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Long-term memory for speaker's voice and source location

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One hundred and twenty-eight subjects tried to recall 20 simple sentences that for some subjects were presented in two different voices or were presented from two loudspeakers on different sides of the room. In addition, some subjects were instructed to remember not only the sentences, but also their voice and location attributes. Intentional instructions for location resulted in poorer recall of the sentences, but intentional instructions for voice did not. The voice attribute seemed to be automatically coded under both intentional and incidental instructions for remembering the attribute, whereas the location attribute seemed to require cognitive processing in addition to that required for encoding the meaning of the sentence. A test for clustering by voice in recall was done to determine if the evidence for automatic coding of voice was merely an artifact resulting from better recall because of organization. However, no clustering was found. The ideas that speaker's voice and sentence meaning were processed in parallel by different hemispheres of the brain and that the connotation of the voice influenced the meaning of each sentence were offered as two possible explanations of the results.

Crowder and Morton (1969) have suggested that acoustical aspects of auditory stimuli which are not coded linguistically are displaced from precategorical acoustic store (PAS) either by subsequent auditory events or by decay within a brief period of time. Based on data from studies of the suffix effect, the capacity of PAS has been estimated to be no more than three items (Morton, 1970). In contrast to these proposals, several studies have demonstrated incidental, postsensory memory for characteristics of a speaker's voice (Cole, Coltheart, & Allard, 1974; Craik & Kirsner, 1974; Hintzman, Block & Inskeep, 1972; Light, Stansbury, Rubin, & Linde, 1973). These results have led some researchers to question the utility of postulating separate sensory and postsensory memory stores (Craik & Kirsner, 1974).

Hintzman et al. have offered two hypotheses as possible explanations for the incidental retention of speaker's voice. The first, the abstract-proposition hypothesis, is consistent with the notion of PAS in that, when a difference in speakers is noticed by the subject, voice characteristics are intentionally encoded as a referent to the linguistic stimuli. The second hypothesis suggested by Hintzman et al. is the literal-copy hypothesis, which is inconsistent with the concept of PAS. Under this hypothesis, a subject can experience an auditory image of a speaker's vocalization several minutes after its occurrence (Craik & Kirsner, 1974). Tulving (1972) cites memory for a melody as one example of such storage and retrieval from episodic long-term memory without mediation from the semantic memory system. To decide between these two hypotheses, Hintzman et al. suggested an experiment in which some stimulus items are repeated by a speaker of the sex opposite to the speaker of the first presentation, while other items are repeated by the same speaker. Hintzman et al. argue that if the abstract-proposition hypothesis is correct, there should be no difference in the recognition of the repetitions; whereas the literal-copy hypothesis, reminiscent of Tulving and Thomson's (1973) principle of encoding specificity, would predict some degree of physical mismatch with the different-voice repetitions, and hence poorer recognition. Although Hintzman et al. did not perform their proposed experiment, Craik and Kirsner (1974) conducted a similar experiment and found that a same-voice repetition of a word was recognized more rapidly and more accurately than a repetition spoken by a member of the opposite sex. Thus, the results were consistent with what Hintzman et al. characterize as the literal-copy hypothesis. However, the results are also consistent with the notion that abstract propositions as well as the denotative meaning and physical characteristics of an item affect its recognition (Kirsner, 1973).

One problem with the Hintzman et al. alternatives of "abstract proposition" vs. "literal copy" is that they do not cover all the possible explanations of what may be occurring. Rather than concluding that a literal copy of the attribute exists in memory, a more general hypothesis that could include the literal-copy hypothesis would assume that the voice attribute is coded automatically. This means that the coding of the voice attribute does not require cognitive processing time on the part of the subject beyond that needed to encode the semantic content of the item. To say that a literal copy of the voice attribute exists in memory is a much stronger hypothesis and is more difficult to test.

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On the other hand, the abstract-proposition hypothesis implies that cognitive processing time is needed for encoding the voice attribute beyond the processing time needed for encoding the semantic meaning of the sentence. The attribute must be "attached" to the code for the item in memory. Hence, the information contained in the abstract proposition is not coded automatically with the meaning of the item and is not inherent in the memory code for the item. These two hypotheses will be referred to as the automatic coding bypothesis and the cognitive coding hypothesis, respectively. Although the discussion so far has assumed the two issues to be related, the issue of automatic vs. cognitive coding can be considered as independent of the storage format issue. Whether or not a code is formed automatically or requires cognitive processing time could be independent of whether the code is a literal copy or an abstract proposition. In this paper the primary concern is with the automaticity issue.

To detect whether or not an attribute is coded automatically or requires processing time, one could look for an item-attribute trade-off (Light, Berger, & Bardales, 1975). If the subject is required to code an attribute along with each item and this attribute coding requires processing time, then the result should be a decrease in the number of items remembered compared to a control situation in which the subject does not have to remember both the item and the attribute, but only the item. However, there is a third possibility which may mask a trade-off in the coding of items and item attributes. This is the presence of an organizational strategy which might erroneously lead one to conclude that attributes are being processed automatically. It may be that the extra processing time needed for the attribute detracts from the storage of semantic information about the item and about other items on the list. However, retrieval of the items may be facilitated and, perhaps, make up for the loss of processing time for the semantic content of the items. This may occur because the attribute information allows the items to be organized on the basis of, for example, the voice attribute. This dichotomous categorization of each item on the basis of whether it was said in a male or in a female voice could result in performance better than it would be without that organization having taken place (Mandler, 1967; Tulving & Pearlstone, 1966). If this organization facilitates retrieval, then the trade-off between attribute processing and item processing predicted by the cognitive coding hypothesis will not be apparent. One way to determine if retrieval is being facilitated by organization of the items is to determine if significant clustering by voice is taking place; then, the lack of an item-attribute trade-off is equivocal and either automatic coding or cognitive coding involving processing time could be occurring.

The primary purpose of the present experiment was to test the automatic coding and cognitive coding hypotheses directly by seeking a trade-off between long-term free recall of sentences and incidental long-ter recognition memory for the sex of the speaker of ea sentence. The automatic coding hypothesis predic that significant incidental recognition of speake voice should occur without any decrease in senten recall. Alternatively, if storage of speaker's voice do not constitute an organizational scheme, then th cognitive coding hypothesis predicts that any significa recognition of speaker's voice under incidental instru tions should be accompanied by a decrease in se tence recall as compared to a control condition where a of the sentences are presented in the same voice. Wit out a difference in speakers, voice would not constitu a dimension on which the sentences could be diffe entially encoded. If speaker's voice is used as an orgar zational scheme, an absence of a trade-off betwee sentence recall and incidental recognition of speaker voice could not distinguish between the automat coding and cognitive coding hypotheses, since any ext amount of intentional processing necessary for estal lishing the organizational scheme could be offset b better recall through the use of the scheme. Therefor a measure of clustering on the basis of speaker's voic for the recall protocol of each subject was obtained. the subjects use speaker's voice as a basis for retriev of the semantic content of the sentences, a significa amount of clustering should be observed.

In addition to speaker's voice, physical source loc tion (left or right) was also chosen to be studied und both incidental and intentional attribute-retention i structions. Source location was selected because pa research seems to indicate that it is a paralinguist attribute which is not stored in long-term memo incidentally (Hintzman et al., 1972). If the automat coding hypothesis for memory of speaker's voice correct, then a second independent location attribut should have little effect on memory for speaker's voic either under incidental or intentional retention of bot attributes. Light et al. (1973) reported only slightl better memory for a male vs. female speaker distinctio for sentences learned under intentional instructio compared to sentences learned under incidental i structions. Conversely, the cognitive coding hypothes predicts that voice and location retention should inte fere with each other, though possibly not to the sam degree. This is because the storage of both attribute would require additional intentional processing.

METHOD

Subjects

The subjects were 128 undergraduates at Ohio Universit who volunteered to participate in a psychology experiment fc course credit.

Materials and Apparatus

Twenty simple active sentences, constructed in the pa tense, were used as the stimulus materials. All of the sentence were of the following form: The–animate subject–action verb–the–inanimate object. The subjects and objects were AA word with an imagery value greater than 5.0 and a concreteness value greater than 5.8 (Paivio, Yuille, & Madigan, 1968). After randomly pairing the subjects and objects, plausible A or AA verbs were chosen to complete the sentence structures. Two examples are: "The teacher picked the cotton" and "The gentleman bought the railroad."

The apparatus was a Sony Quadradial tape recorder which allowed the different recorded channels to emanate from different loudspeakers. One AR5 speaker was placed at each side of the experimental room, approximately 35 deg to the left and right of the subjects' line of forward vision.

Four different tape recordings of the 20 sentences were made, with 5-sec blank intervals between sentences. One tape was constructed with the same male speaking all of the sentences and with half of the sentences recorded on each channel (left and right). A similar tape was made with a female speaking all of the sentences. The only sequencing restriction was that no more than two instances of the same channel could occur in a row. A third tape was made with half of the sentences spoken by the male and half by the female. The left-right attribute was also varied independently of the speaker attribute. A fourth tape was made, identical to the third, with the exception that the sex of the speaker was reversed for each sentence. This tape was included to control for the possibility that some sentence-sex matchings would be more meaningful than others.

Procedure

Incidental condition. The eight groups of eight subjects in the incidental condition heard the 20 sentences in one of four presentation modes. One group heard the male speaking all of the sentences from both loudspeakers and one group heard the female speaking all of the sentences from both loudspeakers. These 16 subjects received the control mode of presentation. Two other groups of subjects heard these tapes with half of the sentences originating from either side of the room. These subjects received the location (left and right) mode of presentation. Two other groups of subjects heard tapes with half of the sentences spoken by the male and half by the female with all of the sentences originating from both loudspeakers. These subjects received the voice (male and female) mode of presentation. The remaining two groups of subjects heard tapes with the location attribute varied independently of the voice attribute. This was the voice plus location mode of presentation.

All subjects were told that they would be asked to write down as many of the sentences as they could remember. No reference was made to the voice or location attributes. After the presentation of the 20 sentences, the subjects were required to solve a deductive reasoning problem for 45 sec. Then a period of 4 min was allowed for free recall of the sentences. Immediately after the recall test, all subjects except the control subjects were given an attribute-recognition sheet containing the sentences randomized with respect to input serial position. The groups receiving the location mode of presentation were required to indicate left or right, while the groups receiving the voice mode were required to indicate male or female. The groups receiving the voice plus location mode of presentation were asked to indicate both the sex of the speaker and the location. All subjects were given as much time as was needed to complete the attribute-recognition task. The average time between the presentation of a sentence and its test for attribute recognition was 6.5 min.

Intentional condition. The procedure for the eight groups of eight subjects in the intentional condition was the same as in the incidental condition, with one exception. All subjects except those receiving the control mode of presentation were told that, following sentence free recall, they would be given the sentences and would be asked to indicate for each sentence whether it was presented from the left or right (the location mode), or whether it was presented in the male or female voice (the voice mode), or both (the voice plus location mode).

Design and Analysis

Sentence recall and attribute recognition. The design for the sentence free-recall analysis was a 2 by 2 by 2 by 5, with the specific factors being instructions (incidental, intentional attribute-retention instructions), voice (male and female, the same speaker), location (left and right, monaural), and serial position (1-4, 5-8, 9-12, 13-16, 17-20). The two designs for the voice and location attribute-recognition analyses were both 2 by 2 by 5, with the specific factors being instructions (incidental, intentional), presentation mode (location or voice alone, voice plus location), and serial position. All factors in all three designs were between-subjects factors except serial position.

Organization. The Bousfield and Bousfield (1966) measure of clustering was used to determine whether voice or source location is used as an organizational scheme. For each subject's recall protocol, the expected number of repetitions in a category was subtracted from the observed number of repetitions. The expected number of repetitions for voice is equal to $[(M_1^2 + M_2^2)/N] - 1$, where M_1 represents the number of sentences recalled which were spoken by the male, M_2 represents the number of sentences recalled which were spoken by the female, and N is the total number of sentences recalled. For source location, M_1 represents the number of sentences recalled which originated from the left side of the room and M_2 represents the number of sentences recalled which originated from the right. The resulting mean values of clustering for voice and for location were compared to the control mean values of clustering of the same sentences obtained from subjects receiving the control presentation mode. Four t tests were used to make these comparisons: one when the voice attribute was presented, one when the location attribute was presented, and two when both attributes were presented. These four t tests were made under both incidental and intentional instructions.

Alpha level. The level of significance for all analyses was set at $\alpha = .05$.

RESULTS

Sentence Free Recall

The analysis of variance for sentence free recall showed a significant main effect of Instructions, $F(1,120) = 16.93$, $MS_e = .67$, with more sentences recalled in the incidental attribute-retention condition. There was also a significant main effect of Location, $F(1,120) = 10.52$, $MS_e = .67$, with more sentences recalled when all the sentences were presented from both loudspeakers. In addition, the Instructions by Location interaction effect was significant, $F(1,120) = 9.90$, $MS_e = .67$. A Cicchetti test (Cicchetti, 1972) on the interaction showed that sentence recall was not reliably different under incidental attribute-retention instructions regardless of whether the location of the sentences was varied, but under intentional attribute-retention instructions, more sentences were recalled if location was not varied. The main effect of Voice was not significant, $F(1,120) = 3.21$, $MS_e = .67$. Hence, the only significant difference in sentence recall was a decrease in recall when there was intent on the part of the subjects to remember source location. The only other significant source of variation was a main effect of Serial Position, $F(4,480) = 13.94$, $MS_e = .75$. The means are shown in Table 1 and the serial position curves for the voice, location, and voice plus location presentation modes under intentional instructions are displayed in Figure 1. The control curve represents data from the 32 subjects receiving the control presentation mode. Because the sentence recall curves for the voice, location, and voice plus location presentation modes under incidental instructions are essentially the same as the control curve, they are not shown. Since the Serial Position factor did not interact with any of the other factors, a single trend analysis was conducted on the five serial position intervals collapsed across conditions. The linear trend was significant, $F(1,480) = 42.76$, $MS_e = .75$, as was the quadratic trend, $F(1,480) = 20.72$, indicating a significant primacy effect in each of the sentence-recall curves.

Attribute Recognition

The analysis of variance for voice recognition showed no main effect of Instructions, $F(1,60) = 1.7$, and no main effect of Presentation Mode, $F(1,60) < 1$. The Instructions by Presentation Mode interaction was also not significant, $F(1,60) < 1$. Four t tests which tested recognition means against chance levels indicated that voice was recognized better than chance regardless of the instructions and regardless of whether the mode of presentation was voice alone or voice plus location. There was also no significant main effect of Serial Position, $F(4,240) < 1$, and the Serial Position factor did not interact with the other factors.

The analysis of variance for location recognition showed a main effect of Instructions, $F(1,60) = 24.5$, $MS_e = .64$, with location being recognized more accurately under the intentional instructions. The main effect of Presentation Mode was also significant, $F(1,60) = 9.9$, $MS_e = .64$, with location recognition being better

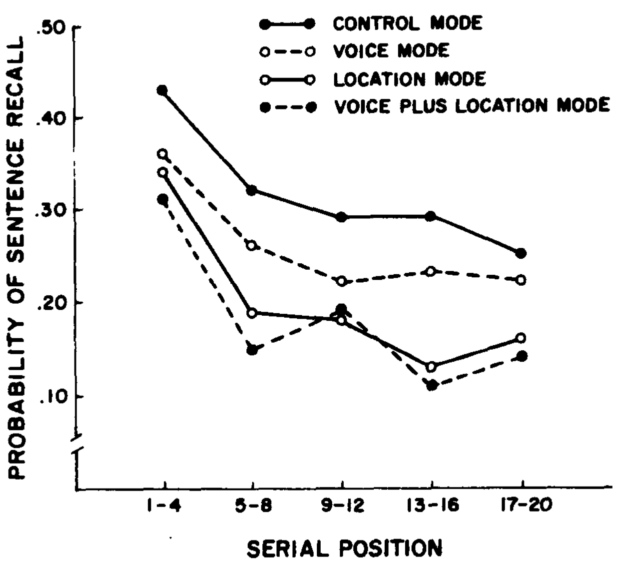

Figure 1. Sentence recall serial position curves for the 32 control subjects and for subjects in the intentional condition under the voice, location, and voice plus location presentation modes.

Table 1
Mean Number of Sentences Recalled as a Function of Instructions and Presentation Mode

	Presentation Mode			
Instructions	Control	Voice	Location	Voice + Location
Incidental	6.4	6.0	6.4	5.9
Intentional	6.4	5.3	4.0	3.6

Table 2
Mean Number of Voice and Location Attributes Recognized Correctly as a Function of Instructions and Presentation Mode

	Alone		Voice + Location	
Instructions	Voice	Location	Voice	Location
Incidental	13.6*	10.4	13.9*	10.0
Intentional	14.4*	13.6*	14.4*	11.3

**Attribute recognition is better than chance.*

with the location presentation mode than with the voice plus location presentation mode. The Instructions by Presentation Mode interaction effect was significant, $F(1,60) = 4.7$, $MS_e = .64$. A Cicchetti test on the interaction showed that location recognition under intentional instructions was better than under incidental instructions when location was the only attribute presented. Also, location recognition was better when the location attribute was presented alone under intentional instructions. Hence, there is a positive effect of intent to remember location on location recognition, but this effect was weakened and made statistically nonsignificant by instructions to also remember voice. Four t tests which tested the mean recognition scores against chance levels indicated that location was recognized better than chance only when the location attribute was presented alone under intentional instructions. The only other significant sources of variation were a main effect of Serial Position, $F(4,240) = 4.80$, $MS_e = 1.04$, and Instructions by Serial Position interaction effect, $F(4,240) = 2.45$, $MS_e = 1.04$.

The attribute-recognition means are shown in Table 2. The average probability of voice recognition, .70, is comparable to that obtained by other researchers (Hintzman et al., 1972; Light et al., 1973). The serial position curves for voice and location under incidental instructions are displayed in Figure 2 collapsed across the voice-alone or location-alone and voice plus location presentation modes. The serial position curves for voice and location recognition under intentional instructions are displayed in Figure 3. Two separate trend analyses conducted on the serial position curves for the voice attribute under intentional instructions indicated no significant trends. However, a trend analysis on the serial position curve for the location attribute under intentional instructions with the location-alone presentation mode showed a significant linear trend, $F(1,60) = 4.32$, $MS_e = 1.45$, a significant quadratic trend, $F(1,60) = 139.38$, and a significant cubic trend, $F(1,60) = 7.14$.

Also, a trend analysis on the serial position curve for the location attribute under intentional instructions with the voice plus location presentation mode showed a significant quadratic trend, $F(1,60) = 24.21$, $MS_e = .97$. These results suggest that the voice attributes are processed differently than are location attributes when subjects are instructed to remember the attributes.

Organization

When compared to clustering of the same sentences with the control mode of presentation, no significant amounts of clustering either by voice or location were found under intentional or incidental instructions. Hence, neither voice nor location appears to have acted as an organizational scheme for the sentences.

DISCUSSION

Storage of Voice and Location

The voice and location attributes seem to be processed in different ways. Voice is stored incidentally in a manner which is relatively unchanged under intentional instructions and does not entail a significant amount of extra processing time. Sentence recall was slightly lower under intentional instructions and voice attribute recognition was slightly higher, but these differences were not significant and were totally unlike the changes due to intent to remember location. With respect to the alternatives of the automatic coding vs. the cognitive coding hypotheses of the retention of speaker's voice, the cognitive coding hypothesis appears untenable in its present form. The storage of voice did not provide an organizational basis for the sentences. That is, there was no evidence for clustering on the basis of voices, and there was no significant trade-off between the mean number of sentences recalled and incidental or intentional storage of speaker's voice. The subjects did not have too much study time (Light & Berger, 1974) because the probability of recall was only .32 under the control presentation mode. The voice results can be contrasted with the results for storage of source location, which is also a paralinguistic stimulus attribute. Location was not stored incidentally, and under intentional instructions there was a significant decrease in the mean number of sentences recalled as compared to the mean number of sentences recalled with the control presentation mode. Also, intent to remember the location attribute did not interfere with storage of the voice attribute, whereas the reverse did occur (see Figure 3). Clearly, storage of location requires intentional processing effort, whereas storage of voice does not. The results are consistent with the automatic coding hypothesis for memory of speaker's voice.

The reason for the primacy and recency effects in the serial position curves for recognizing the location of each sentence under intentional instructions (see Figure 3) is not clear, but one explanation was obtained during postexperimental interviews with the subjects.

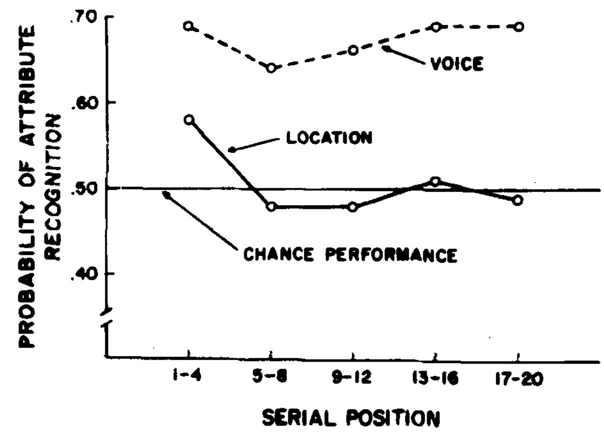

Figure 2. Serial position curves for incidental recognition of voice and location. Each curve represents data from the voice plus location presentation mode as well as from the respective voice-alone and location-alone presentation modes.

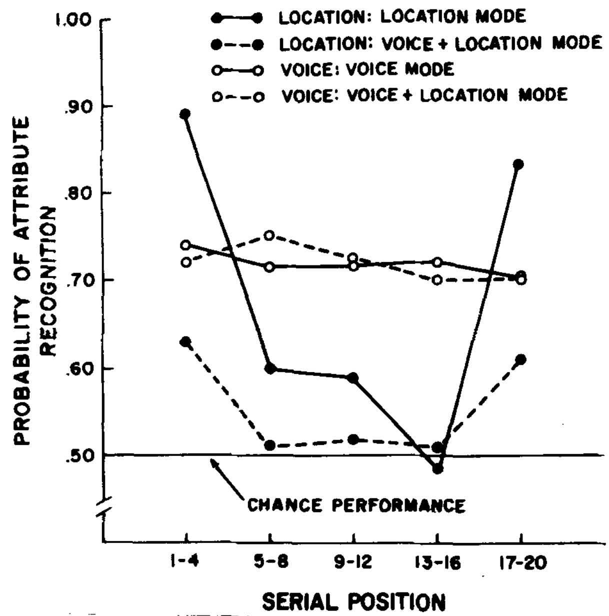

Figure 3. Serial position curves for intentional recognition of voice and location.

Many subjects said that they tried to remember the pattern of the left-right occurrences. During the recognition test, they then matched this pattern with their memory for the input position of each sentence. For example, a subject might remember that a particular sentence was presented third from the last and also remember that the third from the last sentence was presented from the right. Such a pattern-matching strategy could explain the bowed retention-of-location curves in Figure 3. The subjects who were instructed to remember voice with the voice mode of presentation apparently did not invent such elaborate processing strategies, possibly because they did not perceive the task to be as difficult. If any strategies were employed to remember voice when subjects were instructed to remember the voice of each sentence, they did not require much processing time and did not significantly increase memory for the voice attribute. However, voice did seem to interfere with retention of location under the voice plus location mode of presentation with intentional instructions to remember both attributes. If voice characteristics are automatically coded and do not have to be cognitively processed, it is not clear why voice should interfere with the retention of location. Perhaps subjects attempted to also code the voice attribute using cognitive processing. This attempt would not improve the retention of the voice attribute, but would interfere with the retention of location as shown in Table 2. Also, as shown in Table 1, an attempt to cognitively code the voice attribute could decrease the recall of the sentences, although this decrease was not significant.

Organization

The present lack of evidence for speaker's voice functioning as an organizational scheme is in conflict with the significant amount of output clustering reported by Hintzman et al. (1972). This discrepancy may be the result of the nature of the stimulus materials used in each experiment. Hintzman et al. used words, while the present experiment employed sentences.

Storage of Voice and PAS

The automatic coding hypothesis, which is consistent with the present voice-recognition data, is inconsistent with the concept of PAS. Crowder and Morton (1969) argue that nonlinguistic information is lost in a few seconds and is not stored in memory. One alternative is to postulate the existence of incidental long-term auditory imagery analogous to incidental long-term visual imagery, where salient acoustical properties of a stimulus may be stored automatically in parallel with the linguistic memory trace. One possible explanation of this automatic coding of the speaker's voice is that it usually takes place in the right hemisphere of the brain, whereas the meaning of the sentences is usually analyzed in the left hemisphere of the brain. Blumstein and Cooper (1974) have argued that the analysis of the phonetic and semantic components of language are conducted primarily in the left hemisphere and the analysis of intonational and perhaps other components of the speech signal are conducted primarily in the right hemisphere. On the other hand, even though the subjects declared that they could "still hear" the speakers for most of the sentences, it might be the case that a sentence spoken by a female simply does not mean the same thing as the same sentence spoken by a male. Osgood, Suci, and Tannenbaum (1957) have shown that the semantic space of a stimulus is much broader than its denotative meaning. A sentence spoken by a female may elicit a connotative meaning which is somewhat different from the same sentence spoken by a male. For example, the sentence, "the horse climbed the mountain," spoken by a female might elicit a visual image of a relatively tame pinto prancing up a mountain, whereas the same sentence spoken by a male might elicit an image of a restless black stallion bolting up a mountain. The voice attribute would then be considered as having automatically changed the meaning of the sentence. These connotative aspects of the semantic space could then mediate the male-female recognition responses. Based on the corpus of speech for the male speaker and for the female speaker, the subjects could have reconstructed the auditory image for a sentence, thereby believing that they could still hear the speaker. By contrast, as in the present experiment, source location would not be expected to affect the connotative meanings of the sentences.

In conclusion, the automatic coding hypothesis is a more plausible explanation of incidental, postsensory storage of characteristics of a speaker's voice than is the cognitive coding hypothesis; but in light of Crowder and Morton's results, some form of the hemispheric processing hypothesis or the voice-connotation hypothesis should be explored. The nonautomatic retention of the source location of a speaker is not in conflict with the notion of PAS.

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