

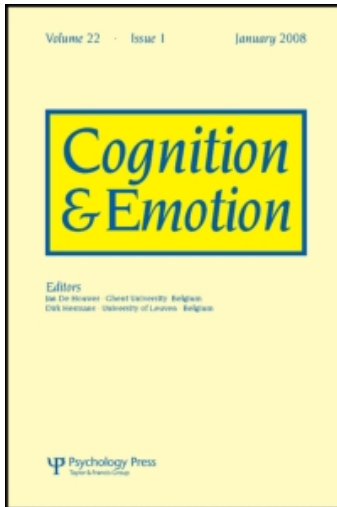
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When affective cues broaden thought: Evidence from event-related potentials associated with identifying emotionally expressive faces

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When affective cues broaden thought: Evidence from event-related potentials associated with identifying emotionally expressive faces

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Divergent theoretical perspectives predict that the valence of affective cues impacts the breadth and flexibility of cognition, but extant data have not clarified whether such effects transpire extemporaneously or only later via processes of evaluation or selection from among thoughts already generated. The present investigation found more prominent electro-cortical event-related-potential (P3) responses among participants focused on identifying a positively valenced social target (an individual with a happy facial expression) than a negatively valenced social target (an individual with a disgusted facial expression). Indeed, even obvious non-targets (scrambled faces) evoked more-prominent P3 responses among participants in the happy-target than the disgusted-target condition, thereby implicating an effect of the valence of affective cues on the extent of cognitive processing as it unfolds.

Investigating how affective cues impact the flexibility of thought has proved fertile ground for integrating the psychology of emotion, cognition, and social behaviour. In this vein, much research now suggests that positively (relatively to negatively) valenced affective experiences and cues facilitate cognitive flexibility, as reflected, for example, in the creativity of

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the uses one generates for a brick (Friedman & Förster, 2001) or the inclusiveness of the categories one devises (Isen & Daubman, 1984). Different theories have assumed different underlying processes, including asymmetries in the volume of positively relative to negatively valenced material stored in memory (facilitating retrieval of more relative to less diverse cognitive material; Isen, 1984); differential informational value of positive relative to negative affective cues (signalling the situation-appropriateness of exploratory relative to conservative processing styles; Fiedler & Bless, 2000; Gasper & Clore, 2002; Schwarz, & Clore, 2007); differential impacts of positive and negative affective cues on the scope of attention, prompting a broad relative to a narrow focus on perceptual inputs (Easterbrook, 1959; Derryberry & Tucker, 1994) and behavioural repertoires (Fredrickson, 2001); and differential impacts of positive relative to negative affective cues on task engagement (prompting more relative to less cognitive productivity; Hirt, Melton, McDonald, & Harackiewicz, 1996; Isen, 2001). Despite important differences, then, divergent theoretical perspectives share the strong prediction that positively (relative to negatively) valenced affective cues increase the breadth and flexibility of cognition.

Data supporting the general prediction that affective cues modulate the breadth and flexibility of cognition have come from varied methodologies that have isolated concomitant processes of attribution (Gasper, 2004), categorisation (Isen & Daubman, 1984), perception (Fredrickson & Branigan, 2005), attention (Derryberry & Reed, 1998), memory retrieval (Friedman & Förster, 2001), cognitive control (Kuhl & Kazén, 1999), and hemispheric asymmetry (Derryberry & Reed, 1998; Friedman & Förster, 2005). Because the vast majority of these findings reflect research participants' eventual motor responses, however, it has not always been clear whether affective cues have facilitated differences in extemporaneous flexibility and breadth of thinking (e.g., generating more cognitive responses, as hypothesised by Gasper, 2004) or differences in later interpretation, correction, or selection from among thoughts already generated (e.g., deciding to report more of one's subjective cognitive responses to the experimenter, as hypothesised by Wyer, Clore, & Isbell, 1999).

To examine the impact of affective cues on spontaneous, generative cognitive processes, the present work capitalised on extensive electrophysiological research on an event-related-potential component known as the P3 response. Among the most-studied phenomena in psychophysiology over the past several decades, the P3 response is a large positive component typically peaking 300–700 ms following stimulus presentation, with a widespread topographical distribution typically of maximal amplitude at central and parietal locations (see Donchin & Coles, 1988; Nieuwenhuis, Aston-Jones, & Cohen, 2005, for reviews). A central functional correlate of P3 responses is

classification of stimuli into generally defined “target” categories, as when, in classic “oddball” paradigms, target and non-target stimuli differ regarding a single perceptual feature (e.g., pitch or colour). Conceptual oddball paradigms entail classification of heterogeneous category exemplars, such as female names intermixed with male names (Kutas, McCarthy, & Donchin, 1977) or body parts intermixed with plants (Kotchoubey & Lang, 2001). In such tasks, highest-amplitude P3 responses are elicited by infrequent target stimuli and by non-target stimuli highly similar to the target (Azizian, Freitas, Watson, & Squires, 2006), thus strongly supporting interpreting P3 responses as related to neurophysiological mechanisms of categorisation. Moreover, P3 amplitude appears unaffected by the modality of task stimuli or by the nature of participants’ motor responses (see Nieuwenhuis et al., 2005, for a review). Whether directed toward target or non-target stimuli, then, higher-amplitude P3 responses can be expected to index a higher degree of extemporaneous cognitive processing of stimuli encountered.

We tested whether focusing on different affective cues would modulate P3 amplitude during a target-detection task. As shown by Friedman and Förster (2001, 2005), it is possible to orient participants toward affectively valenced environmental cues without explicitly manipulating their moods or focusing their attention on their own personal emotional experiences. In such research, participants often are asked to complete identical paper-and-pencil mazes, framed in terms of either avoiding a negatively valenced cue (as a mouse would avoid an owl) or approaching a positively valenced cue (as a mouse would approach a piece of Swiss cheese), and significant differences in cognitive processing (such as in creativity) have resulted. Following an analogous logic, the present study required all participants to complete an identical picture-identification task, with half of participants assigned a positively valenced picture and half assigned a negatively valenced picture. We reasoned that comparing incoming stimuli to a positively valenced prototype (the positively valenced target), relative to a negatively valenced prototype (the negatively valenced target), would change the implicit affective context in which the task was completed, thereby modulating participants’ cognitive and neurophysiological responses.

In the experiment described below, participants identified a target person (interspersed with images of other persons and with jumbled images) shown with either a positive (happy) or negative (disgusted) facial expression. Assignment of targets with happy versus disgusted facial expressions can be assumed to manipulate affective cues’ valence without unduly impacting the separate and important dimension of certainty, given that emotional experiences of disgust and happiness have been found to differ clearly in valence but not in subjective evaluations of the certainty of their origins

(Tiedens & Linton, 2001). If the valence of affective cues modulates the breadth and flexibility of cognition, as proposed by the above theoretical review, then participants focused on identifying a positively valenced target should relatively extensively evaluate both target and non-target stimuli as they view them, thereby manifesting larger-amplitude P3 responses. Accordingly, it is important to note that the present research is orthogonal to electrophysiological research on the “negativity bias” (of attention toward negatively rather than positively valenced stimuli; Ito, Larsen, Smith, & Cacioppo, 1998; Smith, Cacioppo, Larsen, & Chartrand, 2003). Whereas research on the negativity bias examines differences in the processing of positively versus negatively valenced stimuli itself, the present work examines how focusing on identifying positively versus negatively valenced targets impacts one’s processing of *whatever stimuli* one encounters.

METHOD

Participants

Eighteen undergraduate women, with normal or corrected-to-normal vision, participated in exchange for course credit. Data were discarded from two additional participants who each had fewer than 35% artefact-free trials.

Experimental stimuli

Experimental stimuli were based on images of 14 individual women’s faces,¹ expressing happiness and disgust (with mouth closed; see Figure 1).

Target images. Throughout the experiment, each participant’s target individual was shown with a single emotional expression (happiness or disgust). To reduce extraneous sources of variability, only the single model depicted in the leftmost of Figure 1 was used as a target for all participants, with participants assigned randomly the happy or disgusted image of that single model.

Emotionally expressive non-target images. The remaining 13 (non-target) individual women each were shown with both happy and disgusted expressions.

¹Face stimuli were drawn from the MacBrain Face Stimulus Set developed by Nim Tottenham and supported by the John D. and Catherine T. MacArthur Foundation Research Network on Early Experience and Brain Development. Please contact Nim Tottenham at tott0006@tc.umn.edu for more information concerning the stimulus set.

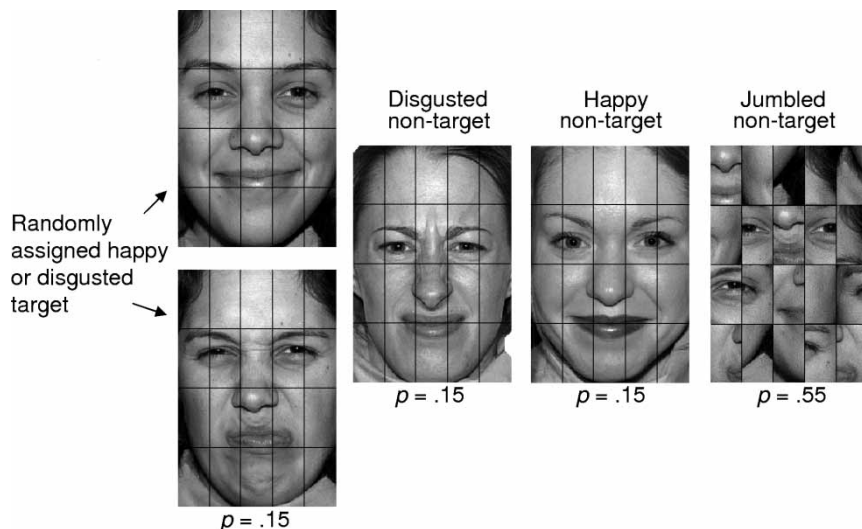


Figure 1. Illustration of experimental stimuli.

Jumbled images. Jumbled images were created by dividing the happy and disgusted versions of participants' target individual into 20 rectangular parcels and randomly combining 10 parcels of each version into composite images.

Procedure

Randomly assigned a target individual with a happy or disgusted expression, participants were instructed to press one of two response keys when their target individual appeared and to press the other key when any other stimulus appeared. Response-key mappings were counterbalanced across participants. In randomised order, participants viewed 48 unique jumbled images (each presented 3 times), 13 unique disgusted non-targets (each presented 3 times), 13 unique happy non-targets (each presented 3 times), and 39 presentations of the single target image, with a brief break halfway through the task. As shown in Figure 1, grids were superimposed over all images to hold constant the appearance of horizontal and vertical lines that resulted from creating the jumbled images. Experimental stimuli ($4.76^\circ \times 4.76^\circ$ visual angle) remained visible until participants responded, and the inter-stimulus interval was 1000 ms. Prior to beginning the experimental trials, participants completed a short (24-trial) training block (with images of individuals not used in the experimental trials); the training block was repeated if a participant committed more than two errors on the initial training block (this was required in only two instances).

Electrophysiological recording

The EEG was recorded continuously using a 64-channel electrode cap (Neuroscan Inc., Charlotte, NC), with impedances below 10 K Ω , a fronto-central electrode as ground, and electronically linked mastoid electrodes as reference. Horizontal EOG was monitored from electrodes at the outer canthi of the eyes, and vertical EOG was monitored from electrodes above and below the left eye. The EEG and EOG signals were digitised at 1000 Hz and were amplified with a gain of 500. The filter bandpass was 0.01–30 Hz. Trials with EEG voltages exceeding $\pm 100 \mu\text{V}$ were excluded from analyses, yielding 71% valid trials overall, with no significant difference ($t = 0.46$) between the percentage of valid trials in the disgusted-target condition (69%) and the happy-target condition (72%). Epochs began 100 ms prior to stimulus onset and continued for 900 ms thereafter, with electrophysiological responses measured relative to each trial's 100 ms baseline.

ERP analysis

Individual ERP averages were created for each stimulus category. The maximal positive peak between 300 and 800 ms, measured as a difference from the negative-most point between 150 and 300 ms, was designated the P3 peak. This approach controls for individual variation in negative deflections (such as the N2) preceding the late-positive P3 component, which can be expected to be a significant source of variability in a between-subjects design such as the present one. The assessment of peaks (i.e., rather than mean area) also allows measuring the P3 response within a single response window across different trial types with heterogeneous amplitudes and latencies (see especially the reduced latency and amplitude of P3 responses to the jumbled non-targets). As in other recent work (e.g., Freitas, Azizian, Leung, & Squires, 2007), to reduce the number of statistical comparisons, data from individual electrodes were grouped into six regions: frontal (AF7, AF3, FP1, FPZ, FP2, AF6, AF8, F7, F5, F3, F1, FZ, F2, F4, F6, F8), central (FC5, FC3, FC1, FCZ, FC2, FC4, FC6, C5, C3, C1, CZ, C2, C4, C6), parietal (CP3, CP1, CPZ, CP2, CP4, P3, P1, PZ, P2, P4), left-temporal (FT7, T7, TP7, CP5, P7, P5), right-temporal (FT8, T8, TP8, CP6, P8, P6), and occipital (PO7, PO5, PO3, POZ, PO4, PO6, PO8, O1, OZ, O2). In the event of a bad electrode, all data from the electrode were excluded from analyses of the corresponding participant's data, with electrode-region averages based on data from the remaining electrodes. The Greenhouse–Geisser (1959) correction was used for all comparisons with more than two within-subjects levels.

RESULTS

Behavioural results

Response times on incorrect trials (1.36%) or greater than 1000 ms (3.09%) were not analysed. In 2 (Target's Expression: disgusted vs. happy) \times 4 (Image Type: target, happy non-target, disgusted non-target, jumbled non-target) ANOVAs, with repeated measures on the last factor, there were no significant main effects of Target's Expression on response time, $F(1, 32) = 2.81$, or accuracy, $F(1, 32) = 1.19$. There were significant effects of Image Type on response time, $F(3, 48) = 75.20$, $p < .0001$, and accuracy, $F(3, 48) = 21.10$, $p < .0001$ (see Table 1). Consistent with extensive previous research using the oddball paradigm, responses were slower and less accurate on the (rarest) target images than on the (most frequent) jumbled non-target images, in both the disgusted-target condition, response-time difference $M = 132.36$, $SD = 52.39$; $t(8) = 7.58$, $p < .0001$; accuracy difference $M = -0.065$, $SD = 0.053$; $t(8) = 3.64$, $p < .001$, and the happy-target condition, response-time difference $M = 139.04$, $SD = 50.97$; $t(8) = 8.18$, $p < .0001$; accuracy difference $M = -0.068$, $SD = 0.051$; $t(8) = 4.00$, $p < .001$. Suggesting that participants were sensitive to non-targets' emotional expressions (or at least to perceptual features, such as a wrinkled brow, that differed across non-targets' different emotional expressions), participants responded more slowly to non-targets with the same emotional expression as their target than to non-targets with a different emotional expression from their target, in both the disgusted-target condition, difference $M = 34.48$ ms, $SD = 16.26$ ms; $t(8) = 6.36$, $p < .0001$, and the happy-target condition, difference $M = 32.23$, $SD = 23.87$; $t(8) = 4.05$, $p < .001$, yielding a significant 2 (Target's Expression: happy vs. disgusted) \times 2 (Non-Targets' Expression: happy vs. disgusted) interaction, $F(1, 16) = 48.03$, $p < .0001$. Finally, there were no significant effects of Target's Expression on

TABLE 1

Average response times and proportion of correct responses on a target-detection task, among participants assigned a disgusted target and a happy target (standard error of the mean in parentheses)

Target's expression	Target person	Happy non-target	Disgusted non-target	Jumbled non-target
<i>Response Time (ms)</i>				
Disgusted	536.12 (11.15)	462.70 (15.31)	497.18 (18.10)	403.76 (14.82)
Happy	533.53 (25.16)	518.02 (22.65)	485.79 (21.89)	394.48 (16.09)
<i>Accuracy</i>				
Disgusted	0.934 (0.020)	0.991 (0.004)	0.986 (0.005)	0.999 (0.001)
Happy	0.932 (0.020)	0.989 (0.006)	0.991 (0.006)	1.00 (0.000)

response times to target stimuli ($F=0.01$) or to jumbled non-targets ($F=0.18$).

P3 peak amplitude

Peak amplitude of P3 responses were analysed in a 2 (Target's Expression: disgusted vs. happy) \times 4 (Image Type: target, happy non-target, disgusted non-target, jumbled non-target) \times 6 (Electrode Region: frontal, central, parietal, occipital, left-temporal, right-temporal) ANOVA, with repeated measures on the last two factors. Most relevant to the current investigation, participants in the happy-target condition had higher-amplitude P3 responses than did participants in the disgusted-target condition, $F(1, 16)=5.92$, $p<.05$, $\eta_p^2=.27$. As indicated in Figure 2, this main effect of Target's Expression was not moderated by two-way interactions with either Image Type ($F=0.85$) or Electrode Region ($F=0.43$) or by the three-way (Target's Expression \times Image Type \times Electrode Region) interaction ($F=1.31$).

To examine the impact on P3 amplitude of the valence of the target participants focused on identifying across the experiment, across the different levels of the valence of the images participants viewed on a particular trial, we next limited our analyses to emotionally expressive non-targets. In this 2 (Target's Expression: disgusted vs. happy) \times 2 (Non-targets' Expression: disgusted vs. happy) \times 6 (Electrode Region) ANOVA, there again was a significant effect of Target's Expression, $F(1, 16)=7.97$, $p<.05$, $\eta_p^2=.33$, whereas there were no significant effects of Non-target's Expression ($F=0.12$), the interaction between these two factors, $F(1, 16)=1.85$), or other interactions ($F_s<1.30$). To analyse only those instances where the images viewed on a particular trial were equivalently similar, on a pixel by pixel basis, to the different targets of participants in the Disgusted-Target and Happy-Target conditions, we next analysed responses to the jumbled non-targets only. This 2 (Target's Expression: disgusted vs. happy) \times 6 (Electrode Region) ANOVA again revealed a significant effect of Target's Expression, $F(1, 16)=4.72$, $p<.05$, $\eta_p^2=.23$, which was not moderated by Electrode Region ($F=0.42$). Finally, when analysing responses only to target images, the effect of Target's Expression was not significant, $F(1, 16)=1.55$, nor was its interaction with Electrode Region ($F=0.37$).

P3 peak latency

Although not central to our hypotheses, latency to peak P3 amplitude also warrants investigation, given much previous evidence that increasing stimulus complexity increases P3 latency (e.g., McCarthy & Donchin, 1981). The time point at which P3 amplitude reached its maximal peak across the 300–800 ms window was defined as peak P3 latency. There was no

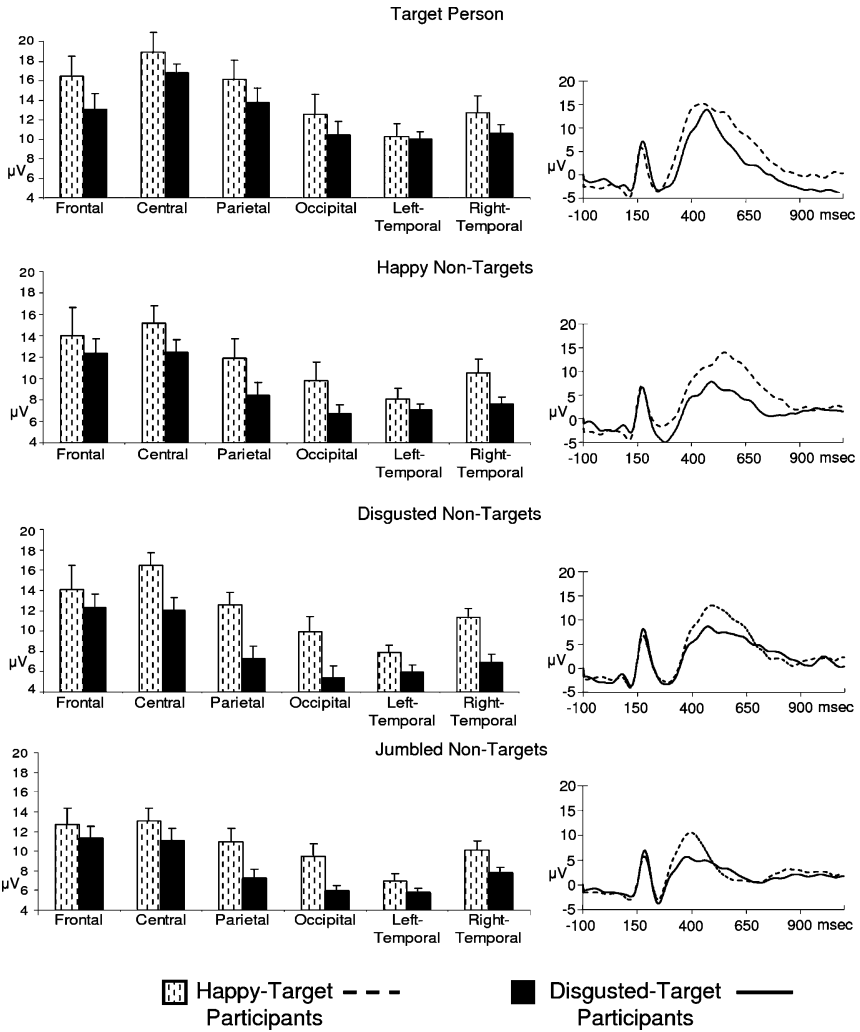


Figure 2. Average P3 peak responses at six electrode regions (left panel), and grand-average waveforms at a central, midline electrode, FCz (right panel), shown separately for participants assigned a disgusted or a happy target.

impact of Target's Expression on P3 latency overall ($F = 0.37$), nor was there any effect of Target's Expression on P3 latency when limiting analyses only to jumbled non-targets ($F = 0.37$) or to target images ($F = 0.37$). Analysing only responses to emotionally expressive non-targets revealed a significant 2 (Target's Expression: happy vs. disgusted) \times 2 (Non-Targets' Expression: happy vs. disgusted) interaction, $F(1, 16) = 13.87, p < .01, \eta_p^2 = .46$, which

was not moderated further by Electrode Region, $F(5, 80) = 1.93$. Closely mirroring the response-time analyses reported above, when averaging across all six electrode regions, participants in the Disgusted-Target condition had slower P3 peak latencies to disgusted than to happy non-targets, difference $M = 29.39$ ms, $SD = 36.39$ ms; $t(8) = 2.42$, $p < .05$, whereas participants in the Happy-Target condition had slower P3 peak latencies to happy than to disgusted non-targets, difference $M = 26.95$ ms, $SD = 27.14$ ms; $t(8) = 2.98$, $p < .05$.

DISCUSSION

Impacts of affective cues on how people construe themselves and their environments appear integral to human concerns ranging from self-control (Robinson & Berridge, 2003) to interpersonal relationships (Gross & John, 2003). With potential to address those broader issues, extensive bodies of conceptual and empirical work now suggest that positively (relative to negatively) valenced affective cues increase the creativity, flexibility, and breadth of cognitive processing. The present investigation found more-prominent electro-cortical P3 responses among participants focused on identifying a positively valenced social target than a negatively valenced social target. This finding suggests that affective cues modulate the extent of cognitive processing as it unfolds, given previous evidence that P3 responses relate functionally to the extent of evaluative processing of target stimuli (Kutas et al., 1977) as well as non-target stimuli (e.g., Azizian et al., 2006). As established in the current behavioural results, for example, participants very rapidly and accurately rejected the jumbled images as non-targets. However, even these obvious non-targets evoked more-prominent P3 responses among participants in the happy-target than the disgusted-target condition, thereby implicating an effect of the valence of affective cues on extemporaneous cognitive processing.

By testing an assumption common to the above-reviewed theories of the impact of affect on cognition, the present investigation is better suited to constraining development of those theories than to discriminating between them. Following the general logic of the affect-as-information theory (Schwarz & Clore, 2007), for example, the present results can be viewed to suggest that focusing on identifying a positively valenced target, relative to a negatively valenced target, facilitates an exploratory cognitive-processing style appropriate to one's presumably reward-rich environment, thus facilitating a liberal sampling and consideration of encountered stimuli, including even obvious non-targets, and thereby culminating in more prominent electro-cortical responses. In a related vein, however, the valence of the affective cues in this experiment might be assumed to have impacted

the breadth of participants' focus on target as well as non-target stimuli (Derryberry & Tucker, 1994; Easterbrook, 1959; Friedman & Förster, 2001), perhaps prompting consideration of a broader array of stimulus information among participants oriented toward the positively (relative to the negatively) valenced social target, thereby modulating participants' electro-cortical responses. Future research will be needed to evaluate these distinct possibilities.

It also may appear possible that target-detection tasks such as the present one will elicit greater effort on the part of participants oriented toward a positively rather than a negatively valenced target, which could be expected to modulate participants' cognitive productivity (e.g., Isen, 2001) as well as their electro-cortical responses. Somewhat incompatible with this possibility in the present case, a behavioural pilot study of the current task (with 34 participants) did not find evidence of increased self-reported effort to "try hard" (assessed on a scale of 1 = "not at all" to 5 = "extremely") among participants in the happy-target condition ($M = 3.40$, $SD = 1.35$) relative to the disgusted-target condition ($M = 3.21$, $SD = 1.13$), $t(32) = 0.44$. Moreover, unrelated research has found that search tasks are sometimes rated as equally engaging when framed as seeking negatively valenced targets ("harmful elements") as when framed as seeking positively valenced targets ("helpful elements"; Freitas & Higgins, 2002). Nevertheless, because self-reports of task engagement provided by participants at the conclusion of an experiment may not capture all aspects of task engagement as it unfolds, it remains possible that differences in participants' engagement in the present task could help explain the present results.

Rather than clarifying *why* affective cues modulate the breadth and flexibility of cognition, then, the value of the present work lies in clarifying *how* and *when* affective cues modulate the breadth and flexibility of cognition. Previous data have not indicated conclusively whether affective cues impact the breadth and flexibility of thought extemporaneously or only later via processes of evaluation or selection from among thoughts already generated. The present work found support for the former possibility, suggesting effects of affective cues on cognitive processing as it unfolds. One practical implication of this apparent immediacy is that earlier divergences in information processing between individuals oriented toward positively relative to negatively valenced cues can be expected to yield larger cumulative differences in their responses to the people and events they encounter in their daily lives. For example, because people often interpret others' behaviours in accord with their own expectations (e.g., Downey, Freitas, Michaelis, & Khouri, 1998), an unfortunate and ironic implication of the present findings is that individuals with negatively (relative to positively) valenced expectations of others may spontaneously evaluate others' behaviours with reduced flexibility and breadth, thus reducing the

likelihood of disconfirming their own negative expectancies. Future research can explore this possibility.

Future research is also needed to isolate the qualities of affective cues that give rise to the presently reported results. Previous findings have suggested relatively symmetrical effects of positive and negative affective cues on exploratory versus conservative processing styles (Friedman & Förster, 2005) as well as more specific effects of negatively valenced cues on narrowing attentional scope (Derryberry & Tucker, 1994) and positively valenced cues on broadening attentional scope (Fredrickson & Branigan, 2005). Accordingly, as a first attempt at detecting electrophysiological correlates of those phenomena, the present work contrasted the impacts of cues opposite in valence. Whereas this approach appears to have been successful in providing new evidence that affective cues modulate the spontaneous breadth and flexibility of cognition, further research will be needed to isolate independent effects of positively and negatively valenced (relative to neutral) cues. Further research also should examine the extent to which the present findings reflect affective cues' valence (apart from other of their qualities, such as their complexity and arousingness; e.g., Bradley, Hamby, Löw, & Lang, 2007). Personality research has found higher-amplitude P3 responses among individuals high in extraversion and related traits (e.g., Brocke, Tasche, & Beauducel, 1996; Cahill & Polich, 1992; DePascalis & Speranza, 2000). Because extraverts generally appear prone to experiencing positive emotions (e.g., Lucas & Baird, 2004), those personality data provide some support for interpreting the present results in terms of the valence of the presently used facial stimuli. Nevertheless, further isolating the impact of valence will require examining broader classes of affective cues (including non-facial stimuli) while orthogonally manipulating valence and other affective dimensions.

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