Since Lee (1958) first reported the disruptive effects on speech of introducing a temporal delay in a speaker's air-conducted sidetone (often referred to as delayed auditory feedback), there has been increasing interest in this phenomenon from the standpoint of pure research as well as practical use. For example, it has been used in the detection of feigned deafness, and as a stressor in studies of personality differences, drug effects, etc. The main disruptive effects of delayed auditory feedback (DAF) are repetition of certain speech sounds (i.e., "stuttering" of certain consonants and prolongation of certain vowels), general slowing of speech with occasional blocking, and increased vocal intensity (Chase, et al., 1959).

A number of studies have indicated that effects of the delayed feedback cannot be viewed simply as a distraction, but rather that the delay in feedback per se is critical in producing the disturbance. Evidence for the criticalness of this time-locked aspect comes from a variety of experiments such as those which demonstrate the relative ineffectiveness for producing speech disturbance of extraneous stimuli, such as white noise, the voice of another speaker, or even a recording of the speaker's own voice repeating the words on a previous occasion (Butler & Galloway, 1957). It has also been shown that similar disturbances in performance of a motor task other than speech can be obtained by delaying the auditory feedback from that task (Chase, et al., 1961a); or, in fact, by delaying feedback in any of several sensory channels (Chase, et al., 1961b).

It is now known that for maximally disruptive effects the delayed air-conducted sidetone should be amplified considerably so as to mask or override synchronous feedback via kinesthetic, proprioceptive, and bone-conduction channels. The exact value of the temporal delay has been shown to be not too critical in the sense that a wide range of delays will cause some disturbance of performance. However, there are large individual differences in the temporal delay necessary for maximally disruptive effects.

Several studies have indicated differences between groups in the effect of delayed auditory feedback on speech performance. One...
Differences between schizophrenics and normals in the utilization of sensory feedback would also not be inconsistent with neurophysiological hypotheses with regard to altered brain function in schizophrenia. Any hypothesized malfunction at a basic neurophysiological level such as altered synaptic transmission time, reduced effectiveness of inhibitory synaptic transmission, altered “switching” time, or higher level of neural “noise,” might be expected to reflect itself in altered utilization or time dependence of sensory feedback.

In either case, whether physiological or personality differences turn out to explain differences in disturbance under delayed auditory feedback, the present study is addressed to the prior question of whether any differences do in fact exist between the performances of adult schizophrenics and normals under delayed auditory feedback.

**Apparatus and Procedure**

Each subject read orally two passages; first, under the control condition of synchronous feedback, and then under the DAF condition with a temporal delay of 0.15 sec. His instructions were to read the passages out loud in his normal reading manner. The subject was not told about the feedback delay and if he stopped reading when he first encountered the delay condition, the experimenter indicated that he was to continue as best he could.

The first passage was 98 words in length and the second passage was 259 words in length. The subjects spoke into an Altec M 11 microphone which was attached to the headset holding the earphones so that the fixed distance between the subject’s mouth and the microphone could not be altered by movement of the head. The output of the microphone was fed into an Ampex 601 tape recorder where the combination of tape speed (7½ ips) and separation of record and playback heads introduced a 0.15 sec. delay. The output of the playback head was fed through an EICO model HF 60 amplifier to a pair of Permoflux PDR 8 earphones with doughnut cushions. The amplification introduced between the microphone and earphones was such that the ratio of voltages, measured for a 400 cycle tone at these two points, was 78 db. This calibration was repeated daily.

The experimental group consisted of 11 male schizophrenic patients with a mean age of 30 years, and 17 female schizophrenic patients with a mean age of 32 years. All of the patients were tested shortly after admission to the hospital and were not yet under any drug or therapy during the week in which they were tested. The normal controls consisted of 13 male hospital personnel with a mean of the more dramatic findings is the fact that one third of a group of stutterers tested (data as yet unpublished) actually improved, in other words, decreased their stuttering under DAF. We have also found in normal children that the amount of speech disturbance under DAF increases with age (Chase, et al., 1961c).

The large differences between individuals and between groups of individuals in the amount of speech disturbance due to delayed auditory feedback, and the differences in the delay times producing maximal speech disturbance can be attributed either to personality differences (which include the degree of ability to ignore auditory sidetone and concentrate on feedback via bone-conduction and kinesthetic and proprioceptive channels) or to some specific neurophysiological differences. The authors’ preference is the latter. It seems unlikely that the stress of DAF could cause the speech of a third of the stutterers tested to improve dramatically merely because their personalities were that different from other stutterers or from normals. In conjunction with this, the study with children of different ages strongly implies physiological maturation. There are other known physiological changes in the brain during this age-span (e.g., EEG changes). The differences between children aged 4-6 years and those aged 7-9 years can probably not be explained by learning processes alone, and it is doubtful that they can be explained by personality differences. Spilka (1954) attempted to relate the changes under DAF in the vocal responses of 150 college males to various personality variables: (1) self-percept stability, (2) schizoid tendencies, (3) paranoid tendencies, and (4) rigidity. He reported that the only investigated voice variable whose change under DAF was significantly related to personality function was that of vocal intensity variation.

The present study is addressed to the question whether there are quantitative or qualitative differences between the performance of schizophrenics and normals under delayed auditory feedback. If one were to hypothesize along lines of personality differences, it might be expected that schizophrenics will be less affected by delayed auditory feedback since they are often said to be out of touch with reality, relatively uninterested in the external environment, and seem to be poorly monitoring their speech (and thoughts) from the standpoint of communication with others, using neologisms, word salads, etc. Goldfarb and Braunstein (1958) reported in their study that schizophrenic children were less affected by delayed auditory feedback than were normal children (ages 8-10½ years). However, no data are as yet available on the performance of schizophrenic adults under delayed auditory feedback.
age of 34 years, and 17 female hospital personnel with a mean age of 28 years. The average educational levels for the four subgroups were between two and four years of high school.

The tape recording of each subject's speech was replayed until the following measurements were obtained: for each passage, the reading time in seconds under each condition; and for Passage I only, the number of words spoken with no error, and the number of errors made in each of the following eight categories:

1. a – Insertion of an extraneous sound
2. s – Repetitive addition – stuttering
3. p – Prolongation of a sound
4. s – Substitution of an incorrect sound for the correct one
5. o – Slighting, as in the dropping of the final d in the word legend.
6. ◄ – Shifted juncture – when the end of one word is dropped and used as the beginning of the next word – "roun darch" for "round arch"
7. ◄ – Contraction – "he's" for "he is"
8. o – Omission of a word or part thereof.

Unless otherwise specified, nonparametric tests were used to analyze the data, the Mann-Whitney U Test was used to test significance (two-tail) of differences between groups and the correlations computed were Spearman rho's (Siegel, 1956).

Results

Time measure. The time taken by each subject to read Passages I and II aloud under the Control (normal feedback) condition, and the DAF (0.15 sec. feedback delay) condition was measured, omitting pauses of longer than three seconds (these usually represented adjustments of earphones, etc.). Also omitted was the time taken by the subject to laugh or make impromptu remarks (e.g., "Oh, I made a mistake."). Testing group differences, it was found that the male and female schizophrenics did not differ significantly under either the Control or the DAF conditions for either passage. The male and female normals did not differ under the control condition, but did differ significantly (p < 0.002) under the DAF condition. Therefore, in the analysis, the male and female schizophrenics are treated as one group and compared separately with male normals and with female normals.

In Figure 1, the medians for each group and condition have been indicated by crossbars. As suggested by McNemar (1949), instead of the quartile deviation, the 25th and 75th percentiles have been indicated by the top and bottom of each bar to show the extent and direction of skewness. The means have been marked by arrows to indicate the degree of skewness.

For Passage I (Figure 1) the combined schizophrenic group read slightly more slowly under the control condition than either the normal males (p < 0.001) or the normal females (p < 0.001). Under the DAF condition, the reading times of the schizophrenic group was not significantly different from those of the normal females but was significantly slower than the normal males (p < 0.003).

As may be seen in Table 1, the correlation between scores under control and DAF conditions was only 0.39 (p < 0.05) for the
### Table 1

**Correlations (rho) Between Education and Response Measures and Correlations Among Response Measures**

<table>
<thead>
<tr>
<th></th>
<th>Passage I</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Education vs. Time control</td>
<td>Education vs. Time DAF</td>
<td>Education vs. CW control</td>
<td>Education vs. CW DAF</td>
</tr>
<tr>
<td><strong>Normal males</strong></td>
<td>-.33</td>
<td>.32</td>
<td>.27</td>
<td>-.25</td>
</tr>
<tr>
<td><strong>Normal females</strong></td>
<td>-.11</td>
<td>.20</td>
<td>.13</td>
<td>-.07</td>
</tr>
<tr>
<td><strong>Izophrenics</strong></td>
<td>-.14</td>
<td>.01</td>
<td>.63†</td>
<td>.56†</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Passage I</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CW control vs. Time difference vs. CW DAF</td>
<td>Time control vs. Time DAF</td>
<td>Passage I</td>
<td>Passage II</td>
</tr>
<tr>
<td><strong>Normal males</strong></td>
<td>.77†</td>
<td>.36</td>
<td>.53*</td>
<td>.51*</td>
</tr>
<tr>
<td><strong>Normal females</strong></td>
<td>.19</td>
<td>-.08</td>
<td>.20</td>
<td>0</td>
</tr>
<tr>
<td><strong>Schizophrenics</strong></td>
<td>.74†</td>
<td>.22</td>
<td>.39*</td>
<td>.56†</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Passage I</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Time control vs. Time DAF</td>
<td>Passage I</td>
<td>Passage II</td>
<td></td>
</tr>
<tr>
<td><strong>Passage I</strong></td>
<td>vs.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Passage II</strong></td>
<td>vs.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Normal males</strong></td>
<td>.72†</td>
<td>.85†</td>
<td>.61*</td>
<td></td>
</tr>
<tr>
<td><strong>Normal females</strong></td>
<td>.71†</td>
<td>.87†</td>
<td>.93†</td>
<td></td>
</tr>
<tr>
<td><strong>Schizophrenics</strong></td>
<td>.76†</td>
<td>.88†</td>
<td>.82†</td>
<td></td>
</tr>
</tbody>
</table>

*Significant at .05 level of confidence.
† Significant at .01 level of confidence.

The schizophrenic group approached significance however and, as will be seen below, this difference becomes significant ($p<0.04$) for the longer Passage II.

If, in the absence of a nonparametric equivalent, analysis of covariance is used (despite the lack of both normality and homoscedasticity) to test whether the groups would differ under the DAF condition when statistically matched under the control condition, a similar pattern emerges – the schizophrenics differing significantly from the normal males, but not differing significantly from the normal females.

The results for the same subjects on the longer Passage II showed an almost identical pattern as on Passage I (see Figure 1), but the significance levels were somewhat higher. The normal males performed similarly to the normal females under the control condition, and both groups spoke faster than the schizophrenics (both $p$ values are less than 0.0005). Under the DAF condition, the scores for the schizophrenic group were not significantly different from those of the normal females, but the schizophrenic group spoke significantly more slowly than the normal males ($p<0.0005$). The normal females spoke significantly more slowly under DAF than did the normal males ($p<0.0002$).

As for the increase in speaking time due to the DAF condition (DAF minus control), the schizophrenic group was more slowed down than the normal males ($p<0.04$) but did not differ significantly from the normal females. (As with Passage I, a covariance analysis yielded identical results.) The normal females were more slowed down by delay than were the normal males ($p<0.02$).

For Passage II, the correlations between the control and the DAF conditions on the time scores were 0.56 ($p<0.01$) for the schizophrenics, 0.51 ($p<0.05$) for the normal males, and 0 for the normal females.

In summary then, for both passages the effect of reading under delayed auditory feedback is to slow down the schizophrenic group more than the normal males but not more than the normal females.

**Correct words.** Passage I was scored by two independent judges for number and type of errors, and number of correct words spoken with no error. The correlation between the correct word scores obtained by the two judges was $\rho = 0.95$ for the control condition and $\rho = 0.93$ for the DAF condition; hence the scores from the two judges were averaged. As with the time measure, it was found that the correct word scores for the male and female schizophrenics did not differ significantly under either the control or the DAF conditions, while for the normals, males and females did not differ...
under the control condition but differed significantly (p < 0.02) under the DAF condition. Therefore, as with the time measure, comparisons with the schizophrenic group were made separately for the normal males and the normal females.

The correct word score distributions have been indicated in Figure 2 in the same manner as were the time score distributions in Figures 1a and b. The schizophrenic group did not differ from the normal males under either the control or DAF conditions. The schizophrenic group was slightly but significantly different from the normal females under the control condition (p < 0.05) and considerably different under the DAF condition (p < 0.001).

With respect to the decrease in correct words due to delay (control minus DAF), the schizophrenics were more affected than the normal females (p < 0.01) but were not more affected than the normal males. The normal females were significantly more affected than the normal males (p < 0.05). As with the time measure, if analysis of covariance is used to test whether the groups would differ under the DAF condition when statistically matched under the control condition, the same pattern emerges — the schizophrenics differing significantly from the normal females but not differing significantly from the normal males.

Figure 3 shows the percentage of subjects in each group who made a particular type of error, and Figure 4 shows the average number of errors made by those subjects who made that type of error. The largest increases from the control to the DAF condition were in the percentages of subjects making the errors of prolongation (p) and shifted juncture (w). There were no remarkable differences between the schizophrenics and the normals with respect to either the percentage of subjects making any particular type of error or the average number of errors made by those subjects. The normal females made higher correct word scores under the DAF condition than either the normal males or the schizophrenics because of a somewhat smaller percentage of subjects making the errors of shifted juncture (w) and omission (o), and a smaller average number of errors per subject for the errors of omission (o), substitution (s), and repetitive addition, or stuttering (q).

In a number of studies, a correct word rate was obtained for each subject by dividing the number of correct words in the passage by the total time to read the passage. One rationale for this procedure was that under DAF some individuals would speak very slowly, waiting for the “echo” of each syllable before phonating the next, and thus obtain a high correct word score whereas others would try to maintain a normal rate of speed at the expense of the correct word score. By using a combination of the two scores, the correct word rate, it was thought possible to compare all individuals on a single measure. In this study, no evidence was found to support such a concept. In fact there was no significant correlation between the increase in time from the control to the DAF condition and the decrease in correct word scores between the two conditions (Table 1). Use of correct word rate score in this study would have completely obscured the most significant findings, because on this score the normal females did not differ significantly from the normal males under either condition, control or DAF, or from the schizophrenics under the DAF condition.
Age was found not to be correlated with either time or correct word scores under either condition. As may be seen in Table 1, there was no significant correlation between education and time score for any group, but there was a moderate correlation between education and correct word scores for the schizophrenic group only. It may also be noted in Table 1, that the correlations between the control and DAF conditions for both the time and correct word measures were much lower for the normal females than for the other two groups. There is no apparent explanation for this curious fact. The correlations between the time measures for Passages I and II were moderate to high for both the control and DAF conditions and were similar for the three groups. This would seem to indicate that Passage I is long enough for experiments of this type. However, it will be remembered that the group differences on the time measure were somewhat more significant for the longer Passage II.

Conclusions

The schizophrenic males and the schizophrenic females did not differ under either the control or the DAF conditions for both the time scores and the correct word scores; whereas the normal males and the normal females performed similarly under the control condition for both the time and the correct word scores, but differed considerably under the DAF condition, and in opposite directions for the time and correct word scores. Using Italian speakers, Black (1955) found that there was a sex difference among normals with females being more retarded by delay than males, but the present writers are not aware of any comparable study of sex differences for English or General American speakers.

The schizophrenics and the normal females were not significantly different with respect to the time scores under DAF, nor with respect to the time difference scores between the control and DAF conditions, whereas the normal males were less affected by delayed auditory feedback than either of the other groups with respect to both time measures. With correct word scores, the pattern was reversed, the normal males performing similarly to the schizophrenics for both correct word and correct word difference scores, and the normal females doing significantly better (i.e., less affected by DAF) than either of the other groups. The writers can offer no satisfactory explanation for this curious reversal, but feel some confidence in its existence, in view of the high significance levels obtained for the group differences, as well as the repeatability of the pattern of time scores of the groups on Passage II.

With respect to the original rationale for this experiment, it may
be definitely concluded that schizophrenics were not less affected by delayed auditory feedback than were normals, since they were more affected than the normal males (but not more than the normal females) on the time measure, and more affected than the normal females (but not more than the normal males) on the correct word measure.

Summary

The speech performance of schizophrenic patients was compared with that of normal individuals under the conditions of undelayed and of delayed (0.15 sec. delay) auditory feedback (DAF). Performance was compared on the basis of oral reading time, number of words enunciated correctly, and number and type of errors made. It was concluded that:

1. The speech of normal females is more slowed by DAF than is the speech of normal males.
2. The speech of normal females is less affected by DAF than is that of normal males with respect to the number of words enunciated correctly.
3. DAF produced equal slowing of speech for both male and female schizophrenics.
4. DAF produced an equal effect with respect to the number of words enunciated correctly for both male and female schizophrenics.
5. The speech of schizophrenics is more slowed by DAF than is the speech of normal males, but not more slowed than the speech of normal females.
6. With respect to the number of words enunciated correctly, the speech of schizophrenics is more affected by DAF than is the speech of normal females, but not more affected than the speech of normal males.
7. There were no remarkable differences in the number and type of errors between schizophrenics and normals.

Acknowledgments

The authors are indebted to Dr. Richard Allen Chase for his assistance with experimental design and procedure; to Mrs. Andrea Rosen and Miss Marion Fishman for assistance with analysis of the tape records; to Miss Joyce Kerr for assistance with the statistical analysis; to Dr. Nathan Beckenstein, Director of the Brooklyn State Hospital, for making available the patient population and testing facilities; and to Dr. Joseph Zubin for his helpful suggestions and encouragement of this work.