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Recall of order information by deaf signers: Phonetic coding in temporal order recall

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To examine the claim that phonetic coding plays a special role in temporal order recall, deaf and hearing college students were tested on their recall of temporal and spatial order information at two delay intervals. The deaf subjects were all native signers of American Sign Language. The results indicated that both the deaf and hearing subjects used phonetic coding in short-term temporal recall, and visual coding in spatial recall. There was no evidence of manual or visual coding among either the hearing or the deaf subjects in the temporal order recall task. The use of phonetic coding for temporal recall is consistent with the hypothesis that recall of temporal order information is facilitated by a phonetic code.

There is a strong tendency for normally hearing adults to recode printed letters into a phonetic code in tasks of short-term serial recall of linguistic stimuli. These adults persist in using this form of memory representation even in some situations in which doing so has detrimental effects on their recall ability. For example, detrimental effects due to phonetic coding have been obtained when items rhyme (Conrad, 1962; Conrad & Hull, 1964; Healy, 1974) and when concurrent competing articulation is required (Conrad, 1972; Healy, 1977; Murray, 1967, 1968). Questions have arisen concerning the reason(s) for the use of this code and whether or not other codes can effectively substitute for phonetic coding in short-term recall.

Studies with deaf subjects have provided one useful means of differentiating between some explanations for this phenomenon and of delineating the role of phonetic coding in short-term memory. One hypothesis tested with deaf subjects was the proposal that the use of a phonetic code reflects primary language experience (Shand, 1982; Shand & Klima, 1981). Contrary to the predictions of this hypothesis, the evidence indicates that deaf signers, for whom sign language is primary, do not always use sign coding. In particular, evidence that deaf signers recode printed words into a manual code in serial recall is lacking, while other evidence indicates that in some cases deaf native signers will use phonetic coding in short-term recall (Hanson & Lichtenstein, 1990). Both of these findings are inconsistent with the primary language hypothesis.

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Another prominent hypothesis for the use of phonetic coding in serial recall is that it reflects the sequential character of speech (Baddeley, 1979; Crowder, 1978; Healy, 1975; Penney, 1985, 1989). According to this hypothesis, there are properties of a phonetic code that make it particularly well suited for temporal recall. That is, the auditory/vocal aspects of speech, being temporally arrayed, promote recall of temporal information.

If a phonetic code is well suited for maintaining temporal order information, then deaf individuals, who would be expected to have difficulty in using a phonetic code, ought to have difficulty in maintaining temporal order information. Evidence consistent with this claim has been obtained repeatedly (for a review, see Cumming & Rodda, 1985). In tasks requiring the serial recall of linguistic stimuli (whether words, digits, signs, fingerspelling, or pictures), deaf subjects have consistently been found to recall fewer items than hearing subjects, even when confounds with spatial order recall have been eliminated (e.g., Bellugi, Klima, & Siple, 1975; Blair, 1957; Hanson, 1982; Krakow & Hanson, 1985; McDaniel, 1980; Pintner & Paterson, 1917; Wallace & Corballis, 1973; Withrow, 1968). However, in the temporal recall of nonsense stimuli, deaf subjects have not been found to recall fewer items than hearing subjects (McDaniel, 1980; Olsson & Furth, 1966).

It appears to be only in the recall of linguistic stimuli that deaf subjects are at a disadvantage. Deaf subjects are at no disadvantage, compared with hearing subjects, in spatial recall of stimuli, regardless of whether the stimuli are linguistic or nonsense (Carey & Blake, 1974; Das, 1983). Indeed, there has even been some evidence that deaf individuals are at an advantage in such situations (Blair, 1957).

In a series of experiments, Healy (1975, 1977, 1978, 1982) convincingly demonstrated that hearing subjects use a phonetic code for the short-term retention of temporal, but not spatial, order information. Using procedures that isolated temporal and spatial information, Healy found evidence of phonetic confusions (e.g., B for P and F for S) in the recall of temporal order information. These phonetic confusions were limited to short retention intervals, suggesting rapid decay of the phonetic component to short-term temporal recall. Healy found that recall accuracy, correspondingly, dropped significantly at the longer intervals during temporal order recall.

The question addressed in the present experiment is whether deaf signers similarly use phonetic coding specifically for the short-term retention of temporal information. Such a finding would present a strong argument for the importance of phonetic coding in temporal recall. For prelingually, profoundly deaf individuals, developing the use of a speech code is a formidable task. Deaf individuals who use sign have potentially another memory code—a manual code—more readily available. Thus, if a manual code can provide an effective medium for retaining temporal order information, then deaf signers would be expected to use it. In the case of the present study, this manual code would be one based on the handshapes of the American manual alphabet. In this alphabet, there is a handshape for each letter, and words can be spelled out, letter by letter, on the hand. Shown in Figure 1 are some examples of letter handshapes from the American manual alphabet.

Studies have shown that some deaf signers use phonetic coding in short-term recall of printed material (for a review, see Hanson, 1989, in press). The present study represents an attempt to clarify the conditions under which this phonetic coding is used; specifically, recall of temporal order information was isolated from recall of spatial information at two short-term retention intervals. Another question investigated was whether or not, in contrast to hearing subjects, deaf subjects make use of manual or visual coding alternatives in the recall of temporal information. Finally, the use of phonetic, visual, and manual codes by deaf signers in spatial recall was also examined.

In the present study, the procedures of Healy (1975) were used to isolate temporal and spatial recall. The general procedure was that on each trial, a series of four letters were shown to the subjects, one letter at a time. After all four letters were shown, there was an interference task, in which the subjects were required to name each digit in a string of digits. In the present study, two

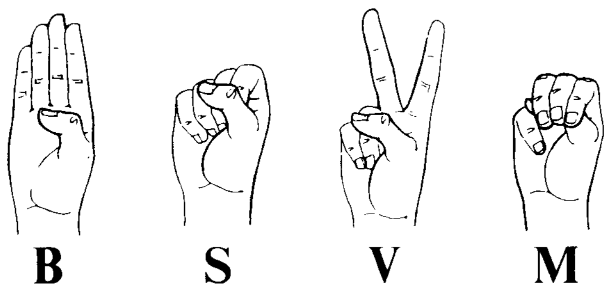

Figure 1. The handshapes B S V M of the American manual alphabet.

interference intervals were used—a short one (3 digits) and a longer one (15 digits). Following the interference task, the subjects were asked to write down the four letters from that trial.

Letter sets designed specifically to test for phonetic, manual, and visual confusions were employed. The identity of the four letters was always known to the subjects, thus eliminating a confound with recall of item information. The subjects were a group of deaf college students and a control group of hearing college students. These subjects participated in both recall tasks, thus allowing a within-subjects comparison of temporal and spatial order recall.

METHOD

Subjects

The deaf subjects were 8 students at Gallaudet University who were paid for their participation. All were congenitally and profoundly deaf, with a hearing loss of 90 dB or greater, better ear average. In addition, all had two deaf parents and were native signers of American Sign Language (ASL). Their median reading proficiency was grade 9.2 (range 3.3–12.9+), according to the comprehension subtest of the *Gates-MacGinitie Reading Tests* (1978, Level F, Form 2) administered to each subject. These subjects were thus excellent deaf readers when rated against national surveys of the reading proficiency of deaf students (Karchmer, Milone, & Wolk, 1979). To obtain a measure of speech production ability for individual subjects, speech intelligibility measures were obtained from school records. This measure rates the speech production ability of individuals on a scale of 1-5, in which 1 is readily intelligible to listeners and 5 is unintelligible. According to school records, the speech intelligibility ratings of these 8 subjects were as follows: One had speech that was rated a "3," 2 had speech that was rated a "4," 3 had speech that was rated a "5," and 2 had speech ratings that were listed as "NONE." Thus, with one exception (the subject with the rating of "3"), the subjects here had poorly intelligible speech as judged by listeners.

The hearing subjects were 8 undergraduates from the University of Connecticut who were paid for their participation. All had normal hearing.

Stimuli

The stimuli for both the temporal and the spatial order recall tasks were the uppercase letters B, S, V, and M. The handshapes corresponding to these letters are shown in Figure 1. This character set provided a test of phonetic similarity with the two letters B-V (Wolford & Hollingsworth, 1974). These two letters are manually (Richards & Hanson, 1985) and visually (Wolford & Hollingsworth, 1974) distinct. This letter set also provided a test of manual similarity with the two letters M-S, which are similar in the American manual alphabet (Richards & Hanson, 1985), but are phonetically and visually distinct (Wolford & Hollingsworth, 1974). Finally, this stimulus set provided two tests of visual similarity with the letter pairs V-M and S-B (Wolford & Hollingsworth, 1974), both of which are phonetically (Wolford & Hollingsworth, 1974) and manually (Richards & Hanson, 1985) distinct.

The same four consonants appeared on each trial in both the temporal and the spatial order recall tasks. In each task, a test sequence of 48 trials was generated. The 24 permutations of these letters each appeared once at the short retention interval (3 digits) and once at the long retention interval (15 digits). The order of trials was randomized, with the constraint that in every block of eight trials there were four trials at the short interval and four trials at the long interval. The digits presented during the retention interval were the digits 1-9. No digit occurred more than once in succession.

Procedure

The subjects were individually tested in the two tasks on successive days. Half of the subjects received the temporal order recall task first; half received the spatial order recall task first. The reading comprehension subtest of the *Gates-MacGinitie Reading Tests* (1978) was administered to the deaf subjects on the 2nd day of testing.

Stimulus presentation in both the temporal recall and the spatial recall conditions was controlled by a microcomputer. A trial began with four horizontally arrayed boxes shown on the monitor with computer graphics. Each box was 5 in. high × 2 in. wide. The four letters of a trial then appeared one at a time in these four boxes. The letters were 1⅜ in. × ¾ in. Each letter was presented for 1,000 msec, followed by a 1,000-msec ISI. The digits were presented simultaneously, following the fourth ISI, appearing as a string of digits. The presentation duration averaged 400 msec per digit, such that the 3 digits of the short interference interval were presented for 1,200 msec and the 15 digits of the long interval were presented for 6,000 msec. Following the offset of the digits, a message appeared on the computer screen instructing the subjects to "write your answer now." After a 16-sec interval, during which the subjects wrote their responses, the next trial began.

Instructions were signed for the deaf subjects by a deaf experimenter, a native signer of ASL, and they were spoken for the hearing subjects by a hearing experimenter. The subjects were instructed that on every trial they would see four letters, one at a time, and that these letters would be followed by a series of single-digit numbers—either 3 or 15 digits. Deaf subjects were told to simultaneously sign and mouth (pronounce without voicing) each letter and digit. Hearing subjects were told to pronounce aloud each letter and digit. The subjects were told that following offset of the digits, they were to write the four letters in the answer booklets provided. They did not have to fill in the four boxes sequentially. Each page in the answer booklets had 12 rows of four boxes drawn on it.

For the temporal order recall task, the subjects were told that they would see the letters B, S, V, and M on every trial, and that the B would always appear in the left-most box, the S in the next box, the V in the next box, and the M in the right-most box. They were told to write the letters in the boxes to show the temporal order in which the letters appeared—that is, to write the first letter they saw in the first (i.e., left-most) box on their answer sheets, the second letter they saw in the second box, and so forth.

For the spatial order recall task, the subjects were told that they would see the same letters on every trial—B, S, V, and M. They were also told that the B would always appear first, the S second, the V third, and the M fourth. The spatial location of each of these four letters would vary from trial to trial. The subjects were told to write the letters in the boxes to show the left-to-right spatial order in which the letters appeared.

The subjects received four practice trials in each condition before beginning the test trials. The practice trials were taken from the same letter and digit sets as were used in the experimental trials.

RESULTS

Responses were scored as incorrect if the correct letter did not appear in the correct serial position. Table1 gives the percentage correct responses for deaf and hearing subjects in the temporal and spatial order recall conditions at the two retention intervals. An arcsine transformation was applied to this accuracy data, and an analysis of variance was performed for the between-subjects factor of group (deaf, hearing) and the within-subjects factors of recall condition (temporal, spatial) and retention interval (3, 15 digits). The analysis indicated a main effect of retention interval [$F(1,14) = 69.38$, $MS_e = .0196$, $p < .001$], as well as an interaction of recall condition × retention interval [$F(1,14) = 11.11$, $MS_e = .0135$, $p < .005$]. This interaction reflected a larger decline in accuracy as the retention interval increased in the temporal order recall condition than in the spatial order recall condition. No significant interactions involving subject group emerged (all $ps > .10$).

Table 1
The Percentage of Correct Responses in the Temporal Order and Spatial Order Recall Tasks

	Temporal Order		Spatial Order	
Interval	Hearing	Deaf	Hearing	Deaf
3 digits	96.1	97.4	95.6	92.3
15 digits	80.2	79.2	90.5	83.2

The conditional probabilities of making confusions related to the phonetic, manual, or visual similarity of the stimulus letters were next computed for each subject; then an analysis of variance was performed on these probabilities. The conditional probability of making a phonetic error was the percentage of incorrect responses of V for B or B for V; these two letters were phonetically similar, but manually and visually distinct. That is, for errors that were made on the letters V and B, this was the percentage of responses with the phonetically similar letter. The conditional probability of making a manual error was the percentage of incorrect responses of S for M or M for S; these two letters are similar manually, but they are phonetically and visually distinct. Finally, the conditional probability of visual errors was the percentage of incorrectly responding V for M, M for V, S for B, and B for S; these letter pairs are similar visually, but they are manually and phonetically distinct. The conditional probability of these visual confusions was computed as the percentage of errors on these four letters that were visually similar. The conditional probabilities for the two subject groups for each error type are shown in Table 2 for both temporal and spatial order recall.

The analysis of these conditional probabilities on the factors of subject group × error type (phonetic, manual, visual) × delay interval (3 digits, 15 digits) × recall condition (temporal, spatial) revealed an interaction of error type × recall condition [$F(2,28) = 18.90$, $MS_e = 1,477.97$, $p < .001$]. This interaction indicated that different error types predominated for temporal and spatial order recall. To determine the source of the interaction of error type × recall condition, the temporal and spatial order data were analyzed separately.

In the temporal order condition, there was a significant main effect of error type [$F(2,28) = 7.28$, $MS_e = 1,332.04$, $p < .005$], which was qualified by an interaction of error type × delay interval that approached significance [$F(2,28) = 2.87$, $MS_e = 1,258.13$, $p < .08$].

Table 2
Conditional Probabilities of Each Error Type for Hearing and Deaf Subjects in the Temporal Order and Spatial Order Recall Conditions

	Recall Condition					
	Temporal Order			Spatial Order		
Interval	Hearing	Deaf	*M*	Hearing	Deaf	*M*
3 digits						
Phonetic	60.7	68.8	64.7*	14.3	4.3	9.3
Manual	8.3	34.4	21.4	14.3	13.5	13.9
Visual	21.9	10.4	16.1	70.5	51.6	61.1*
15 digits						
Phonetic	57.1	35.6	46.3	8.7	19.6	14.2
Manual	47.4	41.3	44.4	24.2	23.0	23.6
Visual	21.6	31.3	26.5	61.5	56.3	58.9*

*Greater occurrence than other error types at that interval ($p < .01$).

Separate post hoc analyses of the short and long delay intervals revealed significantly more phonetic confusions than either manual or visual confusions at the short interval (Newman-Keuls, $p < .05$), but no difference in the frequency of the three types of confusions at the long interval (Newman-Keuls, $p > .05$). There were no significant effects involving subject group in this analysis of the temporal order condition (all $ps > .10$).

In the spatial order condition, there was also a main effect of error type [$F(2,28) = 15.39$, $MS_e = 1,413.83$, $p < .001$], this time reflecting more visual confusions then either phonetic or manual confusions (Newman-Keuls, $p < .05$). The proportions of phonetic and manual confusions were not significantly different from each other (Newman-Keuls, $p > .05$). In this spatial order condition, the interaction of error type × delay interval was not significant ($F < 1$), indicating a similar pattern of errors at the two delay intervals. As with the temporal order condition, there were no significant effects involving subject group (all $ps > .10$).

DISCUSSION

Consistent with Healy (1975, 1982), evidence was found in the present study for the use of a phonetic code in temporal order recall among the hearing subjects, as indicated by the predominance of phonetic confusions in temporal recall at the short interval. This phonetic code appeared to decay relatively quickly, with the consequence that temporal order recall ability declined significantly after only a few seconds of interpolated activity.

Deaf children receive training in lipreading and speaking. They also have everyday exposure to watching other people speak. Through such experiences, they may pick up information about the phonetic structure of language. Of interest here is the finding that the deaf subjects used a phonetic code, as indicated by the predominance of phonetic confusions in temporal recall at the short interval. As with the hearing subjects, this phonetic code appeared to decay relatively quickly. Associated with this decay of the phonetic code, the accuracy of the deaf subjects declined significantly at the long interval.

The pattern of recall confusions indicated different coding in the spatial than in the temporal order recall task for subjects in both groups. There was no indication of phonetic coding in spatial order recall. Rather, the error pattern showed a predominance of visual confusions in letter recall at both delay intervals. Thus, there was evidence for the use of a relatively long-lasting visual code mediating spatial recall for subjects in both groups.

As noted previously, deaf subjects typically perform more poorly on temporal recall of linguistic stimuli than hearing subjects do. Yet, in the present study, recall accuracies of the deaf and hearing subjects were comparable. There are two factors, either or both of which may have contributed to this unexpected result. The first is the use of phonetic coding among the deaf subjects. Previous research has indicated that deaf subjects who do not show evidence of the use of phonetic coding tend to recall fewer items than hearing subjects who do use phonetic coding (e.g., Conrad & Rush, 1965; Wallace & Corballis, 1973). The accuracy of deaf subjects may also be less even when phonetic coding is used, although there is evidence that as deaf subjects' use of phonetic coding increases, their temporal recall accuracy improves (Conrad, 1979; Hanson, 1982; Hanson & Lichtenstein, 1990). In the present study, where no differences in the use of phonetic coding between hearing and deaf subjects were obtained, the deaf subjects' temporal recall accuracy was comparable to that of the hearing subjects. The second factor that may have contributed to the comparable accuracy of the two groups is the overall high level of accuracy of both deaf and hearing subjects. This level of accuracy is higher than is generally obtained with this paradigm (see Healy, 1975, 1982), most likely due to the use of longer stimulus presentations in this study than in others. These longer intervals likely allowed for more phonetic rehearsal during stimulus presentation. In particular, ceiling effects of hearing subjects may have masked any potential group differences.

Anecdotally, it is worth reporting that one difference in the performance of the hearing and the deaf subjects in the present study was that the temporal order recall task appeared more "natural" to the hearing subjects, while the spatial order task seemed more "natural" to the deaf subjects. That is, when giving instructions to the subjects, the hearing subjects assumed a temporal recall task. It required elaboration for them to understand what to do in the spatial order task. In contrast, many deaf subjects assumed a spatial recall task, and needed elaboration of the temporal order instructions. This observation is consistent with experimental evidence of differences in temporal and spatial order preference for hearing and deaf subjects (O'Connor & Hermelin, 1972, 1973). Despite the preference on the part of the deaf subjects for spatial order recall, their accuracy was not significantly better in this condition than in the temporal order recall condition (see also Das, 1983). Similarly for the hearing subjects, their preference for temporal order recall did not translate into greater accuracy in this condition than in the spatial order recall condition, although, as noted previously, there may have been ceiling effects obscuring possible differences here.

The deaf subjects' use of a phonetic code in temporal recall is consistent with the claim that recall of temporal order information for linguistic stimuli is facilitated by the use of a phonetic code. For deaf subjects, the acquisition and use of a phonetic code is extremely difficult. Thus, they would be expected to use visual or manual codes, if such codes were effective. Yet, in the present study, evidence was not obtained that the deaf subjects, all native signers of ASL, relied on these alternatives for temporal order recall.

The finding that the deaf subjects used a phonetic code is especially impressive, given the fact that most of them had speech that was rated as only poorly intelligible. These intelligibility ratings, however, are based on listeners' ratings of intelligibility, and may not reflect the extent to which an individual deaf subject can effectively use a phonetic code to mediate temporal recall. The fact that speech production ability does not reflect ability to use a phonetic code is dramatically demonstrated by research with some brain-damaged patients who have lost the ability to produce speech. These patients can still retain the ability to use a phonetic code (e.g., Baddeley & Wilson, 1985; Bishop & Robson, 1989; Martin, 1987).

There is reason to believe that the results obtained here might not have been obtained if less skilled deaf readers had been tested. Within the deaf population, the evidence indicates that phonetic coding is used primarily by good readers, whether beginning readers (Hanson, Liberman, & Shankweiler, 1984), high school students (Conrad, 1979; McDermott, 1984), or college students (Lichtenstein, 1985). The subjects of the present study were college students, and most were excellent readers when rated against national norms for the reading levels of deaf adults (Karchmer et al., 1979). The importance of the present study, therefore, is not the suggestion that phonetic coding in temporal recall will be characteristic of all deaf subjects, but rather the finding that, for deaf subjects who *are* able to use a phonetic code, this code is used specifically for temporal recall.

There were no significant effects of manual coding for either temporal or spatial recall. In the short interval condition, where temporal order recall was best, the incidence of manual confusions by the deaf subjects was only half the incidence of phonetic confusions. Were the deaf subjects using manual coding that the experimental procedures failed to detect? This possibility cannot be completely ruled out solely by failure to find an effect of manual coding. For example, it is possible that the letters used to test sign confusability were not similar enough to produce confusions. Although the letters M and S have been judged to be manually similar by deaf subjects such as those of the present study (Richards & Hanson, 1985), it is possible that this pair was not *as* similar as the phonetically or visually similar pairs. Indeed, such a ranking of similarity across stimuli is not possible. It should be noted, however, that the letters M and S were part of a stimulus set previously found to produce performance decrements in written letter recall among deaf children (Hanson et al., 1984).

Some studies done with self-report (Lichtenstein, 1985) or observation of overt rehearsal (e.g., Liben & Drury, 1977; Locke & Locke, 1971) have suggested that deaf subjects may use manual rehearsal in the temporal recall of letters and words. However, such reports and observations do not, necessarily, indicate the use of an internal code based on signs. That is, rather than being an indicator of internal coding, overt manual rehearsal may, at least in some cases, be serving as a supplemental storage mechanism. This overt use of sign may provide some recall of information in addition to that supplied by the internal code. For example, in various studies over the years, the author has noticed that deaf subjects will use memory "tricks" (unless specifically directed not to do so), such as manually recording some stimulus letters on their hands, and keeping the fingers in position for these letters throughout the stimulus sequence while memorizing other letters in the sequence. Similar observations were reported by Locke and Locke (1971). In these cases, the manual signal appears to serve not as an internal code, but rather as a visible reminder of the stimuli.

This discussion should not be taken to mean that a manual code based either on signs or on handshapes of the manual alphabet cannot serve as a short-term memory code. There is clear evidence in the literature for manual coding in short-term memory studies. If we look closely at these studies, however, we notice that a pattern begins to emerge. For signed stimuli, evidence of sign intrusions or decrements related to the formational similarity of signs has been reported in temporal recall (Bellugi et al., 1975; Hamilton & Holzman, 1989; Hanson, 1982; Krakow & Hanson, 1985; Shand, 1982). Recall accuracy for a sequence of signs in these studies, however, tends to be poorer than hearing subjects' recall accuracy for a sequence of words. Moreover, correlations between the use of sign coding and memory span have not been demonstrated (Kyle, 1980). In contrast to these studies with signed stimuli, there has been no clear evidence of manual coding obtained in studies that have examined the temporal order recall of printed letters or words (Hanson & Lichtenstein, 1990). Evidence of manual coding of print has generally been obtained only under conditions in which temporal order recall is not required. For example, evidence of sign coding has been obtained in paired associate and free recall tasks, facilitating, in these cases, the learning of items that have formationally similar signs (Conlin & Paivio, 1975; Moulton & Beasley, 1975; Odom, Blanton, & McIntyre, 1970; Putnam, Iscoe, & Young, 1962).

In conclusion, the finding that the deaf college students in the present study used a phonetic code specifically in temporal recall, despite their difficulty in using speech and despite their having a manual code available to them as an alternative short-term memory code, is consistent with the claim that a phonetic code is particularly well suited for recall of temporal order information (Baddeley, 1979; Crowder, 1978; Healy, 1975; Penney, 1985, 1989). This evidence also adds to a growing body of literature indicating that deaf subjects have available to them a variety of short-term memory coding options, the use of which varies as a function of specific subject characteristics (e.g., reading proficiency), stimulus characteristics (e.g., signed vs. print stimuli), and task characteristics (e.g., temporal vs. spatial order recall).

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