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Reflex modulation in humans by monaural and binaural auditory stimulation

JAMES R. ISON
University of Rochester, Rochester, New York 14627

and

LINDA PINCKNEY
Nazareth College, Rochester, New York 14610

Eye blink reflexes were elicited by percutaneous stimulation of the supraorbital branch of the trigeminal nerve in six human adults. On some trials the eliciting stimuli were preceded (100 msec before) by 1-kHz tone bursts delivered to one or to both ears at 30 dB or 90 dB SPL. The bilateral component of the reflex was inhibited by the tones, more so by monaural than binaural. The advantage of the monaural tone was more apparent at 90 dB, but it remained reliable at 30 dB. These data have some practical significance for using reflex modification procedures for audiometry. With other reports, they suggest that the degree of stimulus laterality is a perceptual attribute to which reflex control is sensitive.

The expression of simple reflexes in humans and other species is affected by the occurrence of innocuous and apparently unrelated stimuli just prior to reflex elicitation (e.g., Bowditch & Warren, 1890; Cohen, Hilgard, & Wendt, 1933; Graham, 1975; Hoffman & Fleshler, 1963; Ison & Hammond, 1971; Krauter, Leonard, & Ison, 1973; Yerkes, 1905). Polysynaptic reflexes such as the acoustic startle reflex in the rat or the bilateral cutaneous eye blink reflexes in the human are inhibited by brief stimuli presented at appropriate times before the reflex-eliciting stimulus. In the numerous parametric manipulations of the characteristics of these preliminary stimuli, the major focus has been on their quantitative intensive variation. One of the major outcomes of this research is the repeated demonstration that from near-threshold values on up to stimulus intensities that are effective in eliciting reflexes, there is a systematic monotonic increase in the inhibitory control produced by the first stimulus (Hoffman & Ison, 1980). A recent finding of Marsh, Hoffman, and Stitt (1976) is especially highlighted by this background. They found that monaural auditory prestimulation was a more effective inhibitor of the cutaneous eye blink reflex in humans than was binaural stimulation. Typically, binaural stimuli are judged as being louder than monaural stimuli, at least in the absence of in-phase masking noise (Licklider, 1951). Thus some other characteristic of a monaural stimulus must also contribute to reflex control in sufficient strength to more than make up for the deficiency in stimulus intensity.

Our experiment verified these findings of Marsh et al. (1976) and replicated them at near-threshold stimulus intensities. The reason for doing the experiment was the need to know more about the consequences of procedural variation in studies of reflex modification. This is a necessary prelude to extending the procedures for the study of sensory dysfunction (Marsh, Hoffman, & Stitt, 1978; Reiter & Ison, 1977) and was the basis for the original Marsh et al. (1976) experiment as well. In reflex experiments auditory stimuli are usually presented "free field" or under binaural conditions. Clinical studies of sensory thresholds are typically concerned with assessing each ear separately and therefore use monaural earphone presentation. A question of some practical importance, then, is whether monaural stimuli might not yield some peculiar effects that restrict the applicability of the reflex procedures for these purposes. It is then significant that the findings of Marsh et al. (1976) reveal that the reflex is especially sensitive to monaural stimuli and, thus, suggest that the phenomenon may be particularly well suited to the requirements of clinical testing. But effects obtained with intense stimuli, 70 dB over threshold, may not occur at near-threshold values, especially as binaural summation appears to be more important with weak rather than intense stimuli (Falmagne, Iverson, & Marcovici, 1979). Because sensory testing would necessarily be most concerned with preliminary stimuli near the sensory threshold, we thought that it would be valuable to examine the phenomenon again.

The reflex used in this investigation was the cutaneous eye blink elicited by an electrical shock (S2) to the forehead over a branch of the supraorbital trigeminal nerve. When measured electromyographically, the ensuing response has a very characteristic form. On the

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side ipsilateral to the shock, there are two response components (Kugelberg, 1952). The first, R1, occurs about 10 msec after S2 and is relatively brief. The second, R2, has a latency of about 35-40 msec and a duration of about 50 msec. Only one response component, sharing latency and duration characteristics with R2, occurs on the contralateral side. Preliminary stimuli enhance R1 and diminish R2, each of these effects increasing linearly with increases in the strength of S1 (Sanes & Ison, 1979).

METHOD

Subjects

Six adult volunteers, five female and one male, were used. None had any known hearing impairment or neurological disturbance.

Apparatus

The subject sat comfortably in a barber shop chair housed within a double-walled sound-attenuating chamber (IAC) approximately 3 x 2 x 2 m. The subject was monitored over closed circuit TV. During the experiment subjects watched silent cartoons on a second closed circuit TV. Acoustic stimuli were delivered through TDH-39 earphones. They were 1-kHz tones, provided by a Hewlett-Packard oscillator, and gated through an electronic switch. The signals were amplified, then delivered to left, right, or both earphones following passage through a relay circuit controlled by the electronic switch. Electrotactile stimuli were used to elicit the eye blink reflex. They were provided by a Grass biomedical stimulator (SD5) and constant-current unit (CCU1) and delivered to the skin through two surface electrodes (Beckman miniature Ag/AgCl) placed on the forehead over the supraorbital branch of the trigeminal nerve (at a site at which a probe stimulus was felt at its lowest intensity as a tingle across the scalp). Durations of the tones and the interval between tones and shock were set by electronic timers. Intensities were controlled by a Daven attenuator network and measured on a General Radio sound-level meter (A-range) using a General Radio phone coupler. Other surface electrodes placed over the inferior orbicularis oculi muscles picked up neuromuscular activity. This was fed through FET preamplifiers to Grass differential amplifiers with half-amplitude settings of 30 Hz to 10 Hz. The EMG signal was observed on a Tektronix storage CRT and stored on magnetic tape for off-line integration.

Procedure

The subjects were first set up with surface stimulating and recording electrodes. Following standard procedures two surface nonpolarizing electrodes were fixed with adhesive disks to the skin overlying the orbicularis oculi muscles, one electrode just lateral to the temporal canthus and one just below and medial to it. Activity in both left and right eyes was measured. Two stimulating electrodes of the same type were placed on the skin over one eye, left or right randomly across subjects, following the procedure described above. In approximation, the sites of these electrodes were on a line vertical to the pupil in forward gaze, about 1 cm and 2 cm above the brow. A ground electrode was placed on the temple midway between stimulating and recording sites. Electrode impedances were less than 10 kohm. The tone stimuli were 25 msec long, including 5-msec rise and decay times. Their intensities were 30 dB and 90 dB (re 20 microN/m^2; a rapid threshold measurement using two or three runs of the method of limits conducted at the end of each session indicated that these were about 5-10 and 65-70 dB over sensation level). The eliciting stimuli were .5-msec square-wave shocks just sufficient to elicit reliably the two components of electromyographic activity characteristic of the cutaneous eye blink reflex (e.g., Kugelberg, 1952; Sanes & Ison, 1979; Shahani, 1970).

The interval between the tones and the shock was 100 msec, and the interval between successive trials ranged from 20 to 45 sec. Seven kinds of trials were given. One type was just the shock, which established a control baseline. The other six were formed of the factoral combination of two intensities (30 and 90 dB) and three methods of delivery (left ear, right ear, and both ears together). Trial types were ordered from 7 x 7 Latin squares in which each type appeared once in each row and each column. In the analysis of the ensuing responses, each subject's mean integrated control response (shock alone) in millivolts was set at 100, and his or her mean responses in each of the other conditions was then expressed as a percentage of the control value. In addition, the occurrence of electromyographic activity associated with each initial stimulus (i.e., in the 100-msec interval prior to the shock) was noted.

RESULTS

Amplitudes of the reflex when preceded by monaural or binaural tones are given in Table 1. For the major response component, R2, it can be seen that the 90-dB stimulus was more inhibitory than the 30-dB stimulus and that the monaural stimulus was more inhibitory than the binaural stimulus. For R1 the tones were facilitatory, the 90-dB tone more so than the 30-dB tone, and the monaural tone was slightly more effective than the binaural. An analysis of variance of the R2 responses yielded significant effects of intensity [$F(1,5) = 11.59$, $p < .05$] and stimulus location [$F(1,5) = 16.05$, $p < .05$], as well as their interaction [$F(1,5) = 16.75$, $p < .01$]. The effect of stimulus location was more evident with the stronger stimuli, although it may be seen that the difference obtained with the less intense stimuli remained significant [$t(5) = 2.81$, $p < .05$]. Subsequent tests of the differences between control values and the several paired values were performed. Both monaural and binaural stimuli were inhibitory at 90 dB [monaural $t(5) = 6.12$, $p < .01$; binaural $t(5) = 3.30$, $p < .05$], but only the monaural stimuli were reliably inhibitory at 30 dB [monaural $t(5) = 2.68$, $p < .05$; binaural $t(5) = 1.14$, n.s.]. Analysis of R1 yielded only a significant effect of intensity [$F(1,5) = 8.80$, $p < .05$], and only the 90-dB stimuli were facilitatory [$t(5) = 2.92$, $p < .05$]. One subject responded

Table 1

	90 dB			30 dB		
	M	B	t(B–M)	M	B	t(B–M)
R2	43.8	60.2	4.94*	84.1	92.9	2.81**
R1	183.4	171.3	n.s.	111.8	109.1	n.s.

Note–Reflex amplitudes are expressed as mean percent control amplitude for the first unilateral response component (R1) and the second bilateral component (R2) and for monaural and binaural stimuli at 30 dB and 90 dB SPL. Statistical analysis is of monaural vs. binaural conditions (t tests).

*$p < .01$. **$p < .05$.

occasionally to the 90-dB stimuli, on 4 of 7 trials to the binaural stimuli, on 4 of 14 trials to the monaural stimuli. No subject responded with lateralized responses to the preliminary stimuli, nor was there any suggestion of lateralized reflex control.

DISCUSSION

The outcome of major significance in these data is that the advantage of the monaural stimulus was present with the near-threshold stimulus. Thus the findings of Marsh et al. (1976), showing that monaural stimuli are more inhibitory than binaural stimuli, are not restricted to their use of relatively intense stimuli. The practical implication of this outcome is that the method for obtaining reflex modification is suitable to the clinical requirement for assessing sensory function in each ear separately. Indeed, the monaural stimulus presentation makes the test somewhat more sensitive than the usual binaural technique. It was seen that the relative effectiveness of the monaural stimulus was reduced with 30-dB stimuli, compared with the 90-dB stimuli. One possible explanation of this, in line with the arguments of Falmagne et al. (1979), is that with the weaker stimuli loudness summation would be more important and might have partially offset the advantage of the monaural stimulus. A second explanation is afforded in recent data provided by Hoffman and Stitt (in press). They show that the monaural effect is an extreme of a binaural disparity continuum, in which as the stimuli delivered to the two ears are made more disparate in intensity, the amount of resulting reflex inhibition is increased. In the present experiment the "binaural disparity" of the intense monaural stimulus was 90 dB, whereas that of the weaker stimulus was but 30 dB, and, thus, its relative effectiveness as a monaural stimulus would necessarily be reduced. These two hypotheses are not exclusive, and both could contribute to the observed outcome.

Monaural stimuli yield a perception of laterality that is independent of other attributes of an acoustic stimulus, such as its loudness or pitch. Both changes in loudness and changes in pitch produce graded amounts of reflex inhibition systematically related to the magnitude of the change (Marsh, Hoffman, Stitt, & Schwartz, 1975; Stitt, Hoffman, & Marsh, 1973). A similar result for binaural stimuli of different degrees of disparity and, therefore, presumed laterality, has been found recently by Hoffman and Stitt (in press). Their data reveal, then, that degree of laterality is a perceptual attribute to which reflex inhibition is sensitive. At present, we can only speculate on the possible basis for this effect, but we suggest it may have something to do with the greater potential orienting response demands of lateralized compared with midline stimuli.

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