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BRIEF REPORT

Automatic influence of arousal information on evaluative processing: Valence–arousal interactions in an affective Simon task

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Previous research showed that evaluation speed is faster for negative stimuli that are high in arousal and for positive stimuli that are low in arousal. The present study investigated whether arousal and valence analogously interact in automatic stimulus evaluations, i.e., if stimulus valence is irrelevant for the task. One sample of participants switched randomly between an evaluation task and an affective Simon task that assessed stimulus evaluations indirectly. Another sample completed a pure Simon task. In all conditions, the influence of affective stimuli on task performance was enhanced when valence and arousal were congruent (i.e., high-arousing negative and low-arousing positive stimuli) than when both stimulus dimensions were incongruent (i.e., low-arousing negative and high-arousing positive stimuli). These findings suggest that evaluative implications of stimulus arousal and valence are automatically inferred even when stimulus evaluation is irrelevant for the task at hand.

Keywords: Arousal–valence interaction; Affective Simon effect; Automatic evaluation.

Affect is typically hypothesised to span various dimensions, and valence and arousal were identified as the most basic dimensions underlying emotional information (Russell, 2003). Arousal refers to a continuum that varies from calm to excited, whereas valence refers to a continuum that varies from pleasant to unpleasant. Both dimensions were shown to contribute to connotative meaning (e.g., Osgood, Suci, & Tannenbaum, 1957), affective experiences (e.g., Russell & Feldman Barrett, 1999), and emotion-related behaviour (e.g., Lang, Bradley, & Cuthbert, 1997), but the relationship between them is still debated. Whereas some theorists argued for independent contributions of both factors to affective experiences (e.g., Russell & Feldman Barrett, 1999), others rejected a complete orthogonality and proposed blends of valence and arousal as basic

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dimensions of feeling states (e.g., Watson, Wiese, Vaidya, & Tellegen, 1999). Similar positions were advocated in discussions of initial stages of affective stimulus encoding that give rise to attentional biases and to emotional appraisals. For instance, Estes and Adelman (2008) argued that disruptive effects of negative stimuli on naming and lexical decision latencies are uniform to all negative stimuli; Larsen, Mercer, Balota, and Strube (2008), on the other hand, obtained evidence that automatic vigilance does not occur among arousing stimuli, arguing against a general influence of negative valence. Thus, even though nearly all theories acknowledge the importance of valence and arousal for affect, little consensus exists about the exact contributions of both dimensions to affective processing and emotional experience.

In this research we investigated joint influences of valence and arousal on the speed and reliability of evaluative appraisals. On the first view, one might think that the speed of evaluative judgements is fully determined by the extremity of evaluative meaning: The more extreme the valence of a stimulus, the quicker the determination of its positive or negative significance. On the second view, however, evidence is accumulating that evaluation is a constructive process that integrates multiple sources of affective information (see Cunningham & Zelazo, 2007; Ferguson & Bargh, 2003; Schwarz, 2007, for overviews). Thus, informational sources other than valence might influence evaluative appraisals, and the congruency between these evaluative sources might affect the speed as well as the consistency of evaluative judgements. Given that valence and arousal account for the largest part of variance in connotative meaning (Osgood et al., 1957), it seems reasonable to assume that arousal is another important factor that influences evaluative judgements.

This hypothesis of joint influences of valence and arousal on evaluative processing was tested by Robinson, Storbeck, Meier, and Kirkeby (2004) in a series of experiments. Previous research indicated that stimuli with a high intensity and an abrupt onset are experienced as aversive, with such events frequently being indicative of potential danger (Öhman, 1997). Based on this research, Robinson and colleagues hypothesised that high-stimulus arousal might be negatively coded relative to low arousal, and that affective implications of valence and arousal might interact in evaluative judgements of emotional stimuli. For a test of this hypothesis, sets of pictorial stimuli were selected from the International Affective Picture System (IAPS; Lang, Bradley, & Cuthbert, 2005) that were completely orthogonal in their ratings of valence and arousal, with other stimulus factors being controlled (see Robinson et al.'s Study 1 for respective analyses). These stimuli were then projected on a screen, and participants were to evaluate each picture as quickly and as accurately as possible. A series of experiments consistently showed the expected interaction between stimulus valence and arousal in evaluation latencies: High-arousing, negative pictures were evaluated faster than their low-arousing counterparts, and positive pictures low in arousal were evaluated faster than high-arousing positive slides. This interactive influence on evaluative processing also affected performance in a secondary, neutral task that followed picture evaluation (Studies 4 and 5). Taken together, these findings corroborate the idea that evaluative implications of stimulus arousal interact with stimulus valence in evaluative appraisals, suggesting that arousal and valence are not completely independent dimensions in the evaluation of stimuli.

Robinson and colleagues (2004) explained the interactive influence of valence and arousal with the operation of two preattentive (i.e., automatic) mechanisms in stimulus evaluations. One mechanism is devoted to the encoding of stimulus valence and another one is related to stimulus arousal. The affective outputs from the two mechanisms are then integrated prior to conscious evaluation, which proceeds more rapidly with congruent outputs (i.e., positive–low, negative–high) than with incongruent ones (i.e., positive–high, negative–low).

For their experiments, however, ambiguities remain about whether the effect of valence and arousal on evaluation speed is indeed attributable to fully automatic processes. First, in all studies participants were explicitly instructed to attend to the valence of the stimuli and to infer their evaluative significance. Thus, it is possible that the influence of arousal on evaluative appraisals is restricted to intentional evaluations of stimuli. Second, more strategic processes could have contributed to the observed interaction as well. For instance, given a strong correlation between arousal and the degree of unpleasantness (Bradley, Codispoti, Cuthbert, & Lang, 2001), participants might have made strategic use of arousal for rapid guesses of valence. Alternatively, participants might have been reluctant to judge the positivity of erotic slides, which were overrepresented in the high-arousal cell, in public. Even though the latter explanation was addressed in experiments that yielded systematic carry-over effects of non-public evaluations on a secondary task (Studies 4 and 5), more than two seconds intervened between picture onset and onset of the secondary task in these studies, granting sufficient time for strategic picture processing. In short, even though Robinson and colleagues provided clear-cut evidence for a valence–arousal interaction in evaluative processing, a contribution of intentional and strategic evaluative inferences to the observed effects cannot be ruled out completely.

Given these ambiguities, it is important to investigate the influence of arousal on evaluative processes in a task setting that does not require intentional stimulus evaluations. In the present experiment, we realised such a setting with an affective Simon task, in which the participants were to respond with pronunciations of "positive" and "negative" to a stimulus feature other than valence (De Houwer & Eelen, 1998). Thus, emotional valence of the presented stimuli was completely irrelevant in this task, allowing for an indirect assessment of stimulus evaluations (affective Simon effect). In addition to this pure-Simon condition, we also realised an intermixed-task condition that randomly mixed evaluation-irrelevant trials with evaluation-relevant trials, in which participants were to directly name the valence of the presented stimuli (see Voss, Rothermund, & Wentura, 2003; Zhang & Proctor, 2008).

With these conditions, we tested the following predictions:

1. For the evaluation-relevant trials in the intermixed-tasks condition, we expected a replication of the findings reported by Robinson and colleagues (2004): High-arousing negative pictures should be evaluated faster than low-arousing negative pictures, and low-arousing positive pictures should be evaluated faster than their high-arousing counterparts.
2. For the evaluation-irrelevant trials in the intermixed-tasks and pure-Simon conditions, we expected a more pronounced affective Simon effect (i.e., faster classifications with evaluatively corresponding responses than with non-corresponding responses) for stimuli that are congruent in arousal and valence (negative/high arousal, positive/low arousal) than for emotional pictures that are incongruent in arousal and valence (negative/low arousal, positive/high arousal). The latter result would indicate stronger automatic evaluative activations through high-arousing negative and low-arousing positive stimuli.

METHOD

Participants

Forty students (27 women) participated in the intermixed-tasks condition and 35 students (22 women) in the pure-Simon condition. All participants were native speakers of German and naïve to the purpose of the experiment.

Apparatus and stimuli

In a dimly lit experimental chamber, participants were seated at a distance of 60 cm from a 17″ VGA colour monitor with 85 Hz refresh rate. A microphone connected to a voicekey apparatus was used for registration of vocal responses.

Stimuli were 56 pictures from the IAPS that were selected from Robinson and colleagues (2004) according to their valence and arousal norms. Half of them were positive, the other half were negative. Within each valence, there were 14 low-arousing and 14 high-arousing pictures. Thus, valence and arousal were manipulated independently in the stimulus material, with other factors like visual complexity and extremity of valence being controlled (see Robinson et al. for respective analyses). For the intermixed-tasks condition, the material was divided into two sets matched for arousal and valence: One set was exclusively presented in the evaluation-relevant trials; the other set was presented in the evaluation-irrelevant trials, with set assignment counterbalanced across participants. An additional 20 positive and 20 negative pictures were selected from the IAPS for task practice. The pictures subtended a visual angle of about $22 \times 15^{\circ}$ at the centre of the screen, and each picture was surrounded by a border (7 pixels) that was coloured blue, green, or white.

Procedure

In the intermixed-tasks condition, participants were to perform two classification tasks that were cued by the colour of the picture border: (1) When the border was white, participants had to evaluate the picture. Responses were given vocally by saying “positive” or “negative”. (2) When the border was coloured, participants had to respond to the colours blue and green with pronunciations of “positive” and “negative”, with response assignment counterbalanced across participants. Thus, in half of the trials the valence of the picture was relevant (evaluation task), in the other half irrelevant (colour-decision task). In the pure-Simon condition, only the colour-decision task was presented.

Each trial started with the presentation of a white fixation cross (250 ms) on a black background, followed by a picture presentation until registration of a vocal response. Feedback was given on a reaction time above one second in the intermixed condition and above 800 ms in the pure-Simon condition. The vocal response and task-irrelevant triggers of the voicekey were coded online by an experimenter; the next trial started after one second.

In the intermixed-tasks condition, the classification tasks were practiced in two separate blocks with 20 trials each. The first block introduced the evaluation task; in the second block colour decisions had to be made. In a final practice block, both classifications were randomly intermixed with 12 trials for each task. The experimental phase consisted of 448 trials, divided into four blocks of 112 trials. Each block mixed both tasks with equal probability, with the following restrictions on list construction: (1) There were no more than three trials of the same classification task in a row; (2) task repetitions comprised approximately 50% of the block trials; and (3) pictures with (mis)matching valence–arousal values were presented in about half of the repetition and alternation trials. Participants were instructed to respond as quickly and accurately as possible in each trial and 1 Eurocent was earned for each correct response with a reaction time below 700 ms. A block summary reported the total amount of money earned in each block. The pure-Simon condition started with a single practice block of the colour-decision task (20 trials) that was followed by 224 trials divided into two blocks of 112 trials. All other procedural details were identical with those of the intermixed-tasks condition.

RESULTS

Trials with voicekey failures comprised 2.9% of all trials in each task condition. Wrong classifications were made in 7.8% of all intermixed trials and in 2.0% of all pure-Simon trials. These trials were discarded from reaction-time analyses. In addition, individual Tukey (1977) outlier thresholds were computed for each task to identify response latency outliers; this truncation removed 3.2% of all evaluation-relevant trials from reaction-time analyses, and 2.8% and 4.5% of all intermixed and pure evaluation-irrelevant trials, respectively. Error rates supported, if anything, the result pattern of the reaction-time analyses.

Pure evaluation-irrelevant trials

A repeated-measures analysis of variance (ANOVA) with Response Valence (positive vs. negative), Picture Valence (positive vs. negative), and Valence–Arousal Congruency (congruent: positive–low, negative–high vs. incongruent: positive–high, negative–low) as factors showed faster pronunciations of "positive" than "negative", $F(1, 34) = 11.4$, $p < .01$, $d = 0.57$, and faster reactions to negative than positive pictures, $F(1, 34) = 9.04$, $p < .01$, $d = 0.51$. In addition, the predicted three-way interaction reached significance, $F(1, 34) = 5.04$, $p < .05$, $d = 0.38$. As shown in Figure 1, when picture arousal was congruent with picture valence, participants responded faster to the coloured picture border with evaluatively corresponding pronunciations than with evaluatively non-corresponding pronunciations ($\triangle M = 6$ ms), $F(1, 34) = 5.68$, $p < .05$, $d = 0.40$. When picture valence and arousal were incongruent, however, picture valence did not interact with response valence ($\triangle M = -1$ ms), $F < 1$. In short, an affective Simon effect was observed when picture valence and arousal were congruent but not when they were incongruent. All other effects were non-significant.

Intermixed evaluation-irrelevant trials

A repeated-measures ANOVA with Task Transition (switch vs. repetition), response valence, picture valence, and valence–arousal congruency as factors revealed slower responses in switch trials ($M = 606$ ms, $SE = 11.7$) than in repetition trials ($M = 537$ ms, $SE = 9.7$), $F(1, 39) = 161.5$, $p < .001$, $d = 2.01$, reflecting task-switch costs. In addition, participants responded faster with "negative" than with "positive", $F(1, 39) = 14.94$, $p < .001$, $d = 0.61$; this difference in response speed was more pronounced in switch trials than in repetition trials, $F(1, 39) = 4.18$, $p < .05$, $d = 0.32$. The main effects of picture valence and valence–arousal congruency were not significant, with both Fs < 1.

As expected, participants responded faster to the coloured picture border when the response valence matched the valence of the picture

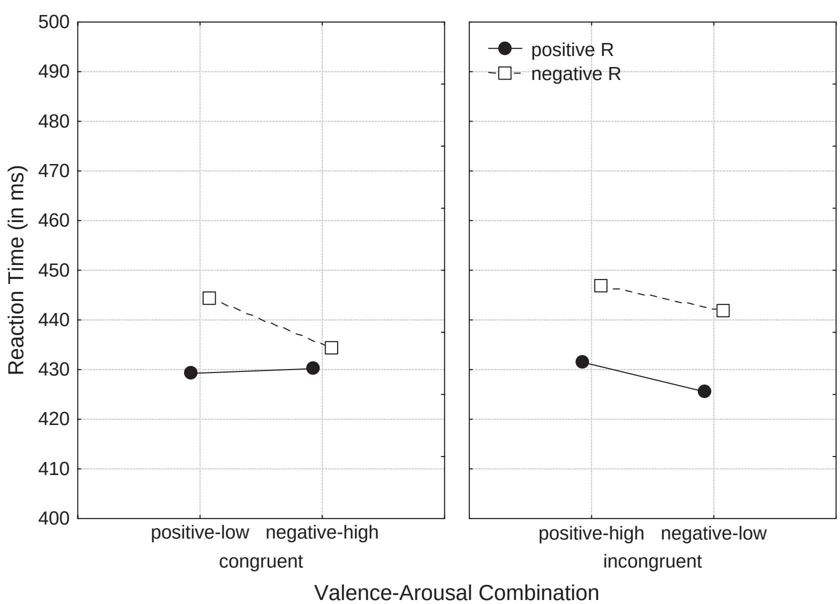

Figure 1. *Mean latencies of "positive" and "negative" pronunciation responses (R) to pictures with congruent (positive–low, negative–high) and incongruent (positive–high, negative–low) valence–arousal combinations in the pure-Simon condition.*

($M = 568$ ms and $M = 547$ ms for positive and negative pictures, respectively) than when stimulus valence and response valence mismatched ($M =$ 573 ms and $M = 598$ ms for positive and negative pictures, respectively), $F(1, 39) = 48.53$, $p < .001$, $d = 1.10$. Thus, an affective Simon effect was observed in the data that was more pronounced in switch trials ($\Delta M = 35$ ms) in comparison to repetition trials ($\Delta M = 21$ ms), $F(1, 39) = 11.18$, $p < .01$, $d = 0.53$. Most importantly, the three-way interaction between picture valence, valence–arousal congruency, and response valence was significant, $F(1, 39) = 4.36$, $p < .05$, $d = 0.33$. As shown in Figure 2, positive and negative pictures with a "matching" arousal value biased the selection between positive and negative pronunciations more ($\Delta M = 34$ ms) than pictures with an incongruent arousal value ($\Delta M = 21$ ms). This influence of valence–arousal congruency on the size of affective Simon effects was not qualified by task transition, $F < 1$. All other effects were nonsignificant, with all ps $> .15$.

Intermixed evaluation-relevant trials

A repeated-measures ANOVA with Stimulus Arousal (low vs. high), Picture Valence (positive vs. negative), and Task Transition (switch vs. repetition) as factors yielded an interaction between Arousal and Valence, $F(1, 39) = 3.89$, $p <$ .05 (one-tailed), $d = 0.31$. Negative pictures were evaluated faster when arousal was high ($M =$ 630 ms, $SE = 10.2$) rather than low ($M = 639$ ms, $SE = 11.4$), whereas evaluation latencies did not differ for positive pictures that were low ($M =$ 624 ms, $SE = 11.0$) and high ($M = 625$ ms, $SE =$ 10.7) arousing. The main effects of Picture Valence, $F(1, 39) = 2.70$, $p = .11$, and Picture Arousal, $F(1, 39) = 1.90$, $p = .18$, were not significant, but the main effect of task transition was: Reaction times were slower in switch trials ($M = 639$ ms, $SE = 10.4$) than in repetition trials ($M = 620$ ms, $SE = 10.1$), $F(1, 39) = 55.68$, $p < .001$, $d = 1.18$. The three-way interaction was not significant, $F < 1$, indicating that the interaction between valence and arousal in evaluative

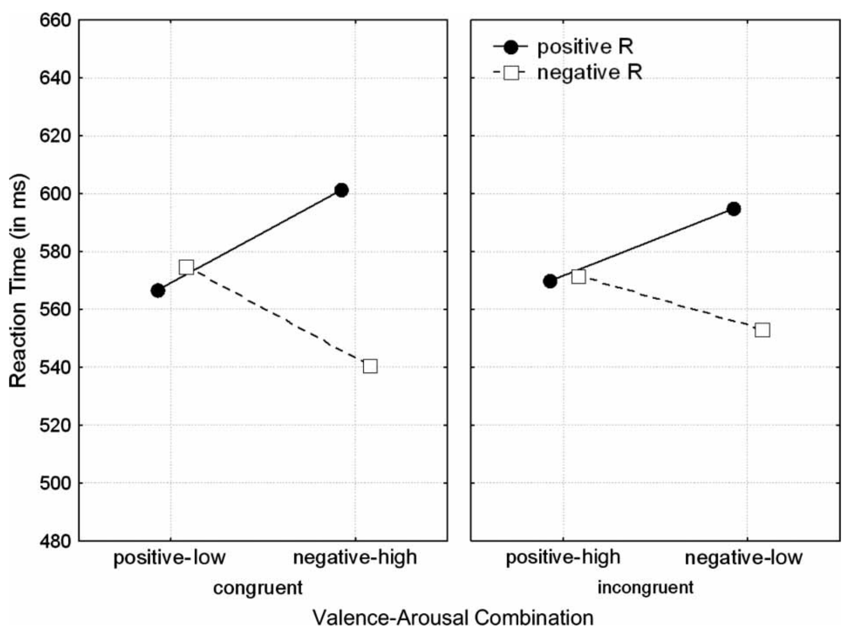

Figure 2. *Mean latencies of "positive" and "negative" pronunciation responses (R) to pictures with congruent (positive–low, negative–high) and incongruent (positive–high, negative–low) valence–arousal combinations in the intermixed-Simon condition.*

categorisations was not restricted to repetitions of the evaluation task. All other interactions were non-significant (with all ps > .25).

DISCUSSION

The present experiment investigated an interactive influence of stimulus arousal and valence in direct and indirect stimulus evaluations. The results can be summarised as follows: When attention was directed to the evaluative picture meaning in intermixed evaluation-relevant trials, participants evaluated high-arousing negative pictures faster than low-arousing negative slides, whereas high- and low-arousing positive pictures did not differ in evaluation speed. This valence–arousal interaction is in line with previous reports of an interactive influence on evaluation speed (Robinson et al., 2004), with the difference that in our experiment the influence of arousal was mainly restricted to evaluations of negative stimuli.

More important, an analogous interaction between picture valence and arousal was inferred from indirect stimulus evaluations (affective Simon task): In intermixed evaluation-irrelevant trials, affective slides with a valence–arousal match (i.e., high-arousing negative and low-arousing positive pictures) produced a stronger affective Simon effect than affective slides with a valence–arousal mismatch (i.e., low-arousing negative and high-arousing positive pictures). An analogous pattern of influence was observed in the pure-Simon condition as a more stringent test of the hypothesis that did not contain any evaluation-relevant trials; here, an affective Simon effect was observed when picture valence and arousal were congruent but not when they were incongruent. In combination, these findings indicate stronger evaluative activations through stimuli that match in arousal and valence, even when attention is directed away from affective valence.

Robinson and colleagues (2004) hypothesised a negative coding of high-stimulus arousal that facilitates negative stimulus evaluations but provides conflicting information in positive stimulus evaluations. In their studies, however, participants were explicitly instructed to evaluate the presented stimuli; hence, it remained unclear whether a negative implication of high-stimulus arousal is restricted to intentional stimulus evaluations, and whether variations in arousal are strategically utilised for evaluative inferences.

The present study ruled out such explicit evaluative inferences with an indirect assessment of stimulus evaluations. In evaluation-irrelevant trials, participants were to respond to border colour rather than picture valence, and attending to picture valence was detrimental to task performance in half of these trials. Nevertheless, picture valence influenced the selection between "positive" and "negative" pronunciation responses, and this task-irrelevant influence was more pronounced when stimulus arousal was congruent with stimulus valence. Note that the valence–arousal interaction in affective processing was not qualified by task transition (task switch vs. repetition) in the intermixed condition, arguing against an evaluative task set inertia as an explanation for the task-irrelevant affective influence in this condition (see Voss & Klauer, 2007). Thus, these findings suggest that a proximal (i.e., task-defined) goal to evaluate the stimuli is not necessary for arousal-based evaluative inferences. Furthermore, an interactive influence on affective processing was also observed in the pure-Simon condition, suggesting that evaluative implications of valence and arousal were integrated even without a distal (i.e., task-independent) evaluation goal. Finally, the indirect assessment of stimulus evaluation rules out strategic guesses that are based on an ecological correlation between high arousal and unpleasantness. Instead, arousal was incidentally encoded in the colour-decision task, suggesting that evaluative implications of stimulus arousal were automatically inferred without proximal and distal goals to evaluate (see Moors & De Houwer, 2008).

In all conditions, stimulus arousal clearly affected responses to negative stimuli, whereas evaluations of positive stimuli were relatively unaffected by the variation of arousal. These observations are interesting given that arousal was not predictive of valence extremity or identification speed of gist information in control analyses of the presented material (Robinson et al., 2004). Thus, stimulus arousal might influence evaluative appraisals of negative stimuli more than those of positive stimuli, in line with hypotheses of a threat advantage or negativity bias that claim a priority of high-arousing negative stimuli in the processing of affective stimuli (Lang et al., 1997; Öhman, 1997). In addition, the asymmetric pattern of influence argues against a general blend of valence and arousal in (automatic) evaluation (but see Robinson et al.); instead, the present results point at the possibility that variations in arousal might be more diagnostic for negative evaluations than for positive evaluations, which is in line with research that showed a higher correlation between arousal and degree of unpleasantness than between arousal and degree of pleasantness in ratings of pictorial stimuli (Bradley et al., 2001; Lang et al., 1997). Further research is necessary that examines an asymmetric influence of stimulus arousal on negative and positive appraisals more in detail.

On a larger theoretical scale, the present study clearly corroborates the idea that stimulus evaluation is based on an integration of multiple sources of affective information. In affective stimulus processing, valence and arousal are assessed and the affective outcomes of these appraisals are integrated into an overall evaluation. As the present study shows, these constructive processes operate automatically, even when stimulus evaluation is irrelevant for the task. Thus, automatic evaluations might be based on similar evaluative inferences from valence and arousal like more strategic, intentional appraisals of affective valence.

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