Middle-ear reflex activity was measured in 14 listeners in response to visual and acoustic exposure to each of seven noisy toys (such as a cap gun, party horn, cow bell, and so forth). Anticipatory middle-ear reflex (AMER) activity was a common occurrence. Normal middle-ear reflex generally occurred after the sound exposure. AMERs generally occurred in the two seconds prior to sound exposure but as early as 10 seconds before sound exposure. Loudness ratings and exposure SPLs were obtained. The presence of acoustically evoked middle-ear (ME) reflex activity and AMERs to the toys was generally unrelated to SPL or reflex threshold. Many reflex responses occurred in response to exposure SPLs below reflex threshold and with low anticipated loudness rating.

The role that has typically been assigned to the middle-ear muscles is that of a protective reflexive response to intense sounds. Their function in this role is to increase the impedance of the middle ear by contracting the stapedius and tensor tympani muscles, thus reducing the potentially harmful intense stimulation reaching the cochlea. It was originally thought that this protective mechanism provided attenuation of sound only below 2000 Hz. However, Reger et al. (1963) demonstrated that, although the attenuation is greatest for the low frequencies, some attenuation is provided for all frequencies from 125–8000 Hz. This has important implications for reduction of temporary threshold shift (TTS). Indeed, Fleer (1963) found less TTS at 4000 Hz, the frequency that shows greatest susceptibility to damage from noise, with the middle-ear muscles voluntarily contracted.

Although it is doubtful that the middle-ear reflex's original purpose was to protect the inner ear from intense sounds (Simmons, 1964), it certainly is a useful function for modern-day man in his noisy environment and may occur in more instances than are usually attributed to it. For example, there is evidence that the reflex can precede rather than follow the onset of the sound. Reger et al. (1963) reported a small percentage of people who could voluntarily contract their middle-ear muscles, and Fleer (1963) trained subjects to bring middle-ear muscle contractions under voluntary control. Also, prior conditioning can cause middle-ear reflexes in response to stimuli with insufficient intensity to elicit the reflex. Carmel and Starr (1963) demonstrated
this in two instances with cats. In one instance, reflex activity occurred to white noise that was of insufficient intensity to elicit a reflex, but that was preceded by a single short and intense noise burst. In the second instance, the middle-ear reflex was observed in response to low-intensity white noise after one pairing of the noise with "electrical shock delivered across the body of the animal 500 msec following sound onset" (p. 604). Thus, the acoustic reflex is influenced by factors other than the intensity of the auditory stimulus itself and may provide even more protection than is usually credited to it.

Marshall and Brandt (1974) measured temporary threshold shift from exposure to the sound of a toy cap gun and found less TTS than expected from the measured SPL. In this experiment the subjects fired the cap gun themselves. Many of the subjects winced prior to pulling the trigger, suggesting the activation of the middle-ear reflex, presumably from facial nerve activity. Measurement with an impedance bridge demonstrated a middle-ear reflex prior to firing the gun in four out of six subjects.

The present investigation was undertaken to determine whether this anticipatory reflex occurred with a number of noisy toys. Of secondary interest was whether the anticipatory reflex was related to the sound pressure of the sound and to estimated loudness.

**METHOD**

**Subjects.** Thirteen young adults and one five-year-old child served as subjects. They demonstrated normal hearing bilaterally (thresholds no worse than 20 dB re: ISO 1964 norms for the frequencies of 250–8000 Hz) and had normal tympanograms in their left ears.

**Apparatus.** The toys used were a cap gun, another gun that did not use caps but made an audible click when the trigger was pulled, a birthday party horn, a cowbell, a police car with a siren, a xylophone, and a baby's squeaky toy. The sound pressure of the toys was measured with a sound level meter (Bruel and Kjaer, 2203) positioned at the subject's ear. Additional measurements were made by tape recording the sounds for analysis by a graphic level recorder (General Radio, 1521-B). The following average measurements in decibels of sound pressure level were obtained: cap gun, 83 dB; gun click, 72 dB; cowbell, 91 dB; xylophone, 85 dB; police car, 80 dB; and party horn, 93 dB. The range in SPLs for all of these toys was approximately ± 5 dB. The squeaky toy was extremely variable, ranging from 80–105 dB.

To obtain reflex thresholds, white noise was led through an electronic switch (Grason-Stadler 829-E), a filter (Krohn-Hite, 3100) set at 5000-Hz low-band pass, an amplifier, an attenuator (Hewlett-Packard 350D), and a transformer to a TDH 39 earphone with an MX 41/AR cushion worn on the subject's right ear. An ear probe leading to the impedance bridge (Madsen, Z0-70) was inserted into the subject's left ear canal, and readings for the reflex threshold were read directly from the bridge. This equipment was located in one room of a two-room double-walled sound-treated suite.
Experimental results were recorded on three channels of a recording oscillograph (Honeywell, 1508) located in the second room. A switch, located in the room with the experimenter and subject, simultaneously activated a counter (Beckman, 7350E) in the experimental room and a pulse generator (Tektronix, 160A) in the second room, the output of which led to one channel of the oscillograph. The output of a one-half inch condenser microphone (Bruel and Kjaer, 4134, 2801), which was situated next to the subject's ear, led through the wall to an amplifier (Fisher X-100-C), to an impedance matching device, and then to a second channel of the oscillograph. The output of the Madsen impedance bridge was led to a third channel. The writing sensitivity of this channel was adjusted so that no responses less than 10% meter deflection on the bridge could be recorded.

Procedure. The subject was seated in the experimental room next to the condenser microphone and facing the counter. The meters of the impedance bridge were out of the subject's sight. The toys (with the exception of the noncap gun) were shown to the subject, who rated the toys on anticipated loudness using a 1–5 scale with 1 signifying very soft and 5 very loud. The toys were then placed out of the subject's sight. The probe for impedance measurements was inserted in the left ear, the right ear was covered with an earphone, and reflex thresholds (defined as a 10% deflection of the meter) were obtained for 5000 Hz low-pass filtered white noise. Following the reflex threshold measurement, the earphone was removed from the subject's right ear, but the probe insert remained in the left ear.

The subject was cautioned to sit quietly and not vocalize or make any other sounds during the experiment. Instructions to the subject were: when the counter reached 10 the experimenter would bring out one of the toys, and when the counter reached 20 the subject would hear whatever sound the toy made. The toys were presented in the following order: cap gun, xylophone, cowbell, party horn, cap gun, police car, cowbell, party horn, gun click, squeaky, and last, the squeaky presented visually at count 10 but not sounded at count 20. Following presentation of all the toys, the subject was instructed to watch the meter of the impedance bridge and try to contract the middle-ear muscles or "do anything to make the needle move to the right." Finally, the subjects rerated the loudness of the toys on the 1–5 scale.

RESULTS AND DISCUSSION

Most of the middle-ear reflex activity described below appears to be of a nonacoustic nature. Subjects knew in advance when a sound would be presented. Reflex activity that occurred prior to the sound presentation or at the anticipated time of presentation of a sound stimulus even in the absence of the sound was labeled as the anticipatory middle-ear reflex (AMER). Further we are reasonably satisfied that the AMER is not artificial since head, jaw, and facial movements were not noted by the experimenter.

Although the presence or absence of an AMER is often noticeable by
watching the balance meter on the impedance bridge, the temporal characteristics of the AMER generally require the comparison of acoustic onset and reflex onset provided by the recording oscillograph tracings. Often the reflex and acoustic activity appear to be simultaneous at onset. There is, however, a response delay in the impedance bridge circuit of approximately 100–150 msec. This delay was taken into account in identifying the AMER. The tracings of several kinds of responses in the figures that follow have not been adjusted in any way as a function of time.

Occurrence. Two subjects failed to show AMER activity. All other subjects (12) showed AMERs. Counting multiple AMERs within a single presentation only once, the greatest number of AMERs by any subject was to six of the 11 sound presentations. Most of the AMERs were to the cap gun presentations although AMERs occurred to all toys except the police car.

Time of Occurrence. All subjects knew when the toy would be visible and when sound would occur. Figure 1 shows the time that all prior reflexes oc-

![Figure 1](image1.png)  
Figure 1. Number of anticipatory middle-ear muscle responses as a function of time prior to acoustic stimulation. The toys were visible at 10 sec and acoustic stimulation occurred at 20 sec. The width of each bar is one second except the bar located in the half second prior to 20 sec.

![Figure 2](image2.png)  
Figure 2. Recording oscillographic tracings: A represents the timing signal seen by the subject; B represents the middle-ear reflex response; C represents the acoustic signal with increasing amplitude toward the bottom. Time increases from right to left. The amplitude of the acoustic signal has been truncated.

curred. No reflex activity was observed in the 9.5 seconds prior to the sight of the toy. Four of the AMER's (from three subjects) coincided with the sight of the toy (defined as 10 seconds ± 1 second). AMERs generally occurred within two seconds of the expected sound, with the greatest number of AMERs occurring within one second prior to the sound.

Figures 2 and 3 show multiple AMERs for one subject to the first presentation of the cap gun and the party horn. This subject not only showed AMERs
immediately preceding these sounds but also had AMERs coinciding with the sight of the toy. In addition, there was in each case an intermediary reflex between the reflex at sight and the reflex just prior to onset of the sound.

**Predicted Loudness of AMER.** There was no correlation between predicted loudness and AMER. Toys that had high anticipated loudness ratings commonly produced no AMER, and toys with low anticipated loudness ratings often caused AMERs.

**Measured SPL and AMER.** There was no correlation between AMER and SPL of the toys. Although the SPLs showed variability, many AMERs occurred when the SPL of the toy was clearly below that necessary to elicit a normal reflex with white noise.

**Measured SPL and Normal Reflex.** Normal reflex activity generally occurred in response to the actual sound stimulus. Of the 14 subjects, only two demonstrated reflexes that were in complete accord with SPL and the normal reflex thresholds. One of these subjects was the five-year-old child.

Middle ear reflexes were present for more than half the test sounds even though they were below the reflex threshold for white noise bursts. These usually occurred for the cap gun and the gun click, which had most often been given high anticipated loudness ratings. However, reflexes occurred to sounds with sufficient SPL to elicit a reflex that had been given anticipated loudness ratings as low as 3 (on a 1-5 scale). Since the subjects knew when the sound would occur by watching the counter count down, it is likely that the reflex activity to sounds with SPL lower than threshold is some sort of anticipatory response.

Figure 4 shows a reflex that occurred at the time that the sound (squeaky toy) was expected to take place, but the squeaky sound was never produced. For another subject, the earphone was not removed following reflex measurements. Presence of the earphone produced a 16-dB or greater attenuation to narrow-band noise with center frequencies of 0.5, 1, 2, 4, and 8 kHz. Since the subject's reflex threshold to white noise was 89 dB SPL, all sound pressure
levels used in this study were insufficient to elicit a reflex. This subject showed reflexes not only to the cap gun, gun click, and cowbell, which were rated as 5, but also to the party horn, which was rated as 3. However, the xylophone, which was given a 3 rating, did not cause a reflex.

Additional Observations. Two of the subjects could voluntarily contract their middle-ear muscles. One subject described the process as “yawning” and indeed demonstrated large jaw movement. This had not occurred during the toy presentations. The other subject described the process as “gritting my teeth together.” This movement was, of course, much more subtle. However, this subject showed AMERs only to the two cap gun presentations, even though his pre- and postloudness ratings of the cap gun were 3 and 4, respectively. He did not show AMERs to other toys with 5 ratings.

Figures 5, 6, and 7 show some of the types of reflex activity obtained. While

![Figure 5. Response to sound of xylophone.](image)

![Figure 6. Response to party horn.](image)

![Figure 7. Response to a cap gun.](image)

the reflex often followed the envelope of the stimulus (Figure 5), this was not always the case. Figure 6 shows the amplitude of the party horn decreasing but the amplitude of the reflex increasing. Reflexes usually began with a positive deflection and then returned to baseline. However, in a few subjects the reflexes to the cap gun began with a small negative deflection (Figure 7). Also, one subject showed an initial negative deflection prior to the positive deflection for all toys and, following the positive deflection, exhibited another negative deflection before returning to baseline. Because of the response delay in the impedance bridge circuit, we have interpreted several responses as being anticipatory although the onset of reflex and acoustic signal appear simultaneous on tracings B and C.

**CONCLUSION**

Anticipatory middle-ear reflex activity and acoustically evoked reflex activity occurred from visual and acoustic exposure to toys with SPLs below that necessary to elicit a normal acoustic reflex. The hypothesis could be that these
responses are a result of some prior conditioning (Carmel and Starr, 1963), except that this learning would have taken place sometime prior to the experiment. Subjective loudness did not seem to provide the cue for AMER. Another hypothesis could be that the AMER also occurs outside the laboratory setting. However, it seems likely that although most people have the ability to unconsciously protect their ears with an AMER to sounds with known onset, they may often fail to do so with many environmental sounds.

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had chronically hoarse voices; (2) the incidence was higher in the primary grades, kindergarten through third grade; and (3) more boys than girls were hoarse. Results of a speech and voice survey of 93 first-grade children enrolled in a northeast Texas elementary school indicated that 8.6% had chronically hoarse voices. The school is located in a milling district for cotton and grains. Five of the eight children had articulation problems in addition to chronic hoarseness. All of the children were from large families, the average family size was 6.5 persons.

The results of this survey and other studies (Baynes, 1966; James and Cooper, 1966; Pont, 1965; Senturia and Wilson, 1968; Wilson, 1971) indicate that approximately 6 to 9% of school-age children have hoarse voices. By contrast, Milisen (1957) and Johnson (1956) estimated that approximately one to two percent of the school-age population has some type of voice disorder. The apparent increase in the percentage of children reported as having voice disorders may reflect an actual increase, or improved identification procedures, or both. Silverman and Zimmer (1975) suggest that the incidence of hoarseness in their population is "strikingly high." Baynes (1966) felt that 7.1% was a conservative figure for chronic hoarseness among children, since children displaying mild hoarseness were excluded from his study. It would appear that data on the prevalence of hoarseness are incomplete.

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ERRATA

Two lines were omitted from A. Damien Martin's letter to the editor, "Reply to Aten, Darley, Deal, and Johns," which appeared on pages 420-422 of the August, 1975, Volume 40, issue of this journal. The paragraph should read:

The writers state flatly "But the simple fact, known to everyone . . . is that not all aphasic patients display phonologic impairment. Only some of them do. And some patients display phonological impairment in pure culture with no associated problems in the use of lexicon or syntax." There is not total agreement on this. Schuell (1965) pointed out that her Group I and II patients presented inconsistent misarticulation, while Group III patients presented phonological difficulties as a major presenting symptom. In some of my own research (Martin and Rigrodsky, 1974a, 1974b) patients who did not present phonological impairment as a major symptom showed it within certain tasks. In a later study (Martin et al., 1975) we found that the incidence, type, and position of error were related to the presence or absence of morphological inflection. The arguments presented by Aten et al. illustrate one of the dangers of categorization, especially dichotomous categorization. It can reflect "the old error of observing only the most obvious symptoms that fit some a priori assumption, or symptoms prominent at one point in time" (Schuell, Jenkins, and Jimenez-Pabon, 1964, p. 101).

In August 1975 issue, the article by Marshall, Brandt, and Marston, "Anticipatory Middle-Ear Reflex Activity from Noisy Toys," contains an error. The sentence, "However, reflexes occurred to sounds with sufficient SPL to elicit a reflex that had been given anticipated loudness ratings as low as 3 (on a 1-5 scale)" found in the full paragraph above the figures on page 324 should read "However, reflexes occurred to sounds with insufficient SPL to elicit a reflex . . ."
Anticipatory Middle-Ear Reflex Activity from Noisy Toys

Lynne Marshall, John F. Brandt, and Larry E. Marston

*J Speech Hear Disord* 1975;40;320-326

A correction for this article has been published. It can be found at:
http://jshd.asha.org/cgi/content/abstract/40/4/549-a

This information is current as of July 6, 2011

This article, along with updated information and services, is located on the World Wide Web at:
http://jshd.asha.org/cgi/content/abstract/40/3/320