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Tests of a principle of reflex modification: Modification of the human eyeblink-reflex is independent of the intensity of the reflex-eliciting stimulus

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The human airpuff-elicited reflexive eyeblink, like the startle reflex of rats and pigeons, occurs with either reduced amplitude or latency when a brief auditory stimulus precedes the reflex-eliciting event by an appropriate lead interval. In common with the overt startle reflex of lower animals, the degree of inhibition or latency reduction of an airpuff-elicited eyeblink in human adults proved to be independent of the intensity of the eyeblink-eliciting airpuff. This finding supports the principle that the amount of a given reflex modification effect (whether latency or amplitude reduction) is determined by the parameters and lead time of the modifying stimulus and not by those of the reflex-eliciting event.

It is well established that a variety of reflexes may be modified by stimuli which do not themselves elicit those reflexes. These interactions have been documented extensively in the case of the abrupt crouching reactions that characterize the acoustic startle reflex in the rat, the light-elicited startle of the pigeon (Stitt, Hoffman, Marsh, & Schwartz, 1976), and the reflexive eyeblink in humans (Krauter, Leonard, & Ison, 1973). In all of these species, mild sensory stimulation preceding the more intense reflex-eliciting stimulus may affect the response to the intense stimulus in at least two ways. (1) The response is inhibited when a brief faint flash of light or burst of noise precedes the eliciting stimulus by 60-2,000 msec (Buckland, Buckland, Jamieson, & Ison, 1969; Hoffman & Searle, 1965; Hoffman, & Wible, 1970; Ison & Hammond, 1971; Schwartz, Hoffman, Stitt, & Marsh, 1976; Stitt, Hoffman, & Marsh, 1976). (2) If a noise burst or light flash of low intensity precedes the eliciting stimulus by a short interval, less than 5-20 msec, the latency of the response is reduced while the amplitude of the response remains unchanged (Hoffman & Searle, 1968; Schwartz et al., 1976; Stitt, et al., 1976b).

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The research reported here was designed to examine further both of these effects. In particular, it asked how they were influenced by the intensity of the reflex-eliciting stimulus. Previous investigations provide a preliminary answer to this question. They reveal that, with the whole-body acoustic startle reaction of the rat, both the reduction in response amplitude (i.e., the inhibitory effect) produced by a prior stimulus with an appropriately *long* lead time and the reduction in response latency engendered by a prior stimulus with an appropriate *short* lead time are independent of the intensity of the reflex-eliciting acoustic signal (Stitt, Hoffman, & Marsh, 1976).

The present investigation asked whether the same pattern of results would emerge in an analysis of reflex modification in man when the target reaction was an airpuff-elicited eyeblink. In view of the previously reported similarities in reflex modification effects in different species and with different target reactions, it seemed possible that it would. It also seemed clear that such findings would provide strong presumptive evidence for what may prove to be a basic principle of reflex modification. Namely, that with a given reflex modification procedure the nature and amount of reflex modification will be determined by

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the lead time and parameters of the reflex modifying event and not by the characteristics of the reflex-eliciting stimulus.

EXPERIMENT 1

This study was designed to determine how the amount of amplitude reduction engendered by an acoustic signal presented prior to an eyeblink-eliciting airpuff would vary as a function of the intensity of the airpuff.

Method

Subjects. Ten undergraduate and graduate students participated in this experiment. Any student whose hearing threshold for a 1-kHz tone was more than 10 dB above the American National Standards Institute (ANSI, 1969) norms for young, otologically normal adults was excused from participation.

Apparatus. The device for generating the eyeblink-eliciting airpuff was an air-suspension acoustic speaker, modified to produce a highly reliable airpuff. The diaphragm of the speaker was coated with silicone rubber, and the speaker was enclosed in such a way that displacement of the diaphragm forced air through a tube leading to the subject. The airpuff was generated by charging a bank of capacitors (400 μF) to 200 V, then discharging them through the modified speaker by means of a silicon-controlled rectifier with a 1-H inductance in series to filter out audio-frequency components from the current surge. An 8-Ω attenuator was constructed to permit adjustment of the airpuff intensity without affecting the current through the solid-state capacitor discharge circuit or the waveform of the airpuff. With the modified speaker device at maximum intensity, the airpuff exerted a peak force of 2,100 N/m^2.

The eyeblink was measured with a modified d'Arsonval meter fastened to the end of an air delivery tube. The pointer on the meter was extended with a length of polyethylene tubing which was taped to the eyelid. This unit translated movements of the eyelid into rotation of the meter coil in a magnetic field and generated a voltage proportional to the velocity of the motion. This voltage was amplified, rectified, and measured by a digital voltmeter with storage capability. The measure described here is the derivative of displacement, which is the traditional measure, but the two measures covary through a large range (Hilgard, 1933).

To simplify preparation of the subject, the airpuff delivery tube, ear-phones, and response transducer were combined in a single assembly. The delivery tube was attached to the earphone headset by a specially designed clamp which permitted adjustment of the tube so that the airpuff would strike the subject's face just lateral to the eye. The response transducer was attached to the end of the tube at an angle such that its housing would rest on the edge of the orbit and the polyethylene sleeve on the pointer would extend to the center of the upper eyelid, just above the eyelashes.

The tones which served as antecedent stimuli were generated by controlling the output of a Hewlett-Packard Model 200AB audio oscillator with a Grason-Stadler electronic switch (Model 829-d). The auditory stimuli were fed through attenuators and then delivered through TDH-39 earphones fitted with MX-41/AR cushions.

Grason-Stadler Model 471-1 interval timers controlled the durations of prestimuli as well as their lead times, measured as the interval between arrival of the leading edge of the prestimulus and the leading edge of the airpuff through the tubing from its generator to the subject. Appropriate solid state and relay circuitry operated the airpuff generator under the control of the interval timers.

The research was conducted in an IAC double-wall sound-treated room with an ambient noise level below 25 dBA. This chamber was suitably furnished and lighted, and equipped with a rear-projection screen so that 35-mm slides could be projected from the control room. A closed-circuit television camera and an intercom permitted continuous monitoring of the subject.

Procedure. After a subject had been apprised of the nature of the research and had agreed to participate, he or she was seated in the chamber and fitted with the headset holding earphones, airpuff delivery tube, and response transducer. The subject's threshold for a 1-kHz tone was then determined by the method of Carhart and Jerger (1959), with this clinical technique being modified so that test tones were varied in increments of 2 dB rather than 5 dB.

Each subject was then tested with airpuff intensities of 20%, 40%, 60%, 80%, and 100% of the maximum intensity available. At each intensity, the airpuff was presented both in silence and preceded by a brief (20-msec) 70-dB SL, 1-kHz binaurally presented tone (rise-fall time, 2.5 msec). For these stimuli, the interval between tone onset and the presentation of the airpuff was 100 msec.

During the experimental session, stimuli (airpuff alone or airpuff preceded by a tone) were presented in random order at intervals of 30 sec. Each stimulus was presented six times. To combat boredom, 35-mm color slides of paintings or nature subjects (wild animals, scenic views, etc.) were shown to the subject on the rear-projection screen in the chamber. Slides were changed a few seconds after each trial.

Results and Discussion

Figure 1 shows the mean amplitude, averaged across subjects, of eyeblink responses produced in each of the 10 experimental conditions. A Treatment by Treatment by Subjects analysis of variance was used to evaluate the reliability of the observed trends. As expected, this test revealed a significant effect of reflex-eliciting stimulus intensity [$F(4,36) = 14.49$, $p < .01$] and a significant effect of the prestimulus vs. silence manipulation [$F(1,9) = 5.74$, $p < .01$]. These findings parallel the earlier cited investigations which have revealed that reflex amplitude is an increasing function of the intensity of the eliciting stimulus and that the presentation of an appropriate

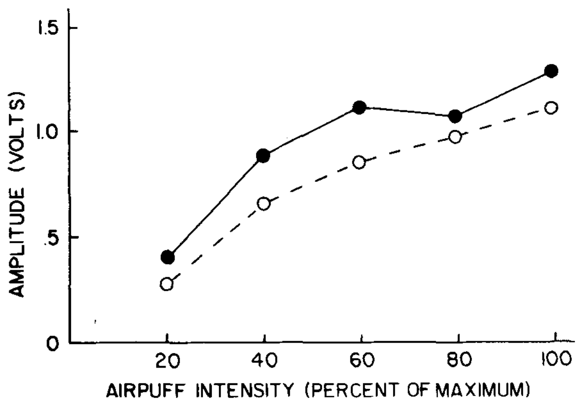

Figure 1. Amplitudes of eyeblinks elicited by airpuffs of various intensities with (dotted line) and without (solid line) inhibitory auditory prestimulation. The maximum airpuff intensity was 2,100 N/m^2. (The standard errors around each point ranged from .098 to .258, and the mean standard error was .190.)

prestimulus produces a reduction in response amplitude.

Finally, and most importantly, the data indicated no interaction between the intensity of the reflex-eliciting stimulus and the prestimulus factor [$F(4,36) < 1$]. The absence of a significant interaction term indicates that inhibition is a subtractive process—a prestimulus with an appropriate lead time reduces the amplitude of the eyeblink response by an amount that is independent of the intensity of the eliciting stimulus. This finding parallels the previously cited work with rats as subjects and supports the hypothesized basic principle of reflex modification.

EXPERIMENT 2

This study was designed to determine how the amount of latency reduction engendered by an acoustic signal presented prior to an eyeblink-eliciting airpuff would vary as a function of the intensity of the airpuff.

Method

Subjects. Ten undergraduate and graduate students participated in this experiment. As in Experiment 1, any subject whose hearing threshold was below the ANSI norms was excused from participation.

Apparatus. The arrangement of the equipment was as in Experiment 1, with the exception that the output of the eyeblink monitoring device was sent to a Heath-Schlumberger electronic timer which was used to measure response latencies. Auxiliary circuitry synchronized the beginning of the timing cycle to the arrival of the airpuff at the subject's face prevented any interference from stimulus artifacts, and permitted adjustment of the timer's threshold for recognition of a response. A storage oscilloscope permitted monitoring of the response and verification of the accuracy of the electronic measurements of response latencies.

Procedure. As before, subjects were briefed, fitted with the apparatus and tested for auditory threshold. Also, as before, each subject was tested with airpuffs at intensities that were 20%, 40%, 60%, 80%, 100% of the maximum intensity available. Again, at each intensity the airpuff was presented both in silence and preceded by a brief 70-dB SL, 1-kHz tone. This time, however, the tone had a fast (nominally .1 msec) rise-fall time and a duration of only 16 msec. When tones were presented, tone onset always began 16 msec before the airpuff and tone terminated with puff onset. Once more, the subjects received the various stimuli in random order at intervals of approximately 30 sec until each of the stimuli had been presented six times. Also as before, the subjects viewed colored slides throughout this procedure.

Results and Discussion

Figure 2 shows the mean latency, averaged across subjects, of the eye-blink response generated by each stimulus configuration. Again a Treatment by Treatment by Subjects analysis of variance was used to evaluate the reliability of the observed trends. As expected, the latency of the response to the airpuff was reliably reduced by the presentation of tone [$F(1,19) = 27.50$, $p < .01$], and latency was reliably reduced by increases in airpuff intensity [$F(4,40) = 70.26$, $p < .01$]. Moreover, the data indicate no evidence of an interaction between the presence or absence of a latency-reducing prestimulus (the tone) and the intensity of the reflex-eliciting event (the airpuff) [$F(4,40) = 1.22$, $p > .05$]. As with Experiment 1, this finding also parallels the previously cited work using rats as subjects. It thus provides additional support for the hypothesized basic principle of reflex modification elaborated earlier.

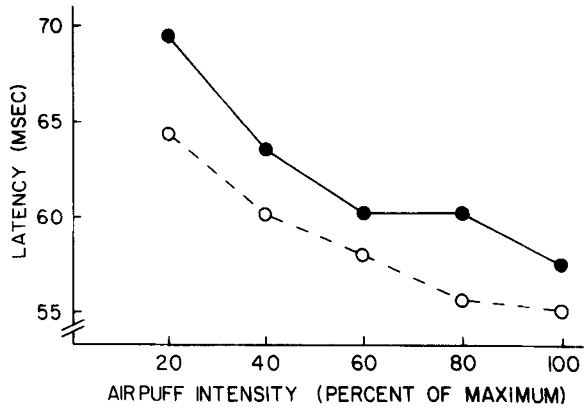

Figure 2. Latencies of reflexive eyeblinks elicited by cutaneous airpuffs of various intensities with (dotted line) and without (solid line) latency-reducing auditory prestimulation. The maximum airpuff intensity was 2,100 N/m^2. (The standard errors around each point ranged from 2.56 to 1.56, and the mean standard error was 2.00.)

Like any other principle, the principle of reflex modification is subject to further test, but even at its present stage of verification, it has a clear implication. The principle of reflex modification asserts that the amount of a given effect (whether latency or amplitude reduction) is determined by the parameters of the reflex-modifying event and not by those of the reflex-eliciting stimulus. This implies that it would be misleading to express the amounts of amplitude or latency reduction engendered by a given reflex-modifying event as a percentage or proportion of the reaction to the reflex-eliciting stimulus. To do so would yield large percentages when the reflex-eliciting stimulus was moderate and elicited only a moderate reflex, and it would yield small percentages when the reflex-eliciting stimulus was intense and elicited large reflexes. Clearly, such a result would lead one to suppose that the amount of reflex modification was determined, at least in part, by the intensity of the reflex-eliciting stimulus, and as revealed here (and elaborated by the reflex-modification principle) this is clearly not the case.

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