The post-auricular myogenic response:

A new instrument which simplifies its detection by machine scoring

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Introduction

There is a need for a reliable and objective means of assessing hearing in infancy and early childhood. Only if deafness is diagnosed early enough can it be corrected before the critical time for language acquisition has passed. We have developed a portable and inexpensive instrument which can detect an electrical evoked response to sound and which is so simple to operate that it can be used for routine screening. This paper describes the apparatus and our early results.

The apparatus detects the post-auricular myogenic response (PAM). This evoked response was chosen because its large amplitude and long latent period (15 msec.) make it the easiest to detect. Other types of evoked response audiometry (E.R.A.) are not suitable as screening tests. Cortical E.R.A. and electrocochleography both require much more complex apparatus and more skilled testers. Electrocochleography can only be done on children under a general anaesthetic.

The PAM response was first described by Kiang *et al.* in 1963. The response is related to muscle tone in such a way that motor activity would appear to pose no serious problems but may even enhance the response. Jacobson *et al.* (1964) described some of the basic response characteristics, and various studies have been made to assess the usefulness of the PAM response. Yoshie and Okuduria (1969) regarded the use of the PAM response as being very promising for the estimation of audiometric threshold. However, Picton *et al.* (1974) reported that the PAM response was variable in occurrence from subject to subject and even within subjects. Douek *et al.* (1973) asserted that recordings should be taken from both sides simultaneously since the PAM response has a bilateral representation. For this reason they termed it the Crossed Acoustic Response (CAR). They contended that the CAR test was reliable and had particular use as a screening test in busy children's clinics. Thornton (1975) employed the PAM response (recording from both sides) from twenty subjects to predict their hearing thresholds with an accuracy comparable with that achieved by conventional audiometry. For some years the technology has been available to miniaturize and simplify electrical evoked response testing

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equipment. We have used these techniques and have also designed a simple form of machine scoring.

Method

The test procedure is extremely simple. Electrodes are applied to the pre- and post-auricular skin on both sides without any skin preparation and an earth electrode is applied to another convenient site such as the back of the neck or the arm. All the tester need do thereafter is press the START button. The machine automatically generates the signal, averages the response and tests it for significance. If there is a significant response a light comes on. The tester then presses a second button to check that the latent period of the response is correct. The latent period is displayed digitally.

The child is usually sitting on the mother's knee and the whole test is usually finished in about 5 minutes. Another light on the apparatus will flash if there is poor electrode contact.

There now follows a more detailed description of the apparatus, but technical knowledge is not needed to operate it.

The apparatus

A prototype instrument was built weighing 33 lb. It could be carried by one person together with the loudspeaker and electrodes in a separate case, and it fitted easily into the boot of a car. Our apparatus was somewhat larger than necessary in order to allow room for modifications, and it is hoped to make a much smaller model for production.

Silver/silver chloride domed disc electrodes were attached to the subject in the positions shown (Fig. 1). The pre-amplifiers were contained in a small metal box which could be worn round the neck.

The block diagram (Fig. 2) shows the system used. The PAM is a bilateral response and its amplitude is related to muscle tone: signals from both sides are therefore measured simultaneously (Douek, 1973). The signals from each pre-amplifier were added and the resulting composite signal was passed through a low pass Bessel filter with a cut-off frequency of 1·2 kHz and an adjustable gain stage before being digitized by a Tracking Analogue to Digital Converter.

A circuit was included which could detect unsatisfactory electrode contact. There were three lights on the front panel which would signal either no contact on the right side, no contact on the left side, or excessive mains interference at 50 Hz. In a small number of cases a good electrode contact could not be obtained without some skin preparation. When this situation arose a blunted needle was inserted through the access hole of the electrode and the skin was lightly abraded. If an electrode became detached from the subject, due for example to excessive movement, the test was automatically suspended until the electrode could be replaced. This proved to be very useful when testing active infants.

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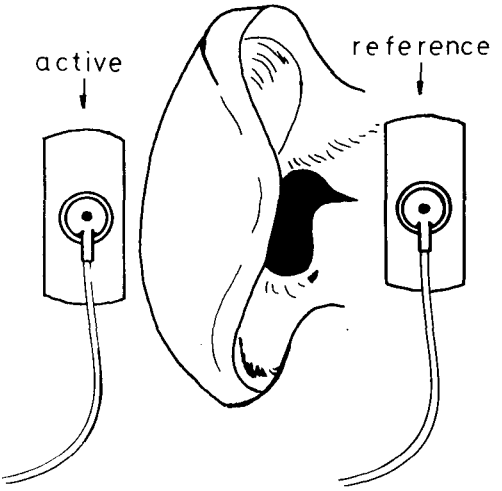


FIG. 1
Electrode positions (earth electrode not shown).

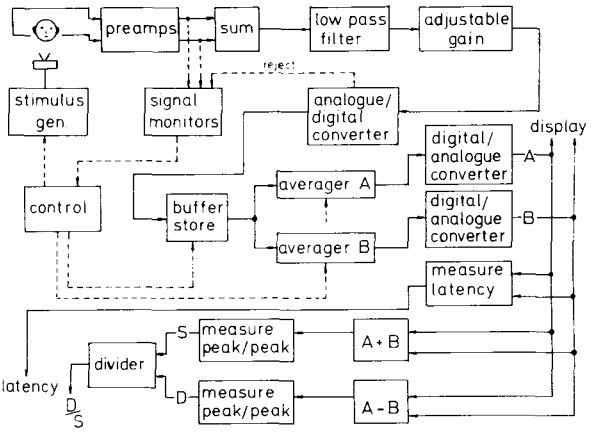


FIG. 2
Block diagram of testing system.

Clicks were generated in the form of a 100-microsecond pulse which was fed into a loudspeaker (Peerless dome tweeter KD 10 DT). The amplitude spectrum of the click was flat (± 2 dB) from 2 kHz to 8 kHz and the clicks were presented at a rate of 10 per second.

For a period of 32 msec, called an epoch, following each click, any myogenic signal was digitized and written into a buffer store (Fig. 2). Each click, therefore, gave rise to one epoch of digitized signal. If at any time the amplitude of the stored signal exceeded the input range of the instrument, this epoch of signal was automatically rejected from the averaging process.

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Each such rejection was signalled by a light on the front panel of the instrument. During each test the rejection light was used to determine the correct gain setting for the e.m.g. amplifier.

The feature which makes the apparatus particularly easy to use is the *machine scoring*. As each epoch of signal was being introduced into the buffer store, the previous epoch was read out of the store. Consecutive epochs were sent alternately to one of two digital averagers. Consider the situation after, for example, 500 clicks have been presented: averager A and averager B would each contain the summation of 250 epochs, assuming there had been no rejected epochs. If each click had evoked a response in every epoch one would expect that the 'picture' derived from each averager would be similar. If no response had been evoked one would expect the pictures to be dissimilar, since the background myogenic activity appears random with respect to the click stimuli.

The contents of averagers A and B were converted to analogue form. The instantaneous analogue summation (A+B) and difference (A−B) were then derived (Fig. 3) from that part of the epoch extending from t = 8 msec to t = 32 msec. This was done to ensure that any artefact arising from the electrical aspect of the stimulus did not interfere with the machine scoring process. The peak value of the summation, S, and peak value of the difference, D, were measured, and the value of $\frac{D}{S}$ was derived.

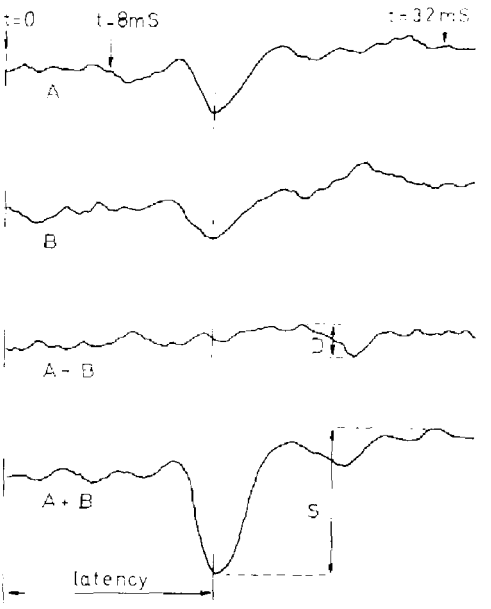


FIG. 3
Derivation of the machine score.

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It was found, by doing a short experiment, that when the instrument operated on purely random signals (EMG from forearm) the ratio $\frac{D}{S}$ was never less than 0·65. We set a threshold value of 0·5 so that when $\frac{D}{S}$ was 0·5 or less, a light labelled Amplitude on the instrument front panel came on. The ratio $\frac{D}{S}$ was displayed continuously on a moving coil panel meter.

The instrument also measured the latency of the largest negative response peak in the averaged record. With reference to Figure 3, latencies were measured from t=0 to the time when the largest negative peak in trace A coincided with the largest negative peak in trace B. The latency was displayed digitally on the front panel of the instrument. Expected latencies for this response, taking into account the delays introduced by the Bessel filter and the time taken for the sound impulse to travel one metre from the loudspeaker to the subject, were between 14 and 19 msec inclusive.

A positive response was scored only if the Amplitude light came on together with a latency reading in the expected range (Fig. 4). If, after 2,000 epochs of averaging, a positive response was not scored, the test was ended and the result was recorded as no response.

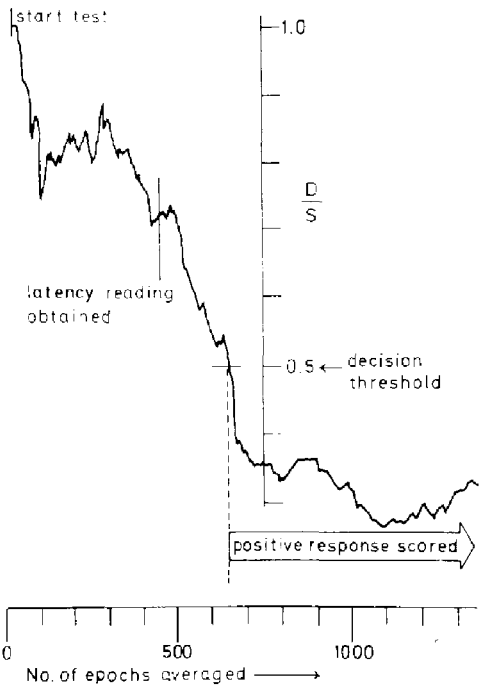


FIG. 4

Chart recorder trace showing the development of the machine score during the test.

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During our evaluation of the instrument we checked the machine scoring by viewing the average responses on an oscilloscope. Using the oscilloscope a subjective judgement was made as to the presence or absence of a PAM response. This judgement was compared with that made by the instrument, in order to ensure that the instrument decision threshold was at the right level. Above all, we wanted to be sure that the instrument could not score a positive result when the subjective judgement was negative.

Subjects

The first 102 subjects were chosen because pure-tone audiograms could be readily obtained. By testing these subjects it was hoped to evaluate the reliability of the response. Afterwards, 46 babies in the age range 6–9 months were tested. Thus 148 subjects were tested, who fell into the following four groups:

Group 1 61 adults aged 20 to 60 years selected at random. Pure-tone audiometry was performed after PAM testing.

Group 2 24 children aged 4 to 14 years (mean 6·9) with normal pure-tone audiograms.

Group 3 17 children aged 5 to 11 years (mean 9·1) with severe sensorineural hearing loss of greater than 60 dB. The mean hearing loss for this group was 100 dB. All used hearing aids and were receiving auditory training in a school for the deaf.

Group 4 46 infants aged 6–9 months. Nine of these were tested at the Local Authority Health Clinic and 37 were from the Low Birthweight Clinic at University College Hospital. The ages of these children were corrected for prematurity.

Test procedure

Group 1—Adults

Each subject was presented with 60 dB H.L. clicks at a rate of 10 clicks per second. In order to promote muscle tone, each subject was instructed to hold an object under his chin. If no response was detected, the subject was instructed to roll his head slowly around while the run was repeated. In some cases this manoeuvre caused the response to appear. If no response was detected at 60 dB with head rolling, the stimulus was increased to 80 dB H.L.

We noted the number of epochs required for the instrument to score a positive response. A second, control run was then performed over the same number of epochs, but without the sound stimulus present. None of these control runs scored a positive response.

Group 2—Children with normal hearing

The procedure was the same as for the adult group except that the control runs were omitted.

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Group 3—Children with severe sensorineural loss

Each child was tested twice at 80 dB H.L. The first test was performed without hearing aids. The second test was performed with hearing aids.

Group 4—Infants aged 6–9 months

Each baby sat on his parent's lap during the test. The parent sat in a position such that the facia of the PAM tester was to his/her side. The baby sat at a right angle to his parent's position, facing the PAM tester, so that he could watch the lights on the instrument facia. The pre-amplifier box was worn by the parent in such a way that it hung behind the baby, out of his field of view. The electrodes were attached and the test was begun. If interest in the instrument lights waned, we attempted to keep the baby alert and happy by offering toys, playing, etc.

Nineteen babies in this group were presented with 50 dB H.L. clicks; however, 9 of these did not show a PAM response until the stimulus intensity was increased to 60 dB H.L. The remaining 27 babies were presented with 60 dB H.L. If no response was detected at this intensity the test was repeated at 80 dB H.L.

Results

Accuracy of the machine score

When the instrument scored positive response, the subjective judgements, made from the oscilloscope traces, always agreed. As would be expected, the instrument consistently took longer to come to a decision than the person looking at the oscilloscope pictures.

When the score was no response, the subjective judgements ranged from 'no' in the vast majority of cases, to 'uncertain'. For one of the control runs (adult group) the subjective judgement might have been positive response had it not been known that no sound stimulus had been presented. The machine score was no response, since the value of $\frac{D}{S}$ was 0·7 even though a latency reading of 14 msec was obtained. A hard copy of this trace was made and shown to a person familiar with the shape of the PAM response; his judgement was positive response. The machine scoring was therefore more accurate on this occasion than subjective judgement.

Group 1—61 Adults

Four subjects in this group did not score a positive response at 60 dB H.L. until the head rolling manoeuvre was performed. They had normal pure-tone audiograms. Four others scored no response at 60 dB H.L. with head rolling. Two of these subjects produced normal pure-tone audiograms but showed no PAM response even to 80 dB H.L. with head rolling. Of the remaining two, one did score a positive response at 80 dB H.L.; his audiogram showed a bilateral sensorineural loss (better ear 35 dB down at

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2 kHz). The other subject had a smaller bilateral sensorineural loss but showed no response to 80 dB H.L.

Of the remaining 57 adults who did score a positive response at 60 dB H.L., three had acoustic trauma (better ears 30, 40, 30 dB down at 4 kHz), and three had marked sensorineural loss (better ears 20, 20, 30 dB down at 4 kHz but with a steep drop to 8 kHz). One subject had a conductive loss (better ear 20 dB down at 2 kHz). Thus only 48 out of our 61 randomly selected adults had normal pure-tone audiograms.

Group 2—24 Children with normal hearing

Five of these subjects scored no response at 60 dB H.L. until the head rolling manoeuvre was performed. Four subjects (aged 4, 5, 7 and 14) showed no response at 60 dB H.L. with head rolling, but scored positive response at 80 dB H.L. One subject showed no response at 80 dB H.L.

One five-year-old boy was tested twice on the same day. For the first test, in the morning, he showed a brisk response at 60 dB. On the second occasion, late afternoon, when he showed obvious signs of tiredness and boredom, he did not respond to 60 dB but he did respond to 80 dB.

Group 3—17 Children with severe sensorineural loss

None of the 17 scored a positive response when tested unaided with an 80 dB H.L. stimulus. However, when hearing aids were worn, for the second part of the test, nine subjects scored a positive response.

Group 4—46 Infants aged 6–9 months

All nine of the babies tested at the Family Health Clinic responded briskly to a 60 dB H.L. stimulus. Of the 38 low birthweight babies tested, 5 scored no response at 60 dB H.L. but positive response at 80 dB H.L., and a further 3 scored no response at 80 dB H.L. These 8 babies were recalled for further tests. To date, 5 of the 8 have been re-tested with the same result. Conventional distraction tests were also performed on these 5 (for results see Table I).

TABLE I

SUMMARY OF RESULTS, INCLUDING RESULTS OF DISTRACTION TESTS PERFORMED ON BABIES

Machine score	Subjects with normal pure tone audiograms 48 adults	24 children	46 babies aged 6 to 9 months	Distraction test
Response at 60	46	19	38	
Response at 80 but not at 60	0	4	5	2 normal responses 1 suspected loss 2 to follow
No response at 80	2	1	3	1 see text (E.B.) 1 negative 1 to follow

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One baby (E.B.) who showed no response to 80 dB H.L. on two occasions (one month apart) responded normally to a distraction test which was performed one month after the second PAM test. Immediately following the distraction test the baby was given a third PAM test at 80 dB H.L., to which he responded. Unforunately we could not go on to test at 60 dB H.L. since the baby began to cry and co-operation ceased.

Of the 85 adults and children tested (Groups 1 and 2) 72 produced normal pure-tone audiograms. Eight of these 72 subjects showed no response to 60 dB H.L. Results obtained from the remaining 64 subjects showed considerable inter-subject variability, as regards amplitude and latency, as did the results from the 36 babies who responded to 60 dB H.L. However, 10 adult subjects were re-tested at a later date and were found to be consistent. Table I shows the results from Groups 1, 2 and 4.

The two non-responding adult subjects with normal pure-tone audiograms were submitted to further investigation. One subject was tested on four occasions at approximately monthly intervals. The other subject was tested twice with a two-week interval. One speculation as to the reason for these negative results was that the PAM responses of the two ears might have been in anti-phase, so that when the two sides were added together they would have cancelled out. We therefore took signals from individual ears only, but again with negative results. We also moved the electrodes to different sites around the ear, but on no occasion was a response seen.

Many of the adult subjects commented that the sound stimulus was very boring and that they tended not to listen to it. It was thought that this boredom might have been responsible for some of our negative results at 60 dB, especially in our groups of children and babies. We therefore decided to try some more interesting click patterns, hoping that this would enhance the PAM response. We are continuing this investigation with the baby group, but we have insufficient results at this stage to come to a firm conclusion as to which pattern is best.

Discussion

There were no false positive results from the machine, so it was possible to say that if the light came on at the end of the test, then the subject could certainly hear. The apparatus should prove useful to all those concerned with assessing the hearing of babies and still in doubt after conventional testing. The instrument we have produced is a research prototype which needs to be made even smaller and ergonomically improved. Present technology makes it possible to build the entire tester into briefcase size, and this we intend to do in the near future. The test is so simple that it should be possible to carry it out in any Child Welfare clinic.

Conventional distraction tests using rattles and a spoon in a cup, etc., can provide more information than the test which we have employed for this study. However, they rely for their accuracy on the training and dedication of the tester, and it is unreasonable to expect these qualities to

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be sustained for each test when each person must test hundreds of babies every year and is looking at a baby population whose expected deafness rate is of the order of one per thousand (Barr *et al.*, 1976). We would hope that errors of judgement on the part of the tester would be considerably reduced using the instrument described. However, since conventional distraction tests are useful for detecting communication disorders other than hearing loss, we feel that the PAM screening test should not be considered in isolation, but as a useful adjunct to existing tests where there is still doubt about the hearing.

The apparatus will be of value when fitting hearing aids to babies, since a response could be shown to appear in severely deaf children when they were wearing their aids.

We found that the response was consistent in our adult group from one session to another, and we found a small number of normally hearing adults who consistently did not show a response. In our groups of children and babies we obtained similar results to those of Picton *et al.* (1974) in that some of our subjects were not consistent from one session to another. We did not find the test as reliable as did Douek *et al.* (1973).

Referring to Table I, and bearing in mind our small sample sizes, there appears to be a markedly higher failure at 60 dB H.L. in the children and baby group than in the adult group. These figures lead us to speculate that the relatively high 60 dB H.L. failure rate in the children and baby group may be connected with the boredom factor mentioned earlier. The lower failure rate at 80 dB H.L. may have arisen because these stimuli were more attention-catching, in addition, of course, to providing greater sound energy input to the cochlea. Each person in the adult group was engaged in conversation and showed interest in the test as it was being explained to them, and as a result they may have paid more attention to the click stimuli than did the babies and children.

It has been established that babies respond more readily to a distraction test which uses interesting and familiar sound stimuli than to the unfamiliar and unnatural pure tones (Robson, 1970; Markides, 1977). We feel that these findings may have some relevance to this study, and that it may be possible to improve the PAM screening test if we can make the sound stimuli more interesting and attention-catching. We are pursuing this line of investigation at present.

Abstract

A portable apparatus is described which can be used for routine audiometric screening in a children's clinic. The apparatus measures the post-auricular myogenic response to click stimuli and the design of the machine makes for great simplicity of operation. A simple form of machine scoring is employed so that a completely objective result is obtained. Evaluating the equipment on 102 subjects produced no false positive results, but a small percentage of normally hearing adults and children failed to produce

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a response. The equipment was successfully evaluated in a routine audiometric screening situation on 46 babies aged 6 to 9 months.

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