Interpolation effects in short-term memory*

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The processing capacity available for rehearsing sequences of 10 random consonants was varied during a 5-sec retention interval. There was a systematic decline in the end peak of the serial-position curve as the information load of the interpolated task was increased; but the first positions were disrupted by a constant amount, regardless of the difficulty of the interpolated task. The results suggest that all verbal interpolated tasks interfere to an equal extent with the active verbal processes used to maintain the structure of STM and that the difficulty level of an interpolated task is only a determinant of recall for those relatively unprocessed items which have not been incorporated into the STM structure.

The importance of rehearsal to short-term memory (STM) has been investigated extensively; it is generally conceded that when rehearsal is prevented by an interpolated task (IT), forgetting is rapid and inevitable. Increases in the difficulty level of an IT have also been shown to increase the rate of forgetting (e.g., Posner & Rossman, 1965). Presumably, more difficult ITs require more of a S's limited central-processing (rehearsal) capacity, and hence, less capacity can be devoted to the maintenance of the to-be-remembered material.

Recently, Glanzer, Gianutsos, & Dubin (1969) have shown that the difficulty of an IT only has a differential effect upon the recall of the last-presented item in a serial list; recall of the early items was the same regardless of the IT difficulty. These findings suggest that ITs may have qualitatively different effects upon recall, depending upon the level to which material has to be processed, following input. If it is assumed that material, in order to be sustained in STM, must eventually be organized into a rhythmic, articulate, patterned structure (Neisser, 1967; Neisser, Hoenig, & Goldstein, 1969), then possibly all verbal ITs interfere with a S's ability to rehearse this patterned structure actively. In addition, any verbal IT, independently of its difficulty, may interfere to an equal extent with the verbal processes used to rehearse and thus to maintain the patterned structure necessary to sustain STM (Lowe & Merikle, 1970). On the other hand, for stimulus input which has yet to be incorporated into the active verbal structure used to maintain STM, IT difficulty may be an important determinant of forgetting. Such material may be subject to limitations or the amount of central processing capacity available for rehearsal of the to-be-remembered material.

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While the above two-stage model of interpolation effects is somewhat sketchy, it does lead to certain testable predictions which the present experiment was designed to investigate. Two different ITs were used. These tasks were the repetition and the classification of two-digit numbers. The tasks were similar to the ones developed by Posner & Rossman (1965) and have been shown to be of unequal difficulty. In addition to IT difficulty, the presentation rate of serial lists was also varied. In light of Aaronson's (1967) finding that Ss employ different processing strategies when faced with different presentation rates, relatively more material should be in the verbal structure used to sustain STM immediately following a slow presentation rate than following a fast rate. Thus, it was expected that the effect of IT difficulty would be more limited following a slow presentation rate, in that fewer of the last-presented items in the lists would be differentially affected by IT difficulty. On the other hand, following both rates of presentation, it was expected that the two ITs would produce equal recall decrements of the first-presented items when performance was compared to that of free-rehearsal (no IT) control groups.

DESIGN AND MATERIALS

The design was a 2 by 3 by 10 factorial. Six different groups of six Ss each recalled 10-consonant sequences which were presented at rates of either 2 items/sec or .5 items/sec. Recall commenced following a 5-sec IT. For different groups, the ITs consisted of repetition of two-digit pairs, classification of two-digit pairs, or no IT (free rehearsal). Each S was given 36 trials under one of the six possible Presentation-Rate by IT conditions.

The materials consisted of 36 sequences of 10 randomly selected consonants No consonant was repeated within a sequence, and alphabetic runs of more than two consonants were disallowed. The two-digit numbers used for the repetition and classification tasks were also selected randomly.

PROCEDURE

The sequences were recorded on a Wollensak tape recorder, and all Ss listened silently through monaural headphones. On each trial, the word "ready" was presented 1 sec before the presentation of the first consonant. At the end of presentation, a slide containing a 3 by 4 matrix of two-digit numbers was displayed for 5 sec on a rear-projection screen by a Kodak Carousel projector. The projector was stepped by a program which was recorded on the same tape as the consonant sequences. During the retention interval (RI), the Ss with the repetition IT just read aloud the digit pairs as single digits, while those Ss with the classification IT classified each number as being either high or low and odd or even. For the free-rehearsal groups, the projector was blurred out of focus, and these Ss were instructed to ignore the screen and just "to think about their answer." Both the repetition and the classification ITs were self-paced and, in order to make them maximally effective, Ss were told that their scores on each trial would be determined on the basis of both the number of consonants correctly recalled and the number of digit-pairs transformed. At the end of the RI, the slide containing the digits was removed and replaced by a blank slide. The presentation of the blank slide signaled the beginning of a 20-sec recall period. The same procedure was followed for all trials.

For all conditions, Ss were instructed to attempt their recall in the exact order of presentation, designating any omitted items by saying "skip." If this was not possible, Ss were encouraged to recall in any convenient order.

SUBJECTS

The six Ss in each group were male and female undergraduate students fulfilling a course requirement at the University of Waterloo. Assignment of Ss to groups was done on the basis of an unsystematic order which insured that one S in each block of six was assigned to each of the six possible Presentation-Rate by IT conditions.

RESULTS AND DISCUSSION

Recall scores for each S were determined by summing the number of consonants correctly recalled from each serial position over all 36 trials. These scores were submitted to a 2 by 3 by 10 analysis of variance which evaluated the effects of presentation rate, IT, and serial position. The results are presented in Fig. 1 in terms of the proportion of consonants correctly recalled at each serial position.

Overall, the slow presentation rate resulted in better performance (53.3%) than the fast rate (46.4%), $F(1,30) = 6.87$, $p < .05$. This

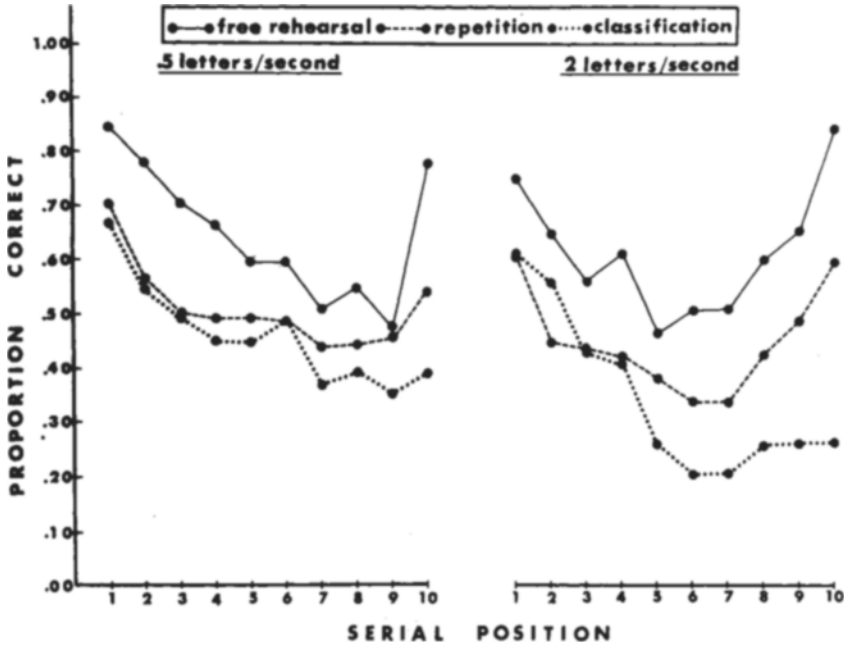

Fig. 1. Proportion correct following each rate of presentation as a function of interpolation condition and serial position.

difference is consistent with the view that Ss were employing different processing strategies with the different rates of presentation and that the slower presentation rate permitted time for more items to be incorporated into the patterned structure necessary to maintain STM. Also, as can be seen from Fig. 1, recall following performance on the classification IT (39.4%) was inferior to that following either the repetition (47.1%) or the free rehearsal (62.7%) conditions, $F(2,30) = 27.01$, $p < .001$. Subsequent analysis also revealed that the classification IT resulted in poorer performance relative to the repetition IT, $F(1,20) = 8.68$, $p < .01$. These differences in performance indicate that the various ITs were successful in manipulating the amount of central-processing capacity made available for rehearsal. This observed difference in difficulty is also supported by the mean number of repetitions (7.52) and classifications (3.92) carried out during the RI.

Turning to a consideration of the serial-position curves, it can be seen in Fig. 1 that there was a systematic decline in the end peaks as the difficulty of the IT was increased. This observation clearly supports the contention that ITs affect the loss of those items which have received the least amount of processing (Aaronson, 1967), and in addition, it appears that the amount of central-processing capacity available is an important determinant of the rate of loss of this partially processed information. No such systematic decrement, however, is observed for the first-presented items; relative to the free-rehearsal condition, there is virtually a constant decrement in performance regardless of the difficulty of the IT. It thus appears that once the stimulus input has been organized or structured, it is no longer subject to the limitations of central-processing capacity. Rather, these items seem prone to a qualitatively different type of interference. Such an observation is expected from the assumption that this store can be best characterized as an articulate, active process which provides a rhythmic organization necessary to maintain and to report the items in STM (Neisser, 1967; Neisser, Hoenig, & Goldstein, 1969). Since maintenance of the items in STM depends upon a verbal structure, any verbally incompatible task, independent of its difficulty, will interfere with a S's ability to sustain this patterned organization and cause forgetting (Lowe & Merikle, 1970). The selective interference effects in the present study are supported by a significant IT by Serial Position interaction, $F(18,270) = 2.50$, $p < .01$.

The above notions gain support from a consideration of the differential interference effects as a function of presentation rate. It can be seen from Fig. 1 that the processing loads imposed by the various ITs produce relatively larger decrements in the recall of the last-presented items following the fast presentation rate. In addition, the difference between the repetition and the classification IT becomes apparent earlier in the list following the faster presentation rate. Individual t tests at each serial position revealed that with the fast presentation rate the classification IT significantly ($p < .05$, two-tailed) impaired recall, relative to the repetition IT, at Serial Positions 8, 9, and 10, while following the slow presentation rate there was a significant difference only at Serial Position 10. These observations support the view that more items were unincorporated within the STM structure following a fast presentation rate and thus more items were prone to loss when the load of an IT was imposed. Figure 1 also suggests that with slow presentation more items were being maintained by the active verbal structure since the ITs produced relatively greater decrements in the recall on the first-presented items. Again, however, the information load of the IT plays no role in determining the magnitude of this decrement. Unfortunately, overall statistical support for these selective effects of the ITs was marginal in that the relevant interaction, Presentation Rate by IT by Serial Position, failed to reach an acceptable level of significance, $F(18,270) = 1.49$, $p < .10$.

In summary, the present results indicate that the decrement in recall produced when an IT prevents rehearsal can be attributed both to a rapid loss of those items which have received minimal processing and are dependent upon central-processing capacity and to a disruption of those verbal organizing processes which are necessary in order to sustain the items in STM for recall. Thus, one must consider the relationship of the IT to the level of processing of the input when referring to the prevention of rehearsal. If this were not the case, then the various ITs would not produce selective effects on the level of recall from the various serial positions.

The present results also provide an explanation of why differential decreases in recall performance produced by ITs of different difficulty occur rapidly and are observed only in the early stages of the retention interval (e.g., Posner & Konick, 1966; Merikle, 1968). From the evidence presented here, it now seems clear that those items which have yet to be incorporated into the patterned verbal structure become immediately unavailable once the load of an IT is imposed. Hence, once these items are lost, the influence of IT difficulty is effectively finished. Subsequently, any more decrements in performance can be attributed to further interference with those verbal processes which maintain the contents of STM.

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Backward masking of visual targets with internal contours: A replication*

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The present results replicate earlier data showing decreased susceptibility to backward masking of disk-shaped targets with increasing numbers of internal black-white segments. Two trends appearing in the earlier study were also investigated: (1) the elevated threshold of a 16-segmented target under a no-masking condition; (2) the facilitation of that target's detectability under a masking condition. Both trends reoccurred in the present data, but only the first was statistically reliable. The results suggest that visual targets with many internal contours in close proximity may generate inhibition as well as excitation, and that for such targets a masking stimulus may serve both to disinhibit and to inhibit target detection.

In a classic study on what is now referred to as backward masking, Werner (1935) investigated, among several other variables, figural properties of the target stimulus. The finding most pertinent to the present study was that stimuli with internal contours were especially hard to mask, compared with the homogeneous black disk typically employed in Werner's many experiments.

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To pursue Werner's findings in a more quantitative and objective fashion, Cox & Dember (1969) compared detectability of the following types of target stimulus: a homogeneous black disk and disks composed of 2, 4, 8, or 16 segments, half black and half white. Target detectability was measured, using the staircase method and a two-alternative spatial forced-choice indicator, both with and without a masking stimulus. The main variable of interest—number of internal contours—did have a significant effect on target maskability, with differences in target detectability under the nonmasking condition controlled for. That is, the greater the number of internal contours, the less maskable the target.

Further post hoc examination of the data revealed two trends that seemed worth following up. First, the 16-segmented target appeared to be unusually difficult to detect under nonmasking conditions (while at the same time relatively easy to detect when followed by a mask). Secondly, introducing a mask seemed to enhance, rather than decrease, detectability of the 16-segmented target. The two trends together suggested the possibility that multisegmented targets were self-inhibiting and that for them a mask might, in part, serve a disinhibiting function.

The present experiment was designed to assess the statistical reliability of the above-mentioned trends as well as to replicate the main finding of the Cox and Dember study, that target maskability decreases with increasing amounts of internal contour.

SUBJECTS

Five female and three male college students, with normal or corrected-to-normal vision, served as paid Ss. All were naive about the purpose of the experiment, and none had had previous experience with backward masking.

STIMULI

The present experiment omitted the homogeneous and the 2-segmented disks used by Cox and Dember. Instead, three half-black and half-white disks were employed, those with 4, 8, or 16 alternating black and white segments. Also omitted was the white-ring mask used by Cox and Dember. Only a pair of black rings, horizontally arranged, served as the masking stimulus; a blank gray card was used in the no-mask condition. The same gray provided the background for the target and mask figures.

The diameter of the disks, as well as the inner diameters of the rings, measured 8 mm, subtending 24 min of arc. The thickness of the walls of the rings subtended 12 min of arc, and the distance between ring centers subtended 58 min of arc.

APPARATUS AND PROCEDURE

Since the apparatus used was identical to that of the Cox and Dember study, and the two procedures the same (except for the fact that fewer conditions were run in the present experiment), the following is taken directly from the Cox and Dember paper, modified only to accommodate the change in number of conditions.