Research Report

STARTLE REFLEX MODIFICATION: Effects of Attention Vary With Emotional Valence

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Abstract—*This report examines the concurrent effects of manipulating attentional focus and emotional context on human blink reflex modulation. Eyeblink reflexes were elicited by air puffs or noise bursts from two groups of subjects while the focus of attention was manipulated. Emotional context was varied by changing the description of the air-puff stimulus between groups, all other protocol parameters were identical. Blink amplitude varied directly with the allocation of attention resources across sensory modalities in the neutral affective context. In the negative context, a general reflex facilitation was augmented when attention was focused on the aversive stimulus. These results indicate that the emotional context can affect the expression of attentional mechanisms involved in modulation of the eyeblink reflex.*

In work reported over the past two decades, modulation of the human blink reflex has been variously conceptualized as either attentional or affective in nature. Studying the effects of attentional modulation, Graham and her colleagues have reported that the blink reflex varies directly with the allocation of attentional resources. The reflex is facilitated when it is elicited by a stimulus presented to the same sensory modality as that to which attention is directed, complementarily, reflex inhibition occurs when the modalities of attentional focus and stimulus presentation mismatch (Anthony, 1985, Anthony & Graham, 1983, 1985, Bohlin & Graham, 1977, Graham & Hackley, 1991, Hackley & Graham, 1983, 1987, Silverstein, Graham, & Bohlin, 1981). This attentional effect has been reported primarily with adults, but has also been observed with 16-week-old infants (Anthony & Graham, 1983).

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The alternative conceptualization is based on the proposition that a given reflex is facilitated when the reflex valence and the emotional state of the organism match and is inhibited when the reflex valence and state mismatch (Bradley, Cuthbert, & Lang, 1990, 1993, Lang, Bradley, & Cuthbert, 1992, Vrana, Spence, & Lang, 1988). Thus, in the case of a defensive reflex such as the startle response, an elicited reflex eyeblink is facilitated when a foreground stimulus evokes a negative emotional state (such as fear) and inhibited when the foreground stimulus evokes a pleasant emotional state.

Intuition suggests the likelihood that the same humans who show startle reflex modulation resulting from the manipulation of either attentional or emotional factors individually also experience both of these processes simultaneously during the course of day-to-day existence. What is not obvious is whether the concurrent effects of these processes are simply additive or interact in a more complex fashion. The startle reflex provides the experimental opportunity to examine this question.

The paradigm used in this experiment was adapted from those used by Graham and her colleagues (e.g., Hackley & Graham, 1983). Although primarily used to study attentional modulation of the reflex, it has also produced results suggestive of affective modulation (Haerich, 1989, Haerich & Berg, 1992). A duration discrimination task in which subjects were instructed to judge the duration of a given stimulus type (either air puffs or noise bursts) was used to focus attention toward a specific sensory modality while blink reflexes were elicited, on individual trials, by stimuli that matched or mismatched the attended modality. The task instructions given each subject were constructed so as to either reinforce or deemphasize the subject's perception of the potential harmfulness of one stimulus and therefore the emotional context of the experimental situation.

The manipulation of both the stimulus description and attentional focus leads to specific hypotheses. If neither Stimulus A nor Stimulus B is perceived as aversive, then reflex modulation should vary with the allocation of attentional resources, with facilitation being observed when the modality of the eliciting stimulus matches that toward which attention is directed, as compared with the mismatch condition. If, alternatively, Stimulus A is perceived as potentially harmful, then a general facilitation of blink reflexes should be observed. If the effects of attentional focus in the negative context are measurable, (a) they may be simply additive, such that further reflex modulation following the match-mismatch distribution of attentional resources would be superimposed on the general facilitation, or (b) they may augment the effects of the negative context in a manner that is not simply additive, such that, regardless of the modality of the eliciting stimulus, reflexes elicited when subjects are anticipating the presentation of (the putatively harmful) Stimulus A would be facilitated in comparison with those elicited when Stimulus B is anticipated.

METHODS

Forty-nine undergraduate students with a median age of 19 years were recruited from the La Sierra University Subject Pool. Each subject was assigned in counterbalanced order to one of two groups.[1] For one group (the eye group),

1. An additional 17 subjects were tested but excluded from the analyses because of equipment problems ($n = 5$), failure to get reliable physiological measures ($n = 9$), experimenter error ($n = 2$), and an unannounced fire-alarm test that disrupted the session ($n = 1$). Failures in physiological measures most commonly resulted from excessive movement of the subject that made accurate photoplethysmographic measurement of heart rate impossible.

the air puffs were described as being directed "near the eye", for the other group (the ear group), the air puffs were described as being directed "toward the ear" In fact, the location and intensity of the air puffs were identical for all subjects irrespective of the description provided in the instructions All other aspects of stimulus presentation and data collection were also constant across the two groups

The duration discrimination paradigm used in this experiment presented each subject with 100 trials (two sets of 50 trials each) Each trial consisted of a target, blink-eliciting stimulus (TS, an air puff or a noise burst) preceded by a visual warning stimulus (WS) During one set of 50 trials, subjects were instructed to discriminate air-puff durations while ignoring noise bursts The instructions were reversed for the other set of 50 trials The order of instructions was counterbalanced within each group of subjects Each set of 50 trials was composed of 25 air puffs and 25 noise bursts, including 5 trials of each stimulus type in which the WS was omitted [2] On a given trial, the TS could be equiprobably a burst of white noise or an air puff The trials were arranged so that every block of 10 trials contained two long-duration, two short-duration, and one unwarned stimulus of each type, in random order The mean intertrial interval was 20 s (range 18–22 s)

Subjects were told that the WS would signal the beginning of a trial and would indicate that they should "be ready for" and "concentrate on" the stimulus that would occur "a few seconds" later Subjects were informed that the other, nontarget, stimulus would sometimes occur, but that if it did, they should ignore that stimulus and need not report a duration judgment Subjects were not required to produce a speeded response and reported their responses using hand signs that the experimenter observed through a two-way mirror

Noise bursts were presented binaurally via headphones at 100 dB(A) with 5-ms rise and fall times, the bursts were presented for 100-ms and 110-ms durations, the short and long durations for the discrimination task, respectively Air for the air puffs was regulated at 25 kPa (constant outflow at 58 cc/s) and gated by a solenoid valve through 4 m of plastic tubing (inner diameter = 4 mm) The air flow was directed so that it struck the subject's left temple, 1 5 cm lateral to the outer canthus, at an oblique angle toward the left ear Air puffs were presented at 75-ms and 110-ms durations, the short and long durations for the discrimination task [3] The WS (duration = 1 s), a green light-emitting diode located 0 75 m in front of the subject, preceded the TS by a constant 6 s (onset to onset)

After each set of 50 trials, subjects reported the feelings of pleasantness, interest, and perception of task difficulty that they experienced while anticipating the TS (i e , during the WS–TS interstimulus interval), these reports were made using three analog-visual scales, and data are reported as the proportion of the full scale value

The electromyogram (EMG) of the *orbicularis oculi* muscle was measured by taping miniature Ag/AgCl electrodes to the lower left eyelid just superior to the orbital bone (center-to-center distance = 13 mm) The signal was amplified, filtered (bandpass 0 1 Hz to 1 kHz), and integrated (time constant = 100 ms) before being digitized at 1,000 Hz The resulting blink waveforms were individually scored for latency to blink onset and peak amplitude [4] Heart rate and skin conductance were also recorded [5]

In summary, this experiment was a mixed 2 (Stimulus Description Group) × 2 (Attention) × 2 (Stimulus Presented) design with stimulus description being a between-subjects factor and attention and stimulus presented being within-subjects factors

RESULTS AND DISCUSSION

Figure 1 presents the mean blink latencies and peak amplitudes for the two

2 Because of the small number of trials and the limited information they provide, data from unwarned trials are not presented in this report

3 White noise was generated by a Coulbourn (S41-02) noise generator and gated through a Coulbourn Shaped Rise/Fall Gate (S84-04) to a Pioneer SX-2600 amplifier The amplified signal was presented via TDH-49 earphones with hard rubber, supra-aural cushions at 100 dB(A) as measured at each ear by a Quest Model 2700 sound-level meter with an appropriate coupler

Air puffs were regulated with an AIRCO 400 Series regulator and gated by an electronic valve (Skinner Electric Valves Series VAO) Air flow was measured using Gilmont Instruments Compact Flowmeters (sizes 13 and 15)

Air-puff apparatuses are notorious for producing acoustic artifacts arising chiefly from (a) the solenoid valve, which produces a noticeable "click" when triggered, (b) the hiss of the air exiting the plastic tube, and (c) the impact of the air on the side of the subject s face transmitted via bone conduction to the cochlea In the current experiment, these artifacts were controlled by (a) housing the electronic valve in a separate room, isolating it from the subject, and (b) reducing the air flow to a level that made the hiss and impact artifacts negligible Lowering the air-flow intensity below what has commonly been used to elicit eyeblinks had the added benefit of lowering the response amplitude away from its ceiling (Haerich, 1989, Haerich & Berg, 1993)

4 A computer program was used to score the individual blink waveforms, it searched for (a) blink onset, defined as a threshold change in EMG (40 μV) above a pre-TS baseline within a window extending from 20 to 160 ms following TS onset, and (b) peak amplitude, defined as the largest deviation from baseline within a window extending to 220 ms following TS onset Blink latency was defined as the latency from TS onset to the onset of the blink Details of the scoring procedure may be found in Haerich (1989)

5 The output of a Contact Precision Instruments (CPI) photoplethysmograph (CPI-FPA coupler, SN 9127), attached to the middle finger of the nonpreferred hand, was directed through a timer (CPI, SN 9151) that returned the interval between successive pulse waves at the finger These data, digitized and sampled at 20 Hz throughout the entire experiment, were used to reconstruct the timing of heart beats during the WS–TS interval according to the recommendations of Graham (1978)

Skin conductance responses were recorded using a constant voltage system (CPI SC4 module, SN 9121, 0 6 V) and miniature Ag/AgCl electrodes attached to the middle phalanges of the first and third fingers of the nonpreferred hand These data were digitized and sampled at 20 Hz throughout the entire experiment Magnitude was scored as the largest increase (in μSiemens) observed with a response onset occurring between 1 and 4 s after TS onset A square-root transformation was applied to these data before analysis (Dawson, Schell, & Filion, 1990) groups Reflex blinks elicited from subjects in the eye group, for whom the air-puff stimulus had been described as "near the eye," were generally larger in amplitude than were blinks produced by subjects in the ear group, $F(1, 47) = 5\ 15$, $p < 01$) This result is consistent with the prediction that perception of the air-puff stimulus as affectively negative would lead to facilitation of the (defensive) blink reflex (Lang et al , 1990, 1992) Supporting this interpretation, the

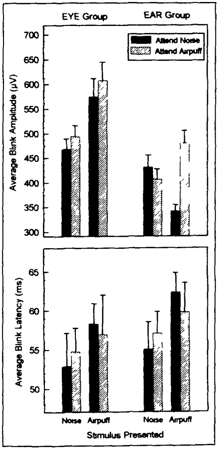

Fig 1 Mean characteristics of the reflex eyeblink, derived from the *orbicularis oculi* electromyogram The upper panel shows mean peak amplitude of reflex eyeblinks for each group The lower panel shows mean latency to blink onset "EYE" indicates the group of subjects told that the air-puff stimulus was directed "near the eye " "EAR" indicates the group of subjects told that the air-puff stimulus was directed along the side of the face "toward the ear " Solid bars represent data from trials in which subjects were instructed to discriminate durations of noise bursts, hatched bars represent air-puff discrimination trials

pleasantness ratings in anticipation of air puffs (but not noise bursts) were consistently lower for the eye group (41 vs 66 for air puffs and noise, respectively) than for the ear group (60 vs 59 for air puffs and noise) This appeared statistically as a significant Attention × Group interaction, $F(1, 47) = 9\ 12$, $p < 01$ ($ts[47] = 2\ 52$ and $1\ 41$, $ps < 05$ and n s , for air-puff and noise comparisons, respectively) Similar analyses on interest and difficulty revealed no significant main or interaction effects

In order to examine the effect of the attention manipulation, because the three-way Attention × Stimulus × Group interaction was marginally reliable, $F(1, 47) = 3\ 34$, $p = 074$, and the strength of startle-probe paradigms is the within-subjects comparisons, the blink amplitudes of each group were analyzed separately The results suggest that the emotional context does affect, at least at the level of expression, the function of attentional mechanisms The subjects in the ear group produced a response pattern in which facilitation occurred when the eliciting stimulus was presented in the attended modality (Attention × Stimulus interaction, $F[1, 22] = 5\ 89$, $p < 05$) In contrast, for subjects in the eye group, not only were responses to air-puff stimuli generally larger than those to noise, but blink responses to both air-puff and noise stimuli were larger while subjects were attending air puffs than while attention was directed to noise In the statistical analysis for the eye group, the main effects of both stimulus and attention, but not their interaction, were significant, $Fs(1, 25) > 4\ 26$, $ps < 05$

In the analysis of blink latency, only the main effect of stimulus was significant, $F(1,47) = 7\ 90$, $p < 01$, with onset latencies being shorter for blinks elicited by noise than for those elicited by air puffs Inspection of the data reveals for both groups the response pattern that would be expected if modulation followed the distribution of attention, that is, shorter onset latencies when the stimulus was presented in the same modality to which attention was directed This interpretation is not supported, however, by the statistical analysis, as the Attention × Stimulus interaction failed to reach significance, $F(1, 47) = 2\ 24$, $p = 14$

A number of measures suggest that this experimental paradigm utilizing the duration discrimination task successfully engaged attentional mechanisms in both groups of subjects First, performance on the discrimination task was similar for both groups (noise discrimination at 78% and 75% correct and air-puff discrimination at 63% and 67% correct for the eye and ear groups, respectively) and significantly better than chance (defined as 50% correct), $F(1, 47) = 176\ 92$, $p < 001$, subjects performed better at noise discrimination, $F(1, 47) = 20\ 58$, $p < 001$, but performance did not differ by groups (all $ps > 1$) Second, heart rate showed the deceleration immediately prior to TS commonly observed in paradigms in which a TS is preceded by a WS with an interstimulus interval of about 1 to 6 s, and interpreted as an orienting response in anticipation of the TS (Bohlin & Kjellberg, 1979, Putnam, 1990) This deceleration (varying between 0 6 and 2 7 beats per minute across groups and attention conditions) was confirmed statistically as a significant linear trend, $F(1, 47) = 30\ 42$, $p < 001$, although the interactions involving the group and attention factors were not significant, $Fs(1, 47) < 2\ 18$, $ps > 1$

Finally, a mismatch between the stimulus presented and the modality to which attentional resources were allocated resulted in an increase in skin conductance response (SCR) magnitudes, $F(1, 47) = 27\ 00$, $p < 001$ (see Fig 2), probably reflecting an automatic call for processing the unexpected stimulus (Öhman, 1979) Taken together, these data indicate that the discrimination task likely engaged attention mechanisms for both groups of subjects Although the task performance and cardiac data do not provide information regarding the selectivity of the attentional focus, results for SCR magnitude suggest that both groups were selectively directing attentional resources toward the modality of the task-relevant stimuli

The effect of the (affective) stimulus description on the attention manipulation appeared only in analysis of blink amplitude No significant group effects were found in analyses of either blink latency or SCR magnitude, rather, the pattern of modulation in these measures, if anything, appeared to follow the allocation of attentional resources Previous reports of affective modulation have fo-

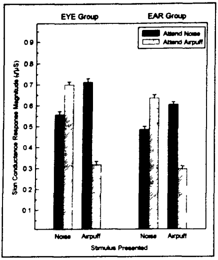

Fig 2 Mean magnitude of skin conductance response "EYE" indicates the group of subjects told that the air-puff stimulus was directed "near the eye " "EAR" indicates the group of subjects told that the air-puff stimulus was directed along the side of the face "toward the ear " Solid bars represent data from trials in which subjects were instructed to discriminate durations of noise bursts, hatched bars represent air-puff discrimination trials

cused on blink magnitude as the dependent measure (Bradley et al , 1990, 1993, Lang et al , 1990, 1992, Vrana et al , 1988), with latency effects being less robust Blink latency, however, has been suggested to be a more reliable index of attention effects than blink magnitude (Hackley & Graham, 1987) It is interesting to speculate that the amplitude of the reflex blink may be particularly sensitive to affective modulation whereas other measures (e g , blink latency or SCR magnitude) may be differentially sensitive to attentional manipulations Of course, because the current experiment employed an affective manipulation of negative valence only, and then in only one stimulus modality, these suggestions will need to be tested by experiments that employ manipulations of positive valence and vary the valence manipulations across sensory modalities

In conclusion, the data from this experiment indicate that the emotional context can affect the function of attentional mechanisms in the modulation of the eyeblink reflex Both groups of subjects were instructed to perform a task that focused attention toward a given sensory modality Data on task performance, heart rate, and SCR magnitude suggest that both groups responded to the task instructions similarly by engaging attentional mechanisms When the affective evaluation of the experimental context was neither strongly negative nor positive (viz , the ear group), reflex amplitude was potentiated and SCR magnitude was decreased if the eliciting stimulus was presented in a sensory modality that matched, as compared with a modality that mismatched, the modality toward which attentional resources were allocated However, when the subjects were encouraged to consider one stimulus as potentially harmful or dangerous (viz , the eye group), a pattern of general response facilitation occurred, additionally, a task that required attending to the potentially harmful stimulus affected the operation of attentional mechanisms to produce further facilitation of blink amplitude independent of the modality of the eliciting stimulus, without affecting the pattern of SCR magnitude modulation

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