using some special cues necessary for the ordering of stimulus pairs. For example, remembering which member of the pair was present at either onset or termination of stimulation could allow correct answers without direct recollection of sequence. Broadbent and Ladefoged (*4*), in a similar evaluation, suggested that the "quality" of pairs rather than sequence itself might have been responsible for correct ordering.

Our series of experiments involved 150 undergraduate students divided into five groups of 30 subjects. Each subject made only one judgment. All sounds were delivered through matched headphones at an intensity of 80 db (0.0002 dyne/cm^2). The first group verified and extended our preliminary observations. They heard four sounds consisting of a high tone (1000 hz), a hiss (2000-hz octave band of noise), a low tone (796 hz), and a buzz (40-hz square wave), each sound lasting 200 msec and followed immediately by the next in the order listed. The last named (buzz) was followed by the first (high tone) without pause, so that the sequence continued without interruption. These subjects were told the names of the sounds in advance, and asked to state their order of occurrence, starting with any sound they chose. They were allowed to listen as long as they wished (most responded within 10 to 30 seconds). At the time of response, most subjects perceived each of the successive sounds, but were uncertain of their order and felt that their responses were guesses. Only five of the 30 reported the order correctly (the most probable chance score, since there is one chance in six of guessing correctly).

To insure that the observed inability to perceive temporal order reflected a basic perceptual limitation rather than special characteristics of the experimental procedure, the additional 120 students were tested (four groups of 30 subjects).

To test the possibility that confusion concerning the appropriate names prevented correct responses, one group heard each sound separately, along with its name, before listening to the experimental tape used in the previous experiment. Nevertheless, correct responses remained at the chance level.

Although the high and low tones were readily discriminated, they were qualitatively similar, and this resemblance of the two sounds might have contributed to the confusion. Therefore, another group was tested with the vowel sound "ee" replacing the low-pitch tone. Again, responses were not significantly different from chance.

It has been assumed thus far that sequence perception of speech sounds could be accomplished readily under the conditions used. To verify this assumption, a group of subjects listened to a repeated sequence of four spoken digits (one, three, eight, two), each statement of the four items taking the same 800 msec as the other series. Despite the fact that individual phonemic orders must be established within digits, the correct identification of all digits and their sequence was made very quickly by all after only one or two repetitions.

It is known that repetition of verbal signals over and over can disrupt perception under certain circumstances (*5*). Although repeated sequences were identified under our conditions for words (digits), repetition itself may have a hitherto unreported effect on perception of nonspeech sounds, and hence sequence might be identified properly if repetition were avoided. Therefore, a group was told that they would hear a high tone, a low tone, a hiss, and a buzz presented in a certain order just once. After hearing each stimulus separately along with its name, they heard the 200-msec sounds in a single sequence. Their task was facilitated by the possibility that the first and last sounds may be identified by their unique position at onset and termination. At the same time, the difficulty was increased by the single opportunity to hear the sequence, and the fact that there was now a correct response for the first sound named (changing the probability of a correct guess from one in six to one in 24). The sequence was reported correctly by five subjects, which, although significantly better than chance ($P < .01$ by binomial expansion), nevertheless indicated that the task was not possible for the great majority of listeners.

Current work on sequences shows that the duration of each item must be increased from 200 to about 700 msec before half the inexperienced subjects can verbally identify the correct order. For experienced listeners such as the experimenters, identification of order remains extremely difficult or impossible at 200 msec, but can be accomplished at 300 msec.

Our experiments have indicated that perception of temporal order is unexpectedly difficult for some sounds. A determination of the critical attributes of sequences permitting accurate pattern recognition should be of interest to theories of auditory perception.

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Sound Velocity in Carbon Suboxide

Carbon suboxide is one of a number of small polyatomic molecules which have one very low vibration frequency, in particular the bending of the central CCC group at about 63 cm^{-1}. Studies of vibration-translation energy transfer suggest that in such a case two relaxation times may be expected; the shorter one is associated with the mode where $\nu_7 = 63$ cm^{-1}, and the longer relaxation time is associated with all other vibrational degrees of freedom.

Ultrasonic dispersion studies (Fig. 1) with a novel optical method have revealed the longer of the two expected relaxation times as $\tau = 48$ nanoseconds at 1 atmosphere. The values of the heat capacity predicted by statistical thermodynamics are (i) $C_v/R = 7.078$ and (ii) $C_v/R = 4.485$ for (i) static

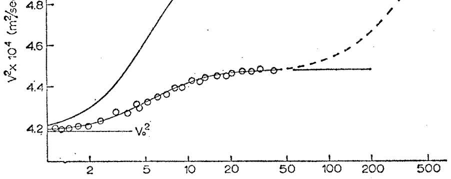

Fig. 1. Ideal sound velocity in O = C = C = C = O.

conditions and (ii) after the loss of excitation of all modes except ν_7.

The sound velocity is related to C_v/R by the equation

$$V^2 = \frac{RT}{M} (1 + \frac{R}{C_v}).$$

The experimental value of C_v/R at low frequencies, V_o^2, and for intermediate frequencies, around 20 to 50 Mhz/atm, agree with the statistical thermodynamic predictions for cases (i) and (ii) to rather better than 1 percent.

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Predation and the Origin of Tetrapods

Romer (*1*) does not take predator pressure into account as a selective force in the origin of tetrapods on the basis that ancestral tetrapods were among the largest and most powerful freshwater animals of their time. But this sidesteps the fact that young animals are usually much more vulnerable to predation than adults. Certainly, small ancestral tetrapods must have been attacked and eaten by Devonian fishes for example, the large, fast, rhizodont crossopterygians), and it seems that this could have been a strong selective force in the evolution of the tetrapod limb. Romer points out that the contemporaneous crossopterygian fishes probably were better swimmers than ancestral tetrapods. Thus, it seems logical that small ancestral tetrapods resting or searching for food in shallow water would elude their predators by scrambling out on land rather than by staying in the water; especially since, in contrast to present times, there were few if any predators on land during the Devonian. Indeed, Romer believes that (probably somewhat later on) predator pressure on aquatic amphibian eggs was strong enough to be one of the evolutionary forces behind the origin of the amniote egg. In summary, it seems possible that the evolving paired limbs of ancestral tetrapods might have given them a twofold advantage over their contemporaries: (i) a means to reach a new aquatic situation in time of drought as postulated (*1*); and (ii) a means by which the young could escape aquatic predators.

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X-ray Fluorescence Spectrography: Use in Field Archeology

Bowman *et al.* (*1*) suggested that high-resolution semiconductor detectors in x-ray emission spectroscopy had possibilities for use in the field.

After extensive laboratory experience, a portable system was prepared to test its feasibility for site analysis on the UCLA-Israel Archaeological Expedition (1968) (*2*). The x-ray detector, cryostat, analyzer, recorder, and the auxiliary equipment (transformers, charger, batteries) were portable, and they were all hand-carried on public carriers with no special precautions. They were easily assembled on the site being investigated, whether or not electricity was available.

The method was that described by Giauque (*3*). A radioactive source, such as ^{241}Am or ^{125}I, is used to excite K x-rays of a selected target material, and these, in turn, excite characteristic x-rays from the sample. More than 300 separate analyses were obtained, often testing for six elements in a single 4-minute run.

The operating environments were of all sorts—from hot, dry deserts to the seacoast with its attendant high temperatures and salty humidity. The only difficulty encountered during the entire expedition was the failure of a "slow blow" fuse which was burned out by a line surge while it was operating off the local power source.

The results are only semiquantitative because of differences in texture, shape, and composition of the objects encountered. The inhomogeneity of the materials tested and the limited range of detection (only elements in the periodic table above calcium are detectable) precludes the possibility of full analysis without further preparation. This seems unnecessary for field work since the information obtained is adequate for much archeological interpretation and can be used to segregate objects worthy of more careful laboratory study.

The speed, precision, economy, and nondestructive qualities of this equipment were amply demonstrated. The particular ability of the detector to handle objects of almost any geometry without special preparation was especially significant. The objects need not be touched by either the detector or the operator.

This method of field survey is applicable to metals, glasses, glazed ceramics, and mineral specimens, but cannot give useful information on unglazed ceramics, nonmineralized rocks, and other building materials. On this particular expedition, the single largest group of artifacts analyzed consisted of glazed ceramics. After a large number had been analyzed, it became possible to develop visual criteria which were fairly reliable for identifying colorants, opacifiers, and the type of glass matrix employed.

It is now entirely feasible to analyze metals, glasses (ceramic glazes), and minerals rapidly on the excavation site. Under field conditions, accuracies of 10 to 20 percent are obtainable when elements are present in the range of 0.1 to 30 percent. The absolute errors on glazes have added uncertainty from the variability of glaze thicknesses. The sensitivity of analysis varies with the atomic number. With somewhat longer analyzing time, results can be obtained down to 100 parts (or fewer) per million for elements in the upper half of the periodic system.

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6 March 1969