Effect of Aging on the Click-Rate Induced Facilitation of Acoustic Reflex Thresholds

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Acoustic reflex thresholds are known to improve with an increase in the click-repetition rates from 50/sec to 300/sec. In the current study this improvement was used to evaluate auditory processing in older subjects. Acoustic reflex thresholds were obtained from 16 human adult ears within each of the following four groups: young male, young female (18-28 years), older male and older female (50-65 years). The probe tone frequency was 226 Hz and the intensity of the probe tone was 85 dB SPL (sound pressure level). Clicks were delivered ipsilaterally to each ear at repetition rates of 50, 100, 150, 200, and 300/sec. The mixed MANOVA revealed a significant effect for the repetition rate and a significant age and rate interaction. Rate integration in dB was computed by subtracting the highest acoustic reflex threshold from the lowest threshold of each ear. Statistical analyses revealed reduced rate integration in the older subjects, suggesting less efficient processing of faster stimuli within the acoustic reflex pathway.

ONE widely reported change within the nervous system of older subjects is the lowered speed for processing a variety of stimuli. The lowering of speed has been reported in the auditory system in a variety of ways including speech perception tasks (e.g., Stine et al., 1986) and backward detection masking tasks (Cobb et al., 1993). Elderly listeners show increased difficulty in perception when compared to younger listeners in understanding temporally altered speech (Bergman et al., 1976; Konkle et al., 1977; Wingfield et al., 1985; Gordon-Salant and Fitzgibbons, 1993). Corso et al. (1976) showed depressed threshold-durations functions with a decreased constant of temporal summation in older individuals.

The latencies of auditory-evoked potentials and the brainstem transmission time as measured by the auditory brainstem response (ABR) I–III, I–V, or IV–V interwave-intervals increase with increasing age (Patterson et al., 1981; Allison et al., 1983). Differential effect of increasing repetition rates on the click-evoked ABR has been reported in the older population (Fujikawa and Weber, 1977; Patterson et al., 1981; Debruyne, 1986).

The acoustic reflex pathway consists of some of the same nuclei that are involved in the elicitation of the auditory brainstem response. Furthermore, the acoustic reflex is altered in the aging population in a variety of ways. Acoustic reflex thresholds elicited with broad band noise are elevated among elderly subjects in the presence of normal auditory sensitivity (e.g., Silman, 1979; Gelfand and Piper, 1981). The growth of the acoustic reflex amplitudes is decreased in the elderly (Thompson et al., 1980; Wilson, 1981; Hall, 1982), and the acoustic reflex growth function saturates more frequently in the elderly (Silman and Gelfand, 1981b; Wilson, 1981). Bosatra et al. (1984) reported the effect of aging on the acoustic reflex latency. The latencies were significantly greater in subjects between 60 and 79 years than in subjects between 20 and 29 years of age. Both the age groups had hearing sensitivity within 10 dB HL (hearing level) at .5, 1, and 2 kHz. The improvement in acoustic reflex thresholds with an increase in the signal bandwidth is significantly less in the elderly when compared to young adults (Jakimetz et al., 1989). Jerger and Oliver (1987) showed that as the interstimulus intervals are decreased from 9 seconds to 1.5 seconds, ipsilateral acoustic reflex amplitudes obtained at 110 dB SPL (sound pressure level) for 1 kHz tone bursts decrease in older subjects, whereas no change in amplitudes is apparent for younger subjects.

It has been established that contralateral (Johnsen and Terkildsen, 1980) and ipsilateral (Rawool, 1995) acoustic reflex thresholds improve with an increase in the click-repetition rates in young normal adults. Since various parameters of the acoustic reflex are affected in the older individuals as described above and since the speed of processing in the older population is generally lowered, the rate-induced facilitation of the acoustic reflex threshold (Rawool, 1995) can be expected to be reduced in the aging population. One purpose of this study was to compare the effect of the click repetition rate on the acoustic reflex threshold in the younger and older adults. Another purpose was to detect any gender differences in the rate-induced facilitation of the acoustic reflex threshold. Age and sex interactions in acoustic reflex measures have been reported (Woodford et al., 1975; Hall, 1982).

METHOD

Subjects. — Acoustic reflex thresholds were obtained from 16 left and/or right human adult ears (total 64 ears) within each of the following four groups: young male, young female, older male, and older female. The age-range for the younger groups was 18 to 28 years (Mean = 22.25) and that for the older group was 50 to 65 years (Mean 54.82). The relatively younger elderly age-group of 50–65 was selected for two reasons. Noticeable decline in speech perception is apparent in the fifth decade of life (Bergman et al., 1976), and the difficulty in finding subjects with relatively normal hearing increases with age (Pearson et al., 1995).
Subjects were selected based on no known history of neurogenic abnormalities, “normal” auditory sensitivity, and normal tympanometric findings. All the younger subjects had auditory sensitivity within 20 dB HL in the frequency range of .25 and 8 kHz. The criteria for the older group were as follows: Auditory sensitivity within 20 dB HL from .25 to 2 kHz, within 30 dB HL at 4 and 6 kHz, and within 35 dB HL at 8 kHz. For the older subjects, relaxed criteria had to be used due to the difficulty in finding subjects with auditory sensitivity within 20 dB HL in the frequency range of .25 to 8 kHz (Pearson et al., 1995). Note that the criteria for the younger and the older group were similar for frequencies up to 2 kHz, since these frequencies are critical for elicitation of the reflex. The 30–35 dB HL criteria for higher frequencies for the older group were expected to have no effect on the acoustic reflex thresholds. Silman and Gelfand (1981a) showed that acoustic reflex thresholds remain constant up to hearing levels of 50 dB. The criteria for normal tympanometric results were middle ear pressure within the range of +50 to -100 daPa and static admittance within the range of .3 to 1.6 ml (Hull and Chandler, 1994).

Procedure. — The procedure for determination of acoustic reflex thresholds was similar to that reported earlier (Rawool, 1995). The commercially available Grason-Stadler GSI 33, Version 2 middle ear analyzer was used for generation and control of stimuli and for recording of the reflexes. The system has a compact probe box. Within the probe box there are two small loudspeakers, a microphone, and a pressure transducer. One loudspeaker delivers the probe tone to the ear canal, while the microphone monitors the intensity of the probe tone in the ear canal. The other loudspeaker delivers the ipsilateral stimuli to the ear canal. The probe attached to the probe box is designed for accurate test results. A variety of ear tips are available to hold the probe in place and to hermetically seal the ear canal. The GSI 33 uses a multiplexed stimulus approach in the ipsilateral mode to minimize stimulus artifacts. Such stimulus artifacts may result from inadequate frequency separation of the reflex-eliciting stimulus and the probe tone, or from intermodulation distortion (Green and Margolis, 1984). Lutman and Leis (1980) reported that the multiplexed stimulus approach is successful in minimizing stimulus artifacts. The total envelope for the multiplexed approach in the GSI 33, Version 2 is 115 msec; the clicks are “on” for 44 msec and “off” for 53 msec (the probe tone is “on” during these 53 msec for measurement of the reflex); and the total rise and fall time is 18 msec. The polarity of the clicks is condensation and the duration is 100 µsec. The frequency range of the ipsilaterally delivered clicks as described in the GSI 33 manual is 50 to 4000 Hz. The reported uniformity across the frequency spectrum is better than 10 dB. For clicks the stimulus intensity levels are calibrated in peak equivalent SPLs using procedures that are similar to those used for insert earphones.

The GSI-33 yields data in terms of maximum change in admittance from the baseline, recorded within the time-frame of the measurement. For a 226 Hz probe tone, the admittance (Y) is reported in ml units by the GSI 33 middle ear analyzer. This is because the admittance of the middle ear at 226 Hz is dominated by compliance, and the compliance of the middle ear can be calibrated with respect to the compliance within an equivalent volume of air in ml or cm³. During acoustic reflex measurements, the air pressure in the ear canal is maintained at the point of peak admittance.

The probe tone frequency used for the measures was 226 Hz and the intensity of the probe tone was 85 dB SPL as measured in an ANSI HA1 coupler. The clicks were delivered ipsilaterally to the right and the left ears at repetition rates of 50, 100, 150, 200, and 300/sec. All the testing was conducted in a relatively quiet environment. The rate of 250/sec was excluded since an increase in the rate from 200 to 250 was not expected to improve the acoustic reflex thresholds significantly (Rawool, 1995).

Each measurement was made over a period of 1.5 seconds; baseline data were obtained 1.5 seconds before the initiation of the measurement and 1.5 seconds following the end of the measurement. The graphic display of acoustic reflex tracings in combination with the event markers that record the time of onset and termination of stimuli (Margolis and Gilman, 1977) were monitored visually on the cathode ray tube (CRT) for any apparent stimulus artifacts. Acoustic reflex thresholds were defined as the lowest intensity value at which a minimum of .02 ml change in admittance was evident on at least two of three trials.

The initial presentation level was 70 dB peSPL. If a reflex was recorded at this level, the intensity was lowered in 5 dB steps until the reflex threshold (as defined above) was found. If a reflex was not apparent at the initial 70 dB peSPL level, the intensity was increased in 5 dB steps until a reflex was apparent. If the amplitude of the obtained acoustic reflex (AR) was noted to be greater than .02 ml, then stimulus presentation at a 5 dB lower level was repeated to ensure the absence of reflex at the lower level. This procedure was adapted considering the finding that no significant differences in thresholds are apparent for ascending or descending procedures (Peterson and Liden, 1972; Wilson, 1979). A step-size of 5 dB was used because experimentation with a 2 dB step-size resulted in generally nonsignificant changes in baseline admittance, as has been noted by Laukli and Mair (1980). All the data were obtained within a single session. The reflex tracings were printed on a thermal paper recorder for future reference.

Statistical analyses. — The statistical analyses were performed using a commercially available statistical package. Rate integration (RI) in dB was computed by subtracting the AR from each ear.

Multivariate analyses of variance (MANOVAs) were performed to evaluate the effect of repetition rate, age, and gender on the acoustic reflex thresholds. Similar procedures were used to reveal any systematic differences in the RI and hearing thresholds across the various groups. Although the subjects in the current study were selected based on specific criteria of middle ear pressure and static admittance presented in the Method section, the Kruskal-Wallis nonparametric ANOVAs were used to reveal any systematic difference in static admittance among the two age groups. Analyses of covariance (ANCOVAs) were performed with age and gender as independent variables, the RI as depen-
dent variable, and the static admittance as a covariate, to further evaluate the age effect on rate integration.

The correlations between acoustic reflex thresholds at each of the click rates and the static admittance were examined using the Gamma procedure (Siegel and Castellan, 1988). This nonparametric correlation procedure was used because the static admittance data did not show normal distribution. The same correlation procedure was used to reveal any correlation between static admittance and the RI.

RESULTS

Mean acoustic reflex thresholds and standard deviations for each of the four groups are presented in Table 1. In two younger male ears, one older male ear, and two older female ears no thresholds were apparent for the 50/sec rate, using the criterion of .02 ml change in admittance at 110 dB peSPL, which is the upper intensity limit of the instrument. The magnitude of the acoustic reflex was .01 ml in these subjects at 110 dB peSPL. Therefore, thresholds were approximated to 115 dB peSPL for these five ears at the rate of 50/sec for statistical analyses.

The mixed MANOVA with age (two levels), gender (two levels), and the repetition rate (repeated factor, five levels) revealed a significant effect for the repetition rate \( p = .0001 \) and a significant rate and age interaction \( p < .0099 \).

The rate and age interaction is displayed in Figure 1. Pooled effects for age (the Least Significant Difference test) among the different rates revealed that the acoustic reflex thresholds improved significantly with the increase in the click repetition rate from 50/sec to 150/sec for both the older and the younger group. The thresholds were significantly different for the 100/sec and 300/sec rates for the younger group, but this difference was not significant for the older group. No other differences were significant.

MANOVA (Age \( \times \) Gender) on the rate integration (RI) revealed significantly reduced rate integration \( (p < .006) \) in the older subjects, no gender effect, and no age and gender interaction (Figure 2). Post-hoc analyses of simple effects revealed that age had a significant effect for both the male and the female groups.

The Gamma correlation between static admittance and RI (Figure 3) was significant \( (p < .0002, \text{Gamma: } -.374) \). The Kruskal-Wallis ANOVA on the static admittance revealed a significant \( (p < .005) \) age effect. This was also true for the parametric ANOVA procedure \( (p < .005) \). Post-hoc analyses (the LSD test) revealed that the younger female subjects yielded significantly smaller static admittance values than the older female subjects, but the younger and the older male subjects did not differ (Figure 4). The static admittance showed significant correlation only with acoustic reflex thresholds obtained at 300/sec \( (p < .028, \text{Gamma: } .213) \); no other correlations were significant. The scatterplot of thresholds at 300/sec and static admittance for 64 ears is shown in Figure 5.

Due to the group difference apparent in static admittance values, the analyses of covariance (ANCOVAs) were performed. The ANCOVA with age and gender as independent variables, the RI as dependent variable, and the static admittance as the covariate confirmed a significant age effect \( (p < .0262) \), no gender effect, and no interactions.
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Figure 3. The relationship between static admittance and rate integration.

Figure 4. Static admittance across the various subject groups. M = Male, F = Female.

Figure 5. The relationship between acoustic reflex thresholds at the rate of 300 clicks/sec and static admittance.

Figure 6. Age, gender, and frequency interaction in hearing thresholds. M = Male, F = Female. The frequencies represented from left to right for each of the subject groups are .25, .5, 1, 2, 4, 6, and 8 kHz. The presented statistics are similar to those in Figure 4.

To reveal any systematic differences in hearing thresholds among the various groups, the mixed ANOVAs were performed with frequency (the repeated factor), age, and gender. These analyses revealed a significant age effect ($p = .0001$), a significant gender effect ($p < .021$), and a significant frequency effect ($p = .0001$). In addition, the interactions between age and frequency ($p = .0001$), age, gender, and frequency ($p < .016$) were significant (Figure 6). Post-hoc analyses (the LSD test) revealed that the thresholds were significantly different for the older and young group for all the frequencies except .25 kHz. Younger females had lower thresholds than younger males at all the frequencies except at 4 and 8 kHz, where there were no differences in thresholds. There were no differences in the older males and the older females except at .25 kHz, where the older males had lower thresholds than older females. Younger males had lower thresholds than older males at 4, 6, and 8 kHz, and older males had lower thresholds than younger males at .25 kHz. Younger females had lower thresholds than older females at all the test frequencies.

As shown in Figure 2, the rate integration values vary across all the groups. Individual variability within each group is also summarized in Table 2 with reference to the percentage of ears showing saturation at each repetition rate. The term “saturation” is used here to indicate no further improvement in acoustic reflex thresholds beyond a specific repetition rate. In four of the ears in the younger group and eight of the ears in the older group, thresholds improved up to a certain increase in the rate and then worsened with a further increase in the rate.

DISCUSSION

This investigation shows that although the acoustic reflex thresholds continue to improve in the younger system up to the rate of 300/sec, the thresholds improve significantly only up to the rate of 150/sec in the older system. The results...
suggest that with increasing age there is a general decrease in the efficiency either throughout the acoustic reflex pathway or at specific sites within the pathway from the tympanic membrane to the neural innervation of the stapedius muscle.

The source of the differential RI in the aging system. — The possible underlying mechanisms for the rate integration effect apparent in the acoustic reflex thresholds have been discussed earlier (Rawool, 1995). Elicitation of the ipsilateral acoustic reflex involves conduction of the sound through the outer ear, the middle ear, and the cochlea. The neural impulses then travel through the auditory nerve to the cochlear nucleus and from the cochlear nucleus to the trapezoid bodies and/or the superior olivary complex (Borg, 1973; Rouiller et al., 1989). A message is then relayed to the stapedius motor neurons (Strutz et al., 1988), which travel through the motor nerve fibers to the stapedius muscle. Aging changes in any of the above systems may be responsible for the RI measured in the current study. These will be considered separately in the following section.

RI and the mobility of the tympanic membrane/middle ear system. — Etholm and Belal (1974) reported arthritic changes in the joints of the middle ear bones with advancing age that were prominent after the age of 70 years. Goodhill (1969) reported a case of malleal fixation that appeared to be an age-related effect. Therefore, altered mobility of the tympanic membrane/middle ear system as a factor causing a change in the RI needs to be considered.

The static admittance is a fair measure of the mobility of the tympanic membrane/middle ear system. As mentioned in the Results section, a significant ($p < .0002$) correlation was present between static admittance and RI (Figure 3). However, the older female subjects had significantly greater static admittance than the younger female subjects, but there were no significant differences between the younger and older male subjects (Figure 4). Although the difference in static admittance was not significant in the younger and older males, these two groups differed significantly with reference to the RI. Thus, the age effect seen in the RI cannot be explained by static admittance alone. Furthermore, analyses of covariance (ANCOVAs) with age and gender as independent variables, the RI as a dependent variable, and the static admittance as the covariate confirmed a significant age effect ($p < .0262$), no gender effects, and no interactions. In summary, the age effect in rate integration in the current study is independent of difference in static admittance or the mobility of the tympanic membrane/middle ear system among the two age groups.

Concerning the relationship between static admittance and acoustic reflex thresholds, various findings have been reported. Fria et al. (1975) reported no relationship between static compliance and acoustic reflex thresholds in a group of normal subjects. Wilson (1981) reported that an increase in the static impedance was generally associated with an increase in the magnitude of the contralateral acoustic reflex in a group of subjects with relatively normal hearing. No correlations between static admittance and acoustic reflex thresholds were apparent in the current study at any of the repetition rates except at 300/sec, where smaller admittance values were associated with lower acoustic reflex thresholds.

RI and auditory thresholds. — Because the sound must pass through the cochlea for elicitation of the acoustic reflex, any systematic differences in the hearing thresholds may be considered as a potential factor contributing to the age effect in RI. In addition, listeners with sensorineural loss tend to have less temporal integration (Jesteadt et al., 1976; Chung, 1982; Florentine et al., 1988; Carlyon et al., 1990). Two studies, using very few subjects, have suggested influence of sensory-neural hearing impairment on temporal integration in acoustic reflex measures (Woodford et al., 1975; Singh and Greenberg, 1976).

Although there were systematic age differences in auditory sensitivity as mentioned in the Results section, the reduced rate integration in the older population is less likely to be related to the auditory sensitivity due to the following findings. First, the differences in hearing thresholds between the older and younger groups did not cause any significant differences in acoustic reflex thresholds at the lower repetition rates in the two groups. Second, the younger females had better thresholds than the younger males except at 4 and 8 kHz (Figure 6), and yet there were no significant differences in the RI between these two groups. Thus, it appears that the differences in hearing thresholds alone cannot explain the age effect on RI, unless the difference is related to hearing thresholds at 4 and 8 kHz. Feldman and Katz (1978) reported no difference in temporal integration in acoustic reflex thresholds between normal subjects and subjects with sensorineural hearing impairments. Corso et al. (1976) reported that temporal integration in older subjects is equally reduced in the presence (mean threshold at 4 kHz, 53.9 dB) or absence (mean threshold at 4 kHz, 23.8 dB) of a significant hearing loss. Future studies with moderate to severe hearing impairments in the higher frequencies would be helpful for further evaluation of the effect of hearing impairment on the rate integration in acoustic reflex thresholds.

### Table 2. The Percentage of Ears Showing Saturation at Each of the Repetition Rates Beyond Which No Further Improvements in Acoustic Reflex Thresholds Were Apparent

<table>
<thead>
<tr>
<th>Click Rate/sec</th>
<th>Younger Male</th>
<th>Younger Female</th>
<th>Older Male</th>
<th>Older Female</th>
</tr>
</thead>
<tbody>
<tr>
<td>50</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>6.25</td>
</tr>
<tr>
<td>100</td>
<td>18.75</td>
<td>6.25</td>
<td>12.50</td>
<td>12.50(18.75)</td>
</tr>
<tr>
<td>150</td>
<td>12.50(31.25)</td>
<td>12.50(18.75)</td>
<td>37.50(50)</td>
<td>18.75(37.5)</td>
</tr>
<tr>
<td>200</td>
<td>50 (81.25)</td>
<td>18.75 (37.5)</td>
<td>37.50 (87.5)</td>
<td>43.75(81.25)</td>
</tr>
<tr>
<td>300</td>
<td>18.75 (100)</td>
<td>62.50 (100)</td>
<td>12.50 (100)</td>
<td>18.75 (100)</td>
</tr>
</tbody>
</table>

Note. The values in parentheses indicate the cumulative percentages.
RI and the central auditory mechanism. — The central factors underlying the threshold advantage with stimuli of higher repetition rates are probably facilitation and summation (Rawool, 1995). Various facilitatory processes as evidenced by an increase in the synchronous release of ACh quanta have been shown following repetitive stimulation of nerve fibers (reviewed in Silinsky, 1985). Temporal and spatial summation can be expected within the acoustic reflex pathway (Rawool, 1995).

Teravainen and Calne (1983) suggested that summation and integration of nerve impulses are delayed in senescence due to a reduction in the number of synaptic terminals, leading to diminished neuronal communication. Possible causes for these neurophysiologic deficits include decrease in neurotransmitter release, loss of cholinergic receptors or beta-adrenergic receptors, and abnormal synaptic Ca** transport (reviewed in Teravaine and Calne, 1983).

Degeneration in the acoustic nerve and in the white matter of the brainstem has been reported by Hansen and Reske-Nielsen (1965). Konigsmark and Murphy (1972) observed a reduction in the volume of the ventral cochlear nucleus (VCN) beyond the fifth decade of life. They suggested that this decrease could be due to a decrease in the number of myelinated axis cylinders in the parenchyma of the VCN. Casey and Feldman (1982) reported a 34% decrease in cell number in the medullar nucleus of the trapezoid bodies in aging rats. Thus, the neural pattern of the sound stimulus from the inner ear to the auditory cortex may be altered by changes within the auditory pathway (Kirikae et al., 1964). The neural loss can occur without a significant hearing loss or pure tone audiometric testing and has been called neural presbycusis by Schuknecht (1964).

RI and the stapedius muscle. — A major component to the improvement of acoustic reflex thresholds when the rates are increased from 50/sec to 100/sec may be the summation at the muscular level, but this summation effect is expected to be limited to 125/sec rate (Rawool, 1995). The stapedius muscle is composed of striated pennate fast-twitch muscle fibers (Zemlin, 1968; Berge and Wirtz, 1989). Besides primary muscle changes, striated muscles may show a variety of regressive changes including partial denervation, trauma to nerves or muscle by entrapment, and disuse (reviewed in Schaumburg et al., 1983). Deterioration of the stapedius muscle fibers leading to reduced capacity for maximum muscle contraction has been suggested as a cause for the frequent reflex growth saturation in the elderly population (Wilson, 1981; Hall, 1982). However, the aging process in the skeletal muscles is highly variable between muscle groups and individuals due to genetic and environmental factors (reviewed in Thompson, 1994). Furthermore, older individuals are known to adapt to resistive and endurance exercise training in a similar fashion as young people. Therefore, the decline in the muscle’s metabolic and force-producing capacity is no longer considered as an inevitable consequence of aging (Thompson, 1994).

The possibility of stapedius muscle weakness as a cause for the depressed rate integration in the elderly subjects in this study is minimal for three reasons. First, the older population in the current study is relatively young (65 or less) with mean age of 54.82 years. Most muscle-related changes are reported in older populations (reviewed in Thompson, 1994). Second, the age-related muscular changes are more likely to be present in muscle groups that are not used frequently. Studies have shown that the decline in motor performance is more related to the general decrease in physical activity accompanying old age than to increasing age per se (Thompson, 1994). In this regard the stapedius muscle can be considered a well-exercised muscle since it contracts during talking and swallowing (Borg and Counter, 1989). Third, data obtained at 5 dB above the reflex threshold at the 300/sec rate showed a significant growth in the amplitudes of the acoustic reflex, indicating that maximum contraction had not occurred at the threshold levels at the rate of 300/sec in the older subjects. Physiological studies of the stapedius muscle in an aging population would be helpful in revealing any systematic age-related changes in the stapedius muscle.

Individual variability. — As can be seen in Figure 2, the rate integration values vary considerably across all the groups. Even in the older age group, some rate integration values are as high as 25 and 30 dB. This variability is also reflected in the percentage of ears in each group showing saturation at various repetition rates (Table 2). For example, at the rate of 150/sec, 31.25% of the male and 18.75% of the female ears showed saturation. At the same rate, 50% of the male and 37.5% of the female ears in the older group showed saturation. Examination of individual data revealed no specific audiometric or tympanometric patterns in ears showing saturation at lower repetition rates. In addition, in some subjects the thresholds improved with the increase in the repetition rate and then decreased with a further increase. However, there were four such subjects in the younger group but eight such subjects in the older group, suggesting greater variability in the older group. Dublin (1976) similarly reported considerable individual variability in the reports of age-related deterioration in the auditory brain stem.

RI and instrumentation recovery time. — A factor that needs consideration in acoustic reflex measures is instrumentation recovery time (Morgan et al., 1977). It can be a critical factor in studies of the dynamic characteristics of the reflex such as latency and recovery time. However, the ability of the instrument to monitor the pattern or recovery time of the reflex accurately may be of little significance to the current study since the measurements involved only detection of the presence of a reflex (Feldman and Katz, 1978) with computerized measurement criteria as opposed to visual detection. In addition, if the instrumentation recovery time is a factor, it is common to both the younger and the older group; thus, the age effect apparent in the rate integration is still valid.

Theoretical implication. — Vierweister and Wakefield (1991) proposed a “multiple look” model for explanation of temporal integration. According to this model, the envelope, or the output of the auditory filters, is sampled at a fairly high rate, and these samples or looks can be accessed and processed selectively. The aging system may not be able to
sample the output at high rates as well as the younger system. Thus, when stimuli are presented at very high rates the slower speed of sampling will allow only limited number of stimuli or “looks” to be processed. This would explain why there is no threshold improvement in the older subjects beyond the click rate of 150/sec.

**Clinical implications.** — When frequency-specific stimuli are used for detection of retro-cochlear pathology, the use of a single frequency criterion, without consideration of other frequencies, is known to yield a high rate of false negatives (Prasher and Cohen, 1993). Click stimuli may be more efficient for this purpose, since clicks have a broader frequency spectrum. The interaural difference criterion suggested by Prasher and Cohen (1993) may prove to be more effective if acoustic reflex thresholds obtained with clicks presented at 50/sec and 150/sec on the normal side are compared with those obtained on the side with auditory nerve pathology. The current findings suggest that a rate that can give the best possible thresholds and yet is not affected by age or gender is 150/sec.

It has been suggested that the deterioration in temporal tasks in older individuals may be due to changes mainly in cognitive processing rather than in sensory processing, since certain tasks may require a considerable amount of cognitive processing (Moore et al., 1992). Other tasks may be affected by short-term memory problems. The older subjects may be slower in learning new tasks or may get fatigued easily. The rate integration procedure as described here is not affected by the above factors, since it is an objective procedure.

It appears that at higher repetition rates the acoustic reflex is not likely to provide as much hearing protection (Borg, 1980) to the elderly as it can to the younger population. This may induce more susceptibility to noise-induced damage in the older population for repetitive stimuli.

The lack of improvement in acoustic reflex thresholds with the increase in the stimulus repetition rate beyond 150/sec may be one of the reasons why the older population may have more difficulty in speech recognition in noise (Jokinen, 1973). Most of the background noise is dominant at lower frequencies. The upward spread of masking of high-frequency sounds by low-frequency sounds is minimized by the reflex, since the reflex attenuates low-frequency components of a complex sound more than it does the high-frequency components (Borg and Counter, 1989). Mahoney et al. (1979) showed that word and sentence discrimination is better in the presence of a functioning acoustic reflex. Results from the current study show that for stimuli presented at faster rates (150/sec), the acoustic reflex-induced attenuation of the low frequencies is achieved more efficiently by the younger group than the older group. Future studies examining the correlation between the rate integration and speech recognition in noise may be helpful.

**Conclusion.** — The rate integration in acoustic reflex thresholds is reduced in the older population, suggesting less efficient processing of faster stimuli within the acoustic reflex pathway. The depressed rate integration in the older population could be due to age-related changes anywhere in the acoustic reflex pathway including the middle ear, the cochlea, the auditory nerve, the central nuclei, the facial nerve, and the stapedius muscle. A careful evaluation of various factors suggests that the depressed rate integration in the older population in the current study is primarily central in nature, and that impaired synaptic potentiation is likely to be an important contributory factor.

The study shows that clicks at higher repetition rates (e.g., 150/sec) are efficient in eliciting well-defined acoustic reflexes for measurements obtained over a period of 1.5 secs. Furthermore, acoustic reflex measurements are efficient in demonstrating the rate-induced facilitation in the auditory system at high-intensity stimuli.

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