The encoding of ignored information*

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An experiment was conducted to study the dimensions of encoding of verbal material in short-term memory as a function of other demands placed on Ss' attention. Eighty Ss shadowed one of two simultaneous lists, under instructions to remember the shadowed or the nonshadowed list. A single recognition probe followed each shadowing trial. Ss judged whether the probed item was (1) identical to, (2) a rhyme of, or (3) a synonym of one of the to be remembered items. Results indicated that acoustic information was encoded from all inputs, regardless of the focus of attention. Evidence for semantic encoding, however, was limited to those conditions in which retention of shadowed material was required. The data were interpreted as contradicting "late selection" theories of attention, which propose that all inputs are analyzed for meaning prior to the focusing of attention.

A unifying theme running through many contemporary approaches to human memory is a concern with identifying the aspects of the information contained in a stimulus that forms the basis for its retention. The distinction between acoustic and semantic coding has been of particular interest. In its most often encountered form, this distinction has been offered as one of the justifications for proposing separate short-term and long-term storage systems. Thus, it is argued that the representation of a verbal item in short-term memory is based primarily on its acoustic features, while the item's meaning is the more important determinant of its retention in long-term memory.

Recent demonstrations of semantic encoding in short-term memory (Bregman, 1968; Shulman, 1970) have called the validity of this argument into question. On the basis of experimental evidence, Shulman (1971) has proposed that the apparent discrepancy between the common finding that acoustic factors account for much of the variation in short-term memory performance and these demonstrations of semantic encoding in similar paradigms can be resolved by considering encoding as a time-dependent process. He argues that features of an item most closely related to its sensory input, such as its phonemic characteristics, are encoded more rapidly than its semantic features. In order to maximize the time available for rehearsal in a short-term memory task, Ss may limit themselves to this more rapid acoustic encoding unless the task explicitly requires encoding of semantic information. Similarly, Eagle and Ortoff (1967) have shown that the requirement to perform a secondary task (digit classification) during presentation

of the to be remembered items increases the relative importance of the acoustic features of those items.

The present experiment used the dichotic shadowing paradigm to manipulate the allocation of attention and examined the effect of these manipulations on the encoding and retention of verbal material. The attractiveness of this method in studying selective attention stems from its assurance that Ss are attending to the shadowed channel: Lapses of attention are immediately apparent as increases in shadowing errors (Mowbray, 1964). However, while it is thus clear that Ss do process the attended message to the point of being able to repeat it, the fate of the "unattended" message is less certain. Yet it is precisely this issue—the extent to which rejected messages are processed prior to selection—that has formed the basis for the continuing controversy between "early" (e.g., Broadbent, 1958; Treisman, 1969) and "late" (e.g., Deutsch & Deutsch, 1965; Norman, 1969a) theories of the selective process.

Two of the original experiments using the shadowing paradigm (Cherry, 1953; Moray, 1959) indicated that Ss could report "crude physical characteristics" of the nonattended message (e.g., the sex of the speaker) but gave no indication of recalling the content of the message presented on that channel. This observation provided the impetus for the "early" selection models, which maintain that the choice of which message to exclude or attenuate is based on analysis of the physical characteristics of each message. But Norman (1969a) has recently shown that Ss can identify items from the nonshadowed message when the delay between presentation and test is minimized. He interprets this as consistent with the "late" selection models, which maintain that selection can take place only after the meaningful components of all incoming signals have been extracted. But in addition to reducing the retention interval, Norman (1969a) altered Moray's (1959) procedure in a second and, it will be argued, critical detail: Moray's Ss did not expect to be tested on their retention of the nonshadowed material, while Norman's Ss were extensively trained in remembering it.

The present paper proceeds from the simple thesis

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that, on logical grounds alone, Ss cannot "try to ignore" a message that they are "attempting to remember." Thus, a demonstration that Ss *can* divide their attention between a shadowed and a nonshadowed message, to the extent of being able to recognize the nonshadowed input immediately after its presentation, does not speak to the issue of the extent to which that message *must* be processed when Ss are in fact trying to ignore it. Thus, it was proposed that the strategy which S is encouraged to use in distributing his attention over the two inputs results in important differences in the encoding of each message. More specifically, the purpose of the reported research was to test the hypothesis that instructional manipulations of attentional strategies produce both quantitative and qualitative changes in the immediate retention of shadowed and nonshadowed inputs. In an attempt to separate the effects of shadowing a message from those of trying to retain it, Ss were required to shadow one of two simultaneous dichotic inputs under instructions to attempt to remember (1) the shadowed message or (2) the nonshadowed message. To gain information about the nature of the encoding process used, Ss were tested with a variant of the probe technique used by Shulman (1970), which requires S to indicate whether a test item is (1) identical to, (2) a rhyme of, or (3) a synonym for an item presented on the to be remembered channel. Evidence of the level of analysis to which distracting material is subjected was obtained by comparing false recognitions of distractor items to false recognitions of test items not previously presented on either channel. By instructing S to indicate whether a test item occurred *on the to be remembered channel*, false recognitions of distractor items would indicate the level of encoding that occurs despite efforts not to remember that material. Finally, the influence of shadowing and of encoding strategies on the rate of forgetting was determined by examining recognition probabilities as a function of input serial position.

METHOD

The method chosen was designed to gain information about the encoding of material from both to be remembered and distractor channels. Ss were presented with two simultaneous 10-item lists, one to each ear, and were instructed to shadow one while also trying to remember either that list or the other list. Following each shadowing trial, Ss were given a single recognition test, with instructions to indicate whether the probed item had occurred *on the to be remembered channel*. On any trial the probed item might in fact have occurred on the to be remembered channel (in which case "Yes" was the correct answer), on the distractor channel ("No"), or not have been presented ("No"). In addition, independent of the source of the item probed, tests might be any of three types—(1) identity: "____ was a memory word," (2) acoustic: "____ sounds like a memory word," or (3) semantic: "____ means the same as a memory word." To encourage Ss to encode each item as fully as possible, probe types were randomly distributed across trials; Ss were unaware of the type of probe to be used prior to its actual presentation. Finally, to permit a possible signal detection analysis of the results and to protect against ceiling effects in cases where very high recognition accuracy might be obtained, in

addition to making "Yes-No" judgments, Ss were required to rate their confidence in those judgments on a six-point scale.

Design

Factorial combination of three types of probes, three sources of probed items, and two designations of the channel to be remembered resulted in 18 basic conditions. Probe types were identity, acoustic, and semantic, as described above. Probe sources were memory list, distractor list, and unpresented items (catch trials). All Ss served under all levels of these two variables. Between groups of Ss either the shadowed or the nonshadowed channel was designated as the channel to be remembered. Thus, for half the Ss (focused attention) instructions indicated that the same channel was to be shadowed and retained, while the remaining Ss (divided attention) were to shadow one channel while attempting to remember items on the other. In each case, Ss were to indicate whether the probed item had been presented on the to be remembered channel.

After being trained in both the dichotic shadowing and recognition aspects of the basic task, Ss were given 90 experimental trials. Each trial consisted of a warning signal (the spoken word "ready") on both channels, followed 1 sec later by synchronized word pairs, one member of each pair to either ear, presented at a 2/sec rate. The channel to be shadowed and the channel to be retained were specified at the beginning of the session and, for a given S, did not change throughout the experiment. Immediately after repeating the last word, S turned over a card from the top of a deck placed before him. Printed on the face of the card was a question indicating the type of probe and the probe item (e.g., "Sounds like CAT"). Ss were given 8 sec to check their response and confidence rating and to set the card aside. At the end of this interval, the warning signal indicated the beginning of a new trial.

Two buffer items that were completely redundant (letters "A," "B" to one ear, digits "1," "2" to the other) preceded every 10-item list and were included simply to offset any irregularities in performance associated with the initiation of shadowing. Lists of 10 unrelated words followed. Across the experimental session, each serial position in both channels was probed once per S under each type of probe. The remaining 30 trials were catch trials, consisting of 10 probes of unpresented words under each probe type. Thus, on 30 trials (when to be remembered words were probed) the correct answer was "Yes," while on 60 trials (30 probes of distractors and 30 catch trials) the correct response was "No." The observation sequence for type of probe, channel probed, and serial position were randomized, with the restriction that runs of probe type not exceed three and channel probed not exceed five.

Ss were 80 undergraduate volunteers (40 per group) who served in a single session lasting approximately 1 h.

Materials and Apparatus

The 90 experimental trials required 180 lists, consisting of a total of 1740 untested filler words, 20 single items for identity probes, 20 synonym pairs, 20 rhyme pairs, and 30 unpresented catch trial probes. With the exception of the rhyme pairs, all items were chosen from the word pool used by Shulman (1970). The synonyms in that set had been chosen "to be of maximum similarity," with preference given responses showing unimodal, peaked frequency distributions in the Riegel (1965) or Jenkins and Palermo (1965) norms. The remaining words were one- or two-syllable words, three to six letters in length, occurring at least once per million in the Thorndike-Lorge count. The 20 rhyme pairs (Shulman's homonyms are inappropriate for auditory presentation) were drawn from a list prepared by Frederiksen and Aaronson (undated mimeographed copy). The probe items chosen from these two sources were matched as closely as possible in both length and frequency.

For each probe type, the 20 pairs were divided into two sets

Table 1
Probability of "Yes" Responses in Each Condition Averaged Over Serial Position

Probe Type	Divided Attention Channel			Focused Attention Channel		
	"Remember"	"Shadow" (Distractor)	Catch Trials	"Remember & Shadow"	"Ignore" (Distractor)	Catch Trials
Identity	.483	.471	.157	.665	.253	.245
Acoustic	.542	.476	.228	.776	.334	.324
Semantic	.527	.448	.280	.692	.361	.376
Mean	.517	.465	.222	.711	.316	.348

of 10 that were assigned to either the to be remembered or the distractor channel. For half the Ss in each group, this assignment was reversed. Within each channel, each pair was tested in each of the 10 serial positions with equal frequency across Ss. Thus, the assignment of words to channels and to serial position was counterbalanced over groups of 20 Ss.

Lists were recorded in a monotone voice by a male speaker on a two-channel stereo recorder. While recording, the speaker monitored metronome clicks played on a second recorder at a 2/sec rate as an aid to pacing and synchronization. Lewis (1970) determined that a mean error of synchronization of no more than 25 msec can be achieved in this way. Counterbalancing of channel shadowed and channel to be remembered insured that there was no systematic relation between variations in synchronization, intensity, etc. and experimental conditions. Lists were presented over a low-impedance stereo headset. Ss shadowing protocols were recorded on a second machine.

Procedure

Prior to the first experimental trial, Ss were practiced on both the recognition and the shadowing tasks. At the beginning of the session, the recognition task was explained and Ss were given 18 practice trials, including five probes of each type and five catch trials. For these practice trials, 10 words lists were presented to both ears at a 2/sec rate.

Ss were next practiced on the shadowing task. After five trials shadowing single lists presented to one ear, Ss were introduced to the dichotic condition and continued shadowing until a criterion of two successive error-free shadowing trials was reached. Twenty pairs of 10 word lists were available for practice. If additional practice was required, these same lists were repeated. During practice, S was told his task was to listen to the words on the designated channel and repeat them as soon as he heard them. The words used in both recognition and shadowing practice were chosen from the filler words in Shulman's (1970) pool not used in the experimental lists.

At the completion of practice, Ss were given further instructions describing the combined task trials. In the focused attention condition, Ss were told to attempt to remember the words they were going to shadow and that a recognition test would follow each trial. They were also informed that items from the nonshadowed channel and new items would also appear as probes but that, since E was interested in their ability to remember the shadowed items, the correct answer to either of these probes was "No." In the divided attention condition, Ss were told to attempt to remember the nonshadowed items; since E was interested in their memory for those items, they should respond "No" to items from the shadowed channel as well as to new items.

RESULTS

The data of primary interest are the proportion of "Yes" recognition responses for each cell of the experimental design. For each of the six Attentional Instruction by Probe Type conditions, three such scores

may be computed: the probability of correctly recognizing a to be remembered item, the probability of erroneously accepting an item for the distractor channel, and the probability of erroneously guessing "Yes" to a probe item not previously presented on either channel. However, in order to properly assign observations to conditions to compute these scores, it was first necessary to screen out the data from those trials on which a shadowing error occurred simultaneously with presentation of a to be remembered item, since compliance with attention directing instructions was assured only while Ss were accurately shadowing the designated channel. This preliminary screening resulted in the loss of slightly less than one-third of the total observations. An analysis of variance indicated no systematic relationship between the frequency of these critical shadowing errors and any of the experimental variables.

The several recognition probabilities were then computed using the remaining data. Table 1 lists these scores, averaged over serial position. The main effect of channel and of instruction were both significant [$F(2,6) = 12.23$, $p < .01$, $SE = .106$ and $F(1,6) = 16.59$, $p < .01$, $SE = .091$], as was the Channel by Instruction interaction [$F(2,6) = 7.9$, $p < .05$, $SE = .106$]. The effects of none of the other variables reached significance in this analysis.

Recalling that "Yes" responses to both distractor and catch trial probes constitute false positives, it is apparent from Table 1 that recognition performance in the focused attention condition was considerably better than that in the divided attention condition. It is also evident from the catch trial data that Ss in the divided attention condition were somewhat more reluctant to respond "Yes" than those in the focused attention condition. This is consistent with statements made by a number of divided attention Ss, who apologized after the session for "being able to remember so few of the words." The extent of this response bias became far more visible when the confidence ratings were analyzed. In the focused attention condition, Ss reported being certain on 74% of the trials on which they correctly responded "Yes," whereas for Ss in the divided attention condition "certain" responses accounted for only 27% of the correct responses. Clearly, the experimental treatments influenced Ss' decision strategies and/or response biases as well as their retention of the stimulus words. Since the hypotheses under investigation were

Figs. 1 and 2. Mean A_g scores as a function of channel probed and serial position for the divided attention (Fig. 1) and focused attention (Fig. 2) groups. (Bars indicate 95% confidence intervals.)

concerned with the influence of attentional variables on encoding and memory processes, a measure of recognition performance that is free of these bias effects was desirable. The measure chosen was the area under the MOC curve (A_g), a nonparametric strength measure based on the application of the theory of signal detectability to recognition tasks. As typically used (cf. Banks, 1970), A_g takes on values between 1.0 (perfect accuracy) and .5 (chance success). Since in this experiment, however, it is possible for the probability of responding "Yes" to a distractor to be less than that of responding "Yes" to a catch trial probe, A_g values between .5 and 0 are also meaningfully defined and indicate that Ss have recognized an item as having

occurred on the nontested channel. The remaining contrasts are based on the appropriate A_g scores.

Figures 1 and 2 show the computed A_g values as a function of instruction, channel, and input serial position. Instruction and channel main effects were both significant [$F(1,6) = 36.02$, $p < .01$, $SE = .098$ and $F(1,6) = 81.2$, $p < .01$, $SE = .084$], as was their interaction [$F(1,6) = 23.7$, $p < .01$, $SE = .084$]. The main effect of position did not reach significance, but its interaction with both instruction and channel did [$F(9,54) = 2.78$, $p < .05$, $SE = .047$ and $F(9,54) = 8.7$, $p < .01$, $SE = .044$]. Tests on simple main effects indicated a significant position effect for both the to be remembered and distractor channels in the divided attention condition [$F(2,30) = 2.76$, $p < .05$, $SE = .095$ and $F(9,30) = 2.78$, $p < .05$, $SE = .049$] but no significant effect of the same variable in the focused attention condition.

Consider first the data for the items from the to be remembered channels. From the limited capacity assumption of most theories of human information processing, one would expect encoding of these items to be interfered with less by their own shadowing (focused attention) than by the shadowing of other items (divided attention). The upper curves in Figs. 1 and 2 clearly support this: Retention is significantly (Tukey simultaneous confidence intervals, Winer, 1962) above the $A_g = .5$ chance level at all serial positions. In the divided attention condition, only the three most recently presented items were recognized at a frequency significantly above chance.

The Instruction by Position interaction is useful in interpreting the superiority of recognition of to be remembered items in the focused attention condition. A major difference between the task demands facing Ss in the two instructional groups was in the opportunity provided for rehearsal of the to be remembered items. In the focused attention condition, Ss shadowed the to be remembered items: This is formally equivalent to a single overt rehearsal. In the divided attention condition, Ss shadowed items from the distractor channel: This procedure would seem to *prevent* rehearsal of to be remembered items at least as effectively as the more conventional rehearsal preventing tasks (e.g., counting backward). The relatively flat serial position curve in the focused attention condition, as compared to the rapid decline to the chance level in the divided attention condition, is consistent with this rehearsal difference interpretation. Thus, it is tempting to speculate that, with regard to the to be remembered items, the "attentional instructions" variable amounted to no more than a comparison of filled and unfilled retention intervals. But if rehearsal differences alone accounted for the instructional effect, one would expect no difference between groups in the recognition scores for items presented in the final serial position. Since these items were tested immediately after presentation, the obtained A_g differences at Serial Position 10 (upper curves, Figs.

1 and 2) cannot be attributed to differential rates of forgetting. Rather it appears also necessary to conclude that the divided attention situation reduced the probability of adequately encoding the to be remembered item at the time of its presentation.

Turn next to the data for false recognitions of distractor items (lower curves, Figs. 1 and 2). In the focused attention condition, Ss did not shadow these items, and the retention test was structured to encourage ignoring them. Any departure from chance ($A_g = .5$) here indicates a limit to Ss' ability to exclude information. As can be seen in Fig. 2, Ss did exhibit retention of distractor items presented in the last four serial positions. Note, too, that these items, although retained, were not confused with to be remembered items: A_g scores below .5 indicate that items from the distractor channel were correctly rejected more often than were catch trial probes.

A similar, though larger, effect is visible in the divided attention condition (lower curve, Fig. 1). Here, Ss had shadowed the distractor channel items. In the final four serial positions, correct rejections were more probable than in the focused attention condition. In addition, in the divided attention condition, some evidence of retention of distractors is exhibited in all but the first three serial positions. Apparently, the act of overtly repeating a distractor both enhances the probability that it will be maintained memorially and prolongs the period for which it will be maintained.

Consider next the information provided by the probe type variable on the dimensions of encoding to be remembered items. From Bregman's (1968) and Shulman's (1970) results, evidence for both semantic and acoustic encoding was predicted for the focused attention condition, with a higher recognition rate for acoustic probes. In accordance with Shulman's (1970) proposal that semantic encoding requires more of the available processing capacity than acoustic encoding, it was also predicted that the relative contribution of semantic cues should be reduced, if not eliminated, in the divided attention condition. To evaluate these predictions, the A_g scores for those serial positions at which recognition performance was significantly above chance were partitioned by type of probe employed. Since not all serial positions in the divided attention condition were thus included, separate analyses were performed for the focused and divided attention conditions. The upper curves in Figs. 3 and 4 portray the data analyzed.

In the divided attention condition (Fig. 3), the main effect of probe type was significant [$F(2,36) = 3.74$, $p < .05$, $SE = .024$]. Post hoc comparisons indicated that the recognition scores for semantic probes were significantly less than those for both acoustic probes [$q(2,36) = 4.91$, $p < .01$] and identity probes [$q(3,36) = 5.43$, $p < .01$]. The latter two levels of the probe type variable did not differ from each other. Thus, as is evident in Fig. 3, with the exception of the last item

Figs. 3 and 4. Mean A_g scores as a function of probe type, channel probed, and serial position for the divided attention (Fig. 3) and focused attention (Fig. 4) groups.

presented, semantic encoding makes virtually no contribution to the recognition of to be remembered items in the divided attention condition.

In the focused attention condition (Fig. 4), by contrast, a quite different picture emerges: Evidence for a considerable amount of semantic encoding of to be remembered items was obtained at all serial positions. Figure 4 also indicates a slight, though consistent, inferiority in responding to semantic as opposed to acoustic probes; this effect, however, did not reach significance [$F(2,36) < 1.0$]. It is also noteworthy that, with probe type included in the analysis, the main effect of serial position was significant [$F(9,108) = 2.17$, $p < .05$, $SE = .039$], while the Probe Type by Serial Position interaction was not [$F(18,90) < 1.0$]. Thus,

while some forgetting of to be remembered items did occur at the longer retention interval, the rate of forgetting was independent of the type of information tested.

Finally, consider the encoding of those items that were retained from the distractor channels. The lower curves in Figs. 3 and 4 show the relevant data. The main effect of probe type was significant in both the divided and the focused attention conditions [$F(2,54) = 4.18$, $p < .05$, $SE = .052$ and $F(2,36) = 3.33$, $p < .05$, $SE = .062$]. The effect of serial position was also significant in the divided attention condition [$F(5,54) = 4.16$, $p < .05$, $SE = .082$]. Post hoc comparisons indicated that, in the divided attention condition, the correct rejection rate was significantly different from chance in the final three serial positions for all probe types and that there was a lower correct rejection rate for semantic probes than for acoustic or identity probes, which did not differ from each other. In Serial Positions 4-7, the recognition rate for semantic probes did not differ from chance. In the focused attention condition, only the acoustic and identity probes differed significantly from the $A_g = .5$ chance level. Again, these two conditions did not differ from each other.

Thus, in the divided attention condition, the task of shadowing the distractor list appears to have resulted in the establishment of a trace that includes semantic as well as acoustic information. In the focused attention condition, Ss appeared to have been unable to comply fully with the suggestion that they "ignore" the distractor lists. Despite the attentional demands imposed by the task of shadowing and attempting to remember the items from the other channel, sufficient information was encoded from the distractor channel to permit the recognition of the *sounds* of the most recent words. In this case, however, no evidence for semantic encoding was obtained.

DISCUSSION

It was proposed that the strategy which S adopts in distributing his attention over two concurrent inputs may produce substantial differences in the encoding and retention of each. The above results reveal at least four such effects of some importance. First, from the data on the recognition of to be remembered items in the divided attention condition (Fig. 1), it may be concluded that the intent to remember material from a given source may itself constitute a condition sufficient to support some retention, even when distracting events prevent focusing one's attention on that source. Second, from the data on the recognition of distractors in both groups (Figs. 1 and 2), it is equally evident that this intent to retain is not a necessary condition. Even in the focused attention condition, which was structured to encourage and permit Ss to totally ignore the distractors, some retention of the most recent distractor items was

clearly indicated. In the divided attention condition, in which Ss were forced to devote sufficient attention to the distractor channel to support its shadowing, the chances that an item from that channel would be subsequently recognized were substantially increased. Finally, the probe type data (Figs. 3 and 4) support previous findings that semantic as well as acoustic encoding is possible in short-term memory. In addition, however, these same data also indicate that rehearsal, not simply the focus of attention or the overall information load, determines whether semantic encoding will, in fact, take place. Each of these major conclusions is of some consequence in understanding the processes of attending and encoding.

The data in Figs. 1 and 2 confirm Norman's (1969a, b) conclusion that verbal material presented on a nonshadowed channel does enter short-term memory. Ss in the divided attention condition of the present experiment worked under instructions equivalent to those given Ss in Norman's "memory while shadowing" group: Shadow material on one channel carefully, while attempting to retain the material on the other. In fact, there is a striking resemblance between the appropriate comparison data in this experiment (upper curve, Fig. 1) and Norman's data. Both experiments found substantial, though hardly error-free, recognition of the most recently presented items that declined steadily with serial position, reaching the chance level for the fourth item back. This latter detail—that in both studies only the last four nonshadowed items were retained—may be of some interest, since the 2/sec presentation rate used here was twice as fast as that in Norman's study. The implication, which clearly requires more direct test, is that Ss' ability to store nonshadowed information may be item as well as time limited.

Norman (1969a, b) explained the discrepancy between his demonstration of retention of nonshadowed material and the negative results of previous studies in terms of his use of an immediate retention test. In the Introduction of this study, it was objected that this difference might rather have been due simply to the fact that Norman, unlike previous Es, encouraged his Ss to attempt to remember the nonshadowed material. In light of the data from the focused attention condition of this experiment, however, that alternative explanation no longer appears tenable. As the lower curve in Fig. 2 shows, Ss retained information about the contents of the nonshadowed channel even when every effort was made to encourage them to ignore that channel. The same data also indicated that the nonshadowed items were encoded in such a way as to permit their differentiation from shadowed items. Since the false positive rate for these items was significantly below chance, it appears that these items were not only entered into short-term memory but also tagged as to their channel of origin. Note, too, that here again retention of nonshadowed input was limited to the last four items presented.

While these results do replicate and extend Norman's

(1969a, b) findings, they no more constitute support for his "late selection" model of attention than do his own data. For, while it is true that a theory of attention which holds that "selection takes place with the aid of both meaningful and physical properties [1969a, p. 85]" does predict memory for all events, even those to which we fail to attend, it does not follow that memory for nonattended events implies that they have been analyzed for meaning. The probe type variable in the present experiment does, however, provide evidence about the level of processing that occurs prior to selection, and the results from the use of semantic probes argue strongly against a late selection approach.

From Figs. 3 and 4 it is notable that in the divided attention condition semantic information about nonshadowed material contributed to the overall recognition rate only for the last item presented. In the focused attention condition, there was no evidence at all for semantic recognition of those distractor items that were retained. If these items had been analyzed for meaning prior to selection, why were Ss unable to use the information provided by this analysis in an immediate test? Nor can it be readily argued that semantic information was extracted but not stored. The recognition scores for semantic probes of to be remembered items in the focused attention condition confirm Bregman's (1968) and Shulman's (1970) demonstration that, when required, semantic information can be maintained in short-term memory. Indeed, as in these previous studies, Fig. 4 indicated that, although retention of semantic information is slightly inferior to that of acoustic information, the time course of forgetting of both types of information is much the same. From these data, then, it appears that the encoding of semantic information *follows* selection of an input, as the early selection models assert. In the focused attention condition, some information was retained from both channels, but knowledge of the meaning of the material was limited exclusively to the attended ear.

The data from the divided attention condition provide further information for determining the boundary conditions for semantic encoding. Recall that Shulman (1970) proposed that semantic encoding is a relatively time-consuming process, which Ss may tend to neglect when required to perform some other activity during the presentation or retention interval. In particular, he singled out rehearsal as one such activity that ordinarily might take precedence over semantic encoding. The data on the retention of to be remembered items in Fig. 3 support the basic notion of time-dependent encoding. When required to shadow material from another source, semantic encoding of to be remembered items was completely neglected for all but the last item. However, the data in the same figure on the correct rejection of distractors seriously questions Shulman's designation of rehearsal of an item as an activity that might preclude its semantic encoding. Notice that Ss did store semantic

information about the shadowed distractor items, even though all the test probes referred only to the contents of the other channel. To the extent that it is reasonable to liken shadowing to overt rehearsal, it appears that rehearsal facilitates rather than competes with encoding. In fact, looking across the four sets of functions in Figs. 3 and 4, it can be seen that, although designating a set of items as those to be remembered did not insure semantic encoding of those items, requiring Ss to shadow a set of items did. Thus, the present data suggest that semantic encoding is a by-product of rehearsal, rather than an alternative to it.

Posner and Warren (1972) have recently proposed an approach to the relationship between encoding and attention that seems useful in attempting to identify the implications of the above results for our understanding of human information processing. Basically, they argue that multidimensional theories of encoding need to distinguish between that restricted set of well learned coding operations that do not require direct involvement of the central processing mechanism ("automatic processes") and the much wider range of more complex coding schemes ("conscious processes") that do. Only the latter set of operations is constrained by Ss' limited capacity. Posner and Warren go on to suggest that rehearsal is one activity that requires "conscious" processing of an item. It may now be concluded that the present experiment has identified shadowing as another such activity. Thus, the acoustic encoding evidenced in all conditions may be considered to have proceeded automatically. Hence, S encoded the sound of an item regardless of his intent to remember it. However, when S was required to shadow an item, he was obliged to admit that item to the limited capacity conscious processor and, having done so, proceeded to encode it semantically as well. It might be noted that this distinction between automatic and conscious processes is in accord with the spontaneous comments of Ss in both groups who reported that they "felt like they didn't know what had been said" on the nonshadowed channel. The proposition that rehearsal required admission of an item to the central processing channel may also help to explain the indication that the final nonshadowed item was encoded semantically if the assumption is made that at the beginning of the 8-sec test interval Ss rehearsed the last item presented. This last assumption might be tested by having the shadowing task continue beyond the presentation of the last to be remembered item.

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