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Effects of approach-avoidance related motor behaviour on the startle response during emotional picture processing

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A B S T R A C T

Affective foreground stimulation has a moderating influence on the startle response, unpleasant stimuli potentiate while pleasant stimuli attenuate the response. This effect has been explained by motivational priming: affective stimuli pre-activate the organism for approach or avoidance behaviour. However, motivational states may also be induced via proprioceptive feedback by certain postures or body movements. In the present study, we addressed the question of an interaction between basic motor actions and the valence of visual stimuli in an affective modulation of startle paradigm: is the potentiation for aversive and the attenuation for pleasant stimuli more pronounced when the muscles for a congruent approach or avoidance action are activated? Thirty-four volunteers (20 female) watched emotional pictures on a computer screen while simultaneously contracting the flexor vs. extensor muscles of the upper arm. After 3–4 s, an acoustic startle stimulus (105 dB, binaural, instantaneous rise time) was presented via headphones. Arm movement interacted with picture valence. Flexion, frequently related to approach behaviour, further attenuated startle eye blink responses when positive pictures were shown but potentiated these responses in the presence of negative pictures ($F = 4.32$, $p < 0.05$). This result suggests integration and not simple summation of postural and body movement effects on startle reflexivity.

1. Introduction

In contrast to traditional cognitivst positions, recent studies were able to demonstrate that proprioceptive, bodily feedback has cognitive, motivational and attitudinal implications (Niedenthal, Barsalou, Winkielman, Krauth-Gruber, & Ric, 2005). Performing certain movements or adapting certain body positions can influence evaluative judgments (Neumann, Förster, & Strack, 2003). Equally, the execution of certain movements is facilitated when they are congruent to internal psychological states. The theoretical framework to explain these effects, commonly referred to as "embodiment", assumes a correspondence between the physical acts and some psychological function: expressing a smile-like gesture corresponds to a cheerful mood (Niedenthal, 2007), expansive posture to a powerful attitude (Huang, Galinsky, Gruenfeld, & Guillory, 2011), flexion of the arm to perform a pulling movement corresponds to approach and, vice versa, the extension to avoidance motivation (Neumann & Strack, 2000). In contrast to an amodal, cognitive perspective on the human mind, embodiment, assumes that high-level, mental processes depend on activations of certain lower level motor systems, which is known as the "motor process hypothesis" (Cacioppo, Priester, & Berntson, 1993).

Beyond the effects that were demonstrated in behavioural and self-reported outcome measures, these embodied manipulations were able to alter physiological variables associated with specific psychological states (for a review, see: Price, Peterson, & Harmon-Jones, 2012). For instance, adopting a dominant vs. submissive posture directly affected the saliva cortisol and testosterone levels, endocrinal measures which are associated with the power motive (Carney, Cuddy, & Yap, 2010). Leaning forward vs. reclining backward in a laboratory chair induces changes in brain potentials that have been associated with approach, or respectively avoidance motivation (Harmon-Jones & Peterson, 2009; Price & Harmon-Jones, 2011).

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The flexion and extension of the arm is associated with motivational implications: while flexion is coupled with consumption and pulling appetitive objects towards oneself, extension is commonly interpreted to reflect avoidance movement. The corresponding paradigm was initially implemented in an experiment by Cacioppo et al. (1993) to activate the approach-avoidance motivational system. Recently it was shown that the startle eye blink response was modulated in such a way that arm flexion attenuates and extension potentiates the response when no further foreground stimulation was provided (Thibodeau, 2011).

The paradigm of affective startle modulation has been developed and validated by exposing participants to emotional foreground stimuli of various modalities, such as pictures (Vrana, Spence, & Lang, 1988), music (Roy, Mailhot, Gosselin, Paquette, & Peretz, 2009) or odours (Miltner, Matjak, Braun, Diekmann, & Brody, 1994), followed by an intense acoustic stimulus. The startle response is potentiated with aversive and attenuated with pleasant foreground stimulation, which has been explained with the concept of "motivational priming" (Lang, 1995). Assuming that emotion reflects a "readiness for action" (Frijda, 1987), negative emotions will activate defensive, avoidance-related response systems while positive emotions activate appetitive, approach-related responses. The startle probe can be conceptualized as a defensive, slightly negative stimulus. When this startle probe is preceded by an emotional foreground stimulus, either an approach- or avoidance response will be primed, depending on the valence of the stimulus. In case of a congruency in response motivation, i.e. when the foreground is negative, the resulting response is facilitated; a mismatch following positive stimuli will result in an attenuation of the response.

Our study extended the design of Thibodeau to the domain of affective startle modulation. Participants had to sit in front of a desk and press with their flat hand against the upper or lower side of that desk, which contracted either the extensor vs. flexor muscles of the upper arm. These two movements were combined with the display of positive, neutral or negative images on a computer screen.

Our objective was to investigate the question of how motivational congruency between the activation of basic muscles that are related to approach or avoidance movements and foreground stimulus valence affect the startle response. The interpretation of attitudinal effects in terms of simple muscle activation has been challenged in recent studies. Centerbar and Clore (2006) proposed that the effect is related to compatibility between the executed action and stimulus valence: congruent responses should result in more positive evaluations. Other studies reported reduced processing of emotional stimuli when the congruent action had to be performed, which was explained by affective blindness towards response-compatible stimuli (Eder & Klauer, 2009). We hypothesize that the startle magnitude reflects the compatibility between stimulus valence and action: startle attenuation (neutral vs. positive stimuli) and potentiation (neutral vs. negative stimuli) should both be enhance by approach-related movements. In other words, if flexion decreases the psychological distance between the object and the person, it should increase the effect of emotional foreground stimuli when contrasted with extension.

2. Methods

2.1. Participants

Thirty-four undergraduate students (20 female) participated in this study (mean age: 23.7 y, SD = 2.8) for course credits. Participants were excluded for any acute or persistent medical or psychiatric diseases and current or past hearing problems (e.g., tinnitus). All participants gave their written informed consent and were compensated with course credit for participation.

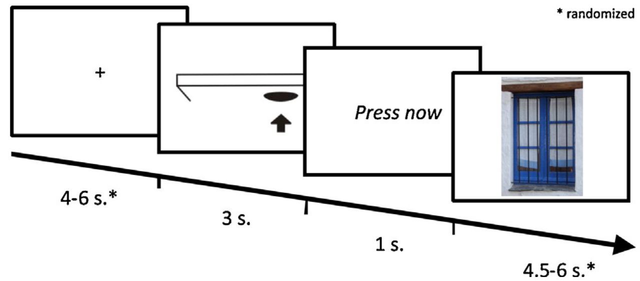

Fig. 1. Experimental protocol.

2.2. Procedure

Participants were seated in a laboratory chair in front of a height-adjustable table. Pressure sensitive, low-profile pads were placed on top and underneath the table on the left and right hand side in fixed positions. The 19 inch computer monitor was placed at a distance of 30 cm from the front edge of the table. Upon entering the laboratory, the participant was told to find a comfortable seating position and instructed about the upcoming task. The experimenter demonstrated the task and had the participant reproduce the movement to ensure proper understanding. After the electrodes for EMG recording were attached and a headphone was put on, the experimenter left the room.

Before the start of the actual experiment, the instructions were again presented in written form. This was followed by eight habituation trials, in which startle stimuli were presented with randomized inter-trial intervals (ITI) of 4–6 s in the absence of any task or visual stimulation.

The experiment consisted of 60 trials that were structured in four separate blocks. The type of movement (flexion vs. extension) and image valence were pseudo-randomised within a block; the use of the left vs. right hand was varied between blocks. Blocks were separated by a short break to provide a rest for the participant and indicate which hand to use in the upcoming block. The experiment was to be continued by button press of the participant.

In the beginning of each trial, the participant had to gaze at a fixation cross in the centre of the screen. The cross was followed by an instruction screen that indicated which type of movement the participant had to perform, i.e. flexion or extension. This screen appeared for 3 s and was succeeded by a 1 s cue screen, which was the signal for the participant to initiate the movement (see Fig. 1).

The participant had to apply the pressure throughout the presentation of the image screen, which was displayed with a randomized duration of 4.5–6 s. After that, the hand had to be placed in a resting position. The other hand, i.e. the hand which was not used in the current block, was resting on the participant's lap. For extension, the participant had to push with the flat hand downward against the upper side of the table, the palm of the hand faced downward. The inverse movement was required for flexion: pushing against the underside of the table with the palm facing upward. For both conditions, the palm of the hand had to be placed on the specified pad and mild pressure had to be applied. This moderate tension had to be sustained until the image disappeared. The arm was slightly bent, with the forearm held in a parallel position to the table (see Fig. 2).

With a randomized stimulus onset asynchrony (SOA) of 3–4 s after image onset, a startle stimulus appeared in 80 percent of the trials.

2.3. Apparatus and materials

2.3.1. Stimulus display

The stimuli were presented on a 19 inch flat screen monitor (1024 × 768 resolution, 150 Hz refresh rate). The monitor was positioned at a distance of 60 cm from the participant's eyes. Images were presented centrally, in an upright position (image dimension: 407 × 600 pixel) against a white background.

2.3.2. Visual stimuli

Forty photographic images of unpleasant, neutral, and pleasant scenes were used. Unpleasant images depicted scenes of threat, disgust, and mutilation, neutral pictures displayed scenes and objects such as household items or furniture, pleasant images depicted sport scenarios and erotic nudes. The pictures were selected from the International Affective Picture System (Lang, Bradley, & Cuthbert, 2008) and from pre-rated image sets used in previous studies (Deuter, Schilling, Kuehl, Blumenthal, & Schachinger, 2013; Lass-Hennemann et al., 2010, 2011). The selection of images was based on previous ratings of valance and arousal. To evaluate the experimental manipulation, each image was rated on these two dimensions by the participants at the end of our study.[1]

[1] Each valence category consisted of 20 images. Of the negative images, 12 were related to disgust/mutilation and 8 depicted violence/threat scenes. The neutral images all depicted objects, such as household items, furniture, clothes etc. Of the

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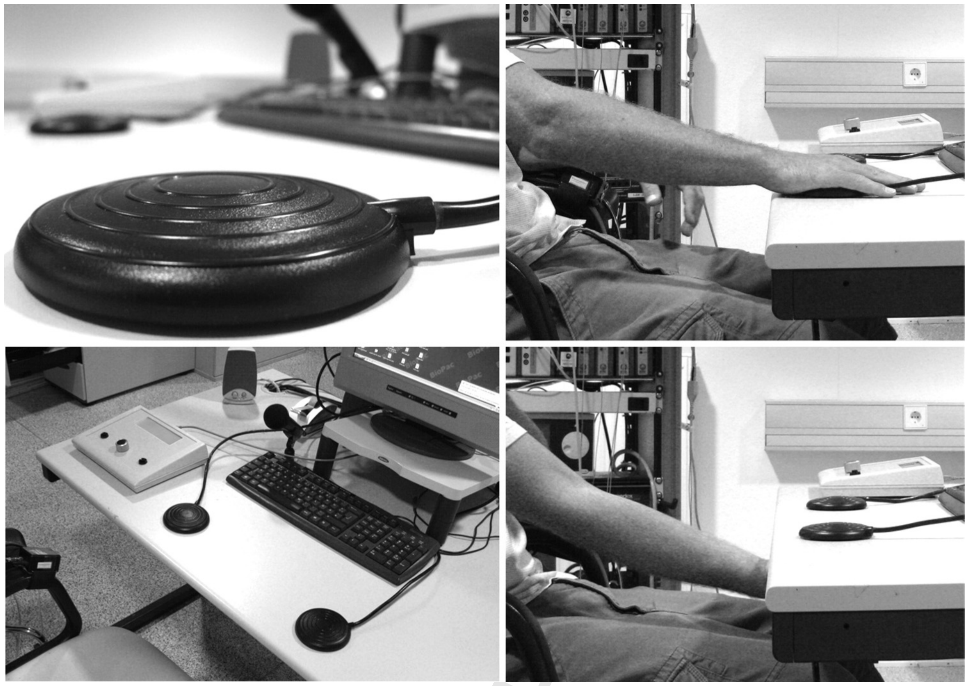

Fig. 2. The participant had to rest his hand on pressure-sensitive sensors (left). When the relevant cue appeared on the screen, he had to press against the top or bottom side of the table (right) with his arm extended.

2.3.3. Startle stimulation

Startle stimuli were acoustic white noise probes (105 dB, 50 ms duration, instantaneous rise time, binaural stimulation) presented via audiometric headphones (Holmco PD-81, Holmberg GmbH & Co. KG, Germany).

2.3.4. Pressure sensor

The pressure, which the participant applied in the flexion/extension task, was measured with a pneumatic pressure sensor (FreescaleMPX5050, Freescale Semiconductor Inc., USA) that was coupled to four table-mounted hand actuators (RS Components Ltd., UK, see Fig. 2).

2.4. Data acquisition and analysis

2.4.1. Startle analysis

Electrodes for EMG recording of the m. orbicularis oculi were attached below the participant's eyes. Two electrodes were placed below the lower eye lid according to Blumenthal et al. (2005) at an inter-electrode distance of 1.5 cm. The EMG-signal was recorded on hard disc with a BIOPAC MP 150 system and an EMG 100 C amplifier via Tyco Healthcare H124SG electrodes at 16 bit resolution and 1 kHz sampling rate. Hardware band-pass filter settings were 10–500 Hz, followed by a 28 Hz software high-pass filter (van Boxtel, Boelhouwer, & Bos, 1998). The raw signal was rectified and integrated online with a time constant of 10 ms (Blumenthal, 1994). The data of seven participants had to be discarded from further analysis because of data acquisition problems.

The EMG-startle responses were analyzed offline with a C++ based, semi-automated programme. Startle response magnitude was defined as difference between peak and baseline signal. The integrated algorithm identified peak in a time interval between 20 and 150 ms after stimulus onset. Baseline was assessed 50 ms prior to stimulus onset. Each response was manually confirmed and corrected for non-responses and artefacts. Non-responses (cases with no discernable response) were set to zero and included in the analysis (3.37% of all trials). Cases with electrical and physiological artefacts (such as voluntary or spontaneous eye blinks coinciding with the startle stimulus, or trials with excessive background noise or multiple peaks) were excluded from analysis (14.05% of all trials). To eliminate the impact of inter-individual differences, we standardized the raw data with intra-individual *T*-scores using all blinks of each participant as the standard distribution (Blumenthal et al., 2005).

2.4.2. Subjective ratings

After the data acquisition phase, the participant was asked to rate the previously presented images on the dimensions of 'valence' and 'arousal'. Each image was displayed together with a five-digit scale for both dimensions (1 = *very unpleasant* or *low arousal* and 5 = *very pleasant* or *high arousal*). The rating was based on the 'Self-Assessment Manikin' rating system (Lang et al., 2008).

The flexion/extension movements had to be rated on eight digits Likert scales on the dimensions 'pleasantness' and 'effortfullness' (1 = *very pleasant* or *low effort* and 8 = *very unpleasant* or *high effort*).

2.4.3. Pressure intensity

The analogue signal of the pressure sensor was recorded on hard disc with the BIOPAC MP 150 system and analyzed offline with a C++ based, semi-automated programme. The pressure response was calculated as the difference between the intensity signals at the time when constant pressure was applied (the mean value over the period when the stimulus picture was displayed) and a baseline at 3 s after image offset (no pressure).

2.5. Statistical analysis

The EMG measured eye blink response magnitude was averaged over both eyes and across trials for each condition (Blumenthal et al., 2005). Since our objective was the motion-induced effect on affective startle modulation and not the affective consequences of flexor/extensor movements in itself, startle response magnitude during neutral slide presentation matching the respective flexor/extensor movements was subtracted from the affective picture conditions. The resulting values represent movement-corrected values, and were subjected to an ANOVA with two two-level within factors "valence" and "movement". It was planned to subsequently calculate a paired *t*-test for the exploration of a resulting interaction.

Subjective rating data for 'valence' and 'arousal' dimensions of the images were subjected to a one-factorial, repeated measure ANOVA (positive vs. neutral vs. negative). Subjective ratings of the flexion/extension movements were analyzed separately for the dimensions 'pleasantness' and 'effortfullness' with Student's *t*-test for paired samples. To check for a possible modulation of the startle effect due to effort or pleasantness of the task, we calculated an ANOVA for repeated measurements with the movement ratings as covariates.

The pressure intensity measures were compared for the factor 'action' (flexion vs. extension) by calculating a Student's *t*-test for paired samples.

Reported *p*-values for factors with more than two conditions are 'Greenhouse–Geisser' corrected. The critical alpha-level was set to .05 in all analyses.

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positive images, 11 depicted erotic scenes, the remaining 9 depicted sport scenes and cute children/kitten. Image codes from the IAPS repository – neg: 1930, 3053, 3061, 3062, 3120, 3168, 3266, 9301, 9326, 9405, 9410, 9582; ntr: 7004, 7006, 7009, 7025, 7026, 7031, 7035, 7040, 7052, 7090, 7100, 7175, 7185, 7186, 7217, 7235, 7504. The non-IAPS images will be provided upon request.

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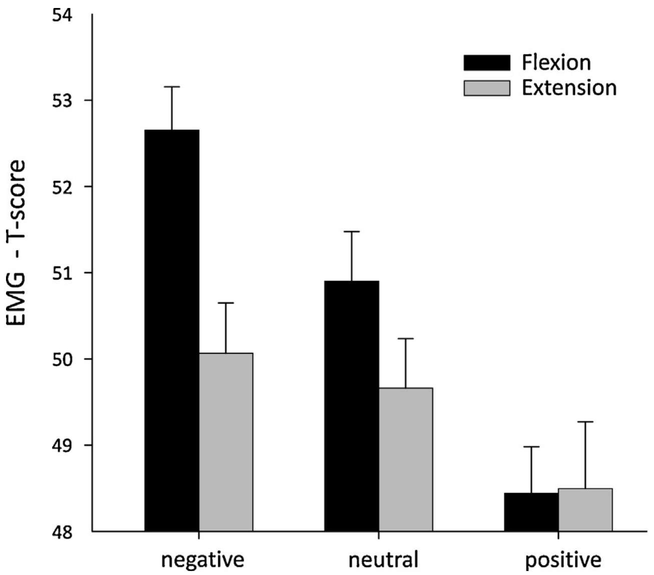

Fig. 3. Startle eye blink responses (*T*-scores), recorded via the orbicularis oculi muscle.

3. Results

3.1. Subjective ratings

3.1.1. Image ratings

Significant differences between image categories were found for the valence dimension ($F_{2,52} = 420.56$; $p < .001$; $\eta^2 = .94$) and the arousal dimension ($F_{2,52} = 132.17$; $p < .001$; $\eta^2 = .84$). Positive images were rated as more pleasant than neutral images, and neutral as more pleasant than negative images ($M = 1.59$ [neg], 3.19 [ntr], 4.01 [pos]). Negative and positive images were both rated as more arousing than neutral images ($M = 3.51$ [neg], 1.38 [ntr], 3.03 [pos]).

3.1.2. Action ratings

Significant differences between flexion and extension of the arm were found for the effortfullness ($F_{1,26} = 7.79$; $p < .05$; $\eta^2 = .23$) and pleasantness dimension ($F_{1,26} = 16.67$; $p < .05$; $\eta^2 = .27$). Flexion of the arm was rated as requiring stronger effort ($M = 4.41$ [flexion], 3.19 [extension]) and more unpleasant ($M = 4.15$ [flexion], 3.04 [extension]), compared to extension.

3.2. Startle EMG response

The ANOVA with the two within factors picture "valence" (two-level: aversive, appetitive) as well as arm "movement" (two-level: flexion, extension), and movement-corrected (see Section 2 above) *t*-scored startle eye blink data as the dependent variable, revealed a significant main effect of "valence" ($F_{1,31} = 17.23$; $p < .001$; $\eta^2 = .36$) with enhanced startle responses during presentation of negative images. No main effect of "movement" ($F_{1,31} = 3.5$; $p > .05$) was detectable. However, a significant interaction between "valence" × "movement" ($F_{1,31} = 4.32$; $p = .046$; $\eta^2 = .12$) was present. Subsequent two-sided paired *t*-testing indicated that within the flexion condition (approach-like movement) startle was higher for aversive than appetitive pictures (4.2 + −0.79 [SEM] *t*-score units; $n = 32$, $T = 5.35$, $p < 0.0001$), however, during the extension condition (avoidance-like movement) this difference disappeared (1.57 + −1.08 [SEM] *t*-score units; $n = 32$, $T = 1.46$, $p = 0.15$). No other direct comparison was significant (see Fig. 3).

To assess whether subjective ratings can account for this effect, we included the values of the action ratings for each person as a covariate in the calculation. However, neither self-reported effortfullness ($F_{1,24} = 0.18$; $p > .05$) nor the pleasantness ($F_{1,24} = 4.08$; $p > .05$) revealed significant interactions.

3.3. Pressure intensity

The intensity of pressure that was applied on the sensor pad did not differ significantly between flexion and extension modes ($F_{1,30} = 1.85$; $p > .1$) or between image valence categories ($F_{1,60} = 1.05$; $p > .05$).

4. Discussion

This study investigated the effects of approach-avoidance related actions on the well established phenomenon of affective startle modulation. We hypothesized that the effect of emotional foreground stimuli on the human startle response would be modulated by arm flexion versus extension. In contrast to extension, we expected stronger responses when flexion is combined with negative pictures and lower responses when combined with positive pictures.

The results are in line with our hypotheses. Considering that the startle response magnitude provides a measure for affective valence, with higher magnitudes indicative of a potentiated defensive reaction, the results of this experiment indeed point in that direction. In contrast to arm extension, arm flexion, i.e. a movement towards the own body, is accompanied by potentiated startle responses when negative pictures are presented. In the presence of positive pictures, flexion significantly reduces startle responses. This effect can be interpreted in a meaningful way. Since flexion pulls objects towards the own body, it should have opposite implication for pleasant and aversive objects.

Unlike other studies before (Cacioppo et al., 1993; Neumann & Strack, 2000; Thibodeau, 2011), our ratings indicated that both movements differed in terms of effort and pleasantness. This could possibly explain the potentiated responses for arm flexion in the neutral condition. Considering that startle stimuli are experienced as mildly aversive in itself (Lang, 1995), arm flexion would have been incongruent for this rather unpleasant setting, even with neutral foreground pictures. Another study that employed this arm flexion/extension manipulation also reported higher subjective effort for the flexion condition (Friedman & Förster, 2002). We used both hands in our study, the dominant and non-dominant hand, in a counter-balanced, within-subject variation. This could potentially increase the required effort and therefore decrease the pleasantness of the task. However, because the applied pressure did not differ between image valence conditions, it seems unlikely that a difference in effortfullness explains our effects. Furthermore, the startle response effect could not be predicted by the ratings alone when these were included as a covariate. We rather suspect that even if effort and subjective pleasantness affects the startle response magnitude in this study, the difference that can be seen between image valance conditions is attributable to motivational tendencies.

Our results are in line with a recent study that could demonstrate that changes in spatial distance, in this case the illusion of a movement towards or away from the participant, can increase the motivational effects of emotional stimuli on the startle response (Muhlberger, Neumann, Wieser, & Pauli, 2008). However, the stimuli in our study remained static and did not respond to the motor action of the participant. Contracting the muscles had no effect for the participant, in the sense that he could really increase or decrease the distance or exposure to the emotional stimuli. Therefore we can conclude that simple activation of muscles that are

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commonly associated with approach or avoidance behaviour is sufficient to alter the effects of affective startle modulation.

As a limitation, the question of how the results of our study generalize to other stimulus material, action manipulations and participant groups remains open. The image material consisted of mixed-emotions sets (disgust and threat vs. erotic and sport scenes) and was validated by subjective ratings and former studies but naturally positive and negative images differ not only in their valence but in their content as well. Future research should set out to investigate whether the effects of embodiment manipulations on other emotional foreground stimuli point in the same direction and whether the effect endures when different movements, postures or target stimuli are used.

With this study we could demonstrate that affective modulation of startle by emotional pictures is enhanced when compatible approach or avoidance related arm movements are executed. Furthermore, our data support the context dependency of embodiment effects on motivational states.

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