have already been discussed in the previous section. And, at least so far as the auditory mode is concerned, there is at least some evidence of the kind needed to support a general account of recency in terms of temporal distinctiveness.

Some of this evidence comes from two studies by Healy (1975, 1977). In Healy's experiments the same sets of four items were shown in a way in which their temporal order and their spatial order could be varied independently. Healy (1977) showed that if a distractor task after the sequence had been presented required reading aloud, as opposed to reading silently, temporal order recall was impaired. Spatial order recall seemed unaffected by distractor mode. Thus there is evidence that the very difference in distractor mode that had been critically linked to the auditory recency advantage selectively interferes with temporal order recall. This finding is consistent with the possibility that the selective interference effect of distractor mode on the auditory recency advantage results from interference with ordinal information. Healy's (1975) study showed that high phonological similarity among the items in the sequence also impaired performance in the temporal but not in the spatial order recall task. This finding might well be related to the effects of phonological similarity on the auditory recency advantage, as well as to the overall decrement in ordered recall that is typically observed with high phonological similarity.

Is there any direct evidence that the auditory mode is more specialized for temporal processing? There is indeed now some evidence to this effect, from a study by Metcalfe *et al.* (1981), who used a somewhat similar procedure to Healy's. In the study by Metcalfe *et al.*, temporal and spatial order recall were compared for both written and spoken input. Temporal order recall was facilitated when the sequences were presented auditorily. This finding incidentally, may not be unrelated to the fact that the auditory recency advantage tends to be more prominent in ordered recall tasks (see also Drewnowski 1980*b*).

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Taken together, these findings do lend some support to the idea that, at least for the auditory mode, temporal discriminability may underlie the recency advantage, its vulnerability to distractor mode, and also perhaps the influence of phonological similarity. If recency phenomena in general conform with the principle of temporal distinctiveness, then it follows that lip-reading and sign-language are similarly specialized with respect to the retention of ordinal information.

An additional advantage of the present approach is that it provides an alternative explanation of those suffix interference effects that are related to the similarity along other physical dimensions of suffix items and items to be recalled, and it integrates those phenomena with phenomena from another short-term memory task, the Brown–Peterson task. This procedure entails presenting a small set of verbal items, often a triad, and testing recall after a brief period of spoken distractor activity. Over several successive trials, proactive interference builds up quite rapidly and there is a marked decline in recall. If some attribute possessed by all the presented items is changed, however, then recall may improve dramatically. This phenomenon has been explained by assuming that the change in the particular attribute enhances the distinctiveness, at retrieval, of the items to be recalled, relative to the 'redundant' items from previous trials (see, for example, Gardiner *et al.* 1972; Watkins & Watkins 1975). Quite a few attributes have been shown to be effective in this task, especially semantic ones (see Wickens 1972). But some non-semantic attributes are effective too, among them a change in speaker's voice (Gardiner & Cameron 1974; see also Gardiner & Klee 1978). That is, recall after a few trials with auditory presentation improves markedly if the items to be recalled are spoken in a different voice from that used on the previous trials. Both this effect and the reduced suffix interference effect that is observed when the suffix is spoken in a different voice than items to be recalled (Morton *et al.* 1971) are interpreted in a common way by the distinctiveness principle. In each task, performance is presumed to reflect the difficulty of discriminating between redundant items and items to be recalled. This interpretation also accords well with the results of a study by Watkins & Watkins (1980*b*). In this study it was shown that although the suffix effect is attenuated when the suffix is spoken in a different voice, the auditory recency advantage itself is quite unaffected if the items to be recalled are spoken in alternate voices, rather than in the same voice. There is also some evidence that another vocal attribute known to reduce the suffix effect, the location of the speaker's voice, may be effective in the Brown–Peterson task too (see Weeks 1975).

Not only can those suffix effects that seemed most germane to the echoic memory theory be readily interpreted by the principle of distinctiveness, other suffix effects may be interpreted in the same way. For example, suffix effects are known to occur not only with speech sounds, but also with naturally occurring environmental sounds, and with ambivalent sounds, provided that *all* items are perceived and interpreted as being similar, in that they appear to belong to the same category (see Ayres *et al.* 1979; Rowe & Rowe 1976; see also Craik 1979).

There is one final point to be made that seems especially apposite to the broad approach advocated here, and it involves reconsidering the issue of the relation between the phenomena under review and recency. The very predominance of echoic memory interpretations of the auditory recency advantage has led to that effect's being emphasized in separation from other modality differences in recall, although other differences involving the auditory mode are well known (see Penney (1975) for an earlier review). For example, there is evidence that an auditory advantage occurs over all positions in the sequence when spoken and written items

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alternate within the sequence (see, for example, Murdock & Walker 1969; Nilsson *et al.* 1980) and when auditory items within a sequence are briefly separated by a silent, item-monitoring task (Routh 1970, 1976). Modality differences also occur in the Brown–Peterson task; there is evidence that a visual–auditory change in mode can act to improve recall, just as a change in voice does (see, for example, Hopkins *et al.* 1973). These findings are listed together with some other modality phenomena by Engle *et al.* (1980) in the context of their discussing requirements for a comprehensive theory of auditory modality effects.

These modality phenomena can be accommodated within the framework provided by the distinctiveness principle. For example, it is possible to view the restriction of the auditory advantage to recency typical of most recall studies as reflecting not the loss of some transient, sensory trace, nor even the overwriting of some more durable echoic memory, but simply the differential accessibility, or utilization, of ordinal information under different task constraints. The utility of such information might be fostered by conditions that encourage a single-item rehearsal strategy, or relatively superficial encoding, as could result from an item-monitoring task (see, for example, Routh 1976), or from mixed-modality sequences (see, for example, Murdock & Walker 1969). This possibility also fits well with evidence that an auditory recency advantage occurs over pre-recency positions with probe test procedures, where retrieval depends heavily on ordinal information and where output interference is minimal (see, for example, Murdock 1967).

Conclusion

In this article I have presented a partial review of the current situation with regard to recency and echoic memory. More specifically, I have examined the theory that echoic memory gives rise to the auditory recency advantage in recall. This theory no longer seems tenable. Not only is an auditory recency advantage now known to occur in longer-term recall under conditions where it cannot possibly be attributed to echoic memory, but in short-term recall, silent lip-read speech appears to give rise to similar recency phenomena, as does sign language. Many of these recency phenomena remain unexplained and the approach adopted in this article was to suggest that they all might be theoretically integrated by the principle of distinctiveness. With respect to the auditory mode, this conjecture is not without empirical support. Enhanced temporal discriminability may account for the auditory advantage in recency recall; its characteristic vulnerability to interference from auditory distractors when they occur just at the end of the sequence; and the influence of phonological similarity. It may also be related to the fact that an auditory advantage is not invariably pinned to recency. Distinctiveness along other dimensions of similarity may affect temporal discriminability and so may account for certain other interference effects that had previously been associated with echoic memory.

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References

Ayres, T. J., Jonides, J., Reitman, J. S., Egan, J. C. & Howard, D. A. 1979 Differing suffix effects for the same physical suffix. *J. exp. Psychol.* 5, 315–321.

Baddeley, A. D. 1978 The trouble with levels: a reexamination of Craik and Lockhart's framework for memory research. *Psychol. Rev.* **85**, 139–152.

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Baddeley, A. D 1982 Domains of recollection. *Psychol. Rev.* **89**, 708–729.

Baddeley, A. D. & Hitch, G. J. 1974 Working memory. In *The psychology of learning and motivation*, vol. 8 (ed. G. H. Bower), pp. 47–90. New York: Academic Press.

Baddeley, A. D. & Hitch, G. J. 1977 Recency reexamined. In *Attention and performance*, vol. 6 (ed. S. Dornic), pp. 647–667. London: Academic Press.

Bartlett, J. C. & Tulving, E. 1974 Effects of temporal and semantic encoding in immediate recall upon subsequent retrieval. *J. verb. Learn. verb. Behav.* **13**, 297–309.

Bjork, R. A. & Whitten, W. B. 1974 Recency-sensitive retrieval processes in long-term free recall. *Cogn. Psychol.* **6**, 173–189.

Broadbent, D. E. 1981 Perceptual experiments and language theories. *Phil. Trans. R. Soc. Lond.* B **295**, 375–385.

Broadbent, D. E. & Broadbent, M. H. P. 1981 Recency effects in visual memory. *Q. Jl exp. Psychol.* A, **33**, 1–15.

Broadbent, D. E., Cooper, P. J., Frankish, C. R. & Broadbent, M. H. P. 1980 Modality differences in relation to grouping in free recall. *Br. J. Psychol.* **71**, 475–485.

Broadbent, D. E., Vines, R. & Broadbent, M. H. P. 1978 Recency effects in memory as a function of modality of intervening events. *Psychol. Res.* **40**, 5–13.

Campbell, R. & Dodd, B. 1980 Hearing by eye. *Q. Jl exp. Psychol.* **32**, 85–99.

Campbell, R., Dodd, B. & Brasher, J. 1983 The sources of visual recency: movement and language in serial recall. *Q. Jl exp. Psychol.* A (In the press.)

Cermak, L. S. & Craik, F. I. M. (eds) 1979 *Levels of processing in human memory*. Hillsdale, N.J.: Erlbaum.

Craik, F. I. M. 1969*a* Modality effects in short-term storage. *J. verb. Learn. verb. Behav.* **8**, 658–664.

Craik, F. I. M. 1969*b* Modality differences in short-term free recall. Paper presented to the American Association for the Advancement of Science, annual meeting, Boston.

Craik, F. I. M. 1979 Human memory. *A. Rev. Psychol.* **30**, 63–102.

Craik, F. I. M. 1981 Encoding and retrieval effects in longer-term memory: a partial review. In *Attention and performance*, vol. 9, (ed. J. B. Long & A. D. Baddeley), pp. 383–402. Hillsdale, N. J.: Erlbaum.

Craik, F. I. M. & Lockhart, R. S. 1972 Levels-of-processing: a framework for memory research. *J. verb. Learn. verb. Behav.* **11**, 671–684.

Crossman, E. R. F. W. 1955 The measurement of discriminability. *Q. Jl exp. Psychol.* **7**, 176–195.

Crowder, R. G. 1969 Improved recall for digits with delayed recall cues. *J. exp. Psychol.* **82**, 258–262.

Crowder, R. G. 1970 The role of one's own voice in immediate memory. *Cogn. Psychol.* **1**, 157–178.

Crowder, R. G. 1971 The sounds of vowels and consonants in immediate memory. *J. verb. Learn verb. Behav.* **10**, 587–596.

Crowder, R. G. 1976 *Principles of learning and memory*. Hillsdale, N.J.: Erlbaum.

Crowder, R. G. 1978*a* Sensory memory systems. In *Handbook of perception*, vol. 8 (*Perceptual coding*) (ed. E. C. Carterette & M. P. Friedman), pp. 343–373. New York: Academic Press.

Crowder, R. G. 1978*b* Audition and speech coding in short-term memory: a tutorial review. In *Attention and performance*, vol. 7 (ed. J. Requin), pp. 321–342. Hillsdale: N.J.: Erlbaum.

Crowder, R. G. 1978*c* Mechanisms of auditory backward masking in the stimulus suffix effect. *Psychol. Rev.* **85**, 502–524.

Crowder, R. G. 1980 Echoic memory and the study of aging memory systems. In *New directions in memory and aging*. (ed. L. W. Poon, J. L. Fozard, L. S. Cermak, D. Arenberg & L. W. Thompson), pp. 181–204. Hillsdale, N. J.: Erlbaum.

Crowder, R. G. 1982 The demise of short-term memory. *Acta psychol.* **50**, 291–323.

Crowder, R. G. & Morton, J. 1969 Precategorical acoustic storage (PAS). *Percept. Psychophys.* **5**, 365–373.

Dalezman, J. J. 1976 Effects of output order on immediate, delayed, and final recall performance. *J. exp. Psychol.: hum. Learn. Memory* **2**, 597–608.

Darwin, C. J. & Baddeley, A. D. 1974 Acoustic memory and the perception of speech. *Cogn. Psychol.* **6**, 41–60.

Drewnowski, A. 1980*a* Memory functions for vowels and consonants: a reinterpretation of acoustic similarity effects. *J. verb. Learn. verb. Behav.* **19**, 176–193.

Drewnowski, A. 1980*b* Attributes and priorities in short-term recall: a new model of memory span. *J. exp. Psychol.: gen.* **109**, 208–250.

Engle, R. W. 1974 The modality effect: is precategorical storage responsible? *J. exp. Psychol.* **102**, 824–829.

Engle, R. W., Clark, D. D. & Cathcart, J. S. 1980 The modality effect: is it the result of different strategies? *J. verb. Learn. verb. Behav.* **19**, 226–239.

Engle, R. W., Spraggins, A. & Rush, P. 1982 A test of sensory store theories of modality effects. Paper presented to the Psychonomic Society, annual meeting, Minneapolis.

Gardiner, J. M. & Cameron, P. C. 1974 Change in speaker's voice and release from proactive inhibition. *J. exp. Psychol.* **102**, 863–867.

Gardiner, J. M., Craik, F. I. M. & Birtwistle, J. 1972 Retrieval cues and release from proactive inhibition. *J. verb. Learn. verb. Behav.* **11**, 778–783.

Gardiner, J. M., Gardiner, M. M. & Gregg, V. H. 1983*a* The auditory recency advantage in longer-term free recall is not enhanced by recalling prerecency items first. *Memory Cogn.* (In the press.)

Gardiner, J. M., Gathercole, S. E. & Gregg, V. H. 1983*b* Further evidence of interference between lipreading and auditory recency. *J. exp. Psychol.: Learn. Memory Cogn.* **9**, 328–333.

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Gardiner, J. M. & Gregg, V. H. 1979 When auditory memory is not overwritten. *J. verb. Learn. verb. Behav.* **18**, 705–719.
Gardiner, J. M. & Klee, H. 1978 Knowledge of speaker's voice and release from proactive inhibition. *Acta psychol.* **42**, 95–101.
Gardiner, J. M., Thompson, C. P. & Maskarinec, A. S. 1974 Negative recency in initial recall. *J. exp. Psychol.* **103**, 71–78.
Gathercole, S. E., Gardiner, J. M. & Gregg, V. H. 1982 Modality and phonological similarity effects in serial recall: does one's own voice play a role? *Memory Cogn.* **10**, 176–180.
Gathercole, S. E., Gregg, V. H. & Gardiner, J. M. 1983 Influences of delayed distraction on the modality effect in free recall. *Br. J. Psychol.* (In the press.)
Glenberg, A. M., Bradley, M. M., Stevenson, J. A., Kraus, T. A., Tkachuk, M. J., Gretz, A. L., Fish, J. H. & Turpin, B. A. M. 1980 A two-process account of long-term serial position effects. *J. exp. Psychol.: hum. Learn. Memory* **6**, 355–369.
Gregg, V. H. & Gardiner, J. M. 1984 Phonological similarity and enhanced auditory recency in longer-term free recall. *Q. Jl exp. Psychol.* A (In the press.)
Healy, A. F. 1975 Coding of temporal-spatial patterns in short-term memory. *J. verb. Learn. verb. Behav.* **14**, 481–495.
Healy, A. F. 1977 Pattern coding of spatial order information in short-term memory. *J. verb. Learn. verb. Behav.* **16**, 419–437.
Hitch, G. J. 1975 The role of attention in visual and auditory suffix effects. *Memory Cogn.* **3**, 501–505.
Hitch, G. J. 1980 Developing the concept of working memory. In *Cognitive psychology: new directions* (ed. G. Claxton), pp. 154–196. London: Routledge & Kegan Paul.
Hopkins, R. H., Edwards, R. E. & Cook, C. L. 1973 Presentation modality, distractor modality, and proactive interference in short-term memory. *J. exp. Psychol.* **98**, 362–367.
Kahneman, D. 1973 *Attention and effort.* Englewood Cliffs, N.J.: Prentice-Hall.
Lockhart, R. S. 1982 Introduction. *Can. J. Psychol.* **36**, 125–129.
Lockhart, R. S. & Craik, F. I. M. 1978 Levels of processing: a reply to Eysenck. *Br. J. Psychol.* **69**, 171–175.
Macdonald, J. & McGurk, H. 1978 Visual influences on speech perception processes. *Percept. Psychophys.* **24**, 253–257.
Madigan, S. A. 1971 Modality and recall order interactions in short-term memory for serial order. *J. exp. Psychol.* **87**, 294–296.
Martin, M. & Jones, G. V. 1979 Modality dependence of loss of recency in free recall. *Psychol. Res.* **40**, 273–289.
Maskarinec, A. S. & Brown, S. C. 1974 Positive and negative recency effects in free recall learning. *J. verb. Learn. verb. Behav.* **13**, 328–334.
Metcalfe, J., Glavanov, D. & Murdock, M. 1981 Spatial and temporal processing in the auditory and visual modalities. *Memory Cogn.* **9**, 351–359.
Morton, J., Crowder, R. G. & Prussin, H. A. 1971 Experiments with the stimulus suffix effect. *J. exp. Psychol.* **91**, 169–190.
Morton, J. & Holloway, C. M. 1970 Absence of cross-modal 'suffix effects' in short-term memory. *Q. Jl exp. Psychol.* **22**, 167–176.
Morton, J., Marcus, S. M. & Ottley, P. 1981 The acoustic correlates of 'speechlike': a use of the suffix effect. *J. exp. Psychol.: gen.* **110**, 568–593.
Murdock, B. B. Jr 1960 The distinctiveness of stimuli. *Psychol. Rev.* **67**, 16–31.
Murdock, B. B. Jr 1967 Auditory and visual stores in short term memory. *Acta psychol.* **27**, 316–324.
Murdock, B. B. Jr & Walker, K. D. 1969 Modality effects in free recall. *J. verb. Learn. verb. Behav.* **8**, 665–676.
Nairne, J. S. & Crowder, R. G. 1982 On the locus of the stimulus suffix effect. *Memory Cogn.* **10**, 350–357.
Nairne, J. S. & Walters, V. L. 1982 Silent mouthing produces modality- and suffix-like effects. Paper presented to the Psychonomic Society, annual meeting, Minneapolis.
Nilsson, L.-G., Ohlsson, K. & Rönnberg, J. 1980 Processing and storage explanations of the modality effect. *Acta psychol.* **44**, 41–50.
Nilsson, L.-G., Wright, E. & Murdock, B. B. Jr 1979 Order of recall, output interference, and the modality effect. *Psychol. Res.* **41**, 63–78.
Penney, C. G. 1975 The modality effect in short-term verbal memory. *Psychol. Bull.* **82**, 68–84.
Penney, C. G. 1979 Interactions of suffix effects with suffix delay and recall modality in serial recall. *J. exp. Psychol.: hum. Learn. Memory* **5**, 507–521.
Roediger, H. L. & Crowder, R. G. 1976*a* A serial position effect in recall of United States presidents. *Bull. psychonom. Soc.* **8**, 275–278.
Roediger, H. L. & Crowder, R. G. 1976*b* Recall instructions and the suffix effect. *Am. J. Psychol.* **89**, 115–125.
Routh, D. A. 1970 'Trace strength', modality, and the serial position curve in immediate memory. *Psychonom. Sci.* **18**, 355–357.
Routh, D. A. 1976 An 'across-the-board' modality effect in immediate serial recall. *Q. Jl exp. Psychol.* **28**, 285–304.
Routh, D. A. & Mayes, J. T. 1974 On consolidation and the potency of delayed stimulus suffixes. *Q. Jl exp. Psychol.* **26**, 472–479.
Rowe, E. J. & Rowe, W. G. 1976 Stimulus suffix effects with speech and nonspeech sounds. *Memory Cogn.* **4**, 128–131.
Shand, M. A. 1982 Sign-based short-term coding of American sign language signs and printed English words by congenitally deaf signers. *Cogn. Psychol.* **14**, 1–12.

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Shand, M. A. & Klima, E. S. 1981 Nonauditory suffix effects in congenitally deaf signers of American sign language. *J. exp. Psychol.: hum. Learn. Memory* **7**, 464–474.
Spoehr, K. T. & Corin, W. J. 1978 The stimulus suffix effect as a memory coding phenomenon. *Memory Cogn.* **6**, 583–589.
Tulving, E. 1970 Short- and long-term memory: different retrieval mechanisms. In *Biology of memory* (ed. K. H. Pribram & D. E. Broadbent), pp. 7–9. New York: Academic Press.
Tzeng, O. J. L. 1973 Positive recency in a delayed free recall. *J. verb. Learn. verb. Behav.* **12**, 436–439.
Watkins, M. J. & Todres, A. K. 1980 Suffix effects manifest and concealed: Further evidence for a 20-second echo. *J. verb. Learn. verb. Behav.* **19**, 46–53.
Watkins, M. J. & Watkins, O. C. 1974 A tactile suffix effect. *Memory Cogn.* **2**, 176–180.
Watkins, M. J., Watkins, O. C., Craik, F. I. M. & Mazuryk, G. 1973 Effects of nonverbal distraction on short-term storage. *J. exp. Psychol.* **101**, 296–300.
Watkins, M. J., Watkins, O. C. & Crowder, R. G. 1974 The modality effect in free and serial recall as a function of phonological similarity. *J. verb. Learn. verb. Behav.* **13**, 430–447.
Watkins, O. C. & Watkins, M. J. 1975 Buildup of proactive inhibition as a cue-overload effect. *J. exp. Psychol.: hum. Learn. Memory* **1**, 442–452.
Watkins, O. C. & Watkins, M. J. 1980*a* The modality effect and echoic persistence. *J. exp. Psychol.: gen.* **109**, 251–278.
Watkins, O. C. & Watkins, M. J. 1980*b* Echoic memory and voice quality: recency recall is not enhanced by varying presentation voice. *Memory Cogn.* **8**, 26–30.
Weeks, R. A. 1975 Auditory location as an encoding dimension. *J. exp. Psychol.: hum. Learn. Memory* **1**, 316–318.
Wickens, D. D. 1972 Characteristics of word encoding. In *Coding processes in human memory* (ed. A. W. Melton & E. Martin), pp. 191–215. Washington, D.C.: Winston.

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