An objective test of hearing is one in which the responses are not under the voluntary control of the subject, or dependent on his subjective awareness of the stimulus. The hearing tests that are usually considered to be objective are: psychogalvanometry, acoustic impedance measurements of the middle ear and evoked response audiometry.

![Graph](image)

**FIGURE 1**
(Bickford et al., 1964)
Evoked responses recorded from the index when the stridural muscles were contracted and relaxed.

Psychogalvanometry is not really objective as it requires conditioning and this is a subjective process. Acoustic impedance measurements can be considered objective, but they...
do not really indicate whether hearing is present, as a low order reflex arc is involved. The only test of hearing that offers hope of being truly objective is evoked response audiometry or E.R.A., but even evoked response audiometry may turn out to be a reflex, and not a truly objective measurement of hearing. In evoked response audiometry it is considered that a brain wave is recorded from the auditory cortex, and even if this is correct there is still little neurophysiological evidence that we hear sounds at the cortical level.

As mentioned, evoked response audiometry may record reflex activity, and not true brain waves. In fact work by Bickford et al (1961) suggests that the waves are really muscle end-plate potentials, produced by the reflex contraction of muscles in response to sound. These conclusions were reached when they showed that the inion response was enhanced by increasing muscle tension, and abolished by reducing muscle tension. Their results can be seen in Figure 1. The top trace shows the large evoked response recorded from the inion when the occipital muscles were contracted, and the bottom trace the almost absent response when the occipital muscles were relaxed.

These research workers also tried to record an evoked response from a patient who had received an injection of curare to paralyse his muscles. Their results can be seen in Figure 2. The evoked responses recorded before the administration of curare are shown on the top, and after curare on the bottom. The absence of responses after the administration of curare also suggests that they are of reflex muscular origin.

To help clarify this question, a separate study was performed by Prichard et al (1965) to see if auditory evoked responses could be recorded from cats, and whether they originated in the brain or muscles. Their results showed that during the alert state, achieved by placing a white mouse in a glass cage opposite the cat, auditory evoked responses could be recorded from scalp electrodes. However, during sleep and deep anaesthesia these responses were minimal. They also found, however, that during sleep and anaesthesia an electrode in the brain continued to record a large evoked response. Their results can be seen in Figure 3.

In this figure the left three columns show the responses from scalp electrodes, and the right column from a brain electrode. The top traces show the responses with the animal asleep, the middle ones with the animal alert.
and the bottom ones during anesthesia. It should be noted that the brain electrode is the only one which records a response during sleep and anesthesia. These results also suggest that the scalp electrode recordings are not from true brain waves.

Both the studies I described above raise the question whether electrical responses can really be recorded outside the skull, or whether they are in fact muscle action potentials. To help decide whether evoked responses from the brain can be recorded from an extracranial site, I have recorded from the basi-occiput in cats and man (Clark and Dunlop, 1970). This area was chosen because the bone overlies an area of the brain where the auditory centres are close to the surface of the brain, and there is the greatest chance of recording an electrical potential. In the cat the area can be cleared of muscles, and in man one can record from an area of the basi-occiput which is free of muscle attachments. In the cat the approach to the basi-occiput was achieved by cutting across the larynx and pharynx. This can be seen in Figure 4. (Clark and Dunlop, 1969.)

The recordings obtained from electrodes placed on the surface of the occipital bone, when clicks were delivered to the ears, can be seen in Figure 5. (Clark and Dunlop, 1970.) The top trace shows the voltage recorded from the surface of the occipital bone. A hole was then drilled through the bone, and the electrode placed on the surface of the

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**Figure 3**

(Color photograph: A graph showing auditory-evoked responses from scalp and brain electrodes with the cat alert, asleep, and under anesthesia.)

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**Figure 4**

(Graph showing the approach to the basi-occiput in the cat, achieved by cutting across the larynx and pharynx.)

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**Figure 5**

(Graph showing the voltage recorded from the surface of the occipital bone, when clicks were delivered to the ears.)
dura. The recording obtained is shown in the second trace, and as can be seen, it occurs at the same time after the click, and has the same shape. The electrode was then advanced into the brain, and the responses retained the same waveform for some distance, as you can see in the third trace.

**FIGURE 4**

(Clark and Dunlop, 1969)

A. Incision for the Ventral Approach to the Medulla.

B. Exposure of Brain-stem and Auditory Bullae.

**FIGURE 5**

(Clark and Dunlop, 1956)

Acoustically-evoked field potentials in the superior olive of the cat recorded from (i) the surface of the base-recipient, (ii) the surface of the dura, (iii) the surface of the brain, and (iv) within the medial superior olivary nucleus.
In this experiment there was good evidence that the extracranial recording was from the underlying brain, and not from the surrounding muscle. The evidence for this was that the extra-cranial response had the same shape as the brain recording, and a similar latency.

In addition, it was only recorded when the bone was cleared of muscle, and not when an electrode was placed on the muscle itself.

These experiments demonstrated that brain waves could be recorded outside the skull. As it was also possible to record these responses from the base of the skull in the cat without a computer, recordings were made from the roof of the nasopharynx in two volunteers as it was hoped that it may be possible to do the same in man. If this is possible it would be an important advance, particularly as expensive computers would not be needed. Another reason for recording from the nasopharynx was that the area concerned is free of muscle attachments, so that the possible effect of muscle action potentials on the evoked response could be kept to a minimum.

The placement of the nasopharyngeal electrode can be seen in Figure 6. (Clark and Dunlop, 1979.)

This shows the electrode in place with the coiled silver wire resting on the occipital bone behind the sphenoid, and in front of the attachment of the longus capitis muscles.

Using this technique of nasopharyngeal recording, it was not possible to record a response without a computer as I had hoped might be the case. However, an auditory evoked response could be obtained by summing the electrical activity with a computer.

The results obtained from a volunteer can be seen in Figure 7. In this graph arbitrary units are along the ordinate, and latency along the abscissa. As shown evoked response had a latency of 42 milliseconds, and was a wave consisting of three negative and four positive peaks.

In summary, the results presented above indicate that it is possible to record brain waves outside the skull in the cat, and that it is also possible to record electrical activity.
from the nasopharynx in man. In carrying out evoked response audiometry in man, it is important to determine whether the recorded activity is neural or muscular. Even when we are sure that the recorded activity is neural, we cannot say, in the light of present knowledge, that we are measuring the patient's hearing ability. A great deal more work in neurophysiology is necessary before it can be said with certainty that a normal evoked response audiogram represents an intact auditory system.

REFERENCES


FIGURE 7

Recording from volunteer with the nasopharyngeal electrode.
Author/s:
Clark, Graeme M.

Title:
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Date:
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Citation:

Persistent Link:
http://hdl.handle.net/11343/27124