LETTERS TO THE EDITORS

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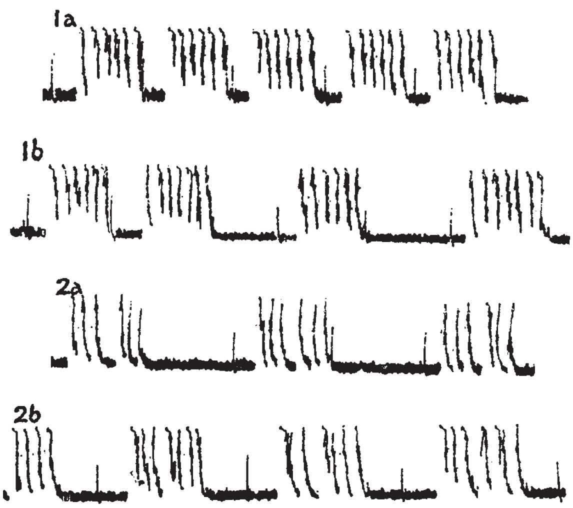
Effect of Delayed Acoustic Feed-back on some Non-vocal Activities

It is well known that difficulties in speaking will result if the speaker is made to listen to the sound of his own voice delayed by about 0·1–0·3 sec. This delayed feed-back will produce stuttering, reduced rate of speaking, distortion of sound quality and other impairments of speech[1].

It was thought interesting to find out how far delayed acoustic feed-back would affect non-vocal activities which one might expect to be controlled more by other means, for example, by proprioception or the sense of touch. Exploratory experiments showed that whistling and the playing of musical instruments were, in fact, strongly influenced by delayed acoustic feed-back, and even such comparatively simple activities as rhythmical hand clapping were disorganized. Results of some experiments of the last type are given below.

In the experiment, any sound produced by the subject was recorded and played back through headphones either immediately or with a delay of about 0·25 sec. Whereas acoustic feed-back was thus controlled, all other sensations such as touch or proprioception connected with the clapping of hands reached the subject without artificial delay. There was also an electronic metronome that produced short timing clicks in his ear at 2-sec. intervals ; this was never delayed. The sound of the handclaps and the metronomic beats were recorded on a second tape recorder in the normal way for later analysis. A pen recorder was used for obtaining from the second record traces of the type shown in Fig. 1. The claps appear as clearly distinguishable deflexions of the pen, and the metronome clicks are indicated by short sharp spikes.

The subject's first task consisted in clapping his hands as regularly as possible six times following each metronome click. Fig. 1*a* shows that this was accomplished quite easily when there was no acoustic delay ; when a 0·25 sec. delay was introduced (Fig. 1*b*), hands were often clapped seven times instead of six times, and at other times clapping ceased altogether after alternate clicks.



The second task consisted in clapping two groups of three beats after each metronome click with a strong accent on the first clap in each group. Playing back without delay again did not disrupt the performance (Fig. 2*a*) ; but delay of 0·25 sec. almost invariably resulted in four claps being produced in the second group instead of three (Fig. 2*b*). It should be mentioned that the subjects were sometimes aware of their mistakes and tried more or less successfully to overcome them, usually by concentrating on the task and slowing down the performance. In other cases, however, people were unaware of their mistakes.

These short preliminary experiments show that acoustic feed-back plays an important part in the performance of tasks which one would have thought to be controlled more by reafference from other senses. It seems that every hearing person is subject to these effects to some degree ; but the response varies a great deal between people, and the study of this variation promises some insight into individual development and possibly into the genetics of certain faculties concerned with rhythm and counting.

H. Kalmus

Galton Laboratory,

P. Denes
D. B. Fry

Department of Phonetics,
University College,
London, W.C.1.
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[1] Lee, B. S., *J. Acous. Soc. Amer.*, **22**, 825 (1950). Black, J. W., *J. Speech and Hearing Disorders*, **16**, 56 (1951).

Improved Resolution with the X-Ray Projection Microscope

A resolution of 0·1μ (1000 A.) has now been reached with the shadow type of X-ray microscope by using a thin gold-leaf X-ray target. The instrument described previously by Cosslett and Nixon[1-4] was limited to a resolution of 0·5μ due to astigmatism in the electron lens and to electron scattering in the metal target. An attempt was made to reduce the astigmatism by stopping down the aperture of the objective lens used for focusing the electrons. No improvement in resolution was found even for a semi-angular aperture of 2×10^{-2} rad. giving an astigmatic disk of confusion of 0·2μ for the worst possible machining errors of the pole pieces. This indicated that electron scattering in the metal foil target was the true limit on resolution.

An electron-range of 0·2μ in gold at 10 kV. is found from the Thomson–Whiddington law[5], and the scattering angles can be very large at this low voltage. In this way the X-rays used for shadow microscopy could have been produced anywhere in a hemisphere of radius 0·2μ, in good agreement with the previous resolution. Recently, Ehrenberg and Franks[6] have shown that the electron-range is even greater than this in transparent phosphors at this kilovoltage. It might be thought that the effect of electron-scattering in the target could be reduced considerably by evaporating a layer of heavy metal, such as gold or tungsten, on to a thicker beryllium foil to provide