Facilitation of human startle eyeblink responses by pure-tone background stimulation¹

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This study investigated the facilitatory effects of pure-tone background stimulation on the human startle response. Startle eyeblink responses of 13 subjects to an intense white noise were measured under four conditions: silence condition and pure-tone background stimulations at one of three intensities (65, 75, or 85 dB). Amplitudes of startle responses were increased with the background stimulation and the extent of amplitude facilitation was positively related to the intensity of the background stimulus. Although the onset latency of startle was also shortened with the background stimulation, no change was shown with the increase of the background stimulus intensity. These results were discussed and compared with the previous studies in rats.

Key words: startle, background acoustic stimulation, facilitation, human eyeblink response, eyeblink amplitude, eyeblink onset latency.

In previous investigations (e.g., Hoffman & Fleshler, 1963), it was found that the amplitude of the rat's acoustic startle reaction was larger when testing occurred in a background of steady acoustic stimulation than when in silence. This facilitation phenomenon is found whether a background of acoustic stimulation is broad-band random noise or pure tone, since it is independent of the frequency components of the background stimulus (Hoffman & Searle, 1968). However, it is dependent on the intensity of the background stimulus. It is generally found that startle responsivity is an inverted U-shaped function of background stimulus intensity (e.g., Ison & Hammond, 1971), although the peak of the function differs from study to study.

Recently Putnam (1977) investigated this facilitation phenomenon in human eyeblink startle and found that the relationship between background noise in-

tensity and startle responsivity was inverted U-shaped. Thus, his study seems to suggest that the phenomena which have been found in rats would be also found in humans. So the present experiment was designed to investigate: (1) whether the amplitude of the human acoustic startle reaction would be facilitated by pure-tone background stimulation; and (2) whether it would be an inverted U-shaped function of the intensity of pure-tone background stimulation.

Furthermore, the present experiment investigated the latency modification of the startle reaction by background acoustic stimulation. Although it is commonly observed that the larger the startle amplitude, the shorter the startle latency, the latter sometimes changes independently of the former. For example, it is well-known that amplitude inhibition and latency reduction in startle are independent phenomena in the lead-stimulation effects on startle (cf. Hoffman & Ison, 1980). It might be possible that latency and amplitude would be modified independently of each other under the influence of background acoustic stimulation

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Method

Subjects

The subjects were 13 undergraduates (four males and nine females), who all had normal hearing. Mean age was 19.7 with a range of 19–21 yrs.

Apparatus

Recording of responses. The startle eyeblink response was measured by an electrode hookup according to Osborne, Roach, Gendreau, and Gendreau (1974). The electrical hookup used Nihon Kodens Sintered Ag/AgCl miniature skin electrodes. The electrodes were placed on the left side of the subject's face; the active electrodes were placed just above the eyebrow and just below the cheekbone, beside the nose; a ground electrode was placed on the fleshy part of the cheek. Attachment of the electrode was made with Beckman electrode paste and Nihon Kodens collars. The electrodes were coupled to a San'ei Model 1117 amplifier (TC 1.5 s) and recorded by a San'ei pen-galvanometer (Rectigraph 8S). The analog output of the amplifier was digitized to μV units by Micro Networks ADC80AG-12 A/D converter and then analyzed by a Fujitsu L-kit 8 microcomputer. The startle eyeblink response was picked up if its onset latency was from 20 to 120 ms and if its peak latency was within 150 ms. The digitized response amplitude was transformed into a logarithmic scale according to Yamada, Yamasaki, Nakayama, and Miyata (1980).

Stimulus conditions. The startle stimulus was a 50-ms burst of white noise at an intensity of 110 dB. The background stimulus was a 1000-Hz pure tone at an intensity of either 65, 75, or 85 dB. The subjects were exposed to the background stimulus for 4 s prior to the startle stimulus, which is a long enough period to facilitate startle (Hoffman & Wible, 1969). These stimuli were gated on and

off with rise and decay time less than 1 ms, controlled by a National reed relay NR-H-5V and presented via Pioneer SE-525 headphones. The intensity level of these stimuli was monaurally measured on the C scale of a Rion NA-20 sound-level meter at the headphones. Stimulus presentation and timing were controlled by a Fujitsu L-kit 8 microcomputer.

Procedure

Each subject, seated in a comfortable chair in a sound-attenuating chamber of $215 \times 135 \times 177$ cm, was told to continue looking at the fixation point located about 1.3 m in front of him or her approximately at eye level. Further, he or she was told which kinds of stimuli would be presented, and the presentation relationship between a pure-tone background stimulus and a white-noise startle stimulus was explained to the subject. This instruction was given to exclude startle facilitation by great uncertainty of startle stimulus presentation (Yamasaki, Yamada, & Miyata, 1980). The startle stimulus was presented in the silence condition (i.e., about 50-dB ambient level of the chamber) or with the pure tone background at one of three intensities: 65, 75, or 85 dB. Thus, the four kinds of stimulus presentations were

Fig. 1. Mean eyeblink amplitude as a function of the intensity of background stimulation.

involved in the present experiment. The subject received two blocks of stimuli; blocks were separated by 5 min rest. In each block, following one presentation of the startle stimulus in the silence condition, four presentations of each of the four conditions (silence, 65-, 75-, or 85-dB condition) were given in a random order. The intertrial interval varied from 28 to 42 s in one-second steps. The first presentation of the startle stimulus in the silence condition in each block received no analysis, since the unusually large responses sometimes occur on the initial trials (Ison, 1978).

Results

Amplitude of Eyeblink Responses

Figure 1 shows the mean eyblink amplitude to the startle stimulus, collapsed over both blocks, at each of the four conditions. The amplitude in the silence condition was significantly smaller than that in the other three conditions (silence vs. 65-dB condition, $t(12)=2.29$, $p<.05$; silence vs. 75-dB, $t(12)=2.38$, $p<.05$; silence vs. 85-dB, $t(12)=3.43$, $p<.01$).³ These results indicate that the amplitude of the human acoustic startle reaction is also facilitated by pure-tone background stimulation.

More important, however, was that the amplitude increased with an increase in the intensity of the background stimulus. An overall analysis of variance revealed a significant difference among the three conditions (i.e., 65-, 75-, and 85-dB conditions), $F(2, 24)=3.42$, $p<.05$, and a significant linear trend of the amplitude as a function of the intensity of the background stimulus, $F(1, 25)=13.26$, $p<.005$.

Onset Latency of Eyeblink Responses

Figure 2 shows the mean eyblink

onset latency, collapsed over both blocks, at each of the four conditions. The latency in the silence condition was significantly longer than that in the other three conditions (silence vs. 65-dB condition, $t(12)=2.76$, $p<.05$; silence vs. 75-dB, $t(12)=2.73$, $p<.05$; silence vs. 85-dB, $t(12)=3.83$, $p<.01$). These results indicate that the latency of the human acoustic startle reaction is facilitated by puretone background stimulation. However, an overall analysis of variance revealed no significant difference among the three conditions (i.e. 65-, 75-, and 85-dB conditions), $F(2, 24)=1.18$.

Discussion

The results of the present experiment indicate that both startle amplitude and onset latency are facilitated by pure-tone background stimulation. Startle amplitude linearly increased as the intensity of the background stimulus was raised from 65 dB to 85 dB, while onset latency showed no change with the increase in the intensity of the background stimulus.

It is reasonable that the relationship between background stimulus intensity and startle amplitude would be inverted U-shaped, since startle will hardly occur when the intensity of the startle stimulus

Fig. 2. Mean eyblink onset latency as a function of the intensity of background stimulation.

³ In this and subsequent usage, the term "significant" refers to $p<.05$.

and the background stimulus is identical. If the more intense background stimuli are employed, the inverted U-shaped relationship will be obtained even in the present experimental conditions. At any rate, the function relating startle amplitude to background stimulus intensity would peak at the more intense level than 85 dB in the present experimental condition, which is a very high intensity level compared with the other studies (e.g., Ison & Hammond, 1971).

Davis (1974) indicated that this function was determined by the signal-to-noise ratio (defined as startle stimulus intensity minus background stimulus intensity), and that the level to which the subjects were habituated to the startle stimulus influenced at which signal-to-noise ratio it peaked. That is, the more habituated the subjects are to the startle stimulus, the lower the intensity of the background stimulus at the peak of the function. The determinants of habituation are in fact numerous: in addition to the number of the stimuli given, stimulus intensity, duration and so on would also influence habituation. And it is very natural that the startle habituation in humans should be different from that in rats. Moreover, it should be pointed out that pure tone and white noise would be subtly different in their characteristics as background stimulation. These points considered, the parametric features of startle facilitation by pure-tone background stimulation in humans should be investigated in future studies.

Startle onset latency is generally shorter with larger startle amplitude, which is consistent with the present result that startle onset latency was much shorter in pure-tone background stimulation. However, startle onset latency showed no significant change as the intensity of the background stimulus was raised from 65 dB to 85 dB, which is inconsistent with the results obtained from the startle amplitude data. Startle onset latency seems to be little influenced by changes in the

intensity of background stimulation. Onset latency and amplitude might be evaluated independently of each other in startle modification studies.

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