Attitudes to the Right: Evaluative Processing Is Associated With Lateralized Late Positive Event-Related Brain Potentials

John T. Cacioppo
Ohio State University

Stephen L. Crites, Jr.
University of Texas at El Paso

Wendi L. Gardner
Northwestern University

The authors recently developed a paradigm to investigate the evaluative categorization stage of attitudes using event-related brain potentials (ERPs). The present series of studies extended this approach by analyzing the spatial topography of the ERP over the lateral scalp region to address complementary questions regarding the nature of operations underlying the evaluative categorization stage of attitude processing. Consistent with the hypothesis that evaluative categorizations engage mechanisms associated with hedonic or global language processing, results revealed that the standardized amplitudes of the late positive potential of the ERP during evaluative categorizations were larger over the right than the left scalp region, whereas nonevaluative categorizations were associated with a symmetrically distributed ERP across the left and right scalp regions.

> In most empirical studies specific attitudes are defined at least implicitly as responses . . . asking the person to assign an object of thought along a dimension of judgment. . . . Advances in measurement may yield a "right brain" equivalent of this typical left-brain verbal operationalization (McGuire, 1985, p. 239).

Attitude processes are characterized by an evaluative categorization of a stimulus and a bivalent action disposition toward or away from the stimulus (Zanna & Rempel, 1988). Despite these distinguishing features, our understanding of attitudes and attitude processes comes primarily from measures of bivalent action dispositions (e.g., self-reports, behaviors, skin conductance responses, electromyographic activity). Isolating and investigating the evaluative categorization stage may reveal underlying processes that are obfuscated by attitude measures dependent, at least in part, on response selection and execution. To avoid measures of evaluative categorizations that are dependent on response processes, we have recently developed a modified oddball paradigm in which event-related brain potentials (ERPs) are used to study attitude categorization that can be isolated from verbal or somatic response requirements (Cacioppo, Crites, Gardner, & Berntson, 1994; Crites, Cacioppo, Gardner, & Berntson, 1995). This brain-based approach to the study of attitudes may provide important information about the neural substrates and the operations underlying evaluative processes (e.g., see review by Cacioppo & Berntson, 1994). This approach has proved informative in the area of memory, for instance, wherein the debate has raged over whether implicit and explicit memory represent different systems or merely different processes emanating from a single system (e.g., Schacter, Chin, & Ochsner, 1993).

Authors' Note: This research was supported by National Science Foundation (NSF) Grants No. SBR-9512459 and DBS-9211483; National Institute of Mental Health Grants No. P50MH52384-01A1, 2R24MH47167-04A1, and T32-MH19728; an NSF predoctoral fellowship; and funding from the John D. and Catherine T. MacArthur Foundation. We thank Gary G. Berntson for his contributions to this research and David Lozano for his assistance in this research. Correspondence should be addressed to John T. Cacioppo, Department of Psychology, Ohio State University, 1885 Neil Ave., Columbus, OH 43210-1222, E-mail cacioppo.1@osu.edu.

PSPB, Vol. 22 No. 12, December 1996 1205-1219

ERPs reflect the temporal sequence of information-processing operations associated with a discrete event (e.g., the presentation of an attitude object). The positive and negative electrical potentials of the ERP, which can be recorded from electrodes placed on the scalp, are produced by a sequence of temporally activated neural generators that are involved in processing information about a stimulus. The ERP can be divided into components that are typically identified by discrete topographical and temporal features (e.g., a peak in the ERP waveform that has a particular spatial distribution across the scalp and occurs within a specific temporal window of the ERP). Components that occur relatively early in the ERP reflect information-processing operations associated with the afferent processing of the eliciting stimulus (exogenous components), whereas later components in the ERP reflect selected information-processing operations that are being performed on the stimulus (endogenous components). One of these latter components, the P300 or P3b is of interest in the present research because the amplitude of this component reflects categorization processes (Coles, Gratton, & Fabiani, 1990; Donchin & Coles, 1988). Furthermore, the P300 does not appear to be affected by factors that affect only response selection or execution stages. In typical research on the P300, simple stimuli representing two distinct categories are presented to participants in long sequences in which stimuli from one category have a low probability of occurrence and stimuli from the other category have a high probability of occurrence (i.e., an oddball paradigm). If individuals attend to and categorize each stimulus in the sequence, a larger-amplitude P300 along the midline centroparietal region of the scalp is evoked by categorically inconsistent stimuli, such as a high tone preceded by a sequence of low tones, than by categorically consistent stimuli, such as a high tone preceded by a sequence of high tones (e.g., see Coles et al., 1990; Donchin, Karis, Bashore, Coles, & Gratton, 1986, for reviews).

Drawing from the literature on the P300 in cognitive psychophysiology, we developed a paradigm for examining evaluative categorizations (Cacioppo, Crites, Berntson, & Coles, 1993). A modified oddball paradigm was employed in which (a) participants were exposed to numerous short sequences of liked and disliked stimuli and (b) participants performed a task that required them to differentiate the liked from the disliked stimulus classes.[1] Results have reliably shown that evaluatively inconsistent stimuli (e.g., a negative stimulus embedded in a sequence of positive stimuli) evoke a larger-amplitude late positive potential (LPP) of the ERP than evaluatively consistent stimuli (e.g., a negative stimulus embedded in a sequence of negative stimuli). Furthermore, this LPP enhancement to an evaluatively inconsistent stimulus is obtained whether the stimulus is positive or negative (Cacioppo et al., 1993). Subsequent research suggests that the amplitude of the LPP evoked in this paradigm (a) increases as the discrepancy increases between a person's attitude toward the stimulus and his or her attitudes toward contextual stimuli (Cacioppo et al., 1994) and (b) is not affected by instructions to intentionally misreport attitudes toward the stimuli (Crites et al., 1995). Together, these studies have revealed that the LPP evoked by *evaluative* categorizations is characterized by some of the signature attributes of the P300 observed in studies using the oddball paradigm to investigate nonevaluative categorizations: (a) The amplitude of the LPP is largest over the midline centroparietal area of the scalp; (b) a larger-amplitude LPP is evoked by categorically (i.e., evaluatively) inconsistent stimuli than by categorically consistent stimuli; and (c) the average latency of the LPP falls within the latency window of the P300.

In our prior research, we have focused exclusively on analyses of the ERP amplitudes along midline sites and how conditions that evoke different cognitive operations affect these amplitudes. To examine the nature of the information-processing operations and the corresponding field (i.e., neural) sources that underlie human cognition and judgment, it has also proved useful to focus on the spatial topography (e.g., the lateral asymmetry of brain activity) of ERP components such as the P300 (Johnson, 1993; Ruchkin, Canoune, Johnson, & Ritter, 1995). Because the effects of conditions (e.g., evaluative inconsistency) influence raw LPP amplitudes, and these differences in amplitudes can produce spurious differences in topographies, the LPP amplitudes must be standardized when determining scalp topographies. This standardization, of course, removes the mean differences that were the focus of our earlier ERP studies of evaluative processes. However, the investigation of standardized ERP amplitudes and spatial topographies allows exploration of questions about the nature of the operations underlying the evaluative categorization stage of attitude processing that complement those that can be addressed in analyses of nonstandardized ERP amplitudes.

Evaluative (or attitude) categorizations and nonevaluative categorizations, though sharing some information-processing stages, differ in that evaluative categorizations necessarily evoke hedonic or valuation processes. Research in the field of neuropsychology has demonstrated a general right hemisphere dominance for the perception and production of affective information (e.g., Kolb & Taylor, 1981; Tompkins & Mateer, 1985). To the extent that the operations underlying evaluative categorizations of attitude stimuli involve some of the same neural structures involved in the processing of affective stimuli, the ERP observed during attitudinal categorization may show an asymmetrical LPP that is larger over the right than the left scalp sites. Furthermore, recent research also suggests a right hemispheric specialization for global language processing (e.g., tasks that require the association of a word with distantly related concepts; Beeman et al., 1994). This differential hemispheric specialization results in the relative capacity of the right hemisphere to gain access to distant associations of the meaning of a word and to organize words into gists or themes (Chiarello & Church, 1986) and the relative capacity of the left hemisphere to activate concepts very closely related to the literal meaning of a word (Dawson & Schell, 1982). Evaluative categorization processes differ from many nonevaluative categorization processes in that the former may involve relatively global associative processes, such as the associ-ation between a stimulus and a global positive or negative evaluation or affective tag. Because attitudinal categorizations involve both hedonic processes and the association of attitude stimuli with a global positive or negative evaluation, we hypothesized that the amplitude of the LPP observed during attitudinal categorizations would be lateralized.

STUDIES 1 AND 2

The existing research on the P300 during *nonevaluative* categorizations has revealed the P300 amplitude to be either symmetrically distributed (e.g., Sanquist, Rohrbaugh, Syndulko, & Lindsley, 1980; Scheffers, Johnson, & Ruchkin, 1991) or inconsistently lateralized on the right or the left (e.g., Snyder, Hillyard, & Galambos, 1980) or small (Alexander et al., 1995). Therefore, our first goal was to determine whether the spatial topography of the LPP observed during *evaluative* categorizations was lateralized. To do this, we analyzed the lateral sites from two recent studies in which we previously indexed the evaluative categorization stage through analyses of (nonstandardized) midline LPPs (Cacioppo et al., 1994; Crites et al., 1995).[2] Specifically, the analyses reported in Cacioppo et al. (1994) and Crites et al. (1995) focused exclusively on data from midline recording sites (Fz, Cz, and Pz) because the hypotheses being tested concerned the effects of evaluatively inconsistent categorizations on the amplitude of the LPP over midline centroparietal regions. However, EEG activity over lateral sites was also recorded to provide a database that would allow us to determine the replicability of any asymmetries in the LPP amplitude observed during evaluative categorizations. We focus here on the standardized LPP amplitudes recorded from these lateral sites.

Topographic analyses are used to determine whether the LPP amplitudes observed in different experimental conditions reflect the activity of more than one combination of neural generators (Johnson, 1993; Ruchkin et al., 1995; Ruchkin, Johnson, Canoune, & Ritter, 1990). As outlined by Ruchkin, Johnson, and colleagues, the underlying assumption is that ERP activity recorded on the scalp is attributable to a combination of neural sources located in various brain regions and/or with different orientations:

> If, in different experimental conditions or different epochs, the combination of brain sources is the same, then the corresponding shapes of scalp topographies will be the same. Conversely, if the shapes of the scalp topographies are different in different experimental conditions or different epochs, then the combination of brain sources must also be different (i.e., the balance of activity among the various sources in the combination must differ for the different conditions or epochs). (Ruchkin et al., 1995, p. 403)

Thus, if the combination of neural sources underlying the LPP during evaluative categorizations tends to be located in or oriented toward the right hemisphere, then a main effect for lateral (left vs. right) scalp regions should be observed. If the combination of neural sources underlying the LPP during evaluative categorizations is different in different experimental conditions, then the shapes of the scalp topographies should also differ across conditions, and there should be a significant interaction in the LPP amplitudes between scalp regions and experimental condition(s).

Method

Participants. Thirty introductory psychology students (17 male, 13 female) at Ohio State University participated in Study 1. Twenty-two different introductory psychology students (9 male, 13 female) served as participants in Study 2. Eleven of the 22 participants in Study 2 were randomly assigned to a negative-focus condition in which they periodically misreported the valence of negative attitudes, and 11 participants were randomly assigned to a neutral-focus condition in which they periodically misreported the valence of neutral attitudes. All participants were right-handed, were in good health, and volunteered to participate as a means of fulfilling a course requirement. The data from 3 participants in Study 1 and from 1 participant in Study 2 were discarded before analysis because of technical problems during data acquisition.

Stimulus materials. In Study 1, four categories of attitudinal stimuli were selected from Anderson's (1968) list: (a) The pool of very positive traits consisted of the 62 most positively rated personality traits (e.g., honest, sincere); (b) the pool of moderately positive traits was the 12 traits whose mean rating was closest to 4.00 on the 0–6 scale (e.g., calm, orderly); (c) the pool of moderately negative traits was the 12 traits whose mean rating was closest to 2.00 (e.g., clumsy, worrier); and (d) the pool of very negative traits was the 12 most negatively rated traits (e.g., phony, dishonest).

In Study 2, three categories of attitudinal stimuli were selected from Anderson's (1968) list: (a) The pool of positive traits was the 52 most positively rated trait adjectives; (b) the pool of neutral traits was the 10 adjectives whose mean rating was closest to 3.00 (e.g., prideful, hesitant); and (c) the pool of negative traits was the 10 most negatively rated trait adjectives. Because the evaluative context of each sequence in Studies 1 and 2 was positive, a greater number of positive trait adjectives were generated to compensate for the number of times each trait adjective was presented.

Procedure. In Study 1, participants were shown a number of personality traits, and their task was to press a key 1 s after presentation of each trait to indicate whether the trait was positive or negative (Cacioppo et al., 1994). The traits were presented in sequences of six, and participants were instructed to indicate whether each trait was positive or negative by pressing the corresponding key on a keypad when the trait was removed from the monitor. Participants initiated each sequence when the word *READY* was displayed on the monitor by pressing a key on a keypad. One sec after the participant pressed a key, the first of the six personality traits appeared at the center of the monitor. Each trait was presented for 1,000 ms, and the interstimulus interval (ISI) was 1,900 ms. A 1,900-ms pause followed the offset of the sixth trait, then the term *READY* appeared on the monitor, and participants initiated the next sequence at their discretion.

In Study 1, EEG and VEOG (vertical electroculography) activity were recorded for 2,128 ms (from 128 ms preceding the onset of a single target stimulus within each sequence to 1,000 ms following the offset of the target stimulus). As outlined in Cacioppo et al. (1994), four types of target stimuli (conditions) were established: (a) a very positive trait that was preceded by very positive traits (i.e., evaluatively consistent trait, (b) a moderately positive trait that was preceded by very positive traits (i.e., mildly evaluatively inconsistent trait), (c) a moderately negative trait that was preceded by very positive traits (i.e., moderately evaluatively inconsistent trait), and (d) a very negative trait that was preceded by very positive traits (i.e., very evaluatively inconsistent trait). The evaluatively positive context of each sequence was established by presenting two, three, four, or five positive traits before the target stimulus. Each of the resulting 16 sequence types was presented 20 times during the study, and the order of these 320 six-trait sequences was randomly determined for each participant. The traits that appeared at the six stimulus positions within each of the 320 sequences were randomly selected from the appropriate valence category. The traits from each of the four valence categories were selected without replacement until all the traits within a valence category had been selected.

The procedure was similar in Study 2. Participants reported or misreported their attitudes toward individuals described by the experimental stimuli (trait adjectives). Whether participants were told to report or misreport their attitudes was manipulated within participants, whereas whether participants were instructed to misreport the attitudes toward individuals characterized by neutral or negative traits was manipulated between participants. Participants again initiated each sequence by pressing a key on a keypad, and 1 s after the participant pressed a key, the first of the six trait adjectives appeared on the screen. Each trait was presented for 1,000 ms, and the ISI was 1,900 ms. Participants were instructed to respond during the ISI by pressing a key to indicate whether they would have a positive or a negative attitude toward a person characterized by that trait. As described by Crites et al. (1995, Experiment 1), three types of target stimuli (conditions) were established: (a) a positive trait that was preceded by all positive traits (i.e., evaluatively consistent stimulus); (b) a neutral trait that was preceded by all positive traits (i.e., moderately evaluatively inconsistent stimulus); and (c) a negative trait that was preceded by all positive traits (i.e., highly evaluatively inconsistent stimulus). The evaluatively positive context of each sequence was established by presenting two, three, four, or five positive traits before the target stimulus. Each of these 12 sequence types was presented 20 times during the study, and the order of these 240 six-trait sequences was randomly determined for each participant. The traits that appeared at the six stimulus positions within each of the 240 sequences were randomly selected from the appropriate valence category. The traits from each of the three valence categories were selected without replacement until all the traits within a valence category had been selected.

Data reduction. The apparatus and data reduction procedure for Studies 1 and 2 are described in Cacioppo et al. (1994) and Crites et al. (1995), respectively. To examine the scalp topography of the LPP, however, differences in the absolute amplitude of the LPP across experimental conditions were eliminated by standardizing the amplitude values following the principles prescribed by McCarthy and Wood (1985). The mean and standard deviation of the LPP amplitude were calculated across the lateral scalp sites within each experimental condition for each participant. Next, a standardized LPP amplitude within each experimental condition and participant was calculated for each scalp site by subtracting the mean amplitude of the LPP across sites from the LPP amplitude at each of the six scalp sites and dividing by the standard deviation across sites.

TABLE 1: Mean Amplitude of the Late Positive Potential (in Microvolts), Study 1

Target[a]	Parietal		Central		Frontal	
	Left	*Right*	*Left*	*Right*	*Left*	*Right*
Very negative	8.85	9.92	7.14	8.82	2.43	4.33
Mildly negative	6.99	8.07	5.98	8.03	2.31	4.15
Mildly positive	4.14	4.72	3.85	4.66	1.71	3.00
Very positive	3.40	4.27	3.06	3.77	1.39	2.61

a. Target stimuli were embedded in a positive stimulus context.

TABLE 2: Mean Amplitude of the Late Positive Potential (in Microvolts), Study 2

Target[a]	Parietal		Central		Frontal	
	Left	*Right*	*Left*	*Right*	*Left*	*Right*
Negative	9.33	10.44	8.21	9.84	3.26	4.41
Neutral	6.54	7.32	6.26	8.02	2.69	4.95
Positive	5.41	6.16	4.63	5.51	1.14	1.92

a. Target stimuli were embedded in a positive stimulus context.

Results

Study 1. The standardized LPP amplitudes were submitted to a 3 (Coronal: frontal, central, or parietal sites) × 2 (Lateral: left vs. right scalp sites) × 2 (Stimulus Valence: positive vs. negative) × 2 (Stimulus Extremity: extreme vs. moderate) multivariate analysis of variance (MANOVA).[3] A main effect for lateral site confirmed that the amplitude of the LPP over the right scalp regions was significantly larger than the amplitude over the left, $F(1, 26) = 14.83$, $p < .001$ (see Table 1). In addition, a significant Lateral × Stimulus Valence interaction indicated that this lateral asymmetry was greater during the categorization of negative (evaluatively inconsistent) ($M_{right-left} = 1.60$ µV) than positive (evaluatively consistent) stimuli ($M_{right-left} = .91$ µV), $F(1, 26) = 7.16$, $p < .05$.

Analyses also revealed a significant coronal main effect, $F(2, 25) = 22.53$, $p < .001$, and a Coronal × Stimulus interaction, $F(2, 25) = 5.34$, $p < .05$. The LPP amplitude decreased across the scalp from the parietal to the frontal sites, and the rate of decrease was greater for the LPP evoked by negative (i.e., evaluatively inconsistent) traits than by positive (i.e., evaluatively consistent) traits.

Study 2. The standardized LPP amplitudes were submitted to a 3 (Coronal: frontal, central, or parietal sites) × 2 (Lateral: left vs. right scalp sites) × 3 (Stimulus Valence: positive, neutral, or negative) × 2 (Attitude-Report Instruction: accurately report valence of negative/neutral traits vs. report negative/neutral traits as positive) × 2 (Focus: report negative traits as positive vs. report neutral traits as positive) mixed-model MANOVA, with the last factor manipulated between participants. As in Study 1, the main effect for lateral site was significant, with the LPP amplitude over the right scalp regions larger than that over the left, $F(1, 19) = 13.77$, $p < .01$ (see Table 2). The coronal main effect was significant, $F(2, 18) = 73.69$, $p < .001$, replicating the decreasing amplitude of the LPP across the scalp from parietal to frontal regions observed in Study 1. That is, evaluative categorization led to an enhancement of the amplitude of the LPP over the centroparietal scalp regions and over the right scalp regions regardless of the valence of the probe.

Discussion

Spatial topographies of the LPP were examined using standardized amplitude measures over the lateral scalp sites. This standardization procedure eliminates the typical main effects for rare versus frequent (e.g., evaluatively inconsistent vs. consistent) stimuli. When LPP amplitudes are equated across conditions, changes in scalp topographies of the LPP reflect changes in the location or combination of neural (i.e., electrical field) sources rather than simply the intensity of the activity from a given source or set of sources (Johnson, 1993; Ruchkin et al., 1995). Studies 1 and 2 provide the first demonstration that the distribution of LPP amplitudes observed during the evaluative categorization stage of attitude judgments is larger over the right than left scalp regions. On the basis of prior research on the relative involvement of the right hemisphere in affective and global language processing, we hypothesized that the LPP observed during evaluative categorizations would be lateralized. That is, we reasoned that to the extent that the operations underlying evaluative categorizations of attitude stimuli involve some of the same neural structures involved in affective or global language processing, the topographic distribution of the LPP observed during evaluative processing should differ in amplitude over the right versus left scalp sites. Our results supported this hypothesis. Furthermore, consistent with the suggestion that the LPP is more sensitive to evaluative categorizations than response processes (Cacioppo et al., 1993, 1994; Crites et al., 1995), the lateralized distribution of the LPP was unaffected in Study 2 when participants falsely reported their attitudes. Finally, results from Studies 1 and 2 revealed a distribution of LPP amplitudes that was larger over centroparietal than frontal scalp regions, a result consistent with recent neuropsychological research indicating that the P300 is more influenced by neural structures underlying centroparietal than frontal regions (Guillem, N'Kaoua, Rougier, & Claverie, 1995).

The results of Study 1 also revealed an interaction showing that the lateral asymmetry was greater during the categorization of evaluatively inconsistent than evaluatively consistent stimuli. This result may reflect the involvement of a different combination of neural sources but it should be considered preliminary in light of the failure of this interaction to reach statistical significance in Study 2. In addition, participants in Studies 1 and 2 were exposed to trait adjectives within a context of positive trait adjectives. In light of research by Davidson and colleagues relating relative right frontal alpha activity to positive or approach states (e.g., Davidson, 1992), it is possible that the lateralized distribution of the LPP observed in the present study is dependent on the positive context. Study 3 addresses whether the lateralized spatial topography of the LPP during evaluative categorizations is dependent on the specific valence of the context (i.e., when target stimuli were presented within a sequence of negative rather than positive trait adjectives).

STUDY 3

Crites et al. (1995, Experiment 2) reported analyses of (nonstandardized) LPP measures recorded over midline sites to investigate the effects of evaluative categorizations and attitude reports when the contextual stimuli are negative. In the present study, we standardized and analyzed the lateral sites from Crites et al. (1995, Experiment 2) to investigate the spatial topography of the LPP in a negative context. The procedures and analyses in Study 3 were similar to those used in Study 2 except that the target traits were presented within negative rather than positive sequences of traits.

Method

Participants. Thirty introductory psychology students (15 female and 15 male) at Ohio State University participated in the experiment. Of these, 15 were randomly assigned to the positive-focus condition, in which they periodically misreported the valence of positive attitudes, and 15 were randomly assigned to the neutral-focus condition, in which they periodically misreported the valence of neutral attitudes.

Stimulus materials. The pool of negative traits was the 52 most negatively rated adjectives from Anderson's (1968) list of trait adjectives, and the pool of positive traits was the 10 most positively rated adjectives. In addition, each participant selected a set of 10 traits that he or she personally rated as neutral from a list of 55 traits whose mean likability ratings ranged from 3.34 (i.e., cautious) to 2.57 (i.e., eccentric) on Anderson's (1968) 0–6 point scale. This was done to ensure that stimuli in the "neutral" category were perceived as neutral by the participants (Crites et al., 1995).

Results

The standardized LPP amplitudes were submitted to a 3 (Coronal: frontal, central, or parietal sites) × 2 (Lateral: left vs. right scalp sites) × 3 (Stimulus Valence: negative, neutral, or positive) × 2 (Attitude-Report Instruction: accurately report valence of positive/neutral traits vs. report positive/neutral traits as negative) × 2 (Focus: report positive traits as negative vs. report neutral traits as negative) MANOVA, with the last factor manipulated between participants. As in Studies 1 and 2, the main effect for lateral site was significant, with the LPP amplitude over the right scalp regions larger than that over the left, $F(1, 28) = 37.74$, $p < .001$ (see Table 3). A significant Lateral × Valence interaction was also observed, $F(2, 27) = 4.04$, $p < .05$. Pairwise comparisons using Tukey's procedure revealed that although the amplitude of the LPP was larger over the right than the left scalp regions for negative, neutral, and positive stimuli, this asymmetry tended to be larger for the evaluatively inconsistent (i.e., positive and neutral) stimuli than the evaluatively consistent (i.e., negative) stimuli (see Table 3). This is the same form of the significant Lateral × Valence interaction as observed in Study 1.

As in Studies 1 and 2, the coronal main effect was significant, $F(2, 27) = 32.70$, $p < .001$, with the amplitude of the LPP again smaller over frontal than centroparietal scalp regions. A significant Coronal × Lateral interaction indicated that the degree of lateral asymmetry was especially apparent over central scalp regions, $F(2, 27) = 25.84$, $p < .001$. Consistent with the results presented in Study 2, the manipulation of attitude report did not alter the spatial topography of the LPP.

Discussion

The pattern of results from Study 3 is similar to that found in Studies 1 and 2 even though the attitude stimuli were presented within sequences of negative rather than positive stimuli. These results, therefore, extend the

TABLE 3: Mean Amplitude of the Late Positive Potential (in Microvolts), Study 3

Target[a]	Parietal		Central		Frontal	
	Left	*Right*	*Left*	*Right*	*Left*	*Right*
Positive	8.36	9.44	6.46	10.68	3.57	4.79
Neutral	9.88	10.60	7.80	12.00	4.42	5.64
Negative	5.99	6.99	4.60	7.69	2.59	2.85

a. Target stimuli were embedded in a negative stimulus context.

generalizability of the LPP asymmetry effect. The present results also exclude the possibility that the asymmetry is attributable to differential hemispheric alpha abundance during pleasant (approach) and unpleasant (withdrawal) states, because we again observed a right-lateralized LPP distribution even though the background stimuli were negative rather than positive.

The results of Study 3 also replicated the interaction in Study 1 showing that the lateral asymmetry was greater during the categorization of evaluatively inconsistent than evaluatively consistent stimuli. It is possible that this interaction failed to reach statistical significance in Study 2 because of the smaller sample size used in that study. Indeed, in Studies 1–3, the effect sizes for the laterality main effect were large (ω^2 = .19, .24, and .38, respectively) and for the Laterality × Valence interaction were generally small to medium (ω^2 = .14, .03, and .02, respectively). These results suggest the possible involvement of a different combination of electrical field sources and of a slightly different set of psychological operations (Johnson, 1993; Ruchkin et al., 1995) when participants are evaluatively categorizing a stimulus that is inconsistent rather than consistent with the evaluative meaning of the stimuli that preceded it in the sequence. We will return to this point.

Beginning with Thurstone's (1928) demonstration of the utility of methods from psychophysics in the study of attitudes, the evaluative processes underlying attitudes have often been depicted as being analogous to the cognitive processes underlying nonevaluative (e.g., perceptual, semantic) judgments. Tourangeau and Rasinski (1988), for instance, depicted attitude as networks of interrelated evaluative beliefs that are comparable in structure and function to other (i.e., nonevaluative) belief networks. The ability to distinguish between hostile and hospitable stimuli, however, is essential for survival and predates the evolution of primates and language processes. Studies 1–3 have required that the participants evaluatively categorize semantic stimuli. If the right-lateralized LPP reflects the involvement of hedonic rather than language operations, then the asymmetries observed in Studies 1–3 should be replicated if participants evaluatively categorize affect-laden pictures (e.g., a tumor growing in the eye of an infant) rather than trait words. We examined this hypothesis in the modified oddball paradigm in Study 4.

STUDY 4

Gardner, Cacioppo, Crites, and Berntson (1994) recently conducted a study to determine whether the LPP was sensitive to differences between groups in evaluative categorizations. Participants were exposed to photographic slides rather than semantic stimuli, and their task was to indicate whether they liked or disliked the slide by pressing a key. As in Studies 1–3, EEG activity from six lateral scalp regions was recorded to allow topographical analyses. We report the results of the topographical analyses of these lateral sites here.

Attitudinal processing of pictorial stimuli involves hedonic or valuation processes, just as does attitudinal processing of semantic stimuli (e.g., trait adjectives). If the lateral scalp distribution of the LPP in the modified oddball paradigm is attributable to these valuation processes, then the LPP should be right lateralized when participants evaluate pictorial stimuli, just as it is when they evaluate semantic stimuli. A right-lateralized LPP should not be observed, however, if this spatial distribution is attributable to the distal associative processing of semantic stimuli.

Method

Participants. Twenty-two introductory psychology students participated for partial course credit. The data from three participants were discarded prior to analysis because of technical problems during data acquisition.

Stimulus materials. Photographic slides from the International Affective Picture Show (Lang, Öhman, & Vaitl, 1988) were used as stimuli. Four categories of target photographs were selected: (a) The pool of positive slides consisted of the 62 most positively ranked slides (with the exclusion of nude photographs); images such as puppies, landscapes, and popular foods and activities were depicted in this category (M = 6.71 on Lang and associates, 1988, 1–9-point scale). (b) The pool of moderately negative slides, characterized by images of pollution and angry faces, consisted of 12 slides with a mean rating close to 4.00 (M = 3.84). (c) The pool of extremely

TABLE 4: Mean Amplitude of the Late Positive Potential (in Microvolts), Study 4

Target[a]	Parietal		Central		Frontal	
	Left	Right	Left	Right	Left	Right
Extremely negative	10.51	12.18	5.96	8.45	3.94	6.10
Phobic relevant	8.13	8.10	6.24	8.40	3.06	5.84
Moderately negative	4.78	5.94	4.08	4.97	2.19	3.93
Positive	4.12	4.19	4.03	3.85	2.24	4.01

a. Target stimuli were embedded in a positive stimulus context.

negative slides consisted of the 11 least positively ranked slides (M = 1.84), which were photographs of mutilated bodies, cancer patients, and starving children. (d) the phobia-relevant slides consisted of 11 photographs of snakes and spiders; the ratings of these slides matched those of the moderately negative slides (M = 3.84) in the Lang et al. (1988) sample of participants.

Procedure. The apparatus and procedure used to record EEG and EOG (electroculography) were identical to those used in previous studies, with the exception that participants responded to photographic slides rather than personality traits. A carousel projector, fitted with a high-speed electric shutter, projected the images onto a 4-ft. by 4-ft. white screen placed approximately 0.75 m in front of the participant. The projector and shutter were controlled by a lab computer.

Procedures for electrode placement and attachment were identical to those in Studies 1–3, and the task and instructions were the same as in Study 1. Each series of six slides was preceded by the word *READY* (also presented on a slide), and participants initiated each sequence by pressing a key on a keypad. The presentation time, ISI, and EEG/EOG recording intervals were identical to those in Study 1, and as in Study 1, the target stimuli were located in the third, fourth, fifth, or sixth position in the sequence. This resulted in 16 types of sequences. Twelve slide carousels, holding 16 sequences each, were presented in an order determined randomly for each participant. Thus participants responded to 192 sequences, 48 of each type of target slide (see Stimulus Materials, above).

Results and Discussion

Data reduction and standardization were identical to those used in Studies 1–3. The standardized LPP amplitude were submitted to a 3 (Coronal: frontal, central, or parietal sites) × 2 (Lateral: left vs. right scalp sites) × 4 (Stimulus Type: positive, moderately negative, snakes/spiders, extremely negative) × 2 (Group: snake/spider-phobic or nonphobic participants) MANOVA, with the last factor manipulated between participants. Results confirmed that the main effect for lateral site was significant, with the LPP amplitude larger over the right scalp regions than over the left scalp regions, $F(1, 17) = 5.56$, $p < .04$ (see Table 4). The Lateral Slide Type interaction approached significance, $F(3, 48) = 2.76$, $p < .08$, with the form of this interaction the same as that observed in Studies 1–3, indicating a systematic enhancement of the LPP lateralization for increasingly evaluatively inconsistent stimuli. Finally, and as expected, the coronal main effect was significant, $F(2, 32) = 39.22$, $p < .001$, with the amplitude of the LPP again smaller over frontal than centroparietal scalp regions. No other effects or interactions were statistically significant.

In sum, the results of Study 4 replicated the right lateralization of the LPP observed in Studies 1–3 even though pictorial rather than semantic stimuli were used. Furthermore, replicating the preceding results, the effect size for the laterality main effect was large ($\omega^2 = .11$) and for the Laterality × Slide Type interaction was medium ($\omega^2 = .07$). These results are consistent with hedonic valuation processes underlying the amplitude enhancement of the LPP over the right scalp regions in our modified oddball paradigm. The right hemisphere, for instance, may play a role in affective language (Gorelick & Ross, 1987) as well as associative tasks that are both linguistically and nonlinguistically based (e.g., Warrington & Taylor, 1973). Hence, it is conceivable that the scalp asymmetry found during evaluative categorizations reflects the evocation of valuation processes or the evocation of memorial processes that rely on activation of distal associates, or both. Regardless of the answer, investigation of the scalp topography of the LPP during evaluative processing can help illuminate the motivational substrates (Staats & Staats, 1958; Zajonc, 1980) and basic information processes (Beeman et al., 1994; Warrington & Taylor, 1973) involved in the evaluative categorization stage of attitude judgments.

The finding of a right LPP asymmetry in Studies 1 through 4 appears to contrast with prior research investigating (nonevaluative) cognitive categorizations: The existing research on the P300 indicates that the amplitude of this component is maximal at midline sites and hemispheric lateralization is small (e.g., Alexander et al., 1995; Sanquist et al., 1980; Scheffers et al., 1991) or inconsistent (e.g., Snyder et al., 1980). These results are generally based on studies of relatively simple, nonevaluative categorization processes using generally neutral stimuli (e.g., tones). Endogenous components of the ERP such as the P300 vary as a function of the psychological operations being performed on a stimulus as well as the paradigm in which they are being recorded. The purpose of Study 5 was to examine the scalp distribution in our modified oddball paradigm during nonevaluative categorization.

STUDY 5

Study 5 was similar to the prior four experiments except that participants performed a nonevaluative task (i.e., searching for specific trait adjectives) rather than an evaluative categorization task. Participants were shown short sequences of trait adjectives such as those used in Studies 1–3 and were instructed to search for the words *pleasant* and *unpleasant*. The descriptors *pleasant* and *unpleasant* served as probe stimuli, and positive and negative traits served as fillers. If the nature of our modified oddball paradigm or the affective nature of the stimuli used in our experiments is responsible for the right-lateralized LPP, we should again observe a right-lateralized LPP in Study 5. If, in contrast, the right-lateralized LPPs observed in Studies 1–4 are attributable to *evaluative* categorizations, we should replicate prior research on the P300 in Study 5 and find a generally symmetric rather than lateralized distribution of the LPP over the centroparietal regions.

Method

Participants. Twenty-one introductory psychology students (8 female, 13 male) at Ohio State University participated in the study. As a result of equipment problems, data from 3 participants were excluded from the analyses on the lateral scalp sites, and data from 4 participants were excluded from the analyses on the midline scalp sites.

Stimulus materials. ERPs were recorded to positive, negative, or probe traits embedded in sequences of positive traits. The traits *pleasant* and *unpleasant* served as the probe traits. The 160 most positively rated traits (e.g., honest, sincere) from Anderson (1968) formed the pool of positive traits (with the exception that *pleasant* was excluded from this pool), and 10 negative traits (evil, stupid, wicked, cruel, rude, dishonest, unkind, deceitful, selfish, conceited) formed the pool of negative traits.

Procedure. EEG activity was measured over four lateral (F3, F4, P3, and P4) and three midline (Fz, Cz, and Pz) scalp locations and was digitized at 727 Hz. In all other respects, the procedures for electrode placement and attachment and the apparatus used for recording EEG and EOG were identical to those used in Studies 1–4. For comparability with these studies, the topographical analyses were performed on standardized LPP amplitudes recorded over the lateral scalp sites.

Participants were told that the traits would be presented in sequences of six on a monitor and that after each sequence they should press one of three keys on a keypad to indicate whether the sequence contained (a) the trait "pleasant," (b) the trait "unpleasant," or (c) neither "pleasant" nor "unpleasant." Each sequence of six traits was initiated when participants pressed a key on a keypad located next to their right hand in response to a prompt on the monitor. Each trait was presented for 192 ms, and the ISI was 1,200 ms. After a 1,200-ms interval following the offset of the sixth trait, participants were prompted with a message instructing them to enter their response for the sequence, which they could do at their discretion.

Three types of target stimuli (conditions) were used: (a) a probe trait (i.e., either the trait "pleasant" or "unpleasant") embedded in a sequence of positive traits, (b) a positive trait embedded in a sequence of positive traits, and (c) a negative trait embedded in a sequence of positive traits. As in Studies 1–4, the target stimuli were located in the third, fourth, or fifth stimulus position, and the location of each target stimulus was randomly determined for each sequence. Each of these three sequence types were presented 80 times during the study, and the order of these 240 six-trait sequences was randomly determined for each participant. The traits that appeared at the six stimulus positions within each of the 240 sequences were randomly selected from the appropriate category. As in Studies 1–3, traits from each of the categories were selected without replacement until all the traits within each of the three categories had been selected. Thus this study was similar to Studies 1–3, a primary difference being that the experimental task required that participants perform (nonevaluative) semantic categorizations rather than evaluative categorizations, and this study was similar to prior research on the effects of infrequent targets on the P300 except that the stimuli were affect-laden words and were presented in short rather than long sequences.

Data reduction and standardization procedures were identical to those used in Studies 1–4 except that, following inspection of averaged waveforms, the latency window was shortened (350-850 ms) to ensure that the peak of the LPP was not missed.

Results

The standardized LPP amplitudes were submitted to a 2 (Coronal: frontal vs. parietal sites) × 2 (Lateral: left vs. right scalp sites × 3 (Stimulus Type: positive, negative, or probe) MANOVA. As in Studies 1–4, the coronal main effect was highly significant, $F(1, 17) = 81.10$, $p < .0001$,

TABLE 5: Mean Amplitude of the Late Positive Potential (in Microvolts), Study 5

	Parietal		Frontal	
Target[a]	*Left*	*Right*	*Left*	*Right*
Probe	16.15	15.71	5.58	6.23
Negative	5.54	5.69	2.73	3.35
Positive	6.24	6.52	0.86	1.41

a. Target stimuli were embedded in a positive stimulus context.

TABLE 6: Mean Amplitude of the Late Positive Potential Over Midline Sites (in Microvolts), Study 5

	Midline Sites		
Target[a]	*Parietal*	*Central*	*Frontal*
"Unpleasant"	20.20	18.21	8.02
"Pleasant"	19.31	18.18	8.36
Negative	7.22	6.53	2.89
Positive	7.83	7.16	1.05

a. Target stimuli were embedded in a positive stimulus context.

with the amplitude of the LPP again smaller over frontal than centroparietal scalp regions. Contrary to the results of Studies 1–4, however, the main effect for lateral site did not approach statistical significance ($F < 1$) when participants performed a nonevaluative categorization task in the modified oddball paradigm. As seen in Table 5, there was no difference between the amplitude of the LPP over the right and left scalp regions. The Lateral × Stimulus Type interaction also did not approach statistical significance (see Table 5). This symmetrical distribution of the LPP is consistent with prior research on the lateral scalp distribution of the P300 during nonevaluative categorization tasks in the traditional oddball paradigm. No other effect or interaction was statistically significant.

One might question whether the *nonstandardized* (i.e., raw) LPP amplitudes recorded in Study 5 mirror the results of prior research on nonevaluative categorizations. For instance, was the amplitude of the LPP larger when the categorically inconsistent target words (*pleasant* and *unpleasant*) were presented than when categorically consistent filler words were presented?[4] To examine these questions, three contrasts were conducted.

First, the amplitude of the LPP from the midline scalp sites of 17 participants was subjected to a 3 (Coronal: frontal, central, or parietal site) × 2 (Categorical Consistency: consistent/filler stimuli or inconsistent/target stimuli) MANOVA. As expected, this analysis revealed that the amplitude of the LPP evoked by categorically inconsistent (target) traits (M = 14.76 µV) was larger than the amplitude of the LPP evoked by categorically consistent (filler) traits (M = 5.44 µV), $F(1, 16) = 27.08$, $p < .001$. In addition, the expected coronal main effect was significant as the amplitude of the LPP decreased across the scalp from Pz to Fz, $F(2, 15) = 55.05$, $p < .001$. Finally, as seen in Table 6, there was a significant Coronal × Categorical Consistency interaction, as the difference between the amplitudes of the LPP evoked by categorically inconsistent and consistent traits was larger over the midline parietal and central scalp regions than the frontal scalp region, $F(2, 15) = 15.44$, $p < .001$. The results of these analyses, therefore, are consistent with prior research on the P300 in which participants nonevaluatively categorized stimuli, as (a) the LPP was larger over the centroparietal than the frontal scalp region, (b) categorically inconsistent as opposed to consistent traits evoked a larger LPP, and (c) the average latency of the LPP fell within the latency window of the P300.

Although most of the filler traits were positive, negative traits were occasionally presented. In the preceding MANOVA, we collapsed across positive and negative fillers. The negative traits were categorically consistent with the positive traits in terms of the participants' categorization task; however, the negative traits were evaluatively inconsistent given the positive context. We next examined whether the evaluative connotations of the stimuli influenced the LPP when participants were performing a nonevaluative categorization task.[5] The amplitude of the LPP evoked by the categorically consistent positive and negative traits was subjected to a 3 (Coronal: frontal, central, or parietal site) × 2 (Filler Type: positive or negative) MANOVA. Results revealed that the LPP amplitude (a) decreased across the scalp from Pz to Fz, $F(2, 15) = 42.85$, $p < .001$, and (b) did not differ in response to positive (M = 5.34 µV) and negative (M = 5.55 µV) filler stimuli, $F < 1$. These results are consistent with prior research on the P300 demonstrating that this component does not differ when stimuli are inconsistent along a dimension that is not being categorized (e.g., Johnson & Donchin, 1980). These results also suggest that the semantic categorization task was truly nonevaluative in nature, despite the affective connotations of the experimental stimuli.

Finally, a planned contrast was performed to examine whether the amplitude of the LPP was influenced by the evaluative significance of a stimulus when participants performed the nonevaluative categorization task. Specifically, the amplitude of the LPP evoked by the categorically inconsistent probe traits "pleasant" and "unpleasant" from the midline scalp sites of 17 participants was subjected to a 3 (coronal: frontal, central, or parietal site) × 2 (Probe Type: "pleasant" or "unpleasant") MANOVA. As expected, results revealed that (a) the amplitude of the LPP decreased across the scalp from Pz to Fz, $F(2, 15) = 39.64$, $p < .001$, and (b) the amplitudes of the LPPs evoked by the traits "pleasant" ($M = 15.28\ \mu V$) and "unpleasant" ($M = 15.47\ \mu V$) did not differ, $F(1, 16) < 1$. The Coronal × Probe Type interaction was also nonsignificant, $F(2, 15) < 1$. These results demonstrate that even though "unpleasant" was both categorically and evaluatively inconsistent and "pleasant" was categorically inconsistent but evaluatively consistent with the stimulus context, the LPPs evoked by these probes were comparable. Together, these planned contrasts indicate that the amplitude of the LPP was not influenced by the evaluative significance of a stimulus when participants performed a nonevaluative categorization task.

GENERAL DISCUSSION

We began this article with McGuire's (1985) observation that studies of attitudes have relied on efferent (typically verbal) operationalizations. As a result, the structure and processes underlying attitudes have been viewed from a somewhat limited perspective (cf. Cacioppo & Berntson, 1994). McGuire (1985) further suggested that a "right brain" perspective may be developed someday. Consistent with the implicit suggestion that CNS probes of attitude processes may be fruitful, recent studies have capitalized on theory and research in cognitive psychophysiology to index the evaluative categorizations through analyses of midline ERPs (Cacioppo et al., 1993, 1994). This research has made it possible to isolate the evaluative categorization stage from response selection and execution stages of attitudinal processing (Crites et al., 1995) and thus provide a new perspective on attitude processes. We extended these analyses in the present article to address a complementary question regarding the nature of the operations underlying the evaluative categorization stage of attitude processing by examining the spatial topography of the ERP over lateral scalp regions within our modified oddball paradigm.

In studies 1 and 2, participants judged the evaluative significance of traits presented within a sequence of positive traits. Results revealed that the standardized amplitudes of the LPP were larger over the right than the left scalp regions, consistent with the hypothesis that evaluative categorizations engage mechanisms associated with hedonic or global language processing. Study 3 was a conceptual replication of Study 2 except that the attitude stimuli were presented within a negative rather than a positive sequence of traits. Results again revealed that the LPP amplitude was larger over the right than the left scalp regions. Thus the lateralized scalp topography was associated with evaluative categorization processes generally rather than with the specific (positive or negative) valence of the contextual stimuli. To determine whether semantic processes were necessary for this asymmetry, Study 4 was conducted using emotionally provocative slides rather than trait words as stimuli. Results again indicated that the LPP amplitude was larger over the right than the left scalp regions, consistent with the notion that the neural source or combination of neural sources underlying the LPP during evaluative categorizations tends to be located in, or oriented toward, the right hemisphere. Thus the right-lateralized LPP manifested as a result of evaluative categorizations despite differences across studies in the experimental stimuli (e.g., semantic, pictorial), response demands, and valence of contextual stimuli.

Study 5 was conducted to explore whether the same laterality would be observed during nonevaluative categorizations of the affectively toned trait adjectives. Participants searched for the traits "pleasant" and "unpleasant" within sequences of trait words. In contrast to Studies 1–4, Study 5 revealed a symmetrically distributed ERP across the left and right scalp regions. Interestingly, Alexander et al. (1995) recently reported P300 asymmetries in a study of ERPs in 80 participants using a cognitive (visual discrimination) task. ERPs were elicited using the oddball procedure. Participants viewed a series of 280 stimuli (210 standard stimuli—a white square; 35 target stimuli—a white *X*; and 35 novel stimuli—various colored geometric shapes). Each stimulus was presented for a duration of 60 ms, and the ISI was 1.6 s. Participants pressed a keypad with their forefinger whenever a target stimulus was presented and refrained from responding when a novel or standard stimulus was presented. Although the mean differences were small, the use of a large sample size revealed that the target and standard stimuli produced a larger-amplitude P300 over the left than the right parietal scalp regions. Evaluative categorizations in Studies 1–4, in contrast, produced larger-amplitude LPPs over the right scalp regions generally, including the parietal regions (see Tables 1–4). Together, these studies suggest that evaluative categorizations produce a more right-lateralized LPP than nonevaluative categorizations. It would be preferable, of course, to contrast the effects of evaluative and nonevaluative categorizations on LPP asymmetries in the same study. Crites and Cacioppo (1996) recently performed such a study, confirming that evaluative categorizations produced significantly more right-lateralized LPPs than nonevaluative categorizations of the same experimental stimuli. As in Study 5, Crites and Cacioppo (1996) found that nonevaluative categorizations were associated with a symmetrical LPP topography when using our modified oddball paradigm.

Cacioppo and Tassinary (1990) have criticized the assumption that the relationships between physiological signals such as the LPP amplitude or right-lateralized topography and psychological operations such as evaluative categorizations must be invariant to be replicable, important, and informative. In Cacioppo and Tassinary's

(1990) framework, the LPP amplitudes and topographies represent markers rather than outcomes, concomitants, or invariants. Thus no claim is being made that evaluative categorizations will be accompanied by a right-lateralized distribution of ERPs regardless of the paradigm in which the measures are secured. In this sense, the LPP is more similar to chronometric measures of cognitive operations than it is to fingerprints. (This distinction holds not only for ERPs but also for brain imaging technologies; Sarter, Berntson, & Cacioppo, 1996.) The same differences in reaction time may mean quite different things psychologically depending on the paradigm and conditions in which reaction times are measured; relatedly, isolating a specific cognitive operation using reaction time measures may be replicable and informative even though the relationship is not generalizable to other reaction time paradigms. Similarly, the relationship between attitudinal (evaluative) processes and LPP amplitudes and topographies is replicable and interpretable within our modified oddball paradigm whether or not it is generalizable to other ERP paradigms.[6]

The finding that the LPP is larger over the right than the left scalp regions during evaluative categorization is consistent with the importance placed on the right hemisphere for processing affective or motivationally significant information and for forming and maintaining a thematic macrostructure for understanding language. Importantly, these two operational characteristics of right hemispheric functioning are not mutually exclusive, as the importance of the right hemisphere for processing emotional information may be due to its more synthetic mode of processing information (Safer & Leventhal, 1977). The lateral scalp distribution of the LPP evoked by evaluative categorizations as opposed to nonevaluative semantic categorizations, therefore, may be caused by the activation of neural units under (or oriented toward) the right scalp regions that perform global processing or integrative functions that are especially important for discriminating hostile (negative) from hospitable (positive) stimuli and events. Of these possible determinants, the former may be especially important.

The essential feature of an evaluative categorization is the discrimination of a stimulus in terms of its positivity (hospitable nature) and/or negativity (hostile nature). Recent studies by Kayser et al. (1995) and Berntson, Boysen, and Torello (1993) suggest that the affective discrimination that underlies evaluative categorizations may be sufficient to produce right-lateralized ERPs. Berntson et al. (1993), for instance, used ERP measures to investigate perceptual processing in a chimpanzee. A female chimpanzee, Sheba, was exposed to 500- and 1500-Hz tones in an oddball paradigm. Analyses of the ERPs to the tones in the oddball paradigm revealed a symmetrical scalp distribution.

In a subsequent session, Sheba was exposed to two stimuli that differed in emotional significance: a 350-ms 500-Hz tone and a 350-ms epoch of human speech—the animal's name, Sheba. Analyses of the ERPs obtained in this session revealed a symmetrical scalp distribution to the control tone (as was observed in the oddball paradigm) but a right-lateralized scalp distribution to the name. This result was obtained even though the two stimuli were equally probable. These results suggest that the processing of the affective significance of a stimulus, whether performed spontaneously (as in the case of Sheba responding to her name) or in response to a task (as in the case of participants in the present studies), may be sufficient to produce a right-lateralized scalp distribution of the late positive potential.

These studies also help rule out several alternative interpretations. In an interesting and important series of studies, Davidson and his colleagues (e.g., Davidson, 1992) have presented evidence for the left frontal region being associated with approach-related emotional behavior and the right frontal region being associated with the withdrawal-related emotional behavior. For instance, Davidson and his colleagues have found that individual differences in the relative activation of the right and left frontal EEG are related to dispositional differences in positive and negative moods and that relative right versus left frontal EEG activity varies as a function of positive and negative events (e.g., Davidson, Ekman, Saron, Senulis, & Friesen, 1990; see Davidson, 1992; Fox, 1991). Several lines of evidence from the present studies indicate that the asymmetries in the LPP that were observed during evaluative categorizations are distinct from the asymmetries Davidson and his colleagues have identified. First, the asymmetries identified by Davidson and his colleagues are localized in the prefrontal and anterior temporal regions and are indexed by the relative absence of alpha (6–8 Hz) activity in the spontaneous EEG. The LPP, in contrast, is an event-related component rather than a component of spontaneous EEG activity and is right lateralized over central and parietal as well as frontal regions. Second, whereas Davidson and his colleagues have found relative right hemispheric EEG activity as a function of positive events (Davidson et al., 1990), we observed a right-lateralized LPP during evaluative categorizations whether the target stimulus was positive or negative (Studies 1–4) and whether the contextual stimuli were positive (Studies 1, 2, and 4) or negative (Study 3). Third, in Davidson and his colleagues' work, either affective states are induced or predispositions toward specific affective states are examined. The LPP paradigm, in contrast, demands evaluative categorizations rather than full-blown affective states. These evaluative categorizations are necessarily made quickly, and hundreds of evaluative categorizations are required during the course of a study. Finally, one might speculate that, given the participants' task (e.g., judging whether each stimulus in a sequence was positive or negative), an approach motivation was aroused regardless of the valence of the contextual stimuli. If this were true, however, the asymmetries should have been greater over the frontal than the central and parietal areas (mirroring the topography observed by Davidson and colleagues) and should have been evident whether the categorization task was evaluative or nonevaluative. Thus the right-lateralized LPP associated with evaluative categorizations in our modified oddball paradigm cannot be explained simply in terms of the interesting but apparently unrelated asymmetries observed by Davidson and his colleagues in their studies of spontaneous EEG activity.

Response requirements in this paradigm also do not appear able to account for the right-lateralized LPP observed as a function of evaluative categorizations or for the exaggerated lateralization observed for evaluatively inconsistent, in contrast to consistent, stimuli. For instance, if the LPP asymmetries were related to the response requirements, then they should vary as a function of the response requirements and should manifest more strongly over anterior than parietal scalp regions. Neither of these patterns of data was observed, however. Indeed, participants were instructed not to respond until the stimulus was removed—which followed the manifestation of the LPP by more than 250 ms. Second, if motor processes were causing the LPP asymmetry, the asymmetrical manifestation of the LPP should have been comparable for evaluatively consistent and inconsistent stimuli, because the response requirements were identical for these stimuli. Instead, the right-lateralized LPP amplitude observed when evaluatively consistent stimuli were categorized a positive or negative was amplified when the stimuli were evaluatively inconsistent with the preceding stimuli in a sequence. Finally, the response requirements were identical in Crites and Cacioppo's (1996) study of evaluative and nonevaluative categorization processes, yet the evaluative categorizations produced significantly more right-lateralized LPPs than nonevaluative categorizations (which produced symmetrical LPPs).

To summarize, the right-lateralized LPP distributions appear to be attributable to categorizing stimuli in the modified oddball paradigm in terms of what Zajonc (1980) called preferanda. This does not mean that the psychological operations underlying evaluative and nonevaluative categorizations are nonoverlapping. Indeed, there are a number of commonalities in the ERPs associated with evaluative and nonevaluative categorizations, including an enhancement of LPP amplitude as a function of the categorical inconsistency of the eliciting stimulus, the average latencies for the manifestation of the LPP, and the coronal distribution of the amplitude of the LPP (i.e., it is largest over the centroparietal in contrast to the frontal areas of the scalp; see Cacioppo et al., 1994; Crites et al., 1995). The present research shows, however, that even though there is considerable overlap in the processes evoked by judging trait descriptors in terms of their semantic versus evaluative significance, the overlap is not complete; judging the evaluative significance of stimuli is associated with an enhancement of the LPP over the right compared with the left scalp regions, and this laterality is heightened for a stimulus that is evaluatively inconsistent with the stimulus context. Thus, rather than a purely cognitive model (Tourangeau & Rasinski, 1988) or a purely affective model (Zajonc, 1980), the present results fit best a hybrid model of evaluative categorization that includes cognitive and affective operations.

What is it about the evaluative categorization of (evaluatively) inconsistent stimuli that produced more right-lateralized LPPs than evaluative categorizations of consistent stimuli? At least three accounts warrant further attention. First, judging a series of positive (or a series of negative) stimuli in terms of the evaluative significance may hinge on hedonic or global associative processes, just as does the judgment of an evaluatively inconsistent stimulus (e.g., a negative stimulus embedded within a series of positive stimuli). However, the attentional and motivational significance of an evaluatively inconsistent stimulus may be considerably greater in an otherwise evaluatively consistent context. It is conceivable, therefore, that the heightened lateralization of the LPP is attributable to the change in motivational significance.

A second possibility is that the LPP to evaluative categorizations is a manifestation of both evaluative *and* nonevaluative information-processing operations. (Indeed, the similarity in some of the features of the LPP and the P300 to which we referred above is consistent with this notion.) The nonevaluative operations should remain the same for evaluatively consistent and inconsistent stimuli, because the LPP paradigm was developed such that the stimuli varied only in their evaluative significance. The evaluative operations, however, may be activated differentially by evaluatively consistent and inconsistent stimuli. For instance, if exposure to an evaluatively inconsistent stimulus produces an evaluative contrast effect, then an enhancement of the right-lateralized LPP could result.

A third possibility is that the neural source responsible for affect switching (or for switching the mode of evaluative activation) is lateralized. Presentation of an evaluatively inconsistent stimulus may activate this neural source, which would, in turn, produce a lateralized LPP distribution when participants were engaged in evaluative (affective) processing.

In sum, the study of ERP scalp morphologies and topographies within the modified oddball paradigm may contribute to our understanding of attitude processes in several ways. From a neurophysiological viewpoint, the ERP topographies reflect manifestations of electrical fields emanating from neural sources. Although scalp manifestations of these source fields do not provide as definitive evidence regarding their neural locus or loci as positron emission tomography (PET) or functional magnetic resonance imaging (fMRI), they provide more specific information about the temporal features of psychological operations. In addition, with dense electrode array recordings, ERP scalp topographies may provide sufficient evidence about spatial features to favor at least some neural hypotheses over null or alternative hypotheses. From a functional perspective, changes in scalp topography can be viewed as evidence that two or more attitude conditions have differential effects. For instance, ERPs or scalp topographies can be used as dependent measures within a subtractive- or addictive-factors paradigm to explore attitude processes (see review by Cacioppo & Petty, 1986). In the case of scalp topographies, the ERP amplitudes are usually standardized within conditions to avoid spurious effects (e.g., Johnson, 1993; McCarthy & Wood, 1985; Ruchkin et al., 1995). As noted above, this standardization removes the mean differences in the amplitude of ERP components across experimental conditions (e.g., larger-amplitude LPPs to evaluatively inconsistent than to evaluatively consistent stimuli) but makes it more likely that differences in scalp topographies reflect differences in attitude operations across these conditions rather than simply differences in the intensity of a given attitude operation across conditions.

For instance, researchers have long realized that attitudes share a motivational role with more rudimentary emotional processes (e.g., Staats & Staats, 1958). However, since Thurstone (1928) first extended the experimental methods and logic of psychophysics to the study of attitudes, attitudinal and nonevaluative semantic processes and judgments have often been treated similarly. A means of integrating these two conceptualizations has been elusive because existing theoretical perspectives and methodologies have not easily allowed investigation of the similarities and differences between evaluative and nonevaluative processes. The analyses of lateral scalp distribution of LPP amplitudes in the modified oddball paradigm may help fill this requirement.

NOTES

1. In the traditional oddball paradigm, participants are exposed to very long series of stimuli. To entrain the timing of the categorization processes, the oddball paradigm was modified so that participants viewed short sequences of stimuli and were instructed, for instance to count the "pleasant" or "unpleasant" pictures in each sequence. Preliminary research indicated that these modifications improved our ability to discriminate attitude judgments, possibly because the shorter sequences enhanced participants' focus on evaluative categorizations rather than other categorical differences among semantic stimuli and reduced temporal variability associated with difficult categorization processes.

2. Analyses of the lateral sites from our earlier LPP studies (e.g., Cacioppo, Crites, Berntson, & Coles, 1993) revealed the same pattern of results as reported here. The studies reported in the text, however, represent our most recent studies of evaluative categorizations, involve more participants, use more lateral electrode sites, and use a larger percentage of the total EEG sweeps to compute the average ERP waveforms.

3. Analyses performed on nonstandardized LPP amplitudes in Studies 1 and 2 provided results that were congruent with those reported in the text except, of course, that the LPP amplitude was larger for evaluatively inconsistent than evaluatively consistent stimuli. The position of the target stimulus was not included in the analyses because it has not been found to alter reliably the amplitude or latency of the LPP (Crites, 1991) and because more reliable LPP amplitudes and latencies are obtained by averaging across this factor.

4. Note that the standardization procedure used to examine spatial topographies in all the preceding analyses precludes examining this question. Analyses of the *unstandardized* LPP amplitudes recorded over the midline scalp sites in Study 5 have not been reported previously and therefore are reported here.

5. Because previous research on the P300 has focused primarily on the amplitude along the midline of the scalp, these contrasts were performed on the amplitude of the LPP along the scalp midline to more easily allow comparisons with previous research. The analyses of the lateral scalp distribution (using unstandardized LPP amplitudes) revealed comparable results.

6. There is conflicting evidence at present regarding whether these relationships generalize to other (e.g., the oddball) paradigms. Crites (unpublished data) has not observed the same right-lateralized LPP distribution during evaluative processing when using the traditional oddball paradigm (i.e., long series of stimulus presentations). Lang and his colleagues (personal communication, June 17, 1995), however, who also used long series of stimulus presentations, replicated the present observations of an LPP scalp distribution that was more right lateralized when participants were instructed to rate the valence, arousal, and dominance of each stimulus in the sequence (evaluative processing) than when participants were instructed to create a mental image of the stimulus (nonevaluative processing). Although this difference may be attributable to a technical problem in Crites's studies using the traditional oddball paradigm, our initial studies of evaluative processes using the oddball paradigm suggested that features unrelated to evaluative processes might obscure some of the effects of evaluative categorization (see Cacioppo et al., 1993, p. 109, N. 1). Consequently, the replicability and interpretability of LPP amplitudes and topographies may be limited to, and to date are clearer in, our modified oddball paradigm.

REFERENCES

Alexander, J. E, Porjesz, B., Bauer, L. O., Kuperman, S., Morzorati, S., O'Connor, S. J., Rohrbaugh, J., Begleiter, H., & Polich, J. (1995). P300 hemispheric amplitude asymmetries from a visual oddball task. *Psychophysiology, 32*, 467-475.

Anderson, N. H. (1968). Likableness ratings of 555 personality trait words. *Journal of Personality and Social Psychology, 9*, 272-279.

Beeman, M, Friedman, R. B., Grafman, J., Perez, E, Diamond, S., & Lindsay, M. B. (1994). Summation priming and coarse semantic coding in the right hemisphere. *Journal of Cognitive Neuroscience, 6*, 26-45.

Berntson, G. G., Boysen, S. T., & Torello, M. W. (1993). Vocal perception: Brain event-related potentials in a chimpanzee. *Developmental Psychobiology, 26*, 305-319.

Cacioppo, J. T., & Berntson, G. G. (1994). Relationship between attitudes and evaluative space: A critical review, with emphasis on the separability of positive and negative substrates. *Psychological Bulletin, 115*, 401-423.

Cacioppo, J. T., Crites, S. L., Jr., Berntson, G. G., & Coles, M.G.H. (1993). If attitudes affect how stimuli are processed, should they not affect the event-related brain potential? *Psychological Science, 4*, 108-112.

Cacioppo, J. T., Crites, S. L., Jr., Gardner, W. L., & Berntson, G. G. (1994). Bioelectrical echoes from evaluative categorizations: I. A late positive brain potential that varies as a function of trait negativity and extremity. *Journal of Personality and Social Psychology, 67*, 115-125.

Cacioppo, J. T., & Petty, R. E. (1986). Social processes. In M.G.H. Coles, E. Donchin, & S. Porges (Eds.), *Psychophysiology: Systems, processes, and applications* (pp. 646-679. New York: Guilford.

Cacioppo, J. T., & Tassinary, L. G. (1990) Inferring psychological significance from physiological signals. *American Psychologist, 45*, 16-28.

Chiarello, C., & Church, K. L. (1986). Lexical judgments after right or left hemisphere injury. *Neuropsychologia, 24*, 623-630.

Coles, M.G.H., Gratton, G., & Fabiani, M. (1990). Event-related brain potentials. In J. T. Cacioppo & L.G. Tassinary (Eds.), *Principles of psychophysiology: Physical, social, and inferential elements* (pp. 413-455). Cambridge, UK: Cambridge University Press.

Crites, S. L., Jr. (1991) *An ERP paradigm and long latency positive brain potential for differentiating attitudinal words*. Unpublished master's thesis, Ohio State University, Columbus.

Crites, S. L., Jr., & Cacioppo, J. T. (1996). Electrocortical differentiation of evaluative and nonevaluative categorizations. *Psychological Science, 7*, 318-321.

Crites, S. L., Jr., Cacioppo, J. T., Gardner, W. L., & Berntson, G. G. (1995). Bioelectrical echoes from evaluative categorizations: II. A late positive brain potential that varies as a function of attitude registration rather than attitude report. *Journal of Personality and Social Psychology, 68*, 997-1013.

Davidson, R. J. (1992). Emotion and affective style: Hemispheric substrates. *Psychological Science, 3*, 39-43.

Davidson, R. J., Ekman, P., Saron, C., Senulis, J., & Friesen, W. V. (1990). Approach/withdrawal and cerebral asymmetry: Emotional expression and brain physiology, I. *Journal of Personality and Social Psychology, 58*, 330-341.

Dawson, M. E., & Schell, A. M (1982). Electrodermal responses to attended and nonattended significant stimuli during dichotic listening. *Journal of Experimental Psychology: Human Perception and Performance, 8*, 315-324.

Donchin, E., & Coles, M.G.H. (1988). Is the P300 component a manifestation of context updating? *Behavioral and Brain Sciences, 11*, 357-374.

Donchin, E., Karis, D., Bashore, T. R., Coles, M.G.H., & Gratton, G. (1986). Cognitive psychophysiology and human information processing. In M.G.H. Coles, E. Donchin, & S.W. Porges (Eds.), *Psychophysiology: Systems, processes, and applications* (pp. 244-267). New York: Guilford.

Fox, N. A. (1991). If it's not left, it's right. *American Psychologist, 46*, 863-872.

Gardner, W., Cacioppo, J., Crites, S, & Berntson, G. (1994). A late positive brain potential indexes between participant differences in evaluative categorizations. *Psychophysiology, 31*, S49.

Gorelick, P. B., & Ross, E. D. (1987). The aprosodias: Further functional-anatomical evidence for the organisation of affective language in the right hemisphere. *Journal of Neurology, Neurosurgery, and Psychiatry, 50*, 553-560.

Guillem, F., N'Kaoua, B., Rougier, A., & Claverie, B. (1995). Intracranial topography of event-related potentials (N400/P600) elicited during a continuous recognition memory task. *Psychophysiology, 32*, 382-392.

Johnson, R., Jr. (1993). On the neural generators of the P300 component of the event-related potential. *Psychophysiology, 30*, 90-97.

Johnson, R., Jr., & Donchin, E. (1980). P300 and stimulus categorization: Two plus one is not so different from one plus one. *Psychophysiology, 17*, 167-178.

Kayser, J., Tenke, C., Nordby, H., Hammerborg, D., Hugdahl, K., & Erdmann, G. (1995, October). *Event-related potential (ERP) asymmetries to emotional stimuli in a visual half-field paradigm.* Poster presented at the 35th annual meeting of the Society for Psychophysiological Research Toronto.

Kolb, B., & Taylor, L. (1981). Affective behavior in patents with localized cortical excisions: Role of lesion site and side. *Science, 214*, 89-91.

Lang, P. J. Öhman, A., & Vaitl, D. (1988). *The international affective picture system* [Photographic slides]. Gainesville: University of Florida, Center for Research in Psychophysiology.

McCarthy, G., & Wood, C. C. (1985). Scalp distributions of event-related potentials: An ambiguity associated with analysis of variance models. *Electroencephalography and Clinical Neurophysiology, 62*, 203-208.

McGuire, W. J. (1985). Attitudes and attitude change. In G. Lindzey & E. Aronson (Eds.), *The handbook of social psychology* (pp. 233-346). New York: Random House.

Ruchkin, D. S., Canoune, H. L., Johnson, R., Jr., & Ritter, W. (1995). Working memory and preparation elicit different patterns of slow wave event-related brain potentials. *Psychophysiology, 32*, 399-410.

Ruchkin, D. S., Johnson, R., Jr., Canoune, H., & Ritter, W. (1990). Short-term memory storage and retention: An event-related brain potential study. *Electroencephalography and Clinical Neurophysiology, 76*, 419-439.

Safer, M. A., & Leventhal, H. (1977). Ear differences in evaluating emotional tone of voice and verbal content. *Journal of Experimental Psychology: Human Perception and Performance, 3*, 75-82.

Sanquist, T. F., Rohrbaugh, J. W., Syndulko, K., & Lindsley, D. B. (1980). Electrocortical signs of levels of processing: Perceptual analysis and recognition memory. *Psychophysiology 17*, 568-576.

Sarter, M., Berntson, G. G., & Cacioppo, J. T. (1996). Brain imaging and cognitive neuroscience: Towards strong inference in attributing function to structure. *American Psychologist, 51*, 13-21.

Schacter, D., Chiu, P., & Ochsner, K. (1993). Implicit memory: A selective review. *Annual Review of Neuroscience, 16*, 159-182.

Scheffers, M. K., Johnson, R., Jr., & Ruchkin, D. S. (1991). P300 in patients with unilateral temporal lobectomies: The effects of reduced stimulus quality. *Psychophysiology, 28*, 274-284.

Snyder, E., Hillyard, S. A., & Galambos, R. (1980). Similarities and differences among the P3 waves to detected signals in three modalities. *Psychophysiology, 17*, 112-122.

Staats, W. W., & Staats, C. K. (1958). Attitudes established by classical conditioning. *Journal of Abnormal and Social Psychology, 57*, 37-40.

Thurstone, L. L. (1928). Attitudes can be measured. *American Journal of Sociology, 33*, 529-554.

Tompkins, C. A, & Mateer, C. A. (1985). Right hemisphere appreciation of intonal and linguistic indications of affect. *Brain and Language, 24*, 185-203.

Tourangeau, R., & Rasinski, K. A. (1988). Cognitive processes underlying context effects in attitude measurement. *Psychological Bulletin, 103*, 299-314.

Warrington, E. K., & Taylor, A. M. (1973). The contribution of the right parietal lobe to object recognition. *Cortex, 9*, 152-164.

Zajonc, R. B. (1980). Feeling and thinking: Preferences need no inferences. *American Psychologist, 35*, 151-175.

Zanna, M. P., & Rempel, J. K. (1988). Attitudes: A new look at an old concept. In D. Bar-Tal & A. W. Kruglanski (Eds.), *The social psychology of knowledge* (pp. 315-334). New York: Cambridge University Press.

Received February 19, 1995
Revision accepted January 2, 1996