Psychophysiology, 50 (2013), 1251–1254. Wiley Periodicals, Inc. Printed in the USA.

DOI: 10.1111/psyp.12135

BRIEF REPORT

Nonaffective motivation modulates the sustained LPP (1,000–2,000 ms)

PHILIP A. GABLE and DAVID L. ADAMS
Department of Psychology, University of Alabama, Tuscaloosa, Alabama, USA

Abstract

Past work has demonstrated that the sustained late positive potential (LPP) is modulated by motivational demands of affective content. The current experiment sought to investigate how motivational demands in nonaffective tasks would modulate the sustained LPP. Using a modified oddball paradigm, participants either counted the number of appearances of a nonaffective target or determined the duration length of the target. Results showed that targets in both the counted and duration tasks produced larger LPPs in the early window (400–1,000 ms) than the neutral standard. Only the duration target produced larger LPPs in the late time window (1,000–2,000 ms) than the neutral standard. These results suggest that the late LPP is a measure of persistent motivated attentional processing and can be modulated by nonaffective motivation.

Descriptors: Late positive potential, Motivation, Task relevance, Affect

Affective stimuli naturally motivate attentional processing (Lang, Bradley, & Cuthbert, 1997). The late positive potential (LPP) is thought to reflect this motivated attentional processing to affective stimuli. Affective pictures evoke larger LPPs than nonaffective pictures (Codispoti, Ferrari, & Bradley, 2006; Pastor et al., 2008; Schupp, Junghöfer, Weike, & Hamm, 2004). The LPP is larger to high arousing than to low arousing affective pictures (Cuthbert, Schupp, Bradley, Birbaumer, & Lang., 2000; Schupp et al., 2000), presumably because high arousing affective stimuli are more motivationally relevant than low arousing stimuli (Bradley, 2009). For example, motivational relevance, as opposed to physiological and self-reported arousal, enhances the LPP to appetitive stimuli (Gable & Harmon-Jones, 2013; Weinberg & Hajcak, 2010). Trait behavioral approach motivation predicts larger LPP amplitudes to positive and angering stimuli high in motivational intensity, but not to neutral stimuli (Gable & Harmon-Jones, 2013; Gable & Poole, 2013).

In addition to affective modulation, the LPP is larger to task-relevant stimuli than task-irrelevant stimuli (Hajcak, Dunning, & Foti, 2009; Ferrari, Codispoti, Cardinale, & Bradley, 2008; Weinberg, Hilgard, Bartholow, & Hajcak, 2012), presumably because task relevance enhances motivated attentional processing of stimuli. For example, Ferrari et al. (2008) found that LPPs in response to human stimuli were larger when participants were asked to categorize pictures based on human presence, as compared to categorization based on animal presence. Studies using an oddball paradigm with nonaffective targets demonstrate that target stimuli reliably produce larger LPPs than nontarget stimuli (for a review, see Kok, 2001), and trait behavioral approach motivation relates to LPPs elicited by nonaffective targets (Nijs, Franken, & Smulders, 2007). Indeed, task modulation of the LPP appears to be driven by motivated attentional processing.

Address correspondence to: Dr. Philip Gable, 505 Hackberry Lane, P.O. Box 870348, Tuscaloosa, AL 35487-0348, USA. E-mail: pagable@gmail.com

The Present Study

Although typically examined until 1,000 ms after stimulus onset, affective stimuli have been found to modulate LPP amplitude for up to 6,000 ms (Pastor et al., 2008). Weinberg and colleagues (2012) presented neutral task-relevant stimuli, and found that task relevance enhanced the LPP from 400–1,000 ms. However, previous studies have not investigated whether nonaffective task-relevant stimuli modulate attentional processing past 1,000 ms, as assessed by the sustained LPP.

The present study was designed to test whether task-motivated attentional processing would modulate the sustained LPP to nonaffective stimuli. Tasks that require both initial and persistent attentional processing should enhance both the early and sustained LPP as compared to neutral task-irrelevant stimuli. In contrast, tasks that only require initial attentional processing should enhance only the early LPP as compared to neutral task-irrelevant stimuli.

In order to test how task motivation modulates persistent attentional processing, as measured by the LPP, the present study used a modified visual oddball task consisting of two blocks. In one block, task relevance was manipulated by having participants keep a mental count of the number of times a neutral target appeared. In the other block, task relevance was manipulated by having participants determine whether the neutral target appeared for a long or short duration.

We hypothesized that a counting task would initially engage attentional resources, but fail to sustain attentional processing. As such, a counting task should enhance early LPP amplitudes, but fail to modulate the sustained LPP, relative to task-irrelevant neutral stimuli. In contrast, we hypothesized that estimation of display duration would initially engage attentional resources and continue to sustain attentional processing. Therefore, the duration discrimination task should enhance early and sustained LPP amplitudes, relative to task-irrelevant neutral stimuli. Consistent with past studies, affective standards should enhance early and sustained LPP amplitudes.

Method

Twenty-five undergraduates (14 women and 11 men) participated in exchange for course credit. Four images (pleasant, unpleasant, and two neutral) were selected from the International Affective Pictures System (Lang, Bradley, & Cuthbert, 2008).[1] Pleasant and unpleasant images were matched on arousal and relative valence. The pleasant, unpleasant, and one neutral image served as standards in a modified oddball task. The other neutral image was designated as the target stimuli by manipulating task relevance. Consistent with previous oddball studies (Brown, Barry, & Clarke, 2009; Weinberg et al., 2012), the target image was displayed less frequently than the standard images. Task relevance was manipulated in one of two ways: (1) counting the number of times the target was displayed, or (2) assessing whether the display duration of the target was a short or long amount of time.

In the counting task, participants were told to keep a mental tally of the number of target appearances. For this block, all images appeared for 2,000 ms followed by a 2,000-ms interstimulus interval. The target image was presented 30 times, and each standard image was presented 40 times. At the end of the block, participants recorded the number of target appearances.

In the duration discrimination task, participants were told that the target image would appear for either a long or short amount of time. The long duration image appeared for 3,000 ms, and the short duration image appeared for 2,000 ms. Participants saw examples of both display durations and completed eight practice trials where they indicated whether the target appeared for a long or short amount of time by pressing one of two corresponding buttons. Again, the target image was presented 30 times in this block, and each standard image was presented 40 times. Half of the standard and target trials were presented for the short duration, and half of the standard and target trials were presented for the long duration.

Tasks were presented in a blocked design. Following task instructions for the block, standards and targets were randomly presented. Block order was counterbalanced between participants.

EEG Assessment and Processing

Electroencephalography (EEG) was recorded from 31 tin electrodes custom mounted in a stretch lycra Quik-Cap (Electro-Cap, Eaton, OH) based on the 10-20 system and referenced online to the left earlobe. A ground electrode was mounted on the midline in front of electrode FZ. Electrode impedances were under 5,000 Ω. Signals were amplified with Neuroscan SynAmps RT amplifier unit (El Paso, TX), low-pass filtered at 100 Hz, high-pass filtered at 0.05 Hz, notch filtered at 60 Hz, and digitized at 500 Hz. Artifacts (e.g., horizontal eye movement and muscle movement) were removed by hand. Then, a regression-based eye movement correction was applied referencing to site FP1 (Semlitsch, Anderer, Schuster, & Presslich, 1986), after which the data were again visually inspected to ensure proper correction.

Data were epoched 200 ms before picture onset until 2,000 ms after picture onset, and were rereferenced using the average of the left and right mastoids. Data were filtered with a low pass of 35 Hz (48 dB), and baseline corrected using the prestimulus interval. Aggregated waveforms for each image type were created. To investigate the impact of image type on the modulation of the LPP over time, the LPP was evaluated in an early (400–1,000 ms) and late (1,000–2,000 ms) time window, based on previous research investigating affective stimuli in early and late time windows (Weinberg & Hajcak, 2011; Weinberg et al., 2012). LPP amplitude was measured as the mean EEG activity from three midline centroparietal sites (Cz, CPz, and Pz) within each of these windows (Weinberg et al, 2012).

Results

A 4 (Picture Type: target, neutral standard, positive standard, negative standard) × 2 (Target Task: counting vs. duration discrimination) × 2 (LPP Window: early vs. late) repeated measures ANOVA revealed a main effect of picture type, $F(3,66) = 5.88$, $p = .001$, $\eta_p^2 = .21$, Huynh-Feldt $\varepsilon = 1.0$, and a main effect for window, $F(1,22) = 116.97$, $p < .001$, $\eta_p^2 = .84$, Huynh-Feldt $\varepsilon = 1.0$. However, there was no main effect for target task, $F(1,22) = 1.27$, $p = .27$, $\eta_p^2 = .05$, Huynh-Feldt $\varepsilon = 1.0$. These main effects were qualified by a three-way interaction between picture type, target task type, and window, $F(3,66) = 6.28$, $p < .001$, $\eta_p^2 = .22$, Huynh-Feldt $\varepsilon = 0.56$ (see Figure 1). Consistent with predictions, these results suggest that LPPs were larger in the early window than the late window and that LPPs differed between stimuli type. Also, consistent with predictions, target task instructions did not modulate LPPs to nontarget stimuli.

To further test whether task instructions may have modulated standards, 4 (Picture Type: target, neutral standard, positive standard, negative standard) × 2 (Target Task: counting vs. duration discrimination) repeated measures ANOVAs were conducted for each window (early and late). For the early window, there was a significant main effect of picture type, $F(3,66) = 11.37$, $p < .001$, Huynh-Feldt $\varepsilon = 1.0$. However, there was no main effect for target task, $F(1,22) = 0.13$, $p = .721$, Huynh-Feldt $\varepsilon = 1.0$. The interaction was also nonsignificant, $F(3,66) = 1.46$, $p = .234$, Huynh-Feldt $\varepsilon = 0.85$. For the late window, there was a significant main effect of picture type, $F(3,66) = 3.91$, $p = .012$, Huynh-Feldt $\varepsilon = 1.0$. However, there was no main effect for target task, $F(1,22) = 2.43$, $p = .133$, Huynh-Feldt $\varepsilon = 1.0$. The interaction was also nonsignificant, $F(3,66) = 1.55$, $p = .207$, Huynh-Feldt $\varepsilon = 0.72$. These results suggest that LPP amplitudes were unaffected by task instructions in either the early or late window. However, picture type did modulate LPP amplitudes.

Further analyses were run separately in the early and late window to more fully examine the influence of picture type and task type on the LPP. In subsequent analyses, standards were collapsed across task type. Also, positive and negative standards were combined to create one variable reflecting LPP amplitudes to affective standards.

1. IAPS picture numbers for stimuli type: target = 2102, neutral standard = 2383, positive standard = 4608, negative standard = 6250.

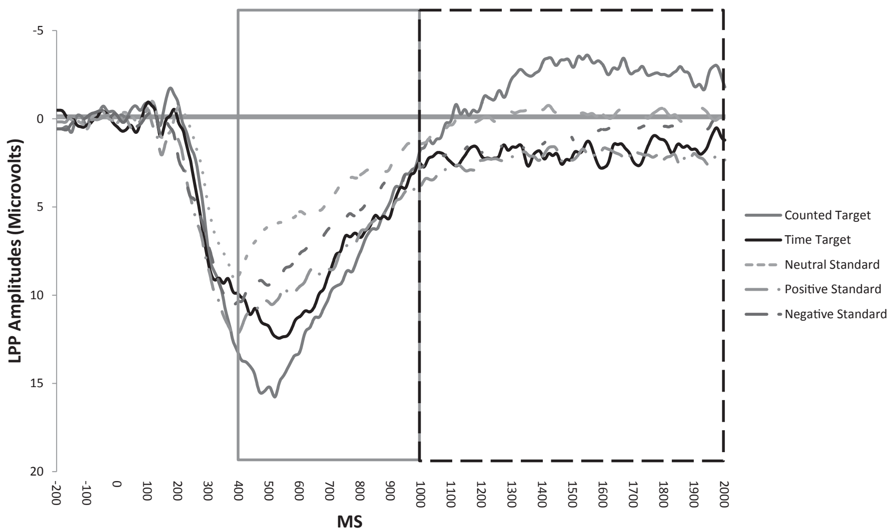

Figure 1. Aggregate waveforms (sites Cz, CPz, and Pz) for targets and standards. The early window (400–1,000 ms) is outlined in a gray box and the late window (1,000–2,000 ms) is outlined in a dashed-line black box.

Early Window

A one-way 4 (picture type: counted target, duration discrimination target, affective standard, neutral standard) repeated measures ANOVA revealed a significant main effect of picture type in the early window, $F(3,66) = 8.45$, $p < .001$, $\eta_p^2 = .28$, Huynh-Feldt $\varepsilon = 0.69$. Post hoc analyses revealed that LPPs to the duration discrimination target ($M = 8.46$, $SD = 5.75$) were larger than LPPs to the neutral standard ($M = 4.63$, $SD = 3.44$), $t(66) = 3.44$, $p = .001$, but similar to LPPs to affective standards ($M = 7.57$, $SD = 4.02$), $t(66) = 0.80$, $p = .428$. LPPs to the counted target ($M = 10.10$, $SD = 6.11$) were larger than LPPs to neutral standards, $t(66) = 4.90$, $p < .001$, and affective standards, $t(66) = 2.26$, $p = .027$ (Figure 2). LPPs did not differ between target type, $t(66) = 1.47$, $p = .146$. LPPs to affective standards were larger than LPPs to neutral standards, $t(66) = 2.65$, $p = .010$.

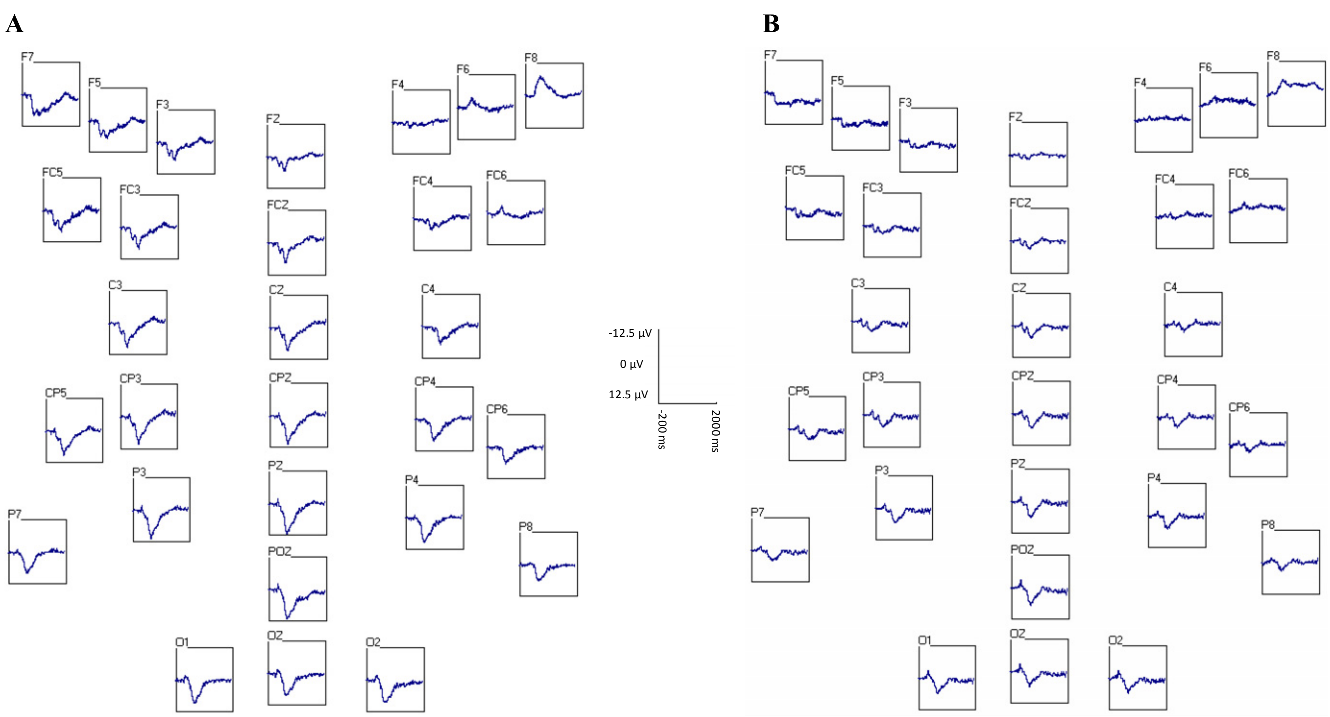

Figure 2. Waveform head map reflecting the difference between targets and neutral standards. A: Counting targets minus neutral standards. B: Duration targets minus neutral standards. Sites FP1 and corresponding site FP2 are removed because of eyeblink correction.

Late Window

A one-way 4 (picture type: counted target, duration discrimination target, affective standard, neutral standard) repeated measures ANOVA revealed a significant main effect of picture type in the late window, $F(3,66) = 2.95$, $p = .039$, $\eta_p^2 = .118$, Huynh-Feldt $\varepsilon = 0.48$. Post hoc analyses revealed that LPPs to the duration discrimination target ($M = 1.91$, $SD = 4.53$) were moderately larger than LPPs to neutral standards ($M = -0.80$, $SD = 3.21$), $t(66) = 1.74$, $p = .087$, but similar to LPPs to affective standards ($M = 1.86$, $SD = 2.72$), $t(66) = 0.03$, $p = .974$. LPPs to the counted target ($M = -1.83$, $SD = 8.64$) were similar to LPPs to neutral standards, $t(66) = 0.66$, $p = .512$, but smaller than LPPs to affective standards, $t(66) = 2.36$, $p = .021$. LPPs were larger to duration targets than counting targets, $t(66) = 2.40$, $p = .019$. LPPs to affective standards were moderately larger than LPPs to neutral standards, $t(66) = 1.70$, $p = .093$.[2]

Discussion

The early and late LPP appear to be a measure of persistent motivated attentional processing. Results of the current study suggest that participants were initially motivated by both tasks, as measured by enhanced early LPPs to targets as compared to neutral standards. The counting task required greater initial attention processing and produced larger LPPs than neutral and affective standards as participants recognized the target and added it to their mental count. The duration discrimination task, however, proved effective at enhancing both the early and late LPP in response to the target stimulus, as compared to the neutral standard stimulus.

We suggest that persistent motivated attentional processing to the duration target resulted in a larger sustained LPP, as compared to the counting task. Once participants had recognized the target in the counting task and added it to their mental count, they disengaged attentional processing from the counting target. In contrast, participants were motivated to persist processing of the duration target in order to determine target duration. This persistent attentional processing likely enhanced the sustained LPP in the duration task. The current results also demonstrated that affective standards evoked slightly larger sustained LPP amplitudes than neutral standards. Together, these results suggest that task-relevant stimuli can modulate the sustained LPP similar to affective stimuli, provided that the task requires persistent motivated attentional processing.

Consistent with much past work on the LPP, the current results indicate that the early and late LPP appear to be driven by motivated attentional processing. Where previous work has largely shown that the sustained LPP (> 1,000 ms) is modulated by affective stimuli, these results show that nonaffective task relevance can also modulate the sustained LPP when the task is sufficiently motivating and requires persistent engagement. These results demonstrate that modulation of the sustained LPP is possible by both affective and task-relevant means, suggesting that the sustained LPP is sensitive to both affective and nonaffective motivational processes.

2. Two hypothesized comparisons between item types in the sustained LPP were marginally significant. It is possible that these marginal differences could be the result of reduced power in the current sample size.

References

Bradley, M. M. (2009). Natural selective attention: Orienting and emotion. *Psychophysiology*, *46*, 1–11.

Brown, C. R., Barry, R. J., & Clarke, A. R. (2009). ERPs to infrequent auditory stimuli in two-and three-stimulus versions of the inter-modal oddball task. *International Journal of Psychophysiology*, *74*, 174–182.

Codispoti, M., Ferrari, V., & Bradley, M. (2006). Repetitive picture processing: Autonomic and cortical correlates. *Brain Research*, *1068*, 213–220.

Cuthbert, B., Schupp, H., Bradley, M., Birbaumer, N., & Lang, P. (2000). Brain potentials in affective picture processing: Covariation with autonomic arousal and affective report. *Biological Psychology*, *52*, 95–111.

Ferrari, V., Codispoti, M., Cardinale, R., & Bradley, M. (2008). Directed and motivated attention during processing of natural scenes. *Journal of Cognitive Neuroscience*, *20*, 1753–1761.

Gable, P. A., & Harmon-Jones, E. (2013). Does arousal per se account for the influence of appetitive stimuli on attentional scope and the late positive potential? *Psychophysiology*, *50*, 344–350.

Gable, P. A., & Poole, B. D. (2013). Influence of trait behavioral inhibition and behavioral approach motivation systems on the LPP and frontal asymmetry to anger pictures. *Social Cognitive and Affective Neuroscience*. Advance online publication. doi: 10.1093/scan/nss130

Hajcak, G., Dunning, J., & Foti, D. (2009). Motivated and controlled attention to emotion: Time-course of the late positive potential. *Clinical Neurophysiology*, *120*, 505–510.

Kok, A. (2001). On the utility of P3 amplitude as a measure of processing capacity. *Psychophysiology*, *38*, 557–577.

Lang, P., Bradley, M., & Cuthbert, B. (1997). Motivated attention: Affect, activation, and action (pp. 97–135). *Attention and orienting: Sensory and motivational processes*. Mahwah, NJ: Lawrence Erlbaum Associates.

Lang, P., Bradley, M., & Cuthbert, B. (2008). International Affective Picture System (IAPS): Affective ratings of pictures and instruction manual. Technical Report A-8. University of Florida, Gainesville, FL.

Nijs, I. M. T., Franken, I. H. A., & Smulders, F. T. Y. (2007). BIS/BAS sensitivity and the P300 event-related brain potential. *Journal of Psychophysiology*, *21*, 83–90.

Pastor, M., Bradley, M., Löw, A., Versace, F., Moltó, J., & Lang, P. (2008). Affective picture perception: Emotion, context, and the late positive potential. *Brain Research*, *1189*, 145–151.

Schupp, H. T., Cuthbert, B. N., Bradley, M. M., Cacioppo, J. T., Ito, T., & Lang, P. J. (2000). Affective picture processing: The late positive potential is modulated by motivational relevance. *Psychophysiology*, *37*, 257–261.

Schupp, H., Junghöfer, M., Weike, A., & Hamm, A. (2004). The selective processing of briefly presented affective pictures: An ERP analysis. *Psychophysiology*, *41*, 441–449.

Semlitsch, H. V., Anderer, P., Schuster, P., & Presslich, O. (1986). A solution for reliable and valid reduction of ocular artifacts, applied to the P300 ERP. *Psychophysiology*, *23*, 695–703.

Weinberg, A., & Hajcak, G. (2010). Beyond good and evil: The time-course of neural activity elicited by specific picture content. *Emotion*, *10*, 767–782.

Weinberg, A., & Hajcak, G. (2011). The late positive potential predicts subsequent interference with target processing. *Journal of Cognitive Neuroscience*, *23*, 2994–3007.

Weinberg, A., Hilgard, J., Bartholow, B., & Hajcak, G. (2012). Emotional targets: Evaluative categorization as a function of context and content. *International Journal of Psychophysiology*, *84*, 149–154.

(Received March 15, 2013; Accepted June 28, 2013)