

Research Report

Dissociating Motivational Direction and Affective Valence

Specific Emotions Alter Central Motor Processes

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ABSTRACT—*We aimed to clarify the relation between affective valence and motivational direction by specifying how central and peripheral components of extension movements are altered according to specific unpleasant affective states. As predicted, premotor reaction time was quicker for extension movements initiated during exposure to attack than for extension movements initiated during exposure to all other valence categories (mutilation, erotic couples, opposite-sex nudes, neutral humans, household objects, blank). Exposure to erotic couples and mutilations yielded greater peak force than exposure to images of attack, neutral humans, and household objects. Finally, motor reaction time and peak electromyographic amplitude were not altered by valence. These findings indicate that unpleasant states do not unilaterally prime withdrawal movements, and that the quick execution of extension movements during exposure to threatening images is due to rapid premotor, rather than motor, reaction time. Collectively, our findings support the call for dissociating motivational direction and affective valence.*

Emotional states alter the speed, force, and accuracy of voluntary movements. For example, exposure to unpleasant emotional stimuli accelerates avoidance movements, whereas exposure to pleasant cues elicits rapid approach movements (Chen & Bargh, 1999; Coombes, Cauraugh, & Janelle, 2007; Rotteveel & Phaf, 2004). Although these collective findings suggest congruence of unpleasant stimuli with withdrawal motivation, and pleasant stimuli with approach motivation, such a conclusion may be premature and oversimplified.

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Recent research evaluating the coupling of affective circuitry and behavioral reactivity indicates that activation of defensive circuits and activation of appetitive circuits do not exclusively prime avoidance and approach behaviors, respectively. That is, global measures of affective valence (Gotlib, Ranganath, & Rosenfeld, 1998) do not always predict motivational direction (Davidson, 1995). For example, Marsh, Ambady, and Kleck (2005) required subjects to either push or pull a lever in response to human faces expressing anger or fear. Although the affective context in each case was unpleasant, anger stimuli yielded faster pushing (avoidance behavior) than pulling movements, whereas fearful stimuli induced faster pulling (approach behavior) than pushing movements. These behavioral findings were interpreted as being emotion-specific, rather than functionally reflective of broad valence dimensions. Harmon-Jones and his collaborators have substantiated the necessity to differentiate specific emotions in studying the parameters of motivational direction, demonstrating that anger can precipitate approach-related brain activity (i.e., left frontal asymmetry; Harmon-Jones, Lueck, Fearn, & Harmon-Jones, 2006). Thus, behavioral responses to unpleasant images are apparently not uniform across unpleasant categories. However, previous empirical work has typically included a broad range of unpleasant stimuli (Chen & Bargh, 1999; Coombes et al., 2007) or only one particular category of stimuli (e.g., threat: Rotteveel & Phaf, 2004), thereby limiting emotion-specific understanding of the relation between affective valence, motivational direction, and behavior.

In addition, because only general measures of movement—movement time and reaction time (RT)—have been reported in this area (Buodo, Sarlo, & Palomba, 2002; Chen & Bargh, 1999; Rotteveel & Phaf, 2004), it has not been possible to draw conclusions concerning how emotion modulates specific movement parameters. In a study addressing this limitation, we (Coombes et al., 2007) found that premotor RT was accelerated and motor RT did not change when subjects initiated extension movements

while viewing unpleasant, rather than pleasant, images. Thus, the increased speed of extension movements during exposure to unpleasant cues is driven by expedited central, rather than peripheral, motor processes. Indeed, peripheral motor processes were only marginally altered by affective context when instructional sets prioritized movement speed. In this previous study, however, we did not explicitly control for specific emotional categories (e.g., threat, disgust) within the broader emotional categories (e.g., unpleasant). As a result, we could not draw firm conclusions concerning how specific unpleasant emotions (e.g., threat, disgust) influence peripheral motor processes and expedite the premotor RTs of withdrawal movements.

Aside from the anger findings reported by Harmon-Jones et al. (2005) and the findings on fear perception reported by Marsh et al. (2005), there is no evidence that contradicts the assumption that all unpleasant affective states prime withdrawal movements similarly. The purpose of the current study, therefore, was to clarify the relation between affective valence and motivational direction by specifying how central and peripheral components of extension movements are modulated by specific unpleasant affective states. We achieved this aim by requiring subjects to make extension movements of the wrists and fingers in response to an acoustic tone while they viewed images from seven valence-specific categories.

If affective valence drives motivational direction in a global fashion, congruent extension movements executed during exposure to threat and disgust images should show similar decreases in RT and increases in strength relative to those executed during exposure to pleasant, neutral, and blank images. However, if motivational direction and affective valence are selectively orthogonal, the necessity of movement in threatening situations should expedite withdrawal movements, resulting in faster extension movements during exposure to threat cues than during exposure to disgust cues (in addition to all pleasant, neutral, and blank cues). Given recent evidence supporting a decoupling between broad categories of affective valence and motivational direction, we expected the latter of these two possibilities to be true. In addition to testing this primary hypothesis, we sought to specify the locus of any observed effects by inves-

tigating the contributions of the central and peripheral nervous systems to the motor task of interest. On the basis of our prior findings, we hypothesized that central (premotor RT), but not peripheral (motor RT), motor processes would be responsible for accelerated movement under fear-prime conditions. In addition, to further investigate the residual effect (given instructions focused on speed of movement) of specific emotions on the magnitude of peripheral motor processes, we tested the prediction that threat cues would elicit greater electromyographic (EMG) and force peaks than all other cue categories.

METHOD

Subjects

Thirty-three (17 female) undergraduate students participated in this study for extra course credit. Subjects ranged in age from 18 to 29 years ($M = 21.19$ years, $SD = 2.17$) and reported no hearing loss or central nervous system disorders that would affect movement. Informed consent was obtained from all subjects. Data points 3 or more standard deviations from the mean were considered extreme scores and were removed prior to analysis, resulting in 31 subjects being included in the analysis of peak force, 32 subjects being included in the analysis of premotor RT and motor RT, and all 33 subjects being included in the analysis of peak EMGs.

Affective Stimuli

Each subject viewed 42 images (see Table 1). Of these, 36 were taken from the International Affective Picture System (Lang, Bradley, & Cuthbert, 2005); they included 6 images representing each of six affective categories: erotic couples, opposite-sex nudes, attack images (e.g., pointed gun), mutilations (e.g., mutilated human, burn victim), neutral human images, and household objects. Images were selected on the basis of their mean ratings on valence (pleasant > neutral > unpleasant) and arousal (unpleasant = pleasant > neutral); images within each broad category were matched for valence and arousal (Lang

TABLE 1

Visual Stimuli Used in the Experiment, With Mean Ratings for Valence and Arousal

Category	Valence	Arousal
Erotic couples: 4607, 4652, 4683, 4687, 4689, 4800	6.70 (0.32)	6.56 (0.29)
Male nudes (viewed by females): 4470, 4490, 4535, 4561, 4572, 4614	6.90 (0.65)	5.88 (0.34)
Female nudes (viewed by males): 4002, 4004, 4279, 4300, 4302, 4320	7.18 (0.53)	6.56 (0.73)
Attack: 3530, 6190, 6360, 6510, 6560, 6570	2.40 (0.61)	6.42 (0.47)
Mutilations: 3053, 3060, 3130, 3140, 3150, 3170	1.71 (0.36)	6.85 (0.33)
Neutral humans: 2200, 2210, 2485, 2495, 2516, 2600	5.14 (0.56)	3.56 (0.37)
Household objects: 7000, 7010, 7050, 7080, 7090, 7175	5.03 (0.16)	2.26 (0.43)

Note. The images are identified by their numbers in the International Affective Picture System (Lang, Bradley, & Cuthbert, 2005). Standard deviations are given in parentheses.

et al., 2005). For a control comparison, 6 blank black images were presented. All pictures were visible for 6 s.

Task and Acoustic Stimuli

While viewing the pictures, subjects were required to respond as quickly as possible to each presentation of an 80-dB acoustic stimulus by initiating a ballistic bimanual extension of the wrist and fingers against two independent load cells (one indexing force for the left limb, and the other for the right limb). Acoustic stimuli were presented binaurally through headphones 2 to 4 s after picture onset. All subjects viewed the same images for all categories, except for the opposite-sex nudes, which were male images for female subjects and female images for male subjects. Sequence orders were randomized, with the constraint that the same valence category not be presented more than twice in succession. To prevent habituation and anticipation, we included two catch trials (no sound) within each valence category. Catch trials and trials with acoustic stimuli were presented in random order. Intertrial intervals varied from 6 to 10 s.

Instrumentation

EMG surface electrodes (Ag-AgCl electrodes, 1 cm in diameter and 2 cm apart, with an epoxy-mounted preamplifier) were placed over the bellies of the extensor communis digitorum and extensor carpi ulnaris muscles of each subject's left and right arms. To index force generation during each wrist-finger extension, we embedded two 34.1-kg load cells in cushioned platforms whose height was altered to accommodate individual hand sizes. Upper-limb EMG (band-pass filter from 1 to 500 Hz) and force data were amplified with a gain of 5,000 and 500, respectively, and were collected at 1000 Hz via Biopac software (Version 3.7.3, Biopac Systems, Inc., Goleta, CA). Each 10-s trial was streamed to disk for off-line analyses (see Fig. 1 for illustrations of the experimental setup and an example of raw data).

Procedure

After all questions were answered and written informed consent was obtained, subjects were seated 1.0 m from an 18-in. LCD presentation screen. Next, height of the force platforms was adjusted, load cells were calibrated, and EMG sensors were attached. Following calibration, subjects were familiarized with the protocol via a four-trial practice session (all neutral images; two trials with a tone and two catch trials).

Subjects were instructed to "look at each picture for the entire time it is on the screen," "consider picture onset as a cue to prepare to make the required wrist and finger extension," and "respond as quickly as possible to an acoustic stimulus by initiating a short-duration bimanual contraction of the wrist and finger extensor muscles." At the conclusion of the experiment, hands were removed from the customized force platform, EMG sensors were removed, and subjects were debriefed.

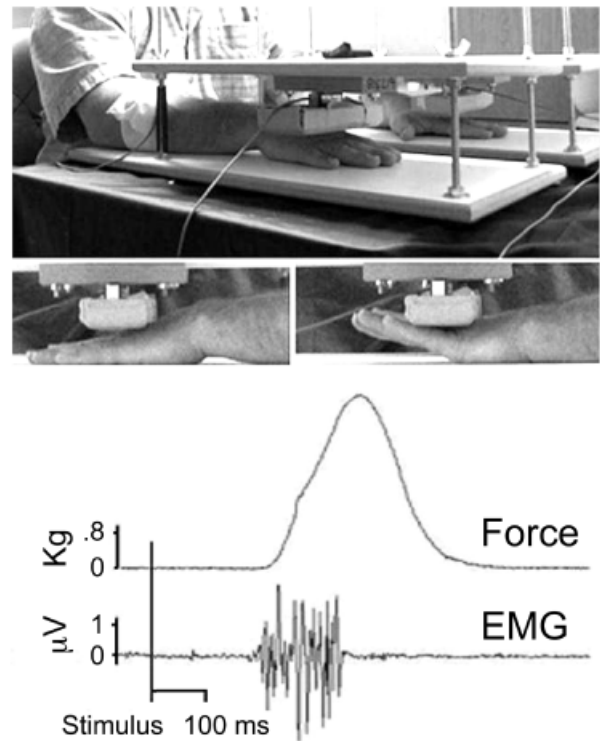


Fig. 1. Illustrations of the experimental setup and sample electromyogram (EMG) and force trace for a single trial. The upper illustration shows the apparatus and postures of the trunk, arms, and forearms before and during the task. The illustrations immediately below show the posture of the hands relative to the load cells during movement preparation and the intertrial interval (left) and during execution of the ballistic movement (right).

Data Reduction

EMG and force data were analyzed off-line via a custom LabVIEW program (Version 7.1; National Instruments, Austin, TX). EMG signals were rectified and filtered with a 25-Hz low-pass elliptic filter. Baseline EMG and force scores were calculated for each trial (mean score during the 150 ms preceding onset of the acoustic stimulus). Four dependent measures were calculated for each trial and limb: (a) premotor RT, (b) motor RT, (c) peak EMG amplitude, and (d) peak force amplitude. The program identified and then inserted cursors at peak force and peak EMG locations within specified windows after onset of the acoustic stimulus (EMG: 40–500 ms; force: 40–800 ms). Baseline-corrected normalized force and EMG peak *T* scores were calculated for each trial prior to statistical analysis. Onset of muscle contraction was identified by locating the first time point at which EMG signal amplitude was greater than double the baseline value, and premotor RT was calculated as the interval between onset of the acoustic tone and initiation of muscle contraction (Wong & Ng, 2005). Likewise, onset of force production was identified as the first time point at which force exceeded double the baseline value, and motor RT was calculated as the interval between onset of muscle contraction and force onset (Li, Stevens, Kamper, & Rymer, 2005). The location of each cursor (positioned

at EMG onset, EMG peak, force onset, and force peak) was verified visually and adjusted manually if necessary. Summary statistics were created by averaging data for left and right limbs for each valence category for each dependent variable.

Statistical Analyses

Each dependent variable was analyzed in a separate one-way within-subjects analysis of variance (ANOVA) with seven levels of valence (erotic couples, opposite-sex nudes, attack images, mutilations, neutral human images, household objects, and blank). To evaluate the sphericity assumption of a repeated measures design, we conducted chi-square tests on the valence factor. If the sphericity assumption was violated, then Greenhouse-Geisser's conservative degrees-of-freedom adjustment was applied to the critical p values. Follow-up analyses on significant main effects were conducted using Tukey's honestly significant difference (HSD) procedure.

RESULTS

Figure 2 displays premotor RT as a function of valence. ANOVA revealed a significant main effect of valence, $F(4.43, 137.31) = 6.48, p < .001, \eta^2 = .17$. Post hoc analysis revealed that movements initiated during exposure to attack images had faster premotor RTs than movements initiated during exposure to all other valence categories. Additionally, blank images resulted in slower premotor RTs relative to all other categories.

Analysis of normalized peak-force-amplitude scores yielded a main effect of valence, $F(6, 180) = 2.66, p < .05, \eta^2 = .08$. Follow-up mean comparisons indicated that exposure to scenes of erotic couples and mutilations yielded greater peak scores than did exposure to scenes depicting attack, neutral humans, and household objects.

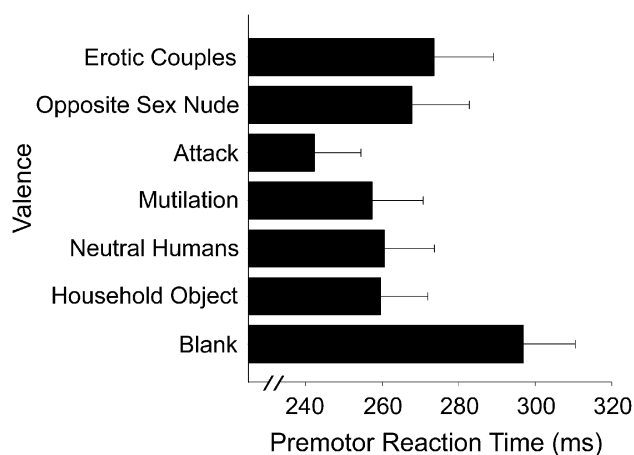


Fig. 2. Mean premotor reaction time, averaged across limbs, for each valence category. Error bars indicate standard errors.

Neither motor RT nor peak EMG was significantly altered by valence, $F(3.92, 121.42) = 2.07, p > .05, \eta^2 = .06$, and $F(6, 192) = 1.71, p > .05, \eta^2 = .05$, respectively.

DISCUSSION

The primary purpose of the current study was to clarify the relation between affective valence and motivational direction by specifying how extension movements are altered during different emotional states. The results for premotor RT supported the prediction that threat cues would expedite the initiation of extension (withdrawal) movements to a greater extent than all other emotional cues. Most notably, premotor RT was accelerated during exposure to threat cues relative to mutilation cues. This result confirms that only specific unpleasant images prime withdrawal movements. Additionally, motor RT was not altered by affective context. This result corroborates previous findings (Coombes et al., 2007) and further suggests that speeded movements are likely the result of central rather than peripheral motor processes (Chen & Bargh, 1999). These data raise the probability that the previously noted associations between unpleasant emotions and speeded withdrawal movements were likely driven by threat cues (within the broad category of unpleasant cues) that expedited central processes (Chen & Bargh, 1999; Coombes et al., 2007). Our data are consistent with Centerbar and Clore's (2006) notion of motivational-compatibility, which suggests that the attitudinal impact of approach-avoidance action will be reflected in its situated meaning, which depends on the valence of the stimuli being approached or avoided. Collectively, these data further support the call for segregating motivational direction and affective valence (Harmon-Jones et al., 2006).

Although our findings for premotor RT corroborate previous evidence associating threat stimuli with rapid extension movements (Rotteveel & Phaf, 2004), they deviate from those of Marsh et al. (2005), who reported an association between threat and speeded flexion movements. The threat images used by Marsh et al., however, depicted human faces experiencing fear or threat. Perhaps perceiving fear in another human promotes empathy and an approach movement (toward that person), whereas experiencing fear directly (i.e., via viewing fearful scenes, as in our study) preferentially drives withdrawal-directed movements. Marsh et al. also reported faster extension movements when subjects viewed images of human faces expressing anger, rather than fear; these data are incongruent with the conclusion of Harmon-Jones et al. (2006), who argued that anger often elicits an approach motivational set. Again, it is plausible that viewing anger in another person and experiencing anger in oneself may activate opposite motivational sets. This subtle, but nevertheless clear distinction between viewing and experiencing anger and threat is crucial when interpreting subjects' overt movements and is a promising avenue for future research.

Peak EMG was not modulated by emotional state, and consequently the prediction that peak EMG would be greater during exposure to attack images was not supported. These data corroborate our previous study (Coombes et al., 2007), which also failed to demonstrate valence effects on peak EMG. Peak force, however, was influenced, although not in the way we predicted. We hypothesized that the magnitude of the extension movement would be facilitated during exposure to attack images, relative to other images, given the congruence between motivational direction and valence in the case of attack images. However, exposure to scenes of erotic couples and mutilations yielded greater peak force than did exposure to images of attack, neutral humans, and household objects. It is likely that subjects closely adhered to the instruction to move as quickly as possible, so that the extent of force production was an ancillary consequence of the movement. In a previous study, we found an increase in force production during a sustained contraction coinciding with exposure to unpleasant images, but subjects were instructed to move with as much force as possible, and instructions did not refer to movement speed (Coombes, Cauraugh, & Janelle, 2006). Taken together, these findings suggest that affective valence may alter only the movement parameter the subject is focusing on. Future studies should vary task instructions, task type (i.e., ballistic, sustained), and goal force targets to examine the interplay between central and peripheral processes.

In summary, specific emotions appear to differentially influence motivational direction, which in turn alters the central processing times of direction-specific movements. Taken together, our findings indicate that unpleasant states do not unilaterally prime withdrawal movements, and that the increased speed of extension movements during exposure to threat images (when subjects are instructed to focus on speeded movements) is due to enhanced premotor rather than motor RTs. Finally, our findings further support calls for segregating motivational direction and affective valence (Harmon-Jones et al., 2006).

To conclude, synthesis between the affective and movement sciences is pivotal to the goal of harnessing the benefits and alleviating the costs associated with emotion-modulated movement. With further specification of how movement parameters are altered by affective valence and motivational direction, the mission of optimizing movement under different emotional states will be advanced.

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(RECEIVED 11/21/06; ACCEPTED 12/21/06;
FINAL MATERIALS RECEIVED 3/13/07)

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