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Rapid Picture Presentation and Affective Engagement

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Emotional reactions were assessed to pictorial stimuli presented in a continuous stream at rapid speeds that compromise conceptual memory and the processing of specific picture content. Blocks of unpleasant, neutral, or pleasant pictures were presented at the rate of either three pictures per second or seven pictures per second. Even with rapid presentation rates, startle reflexes, corrugator muscle activity, and skin conductance responses were heightened when viewing unpleasant pictures. These effects were stronger later in the aversive block, suggesting that cumulative exposure increasingly activates the defense system. The findings suggest that, despite conceptual masking inherent in rapid serial visual presentation, affective pictures prompt measurable emotional engagement.

Keywords: pictures, emotion, mood, international affective picture system, rapid serial visual presentation, startle reflex

The rapid presentation of a stream of pictures, at rates from three to nine pictures per second, results in the conceptual masking of individual exemplars and impairment of later recognition memory (Intraub, 1980; Potter, 1976). That is, although participants are able to detect targets when instructed to monitor the stream for a particular exemplar, later recognition for unmonitored pictures is greatly impaired. These data suggest that rapid presentation supports initial recognition processing, but that brief exposure (and stimulus masking) interferes with subsequent memory consolidation.

Using rapid serial visual presentation (RSVP) with explicitly affective stimuli, Junghöfer, Bradley, Elbert, and Lang (2001) measured event-related potentials (ERPs) for emotional and neutral pictures presented at rates from three to five pictures per second. Emotional pictures elicited an enhanced negative potential measured over visual cortex between 100 and 270 ms after picture onset, suggesting that these affectively salient stimuli were discriminated from neutral pictures, even at rapid presentation rates.

On the other hand, the design of that study did not allow a simultaneous assessment of the reflex physiology of emotion, that is, the autonomic and somatic responses that define strong emotional engagement. In the current study, we presented affective or neutral pictures at rapid presentation rates and measured skin conductance responses, facial electromyography (EMG) reactions, and probe startle reflexes as indices of affective engagement. The aim is to determine if, despite reported conceptual masking and impoverished memory for pictures presented in a rapid stream: a) affectively arousing pictures presented at extremely rapid rates prompt a reflex physiology of emotion; b) these reflex changes are augmented with more sustained picture presentation; and c) emotional engagement is apparent after the termination of picture exposure.

When affective pictures are presented at normal presentation rates (e.g., 6 seconds per picture), phasic facial EMG indices of emotion, including the acoustically elicited startle eyeblink response and corrugator supercilii activity, as well as initial heart rate deceleration, are heightened when viewing unpleasant, compared with pleasant, pictures (Bradley, Codispoti, Cuthbert, & Lang, 2001). Furthermore, electrodermal reactivity is reliably greater when viewing emotional (pleasant or unpleasant), compared with neutral, pictures (e.g., Lang, Greenwald, Bradley, & Hamm, 1993). These physiological responses during picture viewing are hypothesized to reflect activation of underlying brain systems that mediate appetitive and defensive motivational behavior (Lang, 1995) and were measured here as indices of affective engagement during rapid picture presentation. If affective stimuli presented at these rapid rates of presentation are able to activate the neural systems mediating affective expression, we expected a pattern of physiological engagement that varies with the emotionality of the pictures.

Thus, if unpleasant pictures are recognized at these rapid rates of presentation, activating the presumably subcortical defensive circuits mediating defensive responding, we expect that startle reflexes, corrugator EMG activity, and skin conductance responses will be heightened compared with when neutral pictures are presented at the same rapid rate. Moreover, we assess emotional reactions both early and late in the exposure series to determine whether affective engagement occurs immediately and whether it strengthens across the exposure series. For instance, if defensive activation occurs immediately, we expect that peripheral physiological reactions indicating aversive responding will occur soon after exposure to an aversive rapid stream has been initiated. If defensive activation increases with increased exposure to aversive

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stimulation, we expect responses to be heightened later in the exposure series.

We also examine whether emotional effects persist after rapid picture presentation. When a block of unpleasant pictures is presented at typical speeds (i.e., 6 seconds per picture), both startle potentiation and corrugator EMG activity persist for at least 30 seconds after exposure, suggesting that sustained exposure to aversive content can prompt a relatively sustained mood state (Smith, Bradley, & Lang, 2005). If rapid presentation effectively engages affective responding during exposure, we expect to find a similarly sustained reactivity immediately after picture exposure.

Two presentation rates were explored in the current study, both involving very rapid presentation. Each participant viewed a stream of unpleasant, neutral, or pleasant pictures presented at the rate of three pictures per second (3 Hz) or seven pictures per second (7 Hz) with no interpicture interval. If 7 Hz is too rapid to support picture identification, we expect to find weaker effects of emotional engagement. Each picture series lasted 20 seconds, and skin conductance and corrugator EMG activity were monitored continuously. Acoustic startle probes were presented early and late both during exposure and after exposure to assess emotional engagement.

Method

Participants

Participants were 24 (12 females) introductory psychology students who received course credit for participation. The Health Science Center Institutional Review Board at the University of Florida approved this experiment, and each participant provided written informed consent before participation.

Materials and Design

Pictures were 630 stimuli selected from the International Affective Picture System (IAPS; Lang, Bradley, & Cuthbert, 2005). Stimuli included 210 pleasant pictures (mean [± standard deviation {SD}] pleasure and arousal ratings of 7.21 [0.46] and 5.01 [1.00], respectively), 210 neutral (mean [± SD]) pleasure and arousal ratings of 5.21 (0.55) and 3.50 (0.87), respectively, and 210 unpleasant pictures (mean [± SD] pleasure and arousal ratings of 2.68 [0.69] and 5.64 [0.90], respectively). An additional 210 IAPS pictures (not among the 630 selected) were shown as "scrambled" pictures (altered using Photoshop software) to control habituation. Pictures of the same hedonic valence content were shown at two rates of presentation, either three pictures per second (3 Hz) or seven pictures per second (7 Hz), in blocks of 60 or 150 pictures, respectively. At the 3-Hz and 7-Hz presentation rates, each picture was shown for 342 and 142 ms, respectively. The pictures used for each hedonic valence and rate of presentation for each participant (among the 210 pictures) were determined pseudorandomly, and the order of the pictures within each block was randomized.

At each of the two presentation rates, each participant viewed four blocks of pictures. An initial practice block of scrambled pictures began the experiment for all participants and was followed by three critical blocks consisting of pleasant, neutral, and unpleasant pictures. The order of the pleasant, neutral, and unpleasant blocks was counterbalanced across participants. Half of the participants first viewed all four blocks of pictures presented at 7 Hz, and the other half of the participants first viewed all four blocks of pictures presented at 3 Hz. The presentation of each block of pictures lasted 20 seconds; within each block the 60 or 150 pictures were presented in a continuous stream with no delay between the offset of a picture and the onset of the next picture; each block of pictures was separated by a 30-second interblock interval during which the participant looked at a black screen. The four blocks and interblock intervals lasted 200 seconds (approximately 3.3 minutes) with presentation at both rates taking 400 seconds (approximately 6.7 minutes) to complete.

After each participant had viewed all the pictures at both rates of presentation, the procedure was repeated in the exact same manner maintaining the same block order, picture order within a block, and rate of presentation order. Thus, the entire data collection procedure lasted approximately 13.3 minutes. The data reported for each presentation rate are the average of the two runs of the experiment.

Acoustic startle probes were presented over headphones approximately every 12 seconds. Two acoustic startle probes were presented at 2 and 14 seconds after the onset of each picture block, and two startle probes were presented at 6 and 18 seconds after picture block offset (i.e., 26 and 38 seconds after picture block onset). During picture viewing, this corresponded to the occurrence of startle probes during the seventh and the 43rd pictures during the 3-Hz presentation rate and during the 16th and the 106th picture during the 7-Hz presentation rate. The startle probe (50 ms in duration) was presented at 50 ms after picture onset to avoid coincidence of the startle probe with picture onset or offset at either presentation rate. In addition, three startle probes were presented before picture viewing to accustom the participant to the startle stimulus.

Apparatus and Physiological Response Measurement

Digitized versions of the IAPS pictures were displayed using Presentation (Neurobehavioral Systems, Inc., Albany, CA) software running on an IBM computer. Pictures were shown on a white screen (1.7 m × 1.2 m) approximately 2.4 m from the participant using an InFocus LCD projector (model LP435Z; Wilsonville, OR). Picture onset was virtually instantaneous and pictures were shown in 24-bit color. The acoustic startle stimulus was a 50-ms, 95-dB(A) burst of white noise with instantaneous rise time generated by a Coulbourn (Coulbourn Instruments, L.L.C., Allentown, PA) V85-05 audio source module amplified with an RCA SA-155 Mini Stereo Amplifier (RadioShack Corp., Fort Worth, TX) and presented over Phillips (Royal Philips Electronics, Amsterdam, The Netherlands) SBC-HE900 headphones.

A second IBM-compatible computer running VPM software controlled physiological data acquisition (version 11.7; Cook, 2001). Physiological signals were continuously sampled at 20 Hz beginning 3 seconds before each series of pictures, with the exception that activity over the orbicularis oculi muscle was sampled at 1000 Hz from 50 ms before the onset of the noise stimulus to 250 ms after stimulus offset. Blink responses were measured from the left orbicularis oculi muscle using In Vivo Metric (Healdsburg, CA) silver–silver chloride electrodes (E220X-LS) and the placement recommended by Fridlund and Cacioppo (1986). The raw EMG signal was amplified 10,000 times, and frequencies below 13 Hz and above 150 Hz were filtered using a Coulbourn V75-04 bioamplifier. The raw signal was rectified and integrated using a Coulbourn V76-23A contour following integrator with a time constant of 100 ms.

Activity over the corrugator supercilii (above left eye) muscles was measured with In Vivo Metric silver–silver chloride electrodes (E220X-LS) using the placement recommended by Fridlund and Cacioppo (1986). The raw EMG signals were amplified 10,000 times, and frequencies below 13 Hz and above 1000 Hz were filtered using a Coulbourn V75-04 bioamplifier. The raw signals were rectified and integrated using a Coulbourn V76-23A contour following integrator with a time constant of 500 ms. The integrated signal was sampled at 20 Hz.

Skin conductance electrodes were placed adjacently on the hypothenar eminence of the left palmar surface using 8-mm In Vivo Metric silver–silver chloride electrodes (E256N) filled with a 0.5 M NaCl and Unibase cream (Warner Chilcott Laboratories, Morris Plains, NJ). The signal was sampled at 20 Hz and recorded with a Coulbourn V71-23 isolated skin conductance coupler calibrated before each session to detect activity in the range of 0 to 40 microSiemens. The calibration value was used off-line to convert the digitized raw signal to skin conductance values in microSiemens.

The electrocardiogram was sampled at 1000 Hz and recorded from the left and right forearms using 8-mm In Vivo Metric silver–silver chloride electrodes (E256N) filled with electrolyte paste. The signal was filtered using a Coulbourn V75-04 bio-amplifier, and a Schmitt trigger interrupted the computer each time it detected a cardiac R-wave (Coulbourn V21-10 dual comparator/window discriminator). Interbeat intervals were recorded to the nearest millisecond and reduced offline using VPM software (Cook, 2001) into heart rate in beats per minute in half-second bins weighting each interval by the fraction of time occupied (Graham, 1980).

Procedure

After signing the informed consent form, the participant sat in a recliner in a dimly lit room. Then, the sensors were placed on the participant and the participant was instructed that several series of pictures would be displayed and that any brief noises heard over the headphones could be ignored. Participants were instructed to maintain a comfortable visual focus on the middle of the screen, where a small red dot from a laser pointer was projected throughout the experimental session. During the first 2 minutes, the participant did not see pictures and three noise probes were presented (not scored). The remainder of the session lasted approximately 13 minutes and consisted of the viewing of the practice series and the three critical series at the two presentation rates. The subject was subsequently debriefed and thanked for their participation.

Data Reduction and Analysis

The eyeblink data were reduced offline using a VPM program (Cook, 2001) that implements a peak-scoring algorithm (Balaban, Losito, Simons, & Graham, 1986) that scores the peak response in onset latency and amplitude. Trials with clear artifacts were rejected, whereas trials with no responses were scored as zero-magnitude blinks. Reactions in corrugator and skin conductance were determined by subtracting the mean activity in the 1 second before each block of pictures from that occurring at each half-second during each 20-second block of pictures and corresponding interblock interval. The mean change over the first 10 seconds (first half of exposure) and the last 10 seconds (second half of exposure) in a block of pictures, and during the first 15 seconds (first half postexposure) and the last 15 seconds (second half postexposure) during each 30-second interblock interval, was used to estimate reactivity. Data collected during the practice block of scrambled pictures were not included in the statistical analyses.

Data were analyzed during picture blocks and interblock intervals using SPSS version 11 (Chicago, IL) general linear model analyses of variance with a 2 (gender) × 2 (presentation rate: 3 Hz, 7 Hz) × 2 (exposure: during exposure, postexposure) × 3 (picture content: pleasant, neutral, unpleasant) × 2 (half: first half, second half) analysis, in which gender was a between-subject factor and the remaining factors were repeated measures. For significant main effects and interactions that do not involve presentation rate (3 Hz or 7 Hz), the data reflect the mean over presentation rates (resulting in, e.g., four startles per cell). The Huynh-Feldt epsilon was used to adjust the degrees of freedom in each repeated-measures analysis with more than two levels when Mauchly's test of sphericity was significant at $p < .10$.

Results

Startle Magnitude

Overall, startle responses were larger during picture exposure compared with during the postexposure intervals ($F[1, 22] = 5.30$, $p = .031$, $\eta^2 = .194$). More importantly, startle reflexes differed as a function of the affective content of the picture stream ($F[2, 44] = 6.48$, $p = .003$, $\eta^2 = .227$). Blink responses were significantly larger when viewing unpleasant, compared with pleasant, pictures ($F[2, 22] = 9.31$, $p = .006$, $\eta^2 = .297$), and viewing pleasant pictures prompted smaller blinks than neutral pictures ($F[2, 22] = 4.86$, $p = .038$, $\eta^2 = .181$). As expected from previous studies, blinks elicited during unpleasant picture viewing were larger than those elicited when neutral pictures were presented ($F[2, 22] = 2.96$, one-tailed $p = .05$, $\eta^2 = .119$). There were no significant effects or interactions involving presentation rate.

Affective startle modulation was clearly present during picture exposure but was reduced in the postpicture period (picture content × exposure × half interaction; $F[2, 44] = 4.16$, $p = .022$, $\eta^2 = .159$). During the first half of picture exposure, a significant main effect of picture content ($F[2, 44] = 6.08$, $p = .005$, $\eta^2 = .22$) indicated that unpleasant pictures prompted larger reflexes than pleasant pictures ($p = .036$), and pleasant pictures prompted smaller reflexes than neutral pictures ($p = .005$), whereas reflexes elicited when viewing unpleasant and neutral pictures did not differ. Later in the exposure series, however, the significant content effect ($F[2, 44] = 8.91$, $p = .001$, $\eta^2 = .29$) indicated that unpleasant pictures prompted larger reflexes than both neutral ($p = .004$) or pleasant pictures ($p = .003$), whereas pleasant and neutral pictures did not differ.

These effects were supported by a significant picture content × half interaction during picture exposure ($F[2, 44] = 7.73$, $p = .001$, $\eta^2 = .260$). Consistent with the hypothesis that defensive activation increases during exposure, startle reflexes significantly increased from early to late in the exposure period for unpleasant pictures ($F[1, 22] = 5.37$, $p = .030$, $\eta^2 = .196$). For neutral pictures, on the other hand, reflexes significantly decreased from early to late in the exposure period ($F[1, 22] = 7.27$, $p = .013$, $\eta^2 = .248$). For pleasant pictures, reflex magnitude was small both early and late in the exposure series (see Figure 1).

After picture exposure, a marginal effect of picture content ($F[2, 44] = 2.64$, $p = .09$, $\eta^2 = .11$) was accompanied by a marginal linear trend ($F[1, 22] = 3.81$, one-tailed $p = .03$, $\eta^2 = .15$), suggesting that unpleasant picture viewing continued to prompt somewhat larger reflexes in the postexposure period than did viewing pleasant pictures (see Figure 1). There were no effects involving time in the postexposure period.

Corrugator Supercilii

Figure 2 illustrates corrugator EMG activity both during and after picture viewing. Overall, corrugator EMG activity was heightened during picture viewing compared with postexposure ($F[1, 22]= 6.65$, $p = .02$, $\eta^2 = .23$). More importantly, corrugator EMG activity was significantly elevated when viewing unpleasant pictures at rapid rates compared with when viewing either pleasant ($p = .022$) or neutral pictures ($p = .041$) (picture content $F[2, 44] = 4.39$, $p = .034$, $\eta^2 = .166$).

The interaction of exposure and content was not significant ($F[2, 44] = 1.56$, $p = .22$, $\eta^2 = .07$), but separate analyses indicated stronger effects during compared with postpicture exposure. A significant effect of picture content during picture viewing ($F[2, 44] = 5.96$, $p = .01$, $\eta^2 = .25$) resulted in significantly greater corrugator EMG activity when viewing

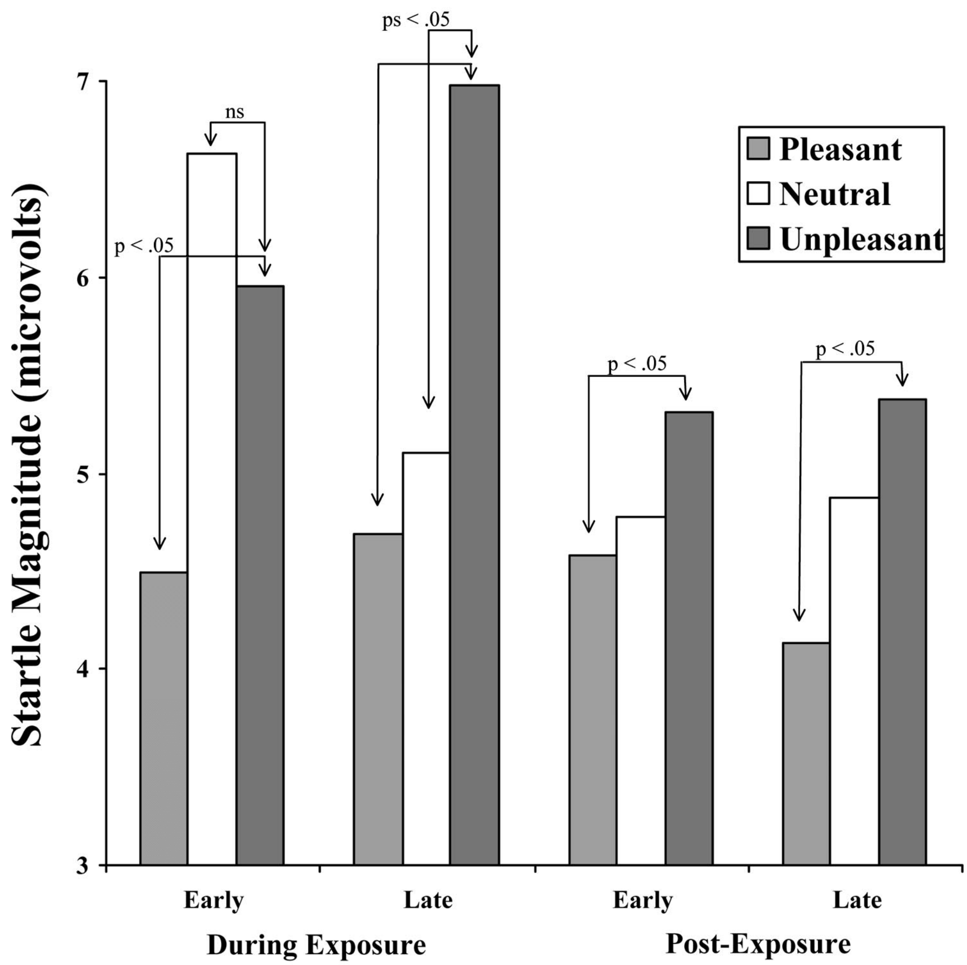

Figure 1. Mean startle magnitude (microvolts) during and after rapidly presented blocks of pleasant, neutral, and unpleasant pictures. Startle noise probes were presented early and late during each picture block and each postexposure interval. Data are averaged across the two presentation rates (3 Hz and 7 Hz).

unpleasant compared with neutral (p = .022) or pleasant (p = .008) pictures. During picture exposure, unpleasant pictures prompted larger responses both early and late in the exposure period, as the interaction of content and half was not significant.

After exposure, the content effect was only marginal (F[2, 44] = 3.78, p = .09, η^2 = .11), with unpleasant pictures prompting more corrugator activity than neutral or pleasant pictures in one-tailed tests (unpleasant versus neutral, one-tailed p = .04; unpleasant versus pleasant, one-tailed p = .05).

Replicating previous research (Bradley, Codispoti, Sabatinelli, & Lang, 2001) corrugator activity was significantly higher for women than for men (F[1, 22] = 5.13, p = .034, η^2 = .189).

Skin Conductance

Skin conductance was affected by the affective content of rapidly presented pictures (F[2, 44] = 3.50, p = .039, η^2 = .137) with larger electrodermal changes when viewing unpleasant compared with neutral pictures (F[1, 22] = 4.08, p = .056, η^2 = .156) or pleasant pictures (F[1, 22] = 8.80, p = .007, η^2 = .286). There were no significant differences in skin conductance change between pleasant (p = .01) and neutral (p = .09) picture blocks (see Table 1).

Skin conductance changes varied across time (picture exposure × half × content interaction; F[2, 44] = 3.11, p = .059, η^2 = .124). During picture exposure, a picture content × half interaction (F[2, 44] = 4.20, p = .02, η^2 = .16) indicated that all picture contents elicited equivalent skin conductance changes during the first half of exposure (content $F < 1$), whereas unpleasant pictures prompted larger conductance changes than pleasant (.01) and neutral (.09) in the second half. Thus, skin conductance remained high from early to late in the block for unpleasant pictures (F[1, 22] = 1.72, p = .20, η^2 = .072), but decreased significantly from early to late in the block when viewing neutral (F[1, 22] = 9.27, p = .006, η^2 = .296) or pleasant pictures (F[1, 22] = 20.31, p < .001, η^2 = .480). A marginal effect of picture content after exposure (F[2, 44] = 3.43, p = .05, η^2 = .14) showed a similar pattern, with higher skin conductance changes persisting into the postexposure period for unpleasant, compared with pleasant, pictures (p = .006; see Table 1).

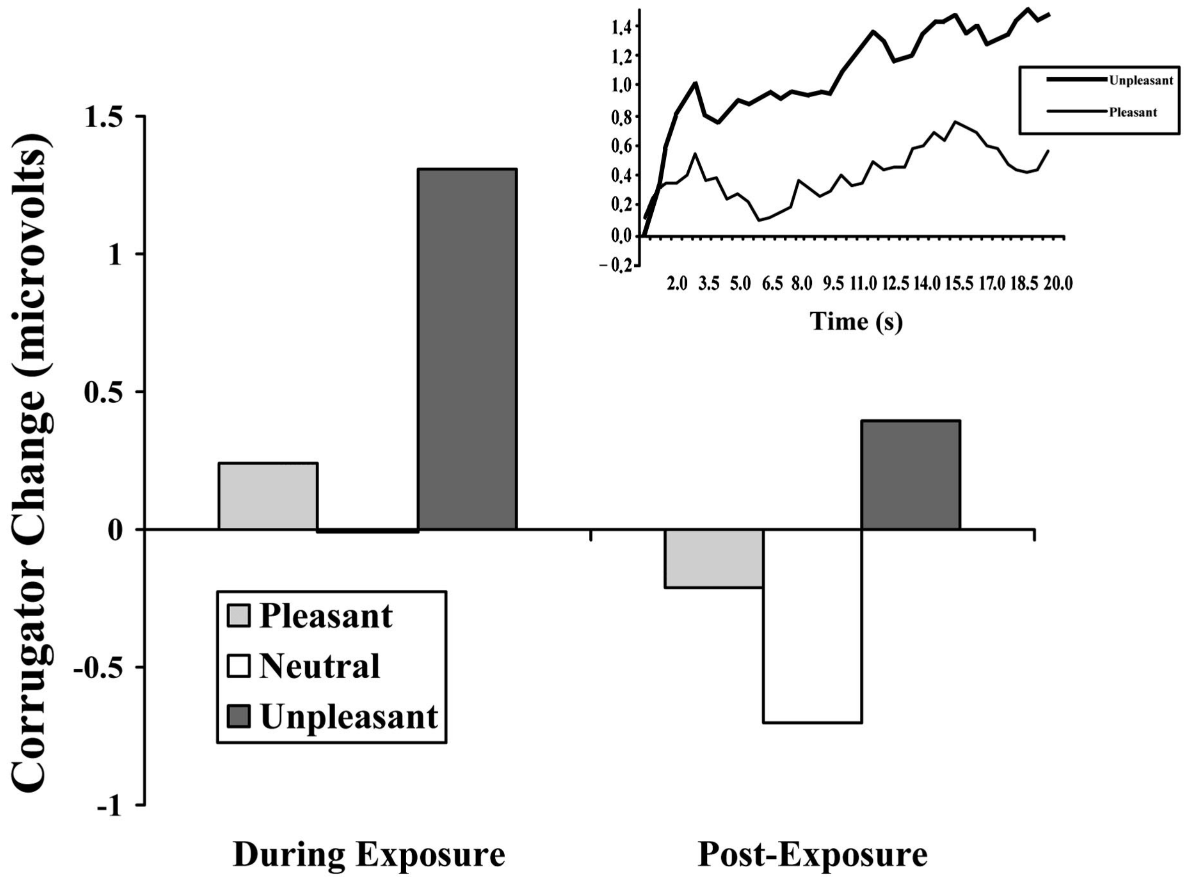

Figure 2. Mean corrugator supercilii change from baseline (microvolts) during and after rapidly presented blocks of pleasant, neutral, and unpleasant pictures. Data are averaged across the two presentation rates (3 Hz and 7 Hz). Inset: the mean change in corrugator EMG during the unpleasant and pleasant picture blocks shown in microvolts over each half second during picture exposure.

Discussion

Very rapid presentation of unpleasant pictures prompts measurable defensive activation as evidenced by heightened startle reflexes, increased corrugator muscle action, and augmented skin conductance responses. These data indicate that rapid picture viewing engages the neural networks mediating defensive reactivity, despite the conceptual masking of individual pictures that occurs at rapid presentation rates. Moreover, with increased duration of exposure to aversive content, startle reflexes increased in magnitude, consistent with a hypothesis of greater defensive activation as exposure duration increases. These effects are consistent with previous studies indicating greater startle potentiation for probes presented late in a 12-second viewing period (Sutton, Davidson, Donzella, Irwin, & Dottl, 1997) and increased potentiation for probes presented late during 90-second exposure to unpleasant pictures (presented for 6 seconds each; Smith, Bradley, & Lang, 2005). In the current study, the rate of picture presentation (e.g., three or seven pictures per second) did not have strong effects on this reflex modulation, suggesting that it is the duration of aversive exposure rather than the number of specific exemplars that may be critical in determining the intensity of defensive activation.

Strong defensive engagement was not clearly immediate, however. Although reflexes elicited during unpleasant picture viewing were augmented compared with those elicited during pleasant blocks both early and late during exposure, reflex magnitude for aversive content was not greater than for neutral pictures for probes presented early in the exposure series. In fact, this pattern of modulation is quite similar to that previously found for pictures presented with short exposure durations (but not at rapid rates). Thus, using a brief, 500-ms picture presentation (followed by a blank interval), Codispoti, Bradley, and Lang (2001) found that startle blinks were larger when viewing unpleasant, compared with pleasant, pictures, but not when compared with neutral pictures, suggesting that isolated, brief picture presentation evokes less intense defensive activation. In the current study, this modulatory pattern was present early in exposure but changed with increasing aversive exposure to include significant potentiation for aversive compared with neutral picture viewing later in the block, consistent with stronger defensive activation.

For neutral pictures, the startle reflex clearly decreased across the exposure period. This decrease in reflex magnitude across time is consistent with much research indicating that, in the absence of other modulatory effects, the startle reflex habituates with repeti-

Table 1
Corrugator and Skin Conductance Responses During the First and Second Half of 20-Second Blocks of Pleasant, Neutral, and Unpleasant Pictures (during exposure), and After Picture Viewing During the First and Second Half of the 30-Second Interblock Intervals (postexposure)

	During exposure		Postexposure	
	First half	Second half	First half	Second half
Corrugator supercilii (μV)				
Unpleasant	1.16 (0.46)	1.45 (0.46)	.30 (0.30)	.49 (0.27)
Neutral	.09 (0.15)	−.10 (0.23)	−.59 (0.36)	−.82 (0.44)
Pleasant	.25 (0.22)	.22 (0.19)	−.23 (0.17)	−.19 (0.15)
Skin conductance (μSiemens)				
Unpleasant	.09 (0.03)	.06 (0.04)	.04 (0.04)	.01 (0.04)
Neutral	.08 (0.04)	.01 (0.03)	.03 (0.06)	.05 (0.08)
Pleasant	.05 (0.03)	−.06 (0.02)	−.11 (0.03)	−.13 (0.05)

Note. Values are expressed as mean change (± standard error) from baseline (1-second before each block) across 10-second intervals during picture exposure and 15-second intervals postexposure.

tive probe presentation (Davis & Wagner, 1969). During unpleasant picture exposure, on the other hand, startle magnitude was not only resistant to habituation, but instead showed significantly greater potentiation for blinks elicited later in the block, consistent with a hypothesis of increased defensive activation. Moreover, reflexes elicited during pleasant picture viewing did not habituate, but remained small and significantly inhibited, compared with unpleasant blocks, throughout the exposure period, suggesting continued appetitive inhibition throughout pleasant picture viewing.

Whereas corrugator EMG activity was evident even early in aversive exposure, skin conductance reflected sustained defensive activation later in the exposure period. After onset of the rapidly presented picture series, conductance increased similarly for all pictures, which is best interpreted as an orienting response routinely evoked by any novel stimulus (Sokolov, 1963). Whereas conductance decreased during the second half of exposure for neutral and pleasant pictures, an elevated response was maintained throughout the exposure series for unpleasant pictures. This sustained reaction is consistent with a state of general sympathetic activation associated with emotional arousal (Greenwald, Cook, & Lang, 1989) and suggests that processing aversive pictures later in the rapidly presented series prompted significant defensive activation.

Pleasant pictures and emotional arousal. Almost immediately after picture onset, pleasant pictures prompted inhibited startle reflexes compared with when viewing neutral pictures. Reflexes continued to be small throughout picture exposure when viewing pleasant pictures, whereas reflexes clearly habituated from early to late in exposure when viewing neutral pictures. From the viewpoint of affective engagement, these data suggest that rapid presentation allowed identification of the appetitive nature of pleasant pictures and that this identification occurred rather early in the processing sequence.

On the other hand, the skin conductance data did not indicate intense affective engagement for pleasant pictures, because responses elicited during rapidly presented blocks of pleasant pictures were generally not different from those elicited during neutral picture viewing and were significantly lower than for aversive blocks. Two issues are pertinent here. First, as noted previously, the onset of rapid picture presentation prompted an increase in skin conductance for all picture contents consistent with the hypothesis that skin conductance change to rapid visual arrays may primarily index an orienting response, sensitive to sensory stimulation and novelty (Sokolov, 1963). Thus, early in the processing sequence, effects of affective valence were minimal, because orienting to the rapidly changing array took precedence.

Later in the sequence, however, skin conductance during pleasant picture viewing did not show sustained activation but decreased in a manner similar to neutral pictures. Recent data indicate that heightened skin conductance responses during pleasant picture viewing are most pronounced for highly arousing contents, including pictures depicting sexually explicit content (Bradley, Codispoti, Cuthbert, & Lang, 2001a). In the present study, the pleasant picture series included many low arousal contents that do not strongly modulate electrodermal reactions, including nature scenes, babies and families, food, and so forth. It is likely that the absence of sustained skin conductance activity for pleasant pictures, relative to unpleasant, is attributable to somewhat lower arousal in the pleasant picture series.

Postexposure and affective engagement. After cessation of the rapid picture stream, the data suggested sustained emotional engagement, particularly for unpleasant pictures, albeit weaker than during exposure. After exposure to a stream of aversive pictures, startle reflexes continued to be heightened, corrugator EMG was elevated, and skin conductance continued to be greater compared with the postexposure period after rapid presentation of pleasant pictures. On the other hand, these postexposure effects were less pronounced than in previous research using slower rates and longer durations of exposure (Smith, Bradley, & Lang, 2005). In part, the reduced mood effect may be attributable to the shorter overall exposure time in the current study, in which each picture sequence lasted only 20 seconds compared to 4.5 minutes in Smith, Bradley, and Lang (2005).

Rapid serial visual presentation and emotion. In the cognitive literature, effects of rapid serial visual presentation on encoding and memory performance have typically been investigated using relatively "neutral" stimuli. The resulting database has indicated that the visual system can resolve and identify specific stimuli presented at rapid rates, whereas later memory for these rapidly presented stimuli is impaired. In the current study, affective information was added to the RSVP array, and the data show clearly that it has emotional impact. Processing unpleasant and pleasant pictures was accompanied by measurable activation of defensive and appetitive motivational systems as indexed by startle modulation, corrugator EMG reactivity, and, particularly for aversive materials, heightened skin conductance responses. These results suggest that differences in the ERP-negative potential (Junghöfer et al., 2001) and functional brain activity (Junghöfer, Sabatinelli, Bradley, Schupp, Elbert, & Lang, 2006) measured over occipital sites during rapid presentation of emotionally arousing, compared with neutral, pictures is related to affective expression in the peripheral physiology. There is some evidence of a persisting emotional response immediately after the rapid picture stream; however, the effect was not strong, which may reflect brevity of the picture stream or the impaired memory consolidation described in previous RSVP studies (Intraub, 1980; Potter, 1993).

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