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Speaker Identification Utilizing Noncontemporary Speech

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ABSTRACT: The noncontemporariness of speech is important to both of the two general approaches to speaker identification. Earwitness identification is one of them; in that instance, the time at which the identification is made is noncontemporary. A substantial amount of research has been carried out on this relationship and it now is well established that an auditor's memory for a voice decays sharply over time. It is the second approach to speaker identification which is of present interest. In this case, samples of a speaker's utterances are obtained at different points in time. For example, a threat call will be recorded and then sometime later (often very much later), a suspect's exemplar recording will be obtained. In this instance, it is the speech *samples* that are noncontemporary and they are the materials that are subjected to some form of speaker identification. Prevailing opinion is that noncontemporary speech itself poses just as difficult a challenge to the identification process as does the listener's memory decay in earwitness identification. Accordingly, series of aural-perceptual speaker identification projects were carried out on noncontemporary speech: first, two with latencies of 4 and 8 weeks followed by 4 and 32 weeks plus two more with the pairs separated by 6 and 20 years. Mean correct noncontemporary identification initially dropped to 75–80% at week 4 and this general level was sustained for up to six years. It was only after 20 years had elapsed that a significant drop (to 33%) was noted. It can be concluded that a listener's competency in identifying noncontemporary speech samples will show only modest decay over rather substantial periods of time and, hence, this factor should have only a minimal negative effect on the speaker identification process.

KEYWORDS: forensic science, speaker identification, voice identification, speech

Identifying speakers from their voice is becoming increasingly important within many facets of our society. While it sometimes is of material value in civil, social and related areas, it can be of fundamental importance to the forensic sciences.

Most forensic approaches to speaker identification take one or the other of two forms. In one instance, a victim or witness is asked to identify the voice of another person; one who is suspected of having committed a crime. A good example here would be the case where the witness is female, has been raped but did not actually see the rapist—only heard his speech and voice. The witness is asked to make an identification at some time after (often long after) hearing the perpetrator. The task presented her often is structured in a manner similar to eyewitness lineups. Thus, the question can be asked: how effective are these earwitness lineups and what is known about them? First, it must be pointed out that a rather substantial amount of research has been carried out on issues that underlie these questions; it is related to aural-perceptual speaker identification in general. Most of these enquires have been basic in nature (1–12); only some of them have addressed problems directly related to earwitness identification itself. Nevertheless, it is known already that, due to a number of circumstances, the reliability of lay witnesses can be somewhat variable (13–19) and that a person's memory for a voice decays as a function of time (2,20–30). Some deviation among the observed patterns and decay slopes has been reported but these shifts appear to be related to differences among: (a) the nature of memory, (b) the specific tasks being carried out, and/or (c) the procedures employed by the investigators. Yet, even with these limitations extant, earwitness lineups (sometimes referred to as "voice parades") are commonly employed by law enforcement agencies; they are carried out all over the world. This approach has been reviewed first simply because the basic problem associated with it (i.e., memory decay for voices) had led to an enigma with the type of speaker identification which is the focus of this report (i.e., when the samples are noncontemporary). As will be seen, this second problem actually is quite different from the one discussed above.

The Present Issue: Noncontemporary Speech

As stated, the thrust of the present project is one where a voice has been recorded (examples: death threats, bombs threats, and sexual harassment) and attempts are made *later* to determine the identity of the speaker, often from a pool of suspects. Here, samples of both the "unknown" speaker (evidence tapes) and various other talkers (knowns) are available; the tapes of the suspects or "knowns" are collected later (often much later than the evidence tapes) in the form of exemplars. Since the samples to be compared are acquired at different points in time, their noncontemporariness can be rather substantial even though processed at a single session. In any event, it is at this later stage that some form of speaker identification is applied (i.e., aural-perceptual assessments by specialists, machine/computer processing or hybrid techniques) in an effort to determine if the two speakers (i.e., the unknown and a known) are a single person or two different individuals (4, 6,8,9,31–33). The prevailing opinion is that samples made at differing times and under different conditions create just as difficult a challenge to the speaker identification process as does the decay in listeners' memory when earwitness lineups are employed (i.e., where no evidence recordings are available).

Surprisingly, very little research has been carried out on this problem. The only known study in which an author directly investigated it was one published in 1977 by Rothman (34). He reported

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on a number of procedures; among the groups studied were 24 talkers who were recorded reading a passage and, then, reading it again a week later. Subsequently, he paired short samples of each talker's speech: (a) with other samples of that same person, and (b) with samples spoken by other people. He then had a large cohort of young adults attempt to identify the pairs that were produced by the same individual and those by different people. In some instances his sets were contemporary and, in others, they were noncontemporary. His results appeared to support the generally held opinion relative to noncontemporary speech. Specifically, while his listeners exhibited the expected level of about 94% correct identification for the contemporary pairs, their performance dropped sharply (to only 42%) in their noncontemporary judgments. Admittedly, Rothman's scores might have been reduced somewhat because some of his speakers were related to each other and sounded similar when they spoke. Nevertheless, he concludes that when speech is text independent "and noncontemporary, the ability to identify individuals is sharply reduced." Moreover, it can be noted that at least some tangential data are provided by Endress et al. (35) and Suzuki et al. (36) both of whom identified changes in the speech of normal individuals as they aged. However, neither of these groups reported shifts that were robust and/or universal; moreover, their comparisons were made over rather long periods of time. Finally, little challenge to this position (i.e., that noncontemporary samples degrade the efficiency of the speaker identification process) occurred for many years; in some cases, the postulate even crept into the writings of forensic phoneticians (6).

Ultimately, Schwartz (37) carried out a pilot study that tested Rothman's findings, at least on a limited basis. Her research was quite similar to his, yet she obtained results that were, on average, 35% higher. This marked disparity led to a reconsideration of the logic upon which the cited position was based. Not surprisingly, it now appears inappropriate to believe that an individual's speech/voice can change dramatically over very short periods of time or that auditors cannot recognize a single speaker when he or she produces speech samples only a few weeks apart. Thus, if listeners are capable of making reasonably accurate identifications over time, the use of noncontemporary speech would hardly be as devastating to the recognition process as was previously thought.

Method

As should be clear by now, research designed to study noncontemporary speech samples will differ sharply from that where earwitness lineups are investigated (Fig. 1). The basic procedure used in this research parallels that seen in the top box; the process of earwitness identification is found in the bottom one. Thus, it can be noted that, while both memory and a listener's ability to remember auditory events can play large roles in the success of earwitness lineups, such variables will have little to no effect on the present research. That is, even though the pairs of speech samples employed were noncontemporary, i.e., recorded weeks, months, or years apart, the present auditors are required to respond to the two samples in a paired comparison design. The question: Are the voices heard in both parts of the sample pair produced by the same or different individuals? Hence, judgments are made almost instantly with the entire task taking but 10–15 s. Accordingly, the encoding-storage-retrieval process (38,39) occurred so quickly that even short-term memory (40,41) was not a factor.

Secondly, and as was stated, this project sharply expanded the Schwartz (37) pilot study. Her data did not support Rothmans but rather suggested that noncontemporary speech samples would have

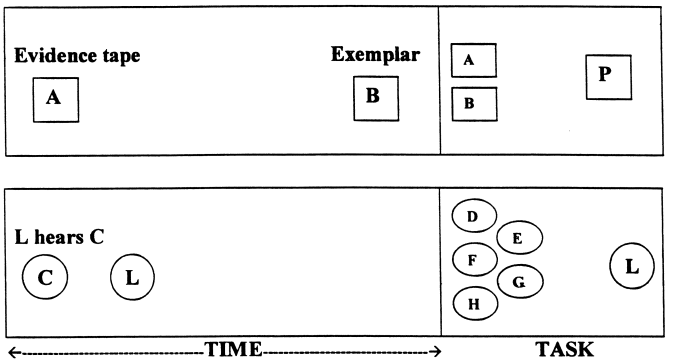

FIG. 1—*A graphic portrayal of the differences between the present experiment (top box) and the way in which research on "voice parades" is carried out (bottom box). In the current instance, a processor (P is an auditor or computer operator) attempts to determine whether or not the speakers heard in samples (A) and (B) are the same person. Note that the recordings here are made at different times. In earwitness identification, there is no recording of the perpetrator (C). Rather the listener (L) attempts to pick him out of a lineup (D to H).*

but a minor effect on the robustness of the speaker identification task. The controversy cited was addressed by means of four parallel experiments. In the first, contemporary speech samples for a number of male talkers were compared with *matched* samples (of their speech) obtained after latencies of four and eight weeks; in the second, the spacing was four and 32 weeks. The third procedure involved yet other speakers; in this case, the time differences between production of the first and the second samples was six years (312 weeks). Finally, a fourth study was carried out with a sample-set latency of 20 years (1040 weeks).

Subjects

All speakers were male; they were randomly drawn from several sources. Those for the first two experiments (i.e., those for 4–8, 4–32 weeks) were drawn from a large population of healthy adult males working or studying at the University of Florida. None exhibited any observable medical problems or a history of speech or hearing disorders. They were recorded and then rerecorded at plus/minus one day of the target dates. That is, ten of the talkers were recorded a second time after four and then eight weeks, whereas a second group of 11 were run again at four and 32 weeks. Finally, it should be noted that three of these men were talkers in both of the studies; however, their performance could not bias the data as none of the listeners were common to both the first and second of the experiments.

As is obvious, the speakers for the third and fourth experiments had to be obtained in a different manner. Specifically, their first recording was obtained from the IASCP database which contains over 15,000 controlled talker-samples. Only high fidelity samples were considered and they had to have been produced by individuals who were currently available for a second recording. Moreover, to be initially recorded, speakers had to have met the basic selection criteria of good health, plus appropriate reading/speaking ability and have exhibited no speech/hearing disorders. To be included in the present research, they had to again demonstrate these same characteristics (i.e., good health, speaking ability, etc). Ten appropriate subjects were found for a six-year comparison (i.e., 1989 to 1995) plus an additional 11 for a 20-year latency (1975 to 1995).

Speech Samples

Overall, the speech materials employed were constant within each of the four experiments. That is, they consisted of 6 to 8 s sentences (mean = 6.8 s) drawn from the Fisher-Logemann (42) articulation test for the first two studies, and 7 to 9 s sentences (mean = 7.6 s) extracted from standard reading passages for the research with greater latencies. Sample sentences were drawn from the "Rainbow Passage" for the six-year comparisons (third study) and similar excerpts from "An Apology for Idlers" for the fourth (i.e., the 20-year latency).

Listeners

In all, a total of 149 listeners (both men and women) were used; those that could meet the selection criteria were randomly distributed into four cohorts which varied in size from 31–41 individuals each (see Table 1). All were young, healthy university students drawn from Linguistics or Speech courses (and given course credit for their participation). While not highly experienced, all had received at least minimal training in speech and language. Further, they first were required to pass a hearing test (>92% correct SRT) and, subsequently, demonstrate that they could recognize if pairs of contemporary speech samples were produced by the same or different talkers at an 85% or better level of correct identification. Actually these "selection criteria" sets were mixed with the experimental materials on the basis of roughly 18 to 20% (same) and 30 to 35% (different) proportions, respectively. They (i.e., the "test" samples) were assessed before subjects' responses to the experimental material were scored; if a subject did not exceed the 85% correct identification criterion for both the known "same" and "different" speaker pairs, his or her responses to the target samples were discarded. Actually, all of the auditors met these (and the hearing) criteria; their overall means were 95.1% (range 90 to 100%) for the "same" judgments and 94.9% (range 87 to 100%) for the "differents" respectively. The correct identification means exhibited by each of the four cohorts may be found in the selection criteria columns of Table 1.

Procedure

An ABX or paired comparison technique (i.e., hear A, hear B, make decision X) was employed with from 64–78 pairs presented in each of the sub-experiments. The structural patterns for each of the four were roughly the same, depending upon whether only one set of noncontemporary contrasts (example: 0–6 years) or two (example: 0–4; 0–8 weeks) were evaluated. To illustrate, the pattern for the first experiment involved 78 sample pairs structured as follows: (a) same talker = 14 samples, (b) different talkers = 24 samples, (c) first latency comparison (0–4 week pairs) = 20 samples, and (d) second latency (0–8 week pairs) = 20 samples. All samples were randomized within the tape and the internal order (i.e., which of a pair came first) was counterbalanced. As stated, listeners heard the pair of utterances and immediately marked their decision as to whether they were produced by one or two people.

TABLE 1—*Summary table of listeners responses to same-different speech samples uttered by male talkers. All scores, except number of subjects, are in percent correct.*

	Subjects		Selection Criteria	
Experiment	Speakers	Listeners	Same*	Different
Study 1 (4, 8 wks.)	10	36	91.2	96.3
Study 2 (4, 32 wks.)	11	31	94.0	93.9
Study 3 (6 yrs.)	10	41	96.6	96.2
Study 4 (20 yrs.)	11	41	97.9	93.7
Mean			95.1	94.9
Range			90–100	87–100
Total	42	149		

* These scores (i.e., the "same" selection criteria judgments) also were used as the baseline (or contemporary) values.

Results and Discussion

The overall results may be best understood by consideration of Table 2. As may be seen, these data appear to form a rather specific set of patterns. First, please consider the contemporary (or baseline) scores found in the first column; they are drawn from the "same speaker" selection criteria data (next-to-last column, Table 1). It was not considered necessary to replicate this process since: (a) the procedure would have been identical, (b) group size was very large ($N = 149$) and (c) the very high level of correct identification clearly demonstrated listener ability. Moreover, the overall group mean of 95.1% equals or exceeds those found in other studies; included are those of 95.6% reported by Schwartz (37) and Rothman's (34) 94.0%.

Second, reductions in correct identification were found for the noncontemporary comparisons even after as short a period as four weeks. However, the decay was only around 15 to 20% rather than that of the over 50% reported by Rothman (34). Moreover, the present scores did not fall very much out of the range noted for a period of up to, at least, six years. It is not until a 20-year break occurred that the identification levels began to fall markedly. For convenience, these data, plus a second order polynomial curve, may be seen plotted in Fig. 2.

Certain other relationships also are apparent. Note that a four-week procedure was included in both of the first two experiments and the level of correct identification was 72.5% in the first and 79.6% in the second. When they were combined for all 67 subjects, the overall mean was 75.8%. As it turns out, these two values are not only reasonably consistent with each other, but roughly outline the band that can be seen to exist for latencies of up to several years. Further, while the subjects in the first experiment scored slightly higher on the eight-week task than they did for the four-week pairs, the reverse was true for the four and 32 week contrasts. It should be remembered that there can be no order effects among these data as all sample pairs were randomized.

The somewhat higher scores found for the six-year comparisons (Experiment 3) were not expected. However these data appear fairly stable. For one thing, since a large cohort of listeners could

TABLE 2—*Summary table of the correct percent of listeners responses to contemporary and noncontemporary speech samples uttered by male talkers. Times are in weeks.*

		Noncontemporary				
Experiment	Contemporary*	4	8	32	312	1040
Study 1	91.2	72.5	81.2			
Study 2	94.0	79.6		73.5		
Study 3	96.6				85.1	
Study 4	97.9					33.0

* The "contemporary" values are drawn from Table 1.

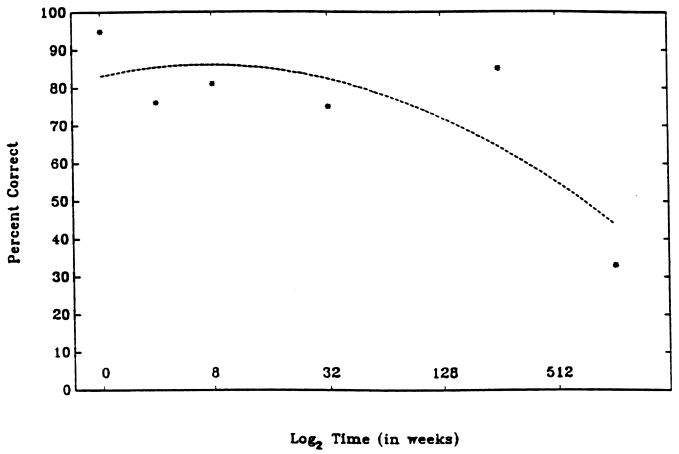

FIG. 2—*Group mean scores when subjects responded to noncontemporary samples as a function of delays of from four weeks to 20 years. The contemporary baseline is the mean (95.1%) for all 149 listeners. The fitted curve is a second-order polynomial.*

not be obtained at one time (i.e., to permit the entire procedure to be completed in one sitting), these materials had to be presented twice, first to a group of 20 subjects, then to a second of 21. The means for these two Experiment 3 "subgroups" were found to be 84.0 and 85.7; hence, good reliability is suggested. In any event, since the data from these two subgroups could be legitimately pooled (as was intended in the first place), only a single mean (85.1%) is reported.

As stated, Fig. 2 provides a visual representation of the data generated. Note that a band of scores, falling roughly between 70 and 85%, is established early and appears to be sustained, at least up until the time the noncontemporary pairings are separated by more that six years. Moreover, the data are consistent with those from the Schwartz pilot study (37) which roughly paralleled Rothman's, as she reported two week and four week correct identifications of 79.3 and 81.6% (respectively). Indeed, even though limited, her data are quite consistent with those generated by this project; they also are useful in confirming that the level of identification is close to 80% (that is, until the 20-year latency is considered).

The developing hypothesis that noncontemporary speech has little effect on speaker identification efficiency was further tested by application of a linear regression statistic. As would be expected, significance was found ($F = 111.21$; df 5, 190; $F\ .01 = 3.11$). However, testing the relationships along the curve found in Fig. 2 appeared to be of yet greater importance. This task was accomplished by means of a Tukey's HSD test for which a minimum significant difference of 8.74 was obtained. As will be seen, the primary differences in the curve occurred at the extremes; that is the contemporary judgments were found to exhibit significantly higher scores whereas the 20-year noncontemporary judgments were significantly lower. Excepting for the small positive reversal for the six-year data, the rest of the noncontemporary scores were statistically similar to each other. The slight upward shift found in Experiment 3 may be due (in part, at least) to the fact that a higher proportion of the speakers in this group had received some sort of professional training. There is at least a possibility that voice training and sustained vocal health may prevent the type of changes that could lead to listener confusions (43).

Finally, a sharply reduced level of correct identification for the contemporary versus the 20-year noncontemporary contrast was expected and, indeed, just such a reduction was found. However, the particularly high levels observed for the earlier latencies would suggest that the original prediction might have been a little severe. First, the reduction could have resulted simply from the fact that many of the speakers' voices actually had changed significantly over the 20-year period; the Endress et al. (35) and Suzuki et al. (36) findings would suggest this as a possibility. However, the identification levels for the other latencies (and especially for the six-year separation) cannot be ignored. In any event, the proportion of correct identifications after 1040 weeks is not much poorer than is Rothman's after just a few days.

Conclusions

First, it can be concluded, that the predicted severe reduction in the ability of listeners to identify individuals from noncontemporary speech samples over long periods of time was *not* substantiated. Second, it appears that noncontemporary speech samples can be expected to show only minimal decay, especially relative to aural-perceptual speaker identification, for periods of up to six years, and perhaps even longer. While it is possible that problems may occur if degrading factors of an external nature are present (i.e., sound alike speakers, talker illness, and channel distortions, etc.), these findings suggest that noncontemporary utterances probably will have but a minimal effect on the accuracy of speaker identification procedures of any type.

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