



## May I have your attention, please: Electrocortical responses to positive and negative stimuli

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### Abstract

Previous research has shown that negative stimuli elicit more attention than do positive stimuli. However, this research has relied on response-based measures to assess attention. The current research uses the P1 component of the event-related brain potential (ERP) as a proximal index of attention allocation to valenced stimuli. In two studies, P1 amplitude was measured while participants evaluated positive and negative pictures. In both studies, principal components analysis showed that P1 amplitudes to frequent stimuli and to rare negative stimuli were larger than P1 amplitudes to rare positive stimuli. This is (a) evidence for the extremely rapid (<120 ms) differentiation of positive and negative stimuli and (b) process-based evidence for a negativity bias in attention allocation.

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Zajonc [42] postulated that affective processing was separable from cognitive processing. Since that time, researchers have sought to characterize the form and function of the affective system. In searching for general principles of evaluative processing, researchers have consistently found that negative stimuli have a greater impact on information processing than do positive stimuli [4,7,38]. Although most theorists agree that this bias toward negative information is evolutionary in origin, there have been few theories attempting to explain the multifaceted effects that negative stimuli can have on information processing.

To address this lacuna, Cacioppo et al. [8] (see also [5]) advanced a model of affective processing which suggests that stimuli are evaluated at multiple points in the information processing stream. The reason for this seeming redundancy, they argue, is that as humans evolved evaluative functions were rerepresented [19] at multiple levels throughout the neuraxis. That is, as we evolved, newer evaluative systems did not replace the more primitive ones, but rather they served to integrate and expand upon the functionality of such systems. Therefore, humans currently possess multiple evaluative systems that vary in the level of the neuraxis in which they exist (e.g. low-level, primitive processing in the amygdala versus integrative processing in the

cortex). Moreover, because these systems are partially independent, the way in which they generate evaluations may differ greatly from system to system. One manifestation of this effect is that as a general rule, the systems responsible for evaluating negative stimuli respond more strongly than those responsible for evaluating positive stimuli [8].

One result of this bias toward negative information is that negative stimuli are often evaluated more extremely than normatively equally extreme positive stimuli [1,18,21]. That is, there is an *extremity bias* in evaluation. Although the extremity bias is an important one, it is not the only bias negative information can evoke. Given that stimuli are being evaluated at many levels of the neuraxis, it stands to reason that biases toward negative information may occur during processing stages other than the explicit evaluation of a stimulus. For example, a growing body of literature is documenting an *attention bias* toward negative information. That is, our attention is automatically drawn to negative information more strongly than it is automatically drawn to positive information [15,34].

In an early study of the attention bias, Hansen and Hansen [15] showed participants grids of happy faces with a lone angry face, and grids of angry faces with a lone happy face. Participants were faster at picking the angry face out of a happy grid than vice versa, suggesting that their attention was automatically drawn to the angry faces. This finding was extended by recent work of Öhman et al. [30] who showed

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that this attention bias held for threatening faces (similar to Hansen and Hansen's angry faces), but not for other types of negative faces (i.e. sad and scheming faces).

Seeking to demonstrate that the attention bias was not limited to facial processing, Pratto and John [34] used the emotional Stroop task to assess the attention demands of positive and negative trait adjectives. In this paradigm, participants are shown positive and negative words written in different colors and asked to name the color in which the word is written as quickly as possible. Differences in color naming latencies for positive and negative words index the extent to which participants' attention is being automatically drawn away from the color naming task and focused on the word being presented. Pratto and John's results showed that negative traits had longer color naming latencies than positive traits, suggesting that participants' attention was being automatically drawn to the negative words more than it was being drawn to the positive words.

One limitation of the research on the attention bias is that it does not specify when in the information processing stream more attention is allocated to negative stimuli, nor does it specify how this differential allocation occurs. This shortcoming can lead to interpretational problems, because of the ambiguity about what mental processes are leading to the observed effects. For example, it is possible that negative stimuli receive more attention beginning extremely early during information processing. This difference is then carried throughout the subsequent processing stages and is thereby reflected in the reaction time measures described in the above studies. An equally viable possibility is that positive and negative stimuli do not differ in the amount of attention that they are initially allocated, but rather they differ in the amount of downstream processing they receive. That is, perhaps people have evolved to have stronger response dispositions when processing negative stimuli than when processing positive stimuli [10]. These stronger dispositions for negative information could facilitate responding in tasks in which participants were responding to the negative features of the stimulus (as in [15]), and interfere with responding on tasks in which some other aspect of the stimulus was being judged (as in [34]). If this were the case, researchers may very well observe differences on attentional measures in the absence of differences in the initial attentional allocation.

## 1. Event-related brain potentials

Measures that provide information about moment-by-moment attention allocation would enable researchers to choose between these two alternative mechanisms of the attention bias. Event-related brain potentials (ERPs) can serve this purpose. ERPs are depictions of the electrical activity on the scalp that results from the neural processing of a given stimulus. To ease analysis, ERPs may be conceptually broken down into a small number of components, each reflecting the extent to which a single information processing

function is engaged. Therefore, selected ERP components may be suitable for examining the extent to which certain categories of stimuli (e.g. positive and negative pictures) evoke discrete information processing functions (e.g. an early allocation of attention) while simultaneously reducing the potential contaminating influences of other processes (e.g. differential response dispositions).

An illustration of the advantages of using ERPs to tap a discrete process is given by Ito et al. [18]. They sought to examine if the extremity bias was due to evaluative categorizations per se or to differences in response dispositions. To test this, they used the late positive potential (LPP), a component of the ERP that indexes the evaluative categorization stage of information processing, with larger LPPs indicating that a stimulus is more evaluatively discrepant from the stimuli that preceded it [6,13]. Participants were shown predominantly neutral pictures with occasional positive and negative pictures interspersed. The positive and negative targets were selected to be equally evaluatively extreme and equally arousing using previously developed norms [17]. Their results showed that negative stimuli elicited larger LPPs than positive stimuli suggesting that, despite being equated on self reported extremity, negative stimuli were being evaluated more extremely than positive stimuli. From these data, Ito and her colleagues were able to reject the idea that the extremity bias toward negative information was solely the result of response processes, and conclude that this bias was occurring at the evaluative categorization stage of information processing.

To use ERPs to examine the attention bias, a component must be found that is sensitive to the amount of attention allocated to a stimulus. The P1, a positive-going component of the ERP that is maximal over the occipital lobe and peaks between 100 and 150 ms after stimulus onset, is such a component. Specifically, the P1 is the result of neural activity in the extrastriate area of the visual cortex [11]. As more attention is allocated to a visual stimulus, more extrastriate neurons are recruited to process the stimulus and P1 amplitude increases, thereby giving a direct measure of attention allocation. Demonstrating this sensitivity to attention, studies in which participants are instructed to attend to stimuli in one location and ignore those in another show larger P1s to targets in the attended area than to those in the unattended area [11]. Similarly, in studies in which attention is involuntarily manipulated (e.g. via the inhibition of return paradigm), P1s are larger to attended than unattended stimuli [28]. Therefore, in order to directly examine the attention bias toward negative information, we presented positive and negative stimuli to participants and measured the extent to which each type of stimulus evoked a P1.

## 2. Processing speed

Prior work within affective and cognitive neuroscience has investigated the role of affect in modulating processing

within the extrastriate cortex. For example, Lane et al. [23] used positron emission tomography (PET) to demonstrate that the valence of a picture can alter the amount of neural activity in the extrastriate cortex. While this evidence is suggestive that the P1 will be modulated by the valence of a picture, PET gives insufficient temporal resolution to make this claim. It is certainly possible that while positive and negative pictures are being initially processed they receive equal attention, but later downstream processing allocates more attention to negative stimuli, and therefore extrastriate activity increases subsequent to the generation of the P1. Therefore, indexing the extent to which positive and negative pictures elicit differential P1s will build on Lane et al.'s [23] prior work by specifying when the differential extrastriate activity is taking place.

Using the P1 as a measure of attention allocation also allows us to answer questions about the speed with which positive and negative information are differentiated that have not been addressed. Many theories suggest that we process affective information rapidly [42] and automatically [2]. However, most methods do not allow us to examine exactly how quickly positive and negative information are differentiated. For example, methods that show participant's positive and negative stimuli and then measure reaction times (e.g. priming paradigms [2]; Stroop color naming tasks; [34]) often show differentiation of positive and negative stimuli 500–600 ms after stimulus onset. Obviously, this long latency is more a function of the time that it takes to generate a response than the time it takes to evaluate a stimulus. A more valid measure of processing time comes from studies that use psychophysiological measures to index the point at which differentiation of positive and negative stimuli occurs. Both studies examining event-related brain potentials [6,9] and those examining the eyeblink component of the startle response [40] have shown discrimination times for positive and negative stimuli as early as 200 ms post-stimulus onset.

If indeed evaluative processing is as ubiquitous and rapid as suggested, then there should be some evidence for differentiation of positive and negative stimuli prior to 200 ms. Given that the P1 component of the ERP peaks between 100 and 150 ms post-stimulus onset, finding modulation of the P1 by valence would be the first evidence of a general evaluative mechanism that differentiates stimuli this rapidly. It would also lend additional credence to the aforementioned theories that postulate the very rapid processing of affective stimuli.

Therefore, the current studies have two aims. First, the studies will test the hypothesis that a measure of attention allocation in the extrastriate cortex will confirm the interpretations made in prior studies that negative information elicits more attention than positive information. Second, if the valence of a stimulus modulates the P1, this will provide evidence that the differentiation of positive and negative information occurs 100 ms after stimulus onset.

### 3. Experiment 1

Because of the preliminary nature of this work and because previous work has not indicated that stimulus valence is able to modulate the amplitude of the P1, in Experiment 1 it was important to use a strong valence manipulation. The use of contrast effects, whereby valenced stimuli may be made to appear more extreme by preceding them with a stimulus of the opposite valence, is one way to do this. That is, by having negative pictures follow positive pictures, the former should seem more negative to the participants. Similarly, having positive pictures follow negative pictures should enhance the participants' positive evaluations of the positive pictures. Therefore, in this experiment, participants were presented with positive and negative pictures embedded in positive and negative contexts and P1 amplitude was measured in order to determine if negative pictures elicit more attention than do positive pictures at the earliest stages of attentional processing.

#### 3.1. Method

##### 3.1.1. Participants

Thirty-four Ohio State University undergraduates participated in this study for partial course credit. All were right handed and had right-handed parents. Data from two participants were excluded because of excessive artifact in the data ( $n = 1$ ), or voluntary withdrawal from the study ( $n = 1$ ). All analyses were performed on the remaining 32 participants, 16 of whom were male.

##### 3.1.2. Materials

Twenty normatively positive and 20 normatively negative pictures were selected from the International Affective Picture System (IAPS) [25] for use during this study. Using norms from Ito et al. [17], the positive and negative pictures were selected such that they were matched on self-reported arousal and evaluative extremity. For the experimental paradigm (see procedure below), the pictures from each valence were further subdivided into three groups, two containing 5 pictures each, the other containing 10 pictures. Each of these subgroups retained the evaluative extremity and arousal of the whole.<sup>1</sup>

##### 3.1.3. Procedure

Upon arrival at the lab, research participants were given an overview of the procedure and gave informed consent. Participants then had electrodes attached to their heads for

<sup>1</sup> Stimuli serving as negative background pictures were IAPS slides 2205, 2490, 2710, 3160, 3550, 7360, 9140, 9415, 9600 and 9910. Stimuli serving as positive background pictures were slides 1463, 2070, 5600, 5623, 5760, 5830, 7580, 8031, 8210 and 8531. The two groups of negative targets were composed of slides 3350, 3530, 6550, 9220 and 9340; and 6570, 9005, 9290, 9320 and 9560. The two groups of positive targets were composed of slides 1540, 1920, 2360, 4610 and 7350; and 1610, 2040, 5626, 7230 and 8500.

the physiological recording. During this time, participants filled out a questionnaire that assessed their handedness.

Participants were then seated in a sound-attenuating, electrically shielded room and given instructions for the task. They were told that they would be watching pictures on a computer monitor and their job would be to indicate if they thought the pictures were positive or negative by pushing the appropriate button on a response pad. After indicating that they understood the task, participants were exposed to four practice trials and began the experiment.

The experimental trials were presented to participants in the following manner. First, a background picture was presented on the computer screen for 11 s. This picture was scaled to take up the entire screen. At 4, 6 or 8 s (determined randomly) after picture onset, a target picture was embedded within the background picture for 1 s. After offset of the target picture, the background picture remained on the screen for the remainder of the 11 s duration. To ensure participants were engaged in the task, they were asked to indicate the valence of the large and small pictures after picture offset. The hand with which they indicated a stimulus was positive was counterbalanced across participants.

Participants viewed stimuli in two counterbalanced blocks, each composed of sixty trials. In one block, the background pictures were always positive whereas in the other block the background pictures were always negative. In both blocks, half of the time, the target picture was positive whereas the other half of the time, the target picture was negative. Different groups of pictures were used in the two blocks. Each individual picture was viewed a total of six times by the participants.

Recapping, the experimental design was a 2 (background picture valence: positive or negative) by 2 (target picture valence: positive or negative) by 2 (block order: positive block first or negative block first) by 2 (hand: right hand indicates positive or right hand indicates negative) mixed-model design with the last two factors manipulated between groups. ERPs were recorded only during presentation of the target pictures. Upon completion of the study, participants were debriefed, thanked and released.

### 3.1.4. Psychophysiological data collection and cleaning

EEG data were recorded from 28 tin electrodes mounted in an elastic cap (ElectroCap International, Eaton, OH). The locations of the electrodes were based on an expanded version of the international 10–20 electrode placement system. Because the component of interest, the P1, is not strongly lateralized when images are presented to both visual fields, we analyzed four sites along midline of the scalp, Fz, Cz, Pz, and Oz. Each of these sites was referenced on-line to the left mastoid while the right mastoid was recorded for later off-line referencing. Additionally, two tin cup electrodes were placed above and below the participants' left eyes to record vertical eye movements and eyeblinks. Finally, two tin cup electrodes were placed

on the outer canthi of both eyes to record horizontal eye movements. Interelectrode impedances were below all 10 k $\Omega$ .

Electrical activity from the scalp (EEG) and eyes (EOG) were amplified by a NeuroScan Synamps amplifier, which applied a band pass filter between 0.1 and 30 Hz (12 dB roll-off). The data were then digitized by a computer at 1000 Hz and stored on the hard drive for later analysis. Each recording epoch began 128 ms before the small picture appeared on the screen and continued for 1024 ms after stimulus onset.

To eliminate extraneous noise, several off-line signal processing techniques were performed. First, in order to remove spurious laterality effects, the data were rereferenced to a mathematically simulated linked ears reference (R.J. Davidson, personal communication, 21 September 1995). Next, in order to remove baseline differences, the average amplitude of each electrode for each trial over the 128 ms baseline period was set to zero. Further, to remove artifacts caused by eyeblinks a regression procedure was used in which variance correlated with vertical EOG activity was removed from the EEG signal [36]. Subsequently, trials were individually inspected and excluded if non-neurogenic artifact was present.

### 3.1.5. Data reduction and analysis

After deleting trials with artifacts, in order to remove all electrical activity that was not time locked to the stimulus, each participant's individual trials were aggregated based on trial type. That is, one average ERP waveform was constructed for each cell of the aforementioned 2 (background picture valence) by 2 (target picture valence). Therefore, from each participant, four averages were generated, each containing data from four scalp electrode sites.

Quantifying the P1 in paradigms with complex stimuli and modest numbers of stimulus presentations can be problematic because of the relatively low signal to noise ratio of the component. Standard peak picking techniques are often unable to pick the signal out of the surrounding noise. To overcome this difficulty, we decided to use principal components analysis (PCA) to separate overlapping components [14,39].

In PCA, a set of averaged ERP waveforms are statistically examined for covariations in amplitude across time points. From patterns of covariation across time points, scalp sites, and participants, the PCA decomposes a set of average waveforms into a small number of voltage  $\times$  time functions (called components) with each component representing a portion of the overall variance in the set input waveforms. Each component consists of one covariance (called a component loading) for each time point in the ERP waveforms, with the loading indicating the extent to which that component has an influence on that time point. Therefore, higher loadings indicate time points where a component is strongly active, whereas small loadings indicate time points where components are relatively inactive.

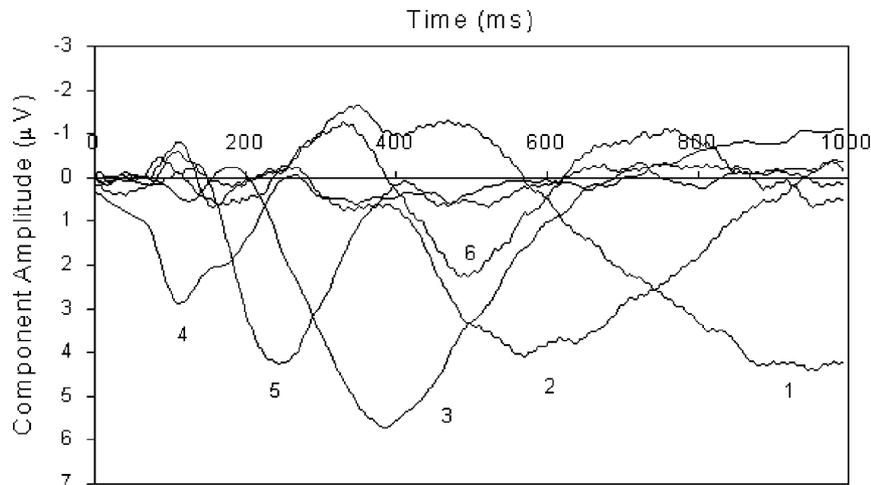


Fig. 1. Component amplitude as a function of time for Experiment 1. Components are numbered by the rank order of proportion of variance for which they account.

In addition to the component loadings, PCA also generates a set of component scores. These scores indicate the extent to which a component is present in a given waveform. Therefore, if a particular component extracted by the PCA is the result of an information processing function (e.g. the allocation of attention), then component scores for that component may be used to make inferences about the extent to which that function is being performed in the relevant experimental condition in the same way peak amplitudes are used to infer process engagement.

Therefore, in lieu of quantifying ERP components by assessing peak amplitude in a given time window, a principal components analysis was performed on the data. As mentioned previously, PCA analyzes the patterns of covariation between time points in the average waveforms in order to consolidate the total variance of the waveforms down into the activity of a small number of underlying components. To do this, each average created previously was entered into the PCA as a voltage  $\times$  time function. Internally within SPSS, the data were converted to a covariance matrix before analysis (as recommended by [14]), so the components outputted would represent deviations from the grand mean waveform. To ensure that the PCA's components would be consistent with the underlying neural functioning, the output of the PCA was subjected to a varimax rotation and six components were extracted. The component scores were then saved for each component by subject by electrode by average combination and analyzed using the GLM module of SPSS.

## 3.2. Results

### 3.2.1. Principal components analysis

The output of a PCA is two matrices, one of component loadings, and the other of component scores. The matrix of component loadings shows the relationship between the extracted components and time. That is, each component

has a loading for each time point that indexes the extent to which that component is active at that time point. In the matrix of component scores, each average that was inputted into the PCA receives a score for each component extracted by the PCA. These component scores index the extent to which each component is present in the given ERP average.

Graphing the component loadings versus time yields a depiction of the time-points over which the components exhibit influence (Fig. 1). In Fig. 1, the six components extracted by the PCA are depicted. The numbering of the components represents the rank order of proportion of variance accounted for by the components. To determine the extent to which each of these components is present at any given electrode site, or in any given experimental condition, the component scores may be statistically analyzed.

### 3.2.2. Component scores

Because of our interest in the P1, we focused our analyses on the component in the appropriate time region, labeled component four in Fig. 1. If this component is indeed a P1, it should possess the characteristic latency, scalp distribution, and polarity of the P1. That is, it should peak between 100 and 150 ms after stimulus onset, it should be maximal at the occipital scalp sites and it should be positive going at that scalp site. Consistent with the first criterion, the peak of the first component in the PCA is at 117 ms, within the appropriate time window. To address the second criterion, we analyzed the mean component scores for the earliest component across all four scalp sites. We found a significant main effect for site  $F(3, 29) = 7.21$ ,  $P = 0.001$ . Follow-up  $t$ -tests confirmed that this main effect was due to the P1 being largest over the occipital electrode site and the other three sites not differing from each other (Oz  $M = 0.480$ , S.E. = 0.131; Pz  $M = -0.0578$ , S.E. = 0.115; Cz  $M = -0.169$ , S.E. = 0.123; Fz  $M = -0.253$ , S.E. = 0.099). Finally, in order to examine the polarity of the component's

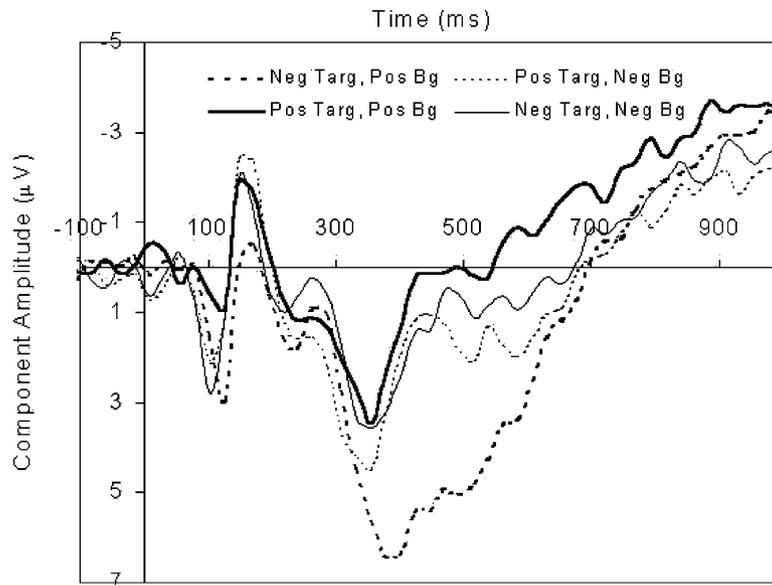


Fig. 2. Averaged ERP waveforms at the midline occipital electrode (Oz) to target positive and negative stimuli preceded by either a positive or negative background stimulus. The earliest positive-going (downward) deflection is the P1, which is larger for negative stimuli than positive stimuli, regardless of the valence of the background picture.

peak at Oz, the component score at Oz must be multiplied by the component loading at its peak value. Because both of these values are positive, the component is positive going at Oz. Based on these three criteria, we are treating the first component as a P1.

To assess the effect of the experimental variables on the amplitude of the P1, we performed a 2 (background picture valence: positive or negative) by 2 (target picture valence: positive or negative) by 2 (block order: positive block first or negative block first) by 2 (hand: right hand indicates positive or right hand indicates negative) GLM of the P1 component scores at Oz. The latter two factors did not interact with the variables of interest in meaningful ways, therefore they were collapsed across (though the statistical results were the same whether these factors were included or excluded).

After removing the between groups factors, the analysis simplified to a 2 (background picture valence: positive or negative) by 2 (target picture valence: positive or negative). Fig. 2 displays the grand average waveforms from

each experimental condition. The valence of the background picture did not have any direct or interactive effects on P1 component scores (both  $F$ s less than one). In contrast, the valence of the target picture did affect component scores with negative stimuli ( $M = 0.723$ ,  $S.E. = 0.131$ ) eliciting larger P1s than positive stimuli ( $M = 0.237$ ,  $S.E. = 0.162$ ),  $F(1, 31) = 13.01$ ;  $P = 0.001$  (see Table 1).

### 3.3. Discussion

Experiment 1 contains several important findings. First, it shows that the P1 can differentiate positive and negative stimuli. Given that the P1 is most often interpreted as being an index of attention allocation in the extrastriate visual cortex, this result suggests that positive and negative stimuli are receiving different amounts of attention very early in the information processing stream. More importantly, the form of this differentiation suggests that, consistent with the prior work in psychology [15,34], negative stimuli receive

Table 1  
P1 component amplitude as a function of scalp site and condition for Experiment 1

Condition	Scalp site			
	Fz	Cz	Pz	Oz
Positive background				
Positive target	-0.207 (0.157)	-0.121 (0.166)	-0.019 (0.183)	0.269 (0.211)
Negative target	-0.441 (0.133)	-0.288 (0.149)	-0.09 (0.49)	0.775 (0.169)
Negative background				
Positive target	-0.222 (0.179)	-0.205 (0.201)	-0.172 (0.179)	0.204 (0.213)
Negative target	-0.141 (0.134)	-0.063 (0.176)	0.05 (0.151)	0.671 (0.138)

Note: Values are unitless component scores. Standard errors are in parentheses.

more visual attention than positive stimuli. Second, this is the first evidence of a general evaluative mechanism that differentiates valence within approximately 100 ms of stimulus onset. Thereby, this result lends additional credence to arguments that suggest that affective information is processed very rapidly.

Like most preliminary data, these have possible alternative explanations. Most problematically, it may be that the positive and negative stimuli differ on some dimension other than valence (e.g. perhaps the negative pictures contain more red, due to their depictions of blood) and it is this other dimension that is eliciting the enhanced P1 amplitude. We have sought to address this issue in two ways. First, we measured the overall mean luminance and luminance of red, green and blue of each the positive and negative stimuli in Experiment 1. This examination showed that the two valences did not differ along any of these dimensions. Second, we designed Experiment 2 to use different stimuli in order to reduce the likelihood that any quirks of Experiment 1's stimulus set were present in Experiment 2.

Further, in order to lend additional credence to the interpretation that negative stimuli are eliciting more visual attention than are positive stimuli, it would be helpful to include a condition in which a known amount of attention is elicited. Previous work has suggested that primed constructs elicit more obligatory attention than those that are not primed [41]. Similarly, Johnston and Hawley [20] have advanced a model of attention in which the mind is initially biased toward expected inputs (i.e. conceptually primed stimuli) and only later sensitive to novel stimuli. Additionally, Roskos-Ewoldsen and Fazio [33] demonstrated that stimuli for which an attitude has been repeatedly expressed evoke enhanced attention. Finally, Schacter et al. [35] have used positron emission tomography to show that processing a primed word leads to greater activity in the extrastriate area of the visual cortex relative to processing an unprimed word, suggesting that priming increases activity in the area responsible for generating the P1.<sup>2</sup>

Experiment 2 was designed with the following characteristics. First, one category of stimuli was presented frequently, so that members of this category could serve as a high attention standard. Second, participants expressed their attitudes toward these stimuli in order to increase the accessibility of the relevant attitudes, and thereby increase attention. Third, the frequently presented pictures were selected to avoid priming the positive and negative targets. Finally, the different positive and negative stimuli were used in Experiment 2.<sup>3</sup>

<sup>2</sup> It is worth noting that researchers have also documented a bias of the mind toward novel inputs [20] and the possibility that decreased alertness can also occur with repeated stimulus presentations [22]. However, it seems to be the case that the effects of stimulus repetition early in the information processing stream (i.e. in the time frame of the P1) are facilitatory whereas inhibitory effects do not occur until later [20].

<sup>3</sup> The study detailed in Experiment 2 was previously published in a study using the LPP to examine the extremity bias [18]. However, the data presented here do not duplicate those in the original report because, (a)

## 4. Experiment 2

Participants were shown predominantly neutral pictures, with occasional positive and negative pictures interspersed. The positive and negative stimuli were selected to be equally extreme and arousing. As was found by Schacter et al. [35], the neutral stimuli in this design should evoke a large amount of attention, thereby generating large P1s and establishing a high attention comparison condition. Further, if the hypothesis that negative stimuli are evoking more visual attention than positive stimuli is correct, then P1s elicited by negative stimuli should be significantly larger than those elicited by the positive stimuli.

### 4.1. Method

#### 4.1.1. Participants

Participants were 33 Ohio State University undergraduates who received partial course credit for participation. In order to decrease the amount of variability in brain organization, all participants were right handed with right-handed parents. The data from five participants were unusable due to equipment malfunction, while data from another two participants were incomplete due to voluntary withdrawal from the study. Finally two participants' data were unusable due to excessive non-neurogenic artifact. Therefore, analyses were conducted on the data obtained from the remaining 24 participants.

#### 4.1.2. Materials

Thirty-six normatively neutral, two normatively positive and two normatively negative pictures were selected from the IAPS [25] for use during this study. The positive and negative pictures were again selected such that they were matched on self-reported arousal and evaluative extremity [17]. For the experimental paradigm (see procedure below), the neutral stimuli were separated into two groups, each with mean valences near the midpoint of the nine-point valence scale (both groups  $M = 5.10$ ). The positive and negative stimuli were chosen to be equally extreme (positive stimuli mean valence rating = 8.31, negative stimuli mean valence rating = 1.89), and equally arousing (positive stimuli mean arousal rating = 7.43, positive stimuli mean arousal rating = 7.34, both on a nine-point scale).<sup>4</sup>

the primary electrode site described in this report (Oz) was not analyzed for the initial paper, (b) the latencies of the ERP components analyzed in the current and initial papers do not overlap (the P1 peaks before 150 ms whereas the LPP does not start to appear until 300 ms) and (c) the research focus of the two articles (i.e. the extremity bias versus the attention bias) is fundamentally different.

<sup>4</sup> Neutral group one (an arbitrary distinction used for counterbalancing) consisted of IAPS slides 5500, 5800, 6150, 7002, 7025, 7035, 7040, 7080, 7090, 7140, 7217, 7224, 7285, 7550 and 7820. Neutral group two consisted of slides 2230, 2840, 5900, 7000, 7006, 7009, 7010, 7030, 7050, 7100, 7130, 7150, 7170, 7190, 7233, 7235, 7284 and 9210. Positive targets were slides 8490 and 8510, whereas negative targets were slides 3030 and 6230.

#### 4.1.3. Procedure

Upon arrival at the lab, research participants were given an overview of the procedure and gave informed consent. Participants then had electrodes attached to their heads for the physiological recording. During this time, participants filled out a questionnaire that assessed their handedness.

Participants were then seated in a sound-attenuating, electrically shielded room and given instructions for the task. They were told that they would see pictures in sequences of five and that after each picture went off of the screen, they should indicate whether it was positive (or negative, by block, see below) or neutral by pushing the appropriate button. After indicating that they understood the task, participants began the experiment.

Participants watched pictures presented in two counterbalanced blocks. In each block, they viewed 60 sequences of five pictures each. In one block, participants saw predominantly neutral pictures with occasional positive pictures. In the other block, participants saw a different group of neutral pictures with occasional negative pictures. The group of neutral pictures that was associated with each valence was counterbalanced across participants. In both blocks, pictures were presented for 1000 ms each with a 1000 ms interstimulus interval, and participants were given a chance to pause after each five picture sequence. ERPs were recorded to all positive and negative stimuli and to an equal number of neutral stimuli in each block. Table 2 shows the arrangement of stimuli within each of the given blocks.

Therefore, the experimental design can best be represented as a 2 (block: positive or negative) by 2 (stimulus probability: high probability neutral or low probability valenced) by 2 (block order: positive block first or negative block first) by 2 (neutral group: neutral group 1 associated with positive or neutral group 2 associated with positive) by 2 (hand: right hand indicates valenced or right hand

indicates neutral) mixed-model design with the last three factors manipulated between groups. Upon completion of the study, participants were debriefed, thanked and released.

#### 4.1.4. Psychophysiological data collection and cleaning

The psychophysiological equipment and data cleaning were identical to those in Experiment 1. Aggregate waveforms were created for each of the four block by stimulus probability conditions. That is, for each participant, four averages were created: one each for positive stimuli, negative stimuli, neutral stimuli in the block with positive stimuli and neutral stimuli in the block with negative stimuli. As in the previous study, four electrodes from each average (Fz, Cz, Pz and Oz) were entered into a PCA. Six components were extracted, and varimax rotated and the component scores were saved and analyzed via GLM.

## 4.2. Results

### 4.2.1. Principal components analysis

In Fig. 3, the six components extracted by the PCA are depicted. The numbering of the components again represents the rank order of proportion of variance accounted for by the components. The component structure of this study is very similar to that of Experiment 1, suggesting that the same basic components are being modulated in the two studies. Again, there is an early component, component number five, peaking 112 ms after stimulus onset. Because it is active in the latency range of the P1, the analyses will focus on this component.

### 4.2.2. Component scores

If component 5 is a P1, it should have the appropriate latency, scalp distribution and polarity. Given that it peaks 112 ms after stimulus onset, it possesses the correct latency. To assess the scalp distribution, the mean component scores for each scalp site were analyzed. Replicating the Experiment 1, there was a main effect for scalp site,  $F(3, 21) = 6.96$   $P < .005$ . Consistent with the notion that component 5 is a P1, it was most positive over the occipital lobe and decreased significantly or marginally at each subsequent scalp site ( $M$  Oz = 0.660, S.E. = 0.183;  $M$  Pz = 0.123, S.E. = 0.154;  $M$  Cz = -0.319, S.E. = 0.138;  $M$  Fz = -0.464, S.E. = 0.119). Finally, the component was again positive going over the occipital lobe. Therefore, as in the previous experiment, analyses focused on component 5 at Oz. See Fig. 4, for the raw grand average waveforms at the occipital site.

To investigate the effect that picture valence had on P1 amplitude, we performed a 2 (block: positive or negative) by 2 (stimulus probability: high probability neutral or low probability valenced) by 2 (block order: positive block first or negative block first) by 2 (neutral group: neutral group 1 associated with positive or neutral group 2 associated with positive) by 2 (hand: right hand indicates valenced or right hand indicates neutral) GLM. The latter three factors did

Table 2  
Stimulus presentation sequences in Experiment 2

Trial type	Stimulus position				
	1	2	3	4	5
Trial type 1—positive block	Neu	Neu	<b>Neu</b>	Nen	Neu
Trial type 2—positive block	Neu	Neu	Neu	<b>Neu</b>	Neu
Trial type 3—positive block	Neu	Nen	Neu	Neu	<b>Neu</b>
Trial type 4—positive block	Neu	Neu	<b>Pos</b>	Neu	Neu
Trial type 5—positive block	Neu	Neu	Neu	<b>Pos</b>	Neu
Trial type 6—positive block	Neu	Neu	Neu	Neu	<b>Pos</b>
Trial type 1—negative block	Neu	Neu	<b>Neu</b>	Neu	Neu
Trial type 2—negative block	Neu	Nen	Neu	<b>Neu</b>	Neu
Trial type 3—negative block	Nen	Neu	Neu	Neu	<b>Neu</b>
Trial type 4—negative block	Neu	Neu	<b>Neg</b>	Neu	Neu
Trial type 5—negative block	Neu	Neu	Neu	<b>Neg</b>	Neu
Trial type 6—negative block	Neu	Neu	Neu	Neu	<b>Neg</b>

Note: Pos indicates a positive stimulus presentation, Neg the negative stimulus presentation, Neu the neutral stimulus presentation. Bold type indicates a trial during which ERPs were recorded.

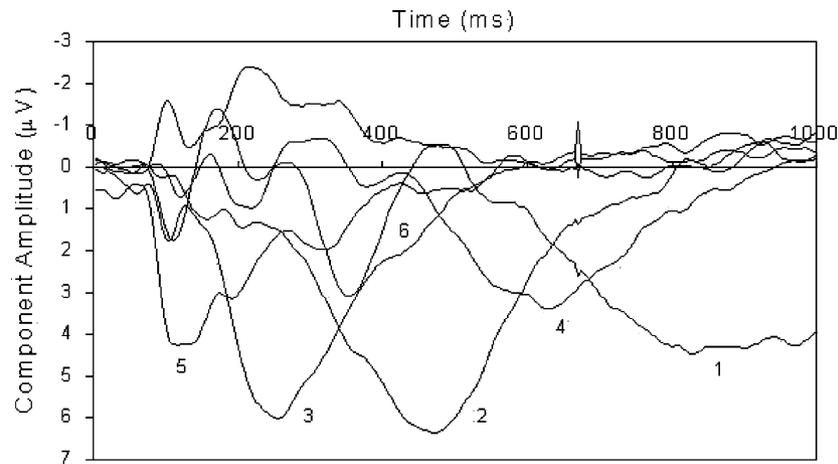


Fig. 3. Component amplitude as a function of time for Experiment 2. Components are number by the rank order of proportion of variance for which they account. Note the similar morphology of the components to those of Experiment 1.

not interact with the first two variables in meaningful ways, therefore they were collapsed across (though the statistical results were the same whether these factors were included or excluded).

After removing the between groups factors, the analysis simplified to a 2 (block: positive or negative) by 2 (stimulus probability: high probability neutral or low probability valenced) design. This analysis yielded a main effect for Block ( $F(1, 23) = 25.3, P < .001$ ), such that the block in which negative stimuli were present yielded larger P1s ( $M = 0.900, S.E. = 0.199$ ) than the block in which positive stimuli were present ( $M = 0.420, S.E. = 0.179$ ), as well as a main effect for Stimulus Probability ( $F(1, 23) = 56.8, P < .001$ ), in which frequently presented neutral targets elicited larger P1s ( $M = 1.053, S.E. = 0.179$ ) than did rarely presented valenced targets ( $M = 0.268, S.E. = 0.201$ ). More important than either of these main effects, however, was the significant two-way interaction between them ( $F(1, 23) = 28.6, P < .001$ ). The form of this interaction was as follows: across both blocks, the amplitude of

the P1s elicited by frequent, neutral stimuli did not differ ( $M$  neutral stimuli in the block with positive targets = 1.06,  $S.E. = 0.172$ ;  $M$  neutral stimuli in the block with negative targets = 1.05,  $S.E. = 0.197, ns$ ). This stands in contrast to P1 amplitudes elicited by the rare, valenced stimuli, which evidenced the same effect as in the previous studies: negative stimuli elicited larger P1s than did positive stimuli ( $t(24) = 6.08, P < .001, M$  positive stimuli =  $-0.219, S.E. = 0.215, M$  negative stimuli = 0.754,  $S.E. = 0.217$ ). See Table 3 for P1 means for each experimental condition at each scalp site.

#### 4.3. Discussion

The results of Experiment 2 replicated and extended the basic findings of Experiment 1. First, despite a different stimulus presentation scheme, the component structure for the two experiments was similar, suggesting that the PCA is representing a stable component structure. Second, the latency, scalp distribution and polarity of the earliest

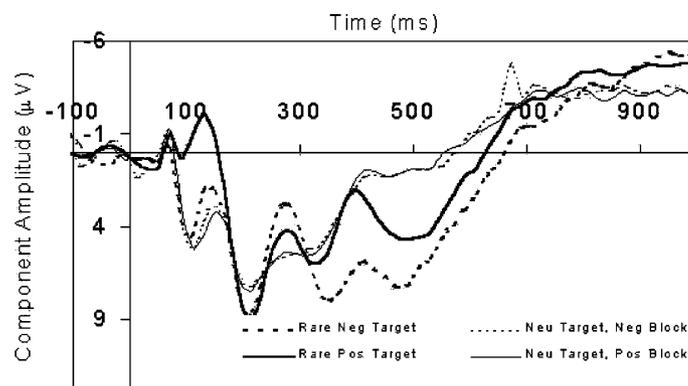


Fig. 4. Averaged ERP waveforms at the midline occipital electrode (Oz) to frequent neutral stimuli and rare positive and negative stimuli. Again, the earliest positive-going (downward) deflection is the P1, which is larger for frequent neutral stimuli and infrequent negative stimuli than for infrequent positive stimuli.

Table 3  
P1 component amplitude as a function of scalp site and experimental condition

Condition	Scalp site			
	Fz	Cz	Pz	Oz
Block with positive targets				
Positive target	−0.323 (0.173)	−0.126 (0.185)	−0.068 (0.192)	−0.219 (0.215)
Neutral target	−0.443 (0.108)	−0.217 (0.134)	0.383 (0.144)	1.06 (0.172)
Block with negative targets				
Negative target	−0.77 (0.144)	−0.677 (0.18)	−0.136 (0.209)	0.754 (0.217)
Neutral target	−0.32 (0.155)	−0.256 (0.167)	0.311 (0.168)	1.046 (0.197)

Note: Values are unitless component scores. Standard errors are in parentheses.

component again suggest that it was indeed a P1. Most importantly, the functionality of the P1 conformed to the predictions derived from the previous experiment. That is, replicating Experiment 1, negative stimuli evoked significantly larger P1s than did positive stimuli. Given our early attentional interpretation of the P1, this suggests that negative stimuli are being allocated more attention than positive stimuli very early in the information processing stream. Further, because different stimuli were used in Experiment 2, the hypothesis that the P1 results were due to some factor other than valence is rendered less likely.

The final difference between Experiments 1 and 2 was the addition of a high probability stimulus group (in this case, neutral stimuli). Designed as a high attention comparison condition, these stimuli were predicted to evoke a large amount of attention early in the information processing stream. Consistent with that prediction, neutral stimuli did evoke larger P1s than positive and negative stimuli, providing converging evidence that P1 amplitude is positively related with attention allocation.

A seeming incompatibility between the results of Experiments 1 and 2 concerns primed neutral stimuli resulting in large P1s in Experiment 2 but frequently presented positive and negative stimuli not demonstrating P1 enhancements in Experiment 1. The most likely explanation for this differentiation is the number of the participants' exposures to the frequently presented stimuli. In Experiment 1, participants in the positive (negative) block viewed a total of 60 positive (negative) picture presentations and 30 negative (positive) picture presentations. In Experiment 2, in each block, participants saw 270 neutral presentations and 30 valenced presentations. Obviously, both the absolute number of stimulus presentations and the proportion of rare to frequent stimuli favored a larger priming effect in Experiment 2 than in Experiment 1.

## 5. General discussion

Across two studies we have demonstrated that negative stimuli evoke larger P1s than positive stimuli. These results address the two research questions set out in the introduction. First, given that the P1 is a measure of early attention

allocation in the extrastriate visual cortex, we have replicated the established social psychological phenomenon of enhanced attention allocation to negative stimuli relative to positive stimuli [15,34]. More importantly, because we used a direct measure of attention allocation, it is not possible that our results are due to differential stimulus processing subsequent to the allocation of attention.

Second, our results show that positive and negative stimuli are being differentiated within 100 ms of stimulus onset. Zajonc [43] and others have suggested that the role of emotion is to focus our information processing resources on and guide our behavioral responses to important stimuli. Clearly, the faster we can separate negative from positive stimuli, the faster we can engage an appropriate response strategy, and the more successful we will be in responding to the world. Understanding that positive and negative stimuli are differentiated within 100 ms of our initial exposure to the stimulus is consistent with the idea of a rapid differentiation of the valences [42].

An interesting question that remains is the cause of the attention bias. That is, although it may be that evolutionary forces caused humans to preferentially attend to negative information (i.e. ultimate causes of the bias), there still must be a set of psychological processes that bring about this result (i.e. proximate causes of the bias). Two interesting proximate causes can be advanced for this bias: one rooted in the affective associations that stimuli possess, the other suggesting that low-level perceptual processes are responsible for the bias.

Given the current results that frequent exposure to neutral stimuli increase the amount of attention paid to those stimuli, and complementary results that show that priming positive stimuli can eliminate the attention bias [37], a logical conceptualization of the origin of the attention bias rests on the relative accessibility of positivity and negativity. That is, negative stimuli attract more attention than positive stimuli because they are more accessible.

There are several plausible mechanisms by which negative stimuli could acquire this enhanced accessibility. First, negative stimuli may simply be more chronically accessible than positive stimuli. Chronic construct accessibility can lead to the attention effects observed [3], however it also should lead to other information processing consequences

(e.g. interpreting stimuli in the environment consistently with the accessible constructs [16]) that do not seem to occur. Therefore, it seems unlikely that a pure accessibility differential is responsible for the attention bias. Second, it is possible that the cognitive organization of negative stimuli allows them to be primed more easily than positive stimuli. For example, if the associations between negative stimuli are stronger than those between positive stimuli, it would take fewer presentations of a negative stimulus to activate an associated negative stimulus than it would of a positive stimulus to activate an associated positive stimulus. Given that in our method we use multiple presentations of a stimulus valence, this result could arise.

Both of these explanations implicitly suggest that the attention bias afforded to negative stimuli does not have anything to do with their negativity per se, but rather emerges as a result of *cognitive priming*. A third possible explanation of the attention bias could suggest that neural projections that the visual cortex receives from rudimentary affective systems facilitate the processing of negative stimuli. That is, it is possible that negative stimuli benefit from *biological preparedness* [7,12,31]. For example, there is evidence that (a) the amygdala processes aversive information very rapidly [26,29] (and perhaps independent of cortical processing for simple auditory and visual stimuli [26,27]) and that, (b) during the processing of the IAPS stimuli, the activity of the amygdala is greater for negative pictures than for positive pictures [24]. Given the large number of connections between the amygdala and the visual cortex [29], it is possible that the amygdala, after rapidly processing a negative stimulus, stimulates extrastriate areas of the visual cortex leading to enhanced neural recruitment.

A thorny issue with this hypothesis concerns how well visual information is represented at various points within the information processing time stream. For example, in order to affect extrastriate neural recruitment in a timely fashion, one might suggest that a direct link from the thalamus to the amygdala [27] could be responsible for modulating visual processing. However, in the absence of cortical processing along that pathway, it is questionable whether visual information is sufficiently well represented for the amygdala to make such fine grained distinctions as differentiating between positive and negative stimuli. Alternatively, a thalamo-cortico-amygdala pathway, which could provide a rich representation of visual information allowing differentiation between positive and negative stimuli, would most likely not be sufficiently timely to modulate processing in the time frame of the P1.

An alternative, perceptual possibility suggests that our nervous system has been sculpted to enhance attention to simple visual stimulus attributes that have proven to be correlated with dangerous stimuli. For example, if, during the course of evolution, the perceptions of threatening stimuli tended to consist of certain spatial frequencies, it is possible that species who evolved to preferentially attend to stimuli that possessed those spatial frequencies would be more

evolutionarily successful. This explanation suggests that people are not rapidly differentiating positive and negative stimuli per se, but instead are responding to stimulus features that suggest threats might be present in the stimulus field.

## 6. Future directions

An interesting question that remains concerns the relationship between the attention bias and the extremity bias. Assessing these two biases simultaneously is possible because ERPs allow monitoring sequential information processing stages without disrupting processing by requiring an overt response. Given in prior work, we have examined the size of the negativity bias in studies such as these, it was reasonable to assess the relationship between the two biases in the two current experiments. The results of these analyses, however, are inconsistent. That is, in Experiment 1 there was a significant correlation between the magnitude of the attention bias and the magnitude of the extremity bias, however this pattern was not replicated in Experiment 2.

The attention bias and extremity bias being inconsistently related is not surprising when one considers that the biases (a) occur at different stages of information processing, (b) are performed by different neural substrates and (c) perhaps serve different functions. Berntson et al. [5] suggested that evaluation is performed by multiple, separate systems in the brain. As a consequence of this separability, different evaluative systems may rely on different aspects of a stimulus in order to form their evaluation of it. For example, the attention bias must rely on a very rapid evaluation, and seems particularly sensitive to threatening information [30], whereas the extremity bias takes longer to occur and does not seem to require a threatening stimulus. Therefore, one could imagine situations in which one would find an attention bias, but not an extremity bias as well as situations in which the reverse is true.

For example, it's possible that a stimulus might be immediately evaluated as threatening enough to require enhanced attention, but might not be perceived as negatively during later evaluations that have the ability to bring additional sources of information to bear. For example, seeing a large snake in a zoo might be sufficiently negative to elicit enhanced attention, but contextual factors not taken into account by the initial evaluation (e.g. the safety of the environment) may mitigate the extremization of the evaluation. On the other hand, it's possible that there are stimuli that require elaborated processing to understand that they are negative. We might not expect this sort of stimulus to bias attention, but rather to bias only the extremity of evaluation. For example, winning US\$ 10 might not evoke any extra attention at all, because it should be initially perceived as neither threatening nor particularly negative. However, when your two options are winning US\$ 10 and winning US\$ 1000, and you only win US\$ 10, the negative feelings

that the disappointing win evoke might be sufficient to increase the extremity of its evaluation.

A second, related question regarding this effect is whether it holds for all stimuli, or is being driven by a specific subset. For example, Öhman and Soares [32] have shown that subliminal aversive conditioning can occur for certain conditioned stimuli (e.g. pictures of snakes), but not others (e.g. pictures of flowers). From this and related work, they theorize that certain types of stimuli (i.e. biologically prepared fear stimuli) humans are especially receptive to classical conditioning. Put another way, our biology is prepared to react in specific ways for certain stimuli, but not for others. This may very well be true for attention as well. That is, do we afford enhanced attention to all negative stimuli or does a snake elicit more than an IRS auditor, because evolution has had time to sculpt our nervous system to prepare for the former but not the latter?

## 7. Conclusion

With these studies, we have illustrated two important points. First, we showed that attention is allocated differentially to positive and negative stimuli, and ruled out the possibility that this due to processes downstream of the initial allocation of attention to the stimuli. Second, we furthered understanding of the chronometry of evaluation. That is, positive and negative information are differentiated from each other within 100 ms of exposure to the stimulus.

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