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A Re-Evaluation of the Auditory "Dead Time Constant"*

By CHARLES D. PARKER and EARL D. SCHUBERT

Cherry (1953) and Cherry and Taylor (1954) reported that a message fed alternately to the two ears can become unintelligible at certain switching rates even though all the speech is physically present at either one ear or the other. Particularly interesting was the reported relation between "recognition time," switching rate and intelligibility. Cherry and Taylor state that there is a time interval, τ , which has the nature of a "dead time constant" during which nothing of the signal is perceived at either ear. Minimum intelligibility occurred for them at a switching rate of three per second, consequently τ is calculated to be about 1/6 of a second.

As part of a study of sidetone phenomena we considered alternating the speaker's own voice from ear to ear via headphones following the same experimental procedure as Cherry. The first problem, of course, when the listener himself is the speaker, is that his direct (non-earphone) sidetone may be sufficiently strong to fill in the supposedly silent periods in the non-signal ear and thus furnish him a total sidetone signal that is, in effect, not being switched. One solution is to fill the ear not receiving the earphone signal during any interval with sufficient noise to mask out unwanted sidetone, i.e., to alternate speech and noise between ears so that each ear gets speech fifty per cent of the time and wide-band random noise the alternate fifty per cent. This, however, was getting sufficiently far from Cherry's original experiment that we thought it best to satisfy ourselves first that we could duplicate his original results within reason.

To this end we set up the following experiment. Sixty passages of approximately 120 words each, from newspaper and light magazine articles, were chosen as materials. Each passage was read by each of three speakers. These 180 recorded passages were arranged on three tapes, with the order of occurrence of the passages being random except for two restrictions: Each tape contained twenty passages by each speaker. Each tape contained the sixty different passages.

Ten switching rates were chosen. We were interested only in the area of the first dip in intelligibility in Cherry's original data, so we chose our switching rates to be equally spaced (logarithmically) between approximately once every two seconds to eighteen

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per second. The dip in intelligibility occurring above the interruption rate of 100 i.p.s. is undoubtedly due to the masking effect produced by the switching signal.*

Each of fifteen subjects listened to and repeated one of the sixty-passage tapes. Half the passages were listened to with random noise in the non-signal ear and half with silence. The score for any passage was computed for only the last 100 words. For any given subject the order in which the switching rates occurred, and the assignment of noise or silence to that rate were determined randomly, though every listener heard every talker twice at each of the switching rates—once with noise and once with silence. Our subjects were highly motivated intelligent adults with essentially normal hearing.

Figure 1 is a graph of the results and Table 1 the outcome of analysis of variance of the intelligibility scores.

Table 1.
Partial results of analysis of variance of the intelligibility scores.

<i>Source</i>	<i>df</i>	<i>ms</i>	<i>F</i>	<i>P</i>
Noises	1	9.558	21.35	.01 = 8.86
NxS	14	447		
IxT	9	342	135.22	.01 = 2.50
IxN	18	323	2.44	.01 = 2.15
TxN	2	59	.29	
IxSxT	252	2.5		
IxSxN	126	132		
IxTxN	18	98	.42	

From the graph it is apparent that we emerged with a much less dramatic dip than did Cherry and Taylor. This is not wholly explained by the leveling effect of averaging fifteen subjects, since of those subjects able to do the task itself well, i.e., those with scores of 95 to 100 at the easy switching rates, only three dipped as low as 25 at their poorest rate. There were also two subjects who refused to stray very far from ninety per cent all the way across the range of switching rates. They simply did not exhibit the phenomenon so strikingly shown by Cherry and Taylor's listeners.

The fascinating finding, however, stems from the relative placement of the "Noise" and "Silence" curves. Apparently the dip in intelligibility to a large degree disappears if the non-signal ear is filled, as it was here, with white noise of about the same average

*The ear, as well as the transducer, is incapable of faithfully following rapid switching without distorting. These distortion products become sufficiently intense at some frequencies to effectively mask the original signal.

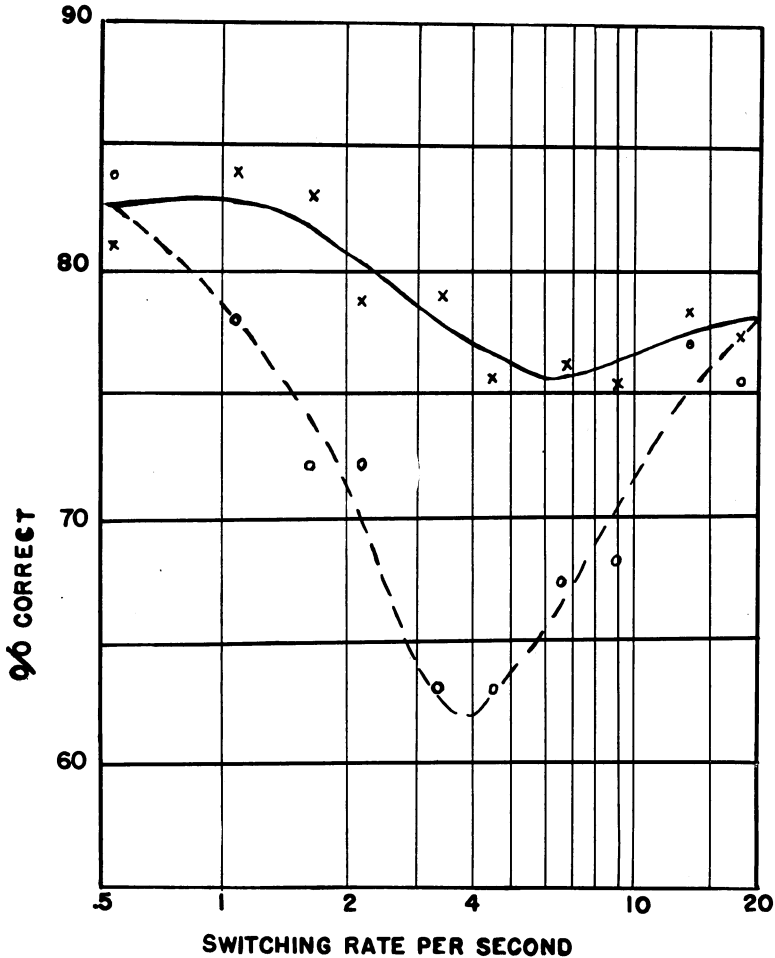


Fig. 1. The change in percentage of words correctly as the rate of switching from ear to ear is increased. The uppermost curve has been fitted by inspection to the means of the trials run with noise in the non-signal ear and the lower curve to the means of the trials run with no noise in the non-signal ear.

SPL as the speech. This is something we certainly had not predicted, and are at something of a loss to explain even after the fact. In addition to the relative placement of the two curves of Figure 1, evidence that this is not a chance difference between the two curves is available in the Noises (N) and Noises-by-Intervals (NI) terms of the variance analysis. The F-ratios associated with these sources of variation indicate we are quite safe in concluding that the two curves lie at different levels of intelligibility and that their shapes over the ten switching intervals differ by more than chance error would allow.

Our best guess at this point is that the effect of Cherry and Taylor got and that our "Silent" condition shows to a lesser degree might be more accurately ascribed to a contralaterally-inhibitive off-effect when one ear is switched abruptly to silence rather than to a dead-time which intervenes "because the attention is being transferred from one ear to the other" as Cherry and Taylor assert.

Our binaural listening system has been shown to exhibit inhibition of a kind (1) when localizing repetitive sounds in highly reverberant areas (Wallach, Newman, and Rosenzweig, 1949) and (2) when under certain conditions of masking the binaural system operates less effectively than the monaural (Hirsh, 1948), and (3) more directly applicable to this situation by Cherry (1953) who demonstrated that subjects when simultaneously fed two messages, one to each ear can "reject" the "unwanted" one to the extent of not understanding anything contained in that message while completely understanding the information contained in the "accepted" message. Further, Miller and Licklider (1950) report data which indicate that such an increase in intelligibility does not occur with the introduction of noise during the "off" portion of the cycle when speech is switched at comparable rates but to the two ears concurrently. This implies a bilateral phenomenon—more meaningfully an inhibitive system triggered by the "off-effect" of the contralateral ear. We are aware that contralateral inhibition does not necessarily add anything to the Cherry and Taylor explanation since "transfer of attention from one ear to the other" probably means, in a functional sense, inhibition at some level in the auditory system. Only an actively inhibiting mechanism, it seems to us, would keep the system from responding as adequately for the time intervals involved here. The addition of the "off-effect" to the explanation is occasioned by the increase in intelligibility when the silent intervals are filled with noise. At the moment, this has the status of only a stop-gap hypothesis for lack of any physiological or psychological (behavioral) rationale for such a mechanism.

A glance at Figure 1, with the reminder that each of the points marked by a circle or a cross represents the mean of forty-five passages, is proof that this is a highly variable phenomenon—at least as we measured it. Inspection of individual data reveals even more variability, though we have no way of knowing which variations are significant. Some subjects exhibit only a narrow dip, i.e., they drop sharply at only one of the points we measured, as opposed to others whose difficulty in repeating may have extended over three or four of our switching rates. Rarely, this difference may occur in the same subject for different speakers. We would like to be able to report that this variation lessens or disappears with the introduction of the noise, but such is not the case.

Our subjects may have found the task a bit more difficult than did Cherry and Taylor's partly because, whereas the average rate of speech for their talker was 136 wpm, ours was 175 wpm for Speaker 1, 178 wpm for Speaker 2 and 182 wpm for Speaker 3. This might appear to have moved our least intelligible switching rate closer to four per second than to the three Cherry and Taylor chose. Actually neither experiment has established the point of least intelligibility rigorously enough to make any such distinction. As a matter of interest, the average intelligibility over all rates of switching was seventy-seven per cent for Speaker 1, seventy per cent for Speaker 2 and seventy-seven per cent for Speaker 3. As noted, the points of Figure 1 have been corrected for these overall differences.

An additional puzzling phenomenon occurs with three of the subjects, who were wives of the talkers. In each case the wife exhibits only a slight dip in intelligibility, if any, at the difficult switching rates when her husband is the talker, but shows about the average dip for either of the other two speakers. We offer no explanation for this effect but mention it for the interest it may arouse in the reader who concerns himself with extra auditory theory.

There is a continued interest in this phenomenon and additional experimentation is under way to further evaluate (1) the effect of noises other than broad band random noise and (2) to establish the level at which the noise begins to affect signal intelligibility.

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