Hemispherically Lateralized EEG as a Response to Television Commercials

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EEG was recorded from 21 right-handed women as they watched commercial television. A significant amount of variance in hemispheric dominance shifts of lateralized EEG was explained as a function of the onset of easily identifiable variables in the stimulus. There were hemispheric differences in EEG due to the verbal and nonverbal components of the stimulus. Lags between stimulus onset and change in EEG also were observable. The data were found to be reliable within this study, between this study and a prior one, and between this study and others in the EEG literature that uses less complex stimuli.

Theories and models of consumer information processing of advertising have changed dramatically in the past few years, leading to new insights for researchers. Although much is known retroactively about how information in general *was* processed and learned when a consumer was exposed to an advertising message, little is known about how information *is* processed at any point during its actual presentation.

One direction for studying on-line processing comes from psychophysiologic variables such as electrodermal (EDA), heart-rate (EKG), and electromyographic (EMG) measures. This study considers the electroencephalograph (EEG), which aids in the study of brain waves. Hemispheric lateralization, the study of the respective roles of the right and left hemispheres of the brain in information processing, is a useful area of study within the EEG field.

Popularist writers have speculated that the right hemisphere is specialized to process pictures and music whereas the left is better suited to process words and numbers. Unfortunately, much of the basis for this conjecture comes from research that used subjects damaged in one hemisphere or with surgically separated hemispheres, or that used extremely simple stimuli (picture of a cat versus the word CAT). Few hemispheric data sets are available based on normal subjects viewing televised advertising or other naturally occurring complex stimuli.

The purpose of this study was to examine hemispheric differences in the EEG of normal subjects watching television commercials to obtain a physiologic parallel to the processing of information. Hemispheric differences data relating to rational and emotional commercials, and the verbal, nonverbal, audio, and visual components of these commercials were examined.

Within recent years, several major studies have been done to evaluate the potential of EEG as an index of response to television commercials. Two of these studies (Olson and Ray 1983; Rust, Price, and Kumar 1985) did not show a strong relation between television commercial stimuli and changes in the EEG. (Alwitt's 1985 reanalysis of Olson and Ray's data is discussed in the Literature Review section under Advertising-Related EEG Issues.) The latest results of the EEG index and television commercials are reported here, beginning with a review of prior work and concluding with a discussion of a relation that is reliable, replicable, and consistent with EEG findings reported for less complex stimuli. In addition, we discuss in this article possible reasons why this study suc-

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cessfully uncovered what other studies failed to find. The discussion also summarizes and integrates other previously reported findings that have emerged from this current stream of research.

LITERATURE REVIEW

EEG potentially is useful in television commercial testing because it can provide a continuous record that reflects cortical arousal in response to a message stimulus (Walker 1980). Although self-report measures provide retrospective static information, a self-report measure is less useful for assessing the impact on memory of a particular scene, a line of script, camera movement, or a piece of music from a commercial. Nonphysiologic, continuous measures such as hand-held potentiometers used in theatre tests yield continuous data, but may disturb the cognitive processes of the subject by requiring a thoughtful response. Passive physiologic measures in general have the advantage of not disturbing cognitive processes.

Basic EEG Issues

If EEG is to be used appropriately, it first is necessary to understand EEG and the difficulties in measuring and interpreting it. For an introduction to EEG, the reader is referred to Greenfield and Sternbach (1972) or Stern, Ray, and Davis (1980); for an introduction to hemispheric laterality, refer to Springer and Deutsch (1981); a shorter review directed toward marketers and those reviewing the work related to advertising can be found in Hansen (1981), Olson and Ray (1983), Rothschild and Thorson (1983), and Rothschild et al. (1986).

A synthesis of these reviews would lead a researcher who wanted to study television (a medium that observers feel consists primarily of visual stimuli) to a range of frequencies (8 Hz to 13 Hz) that are most prominent in the occipital region of the brain. This so-called alpha frequency is useful because it covaries strongly (and inversely) with arousal and cognitive activity; also, it is more prominent and seems to be more sensitive to external stimuli than other frequency ranges.

The occipital lobe is appropriate because this area of the brain shows the clearest reactions to visual stimuli. Occipital alpha has been the dominant choice in basic EEG studies as well as in more recent advertising related EEG studies;[1] arousal can be observed by a rapid (within 300 milliseconds) reduction of electrical activity in the alpha frequency (alpha blocking).

Alpha blocking occurs when subjects actively respond to a wide variety of stimuli (e.g., Doyle, Ornstein, and Galin 1974; Spydell and Sheer 1982) and when they passively receive these stimuli (e.g., Morgan, Macdonald, and Hilgard 1974; Mulholland et al. 1971). For example, alpha blocking occurs when subjects are exposed to simple stimuli such as tones and light flashes, moderately complex stimuli such as verbal analogies and block designs (e.g., Gevins et al. 1979; Warren, Peltz, and Hauter 1976), and extremely complex stimuli such as television scenes and sophisticated musical rhythms (e.g., McKee, Humphrey, and McAdam 1973; Schafer 1978). These observations are encouraging for the study of television commercial viewing where complex stimuli are received passively.

Very few tests have examined EEG and memory in the psychophysiology literature. Typical of these tests is the work of Seamon (1974) and Madden and Nebes (1980). Both of these studies examined memory for words or figures that had been presented in the right or left visual field. Results showed that memory was stronger and responses were faster when these verbal and numerical stimuli were presented in the right visual field and therefore first were received for processing in the left hemisphere. We have found no studies that deal with stimuli nearly as complex as a television commercial.

Advertising-Related EEG Issues

In advertising studies, Rothschild et al. (1986), Reeves et al. (1985), and Weinstein, Appel, and Weinstein (Appel, Weinstein, and Weinstein 1979; Weinstein, Appel, and Weinstein 1980) have shown that there is an inverse relation between the electric power of occipital alpha and television commercial stimuli. The work presented in this article describes data collected in the second of a series of studies. The major findings of the first study were reported in Rothschild et al. (1986) and Reeves et al. (1985). That study examined the power of occipital alpha collapsed across the hemispheres. The findings included the following:

- A strong negative correlation was found between the mean level of alpha across an entire commercial and recall and recognition tests. This finding confirms Appel et al. 1979 and is consistent with the extensive psychophysiology literature that shows alpha blocking to relate to an increase in arousal.
- Definable patterns of alpha change occurred across periods (epochs) of three to eight seconds, during which alpha dropped in response to definable changes in the commercial such as

[1] The occiput is the primary visual receptor of the brain, but the parietal and temporal cortices also process complex visual stimuli. Although the occiput shows the clearest response to basic visual stimuli, the parietal cortex may show greater laterality responses to complex stimuli such as television commercials and may ultimately be the location of choice for studying laterality.

edits and movements. These decreases in alpha were followed by a period of alpha increase (attenuation of blocking).

- Regression analyses showed that alpha decreased most sharply within one-half second of an edit or the onset of movement. Thirty-seven percent of the variance in alpha was accounted for by changes in these two variables. Another 20 percent of the variance was accounted for by autocorrelation.

In a reanalysis of Olson and Ray's (1983) data, Alwitt (1985) used time-series analysis and found a negative relation between several elements of the television commercial stimulus and alpha in the same period (she used two-second periods), but many positive relations between the stimulus and alpha in following periods. This finding is consistent with Rothschild et al. (1986) where processing epochs were shown to occur. In these epochs, alpha dropped at the onset of a stimulus (such as a scene change) and then slowly recovered over several seconds until there was another stimulus change or onset. Alwitt's finding also is consistent with the time series analysis of Reeves et al. (1985), but Reeves' data were aggregated in half-second increments and, therefore, showed more detail about the presence and length of lagged responses to televised stimuli. A more complete review of advertising-related EEG studies can be found in Rothschild et al. (1986).

Other studies that have employed EEG to examine advertising effects on memory show a mixed set of results. Although Appel et al. (1979) demonstrated a relation between these two variables, Weinstein et al. (1980) did not replicate this finding and found no relation between EEG and memory. Rust et al. (1985) also showed no consistent relation between EEG and recall; Rockey, Greene, and Perold (1980) showed no difference in EEG patterns between high- and low-recall commercials. Although some studies have found a relation between EEG and memory for commercials, most studies have not shown this relation.

Hemispheric Laterality Issues

The effect of the reduction of alpha is distinctly different between the left and right hemispheres of the brain (e.g., Galin and Ornstein 1972; Osaka 1984; Walker 1980). This first was observed during World War II when clinicians found that people damaged in the left hemisphere of the brain showed abnormalities in their verbal, audio, and piecemeal-like analytic skills, whereas those damaged in the right hemisphere showed abnormalities in their nonverbal, visual, and holistic (spatial) analytic skills. These results were interpreted to mean that the left hemisphere specializes in verbal and audio skills, whereas the right hemisphere specializes in nonverbal and visual skills (Corballis 1980; see Allen 1983 and Sergent 1983 for reviews).

More recently, much research on hemispheric lateralization has been conducted with normal subjects. This research generally revealed significant hemispheric differences, although the effect sizes tended to be smaller than that in the research using samples of abnormal people (e.g., Kinsbourne 1982; Sperry 1968, 1973). Whether a particular hemisphere can or cannot do a particular task after injury or surgery does not speak directly to the abilities of the normal brain; although there is some dominance of skills, each hemisphere can do the tasks of the opposite hemisphere well (Kinsbourne 1982), even though executional strategies may differ. In normal subjects, the difference in EEG power between hemispheres tends to be in the 10 to 15 percent range (Andreassi 1980).

Galin (1979) reached a similar conclusion; there is more likely to be a bihemispheric response than an asymmetric response to complex stimuli. Both hemispheres are doing their own tasks and both are performing at the same time. Therefore, it is difficult to determine if the hemispheres are cooperating, interfering, or operating in an independent manner.

Currently, the most popular theory of laterality is that both hemispheres of the normal person's brain process stimuli in parallel; however, depending on the nature of the stimulus or task, one hemisphere is more likely to dominate. Parallel processing is less likely to be found in an abnormal person's brain if one of the hemispheres is damaged or the hemispheres have been separated. Therefore, the effect size for hemispheric lateralization must be smaller in normal subjects simply because parallel processing is able to occur.

Other hemispheric findings relevant to this article include the following:

- For audio stimuli, language is more likely to be processed in the left hemisphere; nonverbal sounds are more likely to be processed in the right hemisphere (Springer and Deutsch 1981).
- No theory of hemispheric laterality and information processing is universally accepted. There are five major models based on correlational data that are related to types of stimuli, tasks, and subjects; the models are not all mutually exclusive. These models suggest unilateral specialization (a hemisphere is totally responsible for processing or completing a task), bilateralization (both hemispheres can perform a task), interaction (the hemispheres perform simultaneously or interact to suppress each other), parallelism (the hemispheres either duplicate each other or share functions), and allocation (tasks are allocated to hemispheres so there is neither interaction nor parallelism; Allen 1983; Donchin, Kutas, and Mc-

Carthy 1977; Janiszewski 1987). This lack of unanimity is quite different from the lay view of unilateral specialization that currently is least favored by students of EEG.

Although lateralization has been reported in the ways previously discussed, lateralization has not been found using complex television stimuli. Weinstein et al. (1980) did not find lateralization; Olson and Ray (1983) and Alwitt (1985) also were unsuccessful in their search. Rust et al. (1985) found lateralization that had a difficult-to-interpret pattern. Hansen (1981), in a summary review, also was negative in his prognosis for finding lateralization effects in response to television commercials.

Other Relevant Issues

Nonhemispheric findings of relevance to this article include:

- Eye movement and muscle artifact are weakest at the occiput (Galin 1979).
- In the occipital region, audio stimuli produce less change in alpha than do visual stimuli (Mulholland 1978) because the occiput specializes in processing visual stimuli.
- The response latency of the suppression of alpha to a simple stimulus such as a tone or a flash of light is about 300 milliseconds (Stern et al. 1980); activation in response to a longer, more complex visual stimulus persists for up to 15 or 20 seconds (Bowers and Heilman 1980).
- EEG has high variance across subjects, but findings are mixed for within-subject designs. Within subjects, a laterality advantage may shift over time in response to the same stimulus, although more recent studies show strong test-retest reliability. Between subjects, EEG may have high variance because of differences in age, gender, handedness, an undiagnosed pathologic condition, eye movement and muscle artifacts, differences in skull thicknesses, and idiosyncratic differences in processing speeds (Davidson 1986; Gasser, Bächer, and Möcks 1982).

These findings provide background for data and discussion about methodologic issues to be presented next.

Method Issues

Two method issues in the extant EEG literature need to be introduced. First, EEG researchers generally choose to aggregate rather than use individual data. The aggregate measure is derived from an averaging process across individual subjects' EEGs. An individual subject's EEG reflects many idiosyncratic factors, and thus the individual measure does not capture sensitively the systematic variance in response to the impact of a particular stimulus (e.g., Gasser et al. 1981; Hansen 1980). Variances due to such idiosyncratic factors can be reduced significantly by aggregating EEG across individuals, or by exposing each subject to the same stimulus many times and then averaging across the exposures. The latter method is impractical for advertising research where there is often interest in repetition effects.

Second, a variety of arithmetic manipulations of hemispheric lateralization can be considered to show asymmetry or dominance. For example, these measures include "Right − Left" ($R - L$), "Right/Left" (R/L) and "Right − Left/Right + Left" $(R - L)/(R + L)$ (McKee et al. 1973; Suter 1982). The choice among these measures does not always affect significantly the results of EEG research (Donchin et al. 1977); amount of variance in the data will affect the choice. Empirical evidence indicates that $(R - L)/(R + L)$ tends to capture the change in hemispheric lateralization more sensitively than does other measures, and, thus, EEG researchers generally seem to prefer this measure (Ehrlichman and Weiner 1980; Galin et al. 1982). These dominance measures are used in addition to measures that examine one hemisphere independently of the other.

OBJECTIVES AND HYPOTHESES

The following data are from the second EEG study, which was designed to expand the findings of the first study (reported in Rothschild et al. 1986 and Reeves et al. 1985) and to continue the examination of EEG as a viable technique in the assessment of the processing of television commercials. There were two specific objectives: (1) hemispheric laterality and lagged effects and (2) reliability, replicability, and consistency.

A synthesis of the literature review shows that EEG manifestations of processing differ for the left and right hemispheres of the brain and show stimulus-response lags. Although these are well-documented findings in the EEG literature, they have not been shown in advertising-related EEG studies. One objective of this study was to investigate hemispheric laterality and lags as responses to television commercial stimuli. This extension was necessary because television commercials are more complex and are changing more rapidly than stimuli typically studied using EEG. The second objective was to seek signs of regularity through reliability within the study, replication of the results of the first study, and consistency with the basic literature from which the method was drawn.

These objectives led to a number of hypotheses. The first hypothesis gives an overview of the data and its viability. Hypothesis 2 through Hypothesis 4 deal with specific issues of information processing of interest to both theoreticians and practitioners. Hypothesis 5 summarizes what is learned in the earlier hypotheses, and Hypothesis 6 examines the reliability issues.

H1: *A significant amount of variance in the hemispheric EEG data can be explained as a function of the changing commercial stimuli.* Variance can be explained in the absolute level of EEG in each hemisphere and in the relative level across the hemispheres. The study of the explanation of variance is an extension of a nonhemispheric finding from Reeves et al. (1985).

H2: *Evidence of processing verbal stimuli will be stronger in the left hemisphere and evidence of processing nonverbal stimuli will be stronger in the right hemisphere.* A basic EEG finding concerns the processing differences of the two hemispheres for verbal and nonverbal stimuli. This is tempered, though, by findings that show only slight laterality effects in response to complex stimuli.

H3: *Evidence of processing emotional commercials will be stronger in the right hemisphere and evidence of processing rational commercials will be stronger in the left hemisphere.* Although there is no literature directly driving this hypothesis, it would seem that rational commercials tend to be more verbal and emotional commercials tend to be more nonverbal.

H4: *There are observable lags between the onset of a stimulus variable and a responsive hemispheric shift in EEG. Different types of stimuli will elicit different lags.* No EEG literature deals with lagged effects. In prior work using television commercials (Reeves et al. 1985), the average lag between the onset of a simulus variable and a change in EEG was 1100 milliseconds.

H5: *Television commercial stimuli are processed in a bilateral fashion with significant dominance tendencies exhibited.* Although it has been shown that simple stimuli are processed primarily in one hemisphere and that pathologic subjects with hemispheric damage or surgically severed hemispheres process in a single hemisphere, these findings have not been generalized to normal subjects receiving complex stimuli. In normal subjects, it has been shown that both hemispheres process together and only slight dominance patterns are exhibited.

H6: *Patterns in EEG are consistent.* This will be examined in a reliability test within this study, in a replication test across our two data sets, and in comparison with some of the basic EEG findings presented earlier in this article.

METHOD

Procedures

The right- and left-hemisphere occipital alpha EEGs of 21 right-handed women were recorded individually during the viewing of a television videotape. One at a time, subjects sat in a comfortable reclining chair in a dimly lit sound-attenuating chamber, six feet from a 19-inch color television. They left the chamber to complete questionnaires and were allowed to take a short break between an acclimation videotape and the actual stimulus videotape. Before viewing, subjects were asked to find a comfortable position in the chair and then to move as little as possible. They were monitored for movement through an observation window behind them.

After having electrodes placed on their scalp, subjects viewed an acclimation/distractor videotape for about 10 minutes. The purpose of this tape was to allow subjects to get used to the attached electrodes and to become comfortable with their strange surroundings. A second purpose of this videotape was to confirm our cover story. Subjects had been told that they would be evaluating program content only; by showing them the first tape and then asking them for program evaluations, the cover appeared to be confirmed. The acclimation/distractor videotape consisted of two, five-minute segments of feature stories, sports, and commercials.

Stimulus

The stimulus was a 27.5-minute videotape. The stimulus tape consisted of nine commercials (4.5 minutes in total), two minutes of TV black, and 21 minutes of programming. The programming included approximately seven minutes each of comedic, violent, and sexual scenes from two television shows and two movies. The stimulus videotape began and ended with one minute of TV black. The seven-minute violent segment was an edited version of "The A Team," the comedic portion was from an episode of "Happy Days," and the sexual scenes were excerpts from the movies *Peter Proud* and *Shampoo*. The program segments were separated by three pods of three commercials each.

The test commercials were selected from a group of 200, 30-second color productions. Each advertised product was intuitively judged to be low involvement; none of the brands were marketed in the test area. The commercials were chosen by having student subjects (not the EEG subjects previously described) rank subsets of the 200 on a scale ranging from 0 (purely emotional) to 50 (a mixture of emotional and rational) to 100 (purely rational); commercials with means nearest to either 0, 50, or 100, and with the least variance were chosen as the stimulus set. Nine commercials were used; three were rational (referred to as RAT1, RAT2, and RAT3), three emotional (EMOT1, EMOT2, and EMOT3) and three balanced (MIX1, MIX2, and MIX3). One commercial from each category had been used in the first study. This overlap allowed for reliability testing.

Three videotapes were constructed to balance the order of programming and the order of commercials within and between the commercial pods. Multiple tapes permitted further reliability testing. Subjects were assigned randomly to one of the three tapes.

Apparatus

EEG data were collected during the viewing of the stimulus videotape, although electrodes were in place for the distractor and stimulus tapes. Electronic pulses placed on an unused audio track triggered the EEG recording device so that data were collected at regular intervals and so that reference marks would appear on the recordings.

The EEG data were recorded from occipital locations (01, 02, according to the International 10-20 System locations). 01 was referenced to A2 (a neutral location on the right earlobe), and 02 was referenced to A1 (a neutral location on the left earlobe).

The EEG was recorded with silver-cup electrodes (Grass E5SH). Amplifiers (Hewlett-Packard 8811A) were set at a gain of 20,000, with a bandpass of 1.5 Hz-100 Hz. Filter slopes were 6 dB/octave. The amplified data were further lowpassed at 50 Hz by filters (Krohn-Hite 3342R) with a 48 dB/octave slope. All amplifiers were calibrated each morning before testing began.

Data collection took place during a three-week period. After the first week, the inputs to the amplifiers were switched, thereby avoiding amplifier bias.

Amplified and filtered data were led to an analog-to-digital converter (Nicolet MED-80) where they were sampled every 7.812 milliseconds. The data were aggregated every half-second and transformed by Fourier spectral analysis across the alpha frequency band (8 Hz to 13 Hz) to show power units for each period.

Memory Response Variables

Although this article deals primarily with the relation between the stimulus and the EEG, the method also included a test designed to replicate the linkage between EEG and memory found in Rothschild et al. (1986). In this test, respondents were given recall and recognition tests after a half-hour delay. The recall test asked subjects to list the product category, brand name, and claims for as many of the nine commercials as possible. After completing the recall questionnaire, subjects received a four-distractor recognition questionnaire that listed product, brand, and claim choices on consecutive pages for each of the nine commercials. Subjects were asked not to return to a page after completing it and were monitored for compliance. The test order of the commercials in the questionnaire was randomized across subjects.

Data Transformations

The EEG data were Fourier transformed (Thompson and Patterson 1974) separately for the left and right occipital locations in the alpha frequency range for each half-second. These data were then standardized to a mean of zero and variance of one (Z transformation; see Ehrlichman and Wiener 1980) using a mean calculated across all program and commercial data within each individual. The normalization was necessary because of the variance in EEG that occurs across individuals, and because the data were bounded at the lower end by a zero level of EEG. The raw data, therefore, were unduly influenced by subjects with high variance or high means. Finally, the median for each half-second of normalized data across all subjects was calculated. The median was selected as the best measure of aggregation because of the occasional high EEG values (over ten standard deviations above the mean) caused by muscle or eye blink artifact and the skew caused by a lower boundary. The following data, then, consist of medians computed across subjects for each half-second after normalization within each subject.

Construction of the Time Series

Independent and dependent variable series were constructed for each commercial. Nine different independent stimulus variables were identified within the commercials; a time series was created for each commercial based on the half-second during which each stimulus first appeared. In these series, dummy variable values for each variable were placed in the first half-second of each appearance of each variable. The Appendix lists the nine variables and their codes. These variables were selected so that the hypotheses could be tested and were influenced by earlier data analysis on the prior data set (Reeves et al. 1985); in retrospect, the variables also were similar to those selected by Alwitt (1985) and Thorson, Papas Heide, and Page (1988). Ultimately, the variables used in this study were selected arbitrarily to represent a number of stimulus conditions that could influence EEG. Clearly, many other such variables could be constructed, and, indeed, should be constructed in future work. The variables in this study were selected to represent the four tracks of a television commercial. These were verbal video (VERBVIS, PKG), verbal audio (VERBAUD), nonverbal audio (NONVERB), and nonverbal video. Nonverbal video was represented by person movement (BODY, HEAD, and STARE) and camera movement/production (EDIT and ZOOMS).

VERBAUD, VERBVIS, and PKG were verbal stimuli; the other six variables were nonverbal. VERBAUD and NONVERB were auditory; the other seven were visual. Of the visual stimuli, BODY, HEAD, and STARE dealt with the movement of the actors, EDIT and ZOOM dealt with camera and technical changes, and VERBVIS and PKG represented verbally-oriented visual stimuli. In Reeves et al. (1985), the independent variables were MOVEMENT (a composite of BODY, HEAD, and STARE) and EDIT (a composite of EDIT and ZOOM); autocorrelation was also considered.

Dependent variable time series also were constructed for each commercial. These consisted of the values of $(R - L)/(R + L)$ for each half-second, where R and L were the value of EEG for that half-second in the right and left occipital location. This series was used to examine relative EEG changes across the hemispheres. Each series consisted of 60 half-second periods for each commercial.

RESULTS

As stated earlier, two specific goals were addressed in this study: (1) examination of hemispheric differences and lagged effects in response to television commercial stimuli; and (2) examination of the consistency of the EEG data within this study, across the two studies, and in relation to the basic EEG literature. This section considers the data for each of these goals and then examines the six hypotheses.

Hemispheric Laterality

Each 30-second commercial was analyzed as a time series of 60 half-second periods where the dependent variable was $(R - L)/(R + L)$. The data, therefore, reflected the shift in hemispheric dominance over time as a function of the nine independent stimulus variables. As a conservative analysis stance, the regression models were constructed to include all nine stimulus variables rather than to include only significant variables. The effect of this decision was to lower the adjusted R^2, but to present data analysis that strictly conformed to the a priori model of commercial impact on EEG. In this way, the nine-variable model shows the impact of each variable in competition with each of the other eight variables.

Note also that some cells of Table 1 show NA (insufficient observations). The occurrence of NA indicates either that a particular stimulus variable did not occur in a particular commercial or that a particular stimulus variable suffered from an extreme level of multicollinearity with some other independent variable. Autocorrelation variables were introduced when time series residuals were significant in estimating regression models without them.

Table 1 shows the dominance regression models for each of the nine commercials. For example, the regression model for hemispheric dominance in commercial RAT1 shows that the model explained 36 percent of the variance in EEG (adjusted $R^2 = 0.23$). The model was significant ($F = 2.68$; $p < 0.05$). All stimulus variables were entered into the equation; significant contributions came from the verbal audio track (VERBAUD) with a two half-second lag ($B = 0.095$; $t = 2.01$; $p < 0.05$), zooms and pans (ZOOM) with a five half-second lag ($B = -0.215$; $t = -2.36$; $p < 0.05$) and the appearance of the package (PKG) with no lag ($B = 0.152$; $t = 1.83$; $p < 0.1$). VERBAUD showed significant positive B, indicating left hemisphere dominance; ZOOM showed a significant negative B, indicating right hemispheric dominance. Eight of these models explained significant amounts of variance in EEG; only one had a marginally significant ($p < 0.1$) autocorrelation component. The Durbin-Watson statistic generally was in the acceptable range.

The contribution of the three verbally-oriented variables (VERBAUD, VERBVIS, and PKG) was in the expected direction, showing left-hemisphere dominance in 23 of 26 cells; in all nine cells where this contribution was significant, it was to left-hemisphere dominance. The contribution of the six nonverbal variables also was in the expected direction, but in this case was to right-hemisphere dominance in 44 of 48 cells; in all 17 cells where this contribution was significant, it was to right-hemisphere dominance. The contribution was in the theoretically expected direction in 67 of the 74 cells of Table 1 where a B value could be calculated. The median t value of the remaining seven cells was 0.196.

The regression models of the emotional and rational commercials did not differ in terms of the mix of verbal and nonverbal independent variables.

Individual stimulus variables did not make consistent contributions across the commercial regression models. This was to be expected because each commercial was unique and employed a unique combination of stimulus variables. ZOOM was the most consistent stimulus variable; it made a significant contri-

TABLE 1

DOMINANCE REGRESSION MODELS

Commercial type		Verbaud	Verbvis	Pkg	Body	Head	Stare	Nonverb	Edit	Zoom	R^2 (Adj. R^2)	F
RAT1	B	^{2}.095	^{1}.102	^{0}.152	^{3}.001	^{5}−.018	^{0}−.070	^{0}−.111	^{4}−.038	^{5}−.215	.359	2.681^{c}
	t	(2.01^{b})	(1.47)	(1.83^{a})	(.03)	(−.47)	(−1.47)	(−1.41)	(−.45)	(−2.36^{b})	(.23)	
RAT2	B	^{4}.060	NA	^{3}.331	^{3}−.176	^{4}.011	^{3}−.170	^{0}−.058	^{1}−.120	NA	.312	2.985^{b}
	t	(1.64^{a})		(2.86^{c})	(−1.53)	(.28)	(−2.38^{b})	(−.50)	(−.75)		(.21)	
RAT3	B	^{1}.076	^{1}.001	^{2}−.018	^{2}−.123	^{0}−.195	^{1}−.009	^{5}.144	^{1}−.055	NA	.314	2.087^{b}
	t	(1.19)	(.02)	(−.20)	(−2.17^{b})	(−2.41^{b})	(−.10)	(.84)	(−.63)		(.16)	
MIX1	B	^{3}.071	^{3}.066	^{4}.115	^{1}−.078	^{1}−.042	^{2}−.300	^{0}−.065	^{2}−.085	^{4}−.159	.463	4.216^{c}
	t	(1.99^{b})	(1.01)	(1.76^{a})	(−1.97^{b})	(−.88)	(−3.31^{c})	(−1.17)	(−1.88^{a})	(−1.75^{a})	(.35)	
MIX2	B	^{2}.048	^{3}.086	^{2}.078	^{0}−.048	NA	NA	^{3}−.159	^{1}.003	^{5}−.072	.228	1.943^{a}
	t	(1.05)	(1.10)	(1.78^{a})	(−.62)			(−1.12)	(.07)	(−1.10)	(.11)	
MIX3	B	^{4}.056	^{5}.080	^{5}.011	^{1}−.033	^{1}−.040	^{2}−.059	^{1}−.105	NA	^{0}−.058	.107	.615
	t	(.94)	(.44)	(.07)	(−.60)	(−.52)	(−.37)	(−.65)		(−.68)	(−.07)	
EMOT1	B	^{3}.021	^{2}.075	^{3}.069	^{2}−.192	^{5}−.290	NA	^{0}−.103	^{0}−.010	^{1}−.237	.416	3.825^{c}
	t	(.51)	(1.66^{a})	(.92)	(−2.19^{b})	(−3.24^{c})		(−.73)	(−.14)	(−2.64^{b})	(.31)	
EMOT2	B	^{4}.139	^{3}−.056	^{3}.322	^{2}−.045	^{3}−.069	^{0}−.183	^{3}−.297	^{4}−.054	^{2}−.557	.321	2.310^{b}
	t	(1.68^{a})	(−.28)	(1.16)	(−.65)	(−.58)	(−.86)	(−2.78^{c})	(−.65)	(−2.54^{b})	(.18)	
EMOT3	B	^{2}−.007	^{1}.016	^{3}.035	^{4}−.191	^{4}−.284	NA	^{5}−.307	^{5}−.119	^{2}−.150	.267	1.956^{a}
	t	(−.12)	(.16)	(.29)	(−1.85^{a})	(−1.69^{a})		(−1.83^{a})	(−1.29)	(−1.69^{a})	(.13)	

$^{a}p < 0.10$.
$^{b}p < 0.05$.
$^{c}p < 0.01$.
NOTE: NA = insufficient observations. Lag effects are shown as superscripts to the left of *B* values. Positive *B* values indicate left hemisphere dominance; negative *B* values indicate right hemisphere dominance.

bution to five of the models and three other stimulus variables contributed to four models.

Lagged Effects of the Independent Variables

The data showed lags between the onset of the stimulus variable and the observable hemispheric change in EEG. Across the dominance models, the average lag was 2.36 half-second periods (or 1.18 seconds). In looking at the lags between the significant stimuli and EEG responses (regardless of model type), EEG lagged the verbal stimuli by a greater amount than it lagged nonverbal stimuli (2.99 versus 2.27 periods; $t = 3.04$; $df = 213$; $p < 0.01$), and lagged in the left hemisphere more than in the right (2.72 versus 2.40 periods; $t = 1.34$; $p < 0.1$). Across all significant stimuli and all models, the average lag was 2.57 periods (or 1.28 seconds).

Correlations Across Hemispheres

Although a substantial body of literature shows lateralized specialization of occipital alpha, data also show that the hemispheres covary, that is, normal subjects' hemispheres work together much more than they compete. Correlation of the time-series data across hemispheres ranged from 0.48 to 0.79 across the nine commercials; the average correlation was 0.62. Consistent with the EEG literature, this level of correlation showed some level of independence between hemispheres yet also showed a strong level of covariance.

The cross-hemispheric correlations also showed differences by commercial type. The rational commercials implied greatest bilateral processing ($r = 0.70$) followed by the mixed commercials ($r = 0.62$); the emotional commercials had the lowest correlation across the hemispheres ($r = 0.54$). This difference in level of bilateral processing between the rational and emotional commercials was significant ($t = 2.59$; $df = 16$; $p < 0.01$).

Relating the Data to the First Five Hypotheses

The data now are reviewed in light of the hypotheses. The first hypothesis dealt with the general introductory issue, that a significant amount of variance in the EEG data can be explained as a function of the changing commercial stimuli. In six of the nine commercial models, the R^2 was significant at $p < 0.05$.

Hypothesis 2 through Hypothesis 5 dealt with specific issues of information processing. All significant contributions to dominant processing of verbal stimuli in the left hemisphere and nonverbal stimuli in the right hemisphere were in the hypothesized direction for Hypothesis 2. The verbal stimuli contributed to the left dominance in all nine cases where the contribution was significant; the nonverbal variables contributed to right dominance in all 17 cells showing significance. The data did not support Hypothesis 3, that there would be evidence of stronger processing in the right hemisphere for emotional commercials and in the left hemisphere for rational commercials. The data did support Hypothesis 4: the average lag between the onset of the stimulus and the change in EEG was 2.57 periods (1.28 seconds); there also was a greater lag after a verbal than a nonverbal stimulus ($p < 0.01$) and a marginally greater lag in the left hemisphere than in the right ($p < 0.01$).

The fifth hypothesis ties the earlier findings together with current hemispheric laterality views that television commercial stimuli are processed in a bilateral fashion with significant dominance tendencies exhibited. First, the average across-hemisphere correlation over all nine commercials was 0.62 ($p < 0.001$); there was greater correlation between the hemispheres during rational commercials (0.70) than emotional commercials (0.54; $p < 0.01$). Second, as seen in the test of Hypothesis 2 in Table 1, there were also clear patterns of dominance of one hemisphere over the other that support one or more of the bilateral models to the exclusion of the unilateral model.

Consistency of the EEG Data

The findings presented in the previous section provide support for four of the first five hypotheses, but are they reliable? Consistency can be shown between subsets of this data set (reliability), in comparison with prior data collected using the same method (replicability), and in comparison with earlier EEG literature (face validity). The first two of these issues are dealt with here; the third is considered in the discussion. In addition, reliability tests could be considered for the relation between the stimulus and EEG, and between EEG and memory. Each of these will be considered.

Reliability of Correlations Across Subsamples. Consistent with the EEG literature, there were no significant between-subject correlations. However, because there were three videotapes, a convenient reliability test could assess the correlation of the aggregate time series across the three tapes. Given the instability of EEG, a low-level of reliability would be expected; in addition, because the commercial context also differed for the viewers of each of the three videotapes, one would expect even lower correlations. Murry (1987) has shown contextual effects on memory and persuasion, and Thorson and Reeves (1986) have shown that program context influences later recall. Given these and other recent findings that show a strong context effect, one would expect the reliability test to yield quite low correlations between the split third samples.

In considering all pairs of comparisons across the three tapes (A-B; A-C; B-C), the two hemispheres, and the nine commercials, there were 54 correlations. More than 75 percent of these pairs had a significant relation ($p < 0.05$). This showed that EEG did vary reliably across subjects in response to television commercial stimuli. Because of the potential for significant context effects on EEG patterns, the actual significant correlations are even more meaningful.

Replications of Earlier Findings. A second form of reliability can be found in the replications between this study and the first study, which used a similar method. For example, this study showed correlations across hemispheres of 0.62; the first study yielded a correlation of 0.68 for the same examination.

The regression models also were similar between the first and second studies. Although there were more complexities in the models in this study (nine independent variables versus two; hemispheric dominance versus aggregated power across hemispheres), there were similarities. The overall R^2s were higher in the first study (Reeves et al. 1985) probably because of greater autocorrelation in the aggregated power data; the increment in R^2 due to the stimulus variables was greater in this study. These changes may be due, at least in part, to the input of more stimulus variables in the second study and to the lateralization, rather than power, analysis. The variables of the first study were included here as BODY and HEAD and as EDIT and ZOOM; these variables were similar in impact in both studies.

The average lag across all variables was 2.57 half-seconds in this study versus 2.20 in the first study. This difference of 185 milliseconds was too large to imply consistent findings across studies ($p < 0.1$). Comparing similar variables across the studies showed lags of 2.35 and 2.20 half-seconds in the two sets of regression models. When comparing only similar variables, the lags were consistent (*ns*). The amount of lag also was similar to that found by Alwitt (1985) in her aggregate power data. Her data were collected in two-second increments and she found that for 14 of 17 variables, the best relations were either in the current or first lagged periods.

In another replication, the time series of three commercials that appeared in both studies were examined. The correlations of the two 60-point time series plots for each of the three commercials were 0.33 ($p < 0.01$), 0.48 ($p < 0.001$) and 0.29 ($p < 0.02$), respectively. Again, this provides strong evidence for reliability because it occurred despite the inherent unreliability of EEG and the fact that the program and other commercial contexts were different in the two studies.

The final replication considered the relation between aggregate mean EEG and aggregate memory. In Rothschild et al. (1986), there were significant relations between EEG and both recall and recognition across the nine commercials. Neither of these relations was found to be significant in the replication although both showed consistent directional tendencies. The tests of memory in the two studies were identical.

Relating the Reliability Data to Hypothesis 6

We hypothesized that patterns in EEG are consistent. Results show that significant similarity existed among the variables that contribute to the dominance models ($p < 0.05$). They also show that significant correlations of time series data were found across three subsamples of subjects (78 percent of 54 pairs of correlations are significant; $p < 0.05$). Across studies, the across-hemisphere correlations were stable (0.68 versus 0.62), and the average lag of similar variables was consistent (2.35 periods versus 2.20 periods). The correlations of the time series plots of the three commercials that appeared in both studies were significant ($p < 0.01$; $p < 0.001$; $p < 0.02$). Although the stimulus-EEG relation showed many consistent patterns, the EEG-memory relation was not replicated.

DISCUSSION

There are few EEG studies that have considered stimuli such as television commercials; those that have generally have aggregated data over long periods of time (from 30 seconds up to several minutes). We know of no EEG studies that have taken as detailed a view of such a complex stimulus; the closest has been Alwitt's analysis (1985), which used a two-second unit of time. Given the complexity of television as a stimulus, this study is more than a mere transference of method or technology from another field to consumer behavior.

A Summary of Findings Across the Two Studies

Table 2 summarizes the issues studied, the relevant findings in the EEG literature, and the findings in the two reported studies. Despite the stimulus complexity, the data were quite consistent with prior EEG work, showed internal reliability, and were replicable. This stability occurred for overall occipital alpha power as well as for the right versus left hemispheres within the occipital region.

The two studies thus far have been concerned with examining EEG that occurs during the viewing of television commercials, that is, during the following stimulus-response relation: S (ADVERTISING) → R (MEMORY). To that end, the studies have examined the intermediate linkages of: S (ADVERTISING) → R (AROUSAL MEASURED VIA EEG) and R (AROUSAL) → R (MEMORY).

STIMULUS → EEG. Both studies have shown a clear relation between television stimuli and changes in occipital alpha. EEG responded rapidly (during a period of a half-second), within 1.5 seconds from the onset of an easily identifiable change in the television commercial. After EEG dropped, it slowly recovered for a period of up to 15 seconds, although the time between sharp drops seemed to average about five to six seconds, and was a function of the individual commercial structure (Rothschild et al. 1986). In addition, each commercial influenced EEG in a unique manner, again based on its own production style. This can be seen in aggregate electrical power across hemispheres (Reeves et al. 1985) and in hemisphere dominance (this study). Processing also was influenced by the commercial: verbal components were more likely to be processed in the left hemisphere; nonverbal components were more likely to be processed in the right hemisphere.

Although there has been speculation about the different processing characteristics of the two hemispheres, the data were most consistent with basic EEG findings that have shown weak but predictable hemispheric differences. The present study showed that the left hemisphere was more responsive to verbal variables and the right was more responsive to nonverbal variables. These tendencies were quite subtle and have not been reported previously in response to television stimuli. The data are consistent with bilateral models, such as that proposed by Janiszewski (1987), where both hemispheres work together but show some specialization. The pop psychology view of unilateral processes has not been supported by the work presented in this article.

EEG → MEMORY. The replications of the STIMULUS → EEG linkage generally were successful, and the comparisons of the aggregate power analysis and the hemispheric lateralization analysis showed similar results. The replication of the EEG → MEMORY linkage was not successful. However, the failure to replicate the EEG → MEMORY linkage found in Rothschild et al. (1986) is a replication of a wider set of studies dealing with EEG as a mechanism for assessing memory response to advertising.

This linkage has been notoriously unreliable as discussed in the literature review earlier in this article. Just as we were not able to replicate this linkage, Weinstein, Appel, and Weinstein (Appel et al. 1979; Weinstein et al. 1980) also found a linkage in one

TABLE 2

SUMMARY OF KEY FINDINGS IN CURRENT STREAM OF RESEARCH

Issue	Basic EEG literature	Study 1 (reported in Rothschild et al. 1986 and Reeves et al. 1985)	Study 2 (study reported in this article)
Relation of alpha power to arousal	Alpha drop indicates arousal	Same finding	Not tested
Relation of alpha to cognitive tests	Negative correlation between alpha and recall/recognition for brief stimuli	Same finding	Not replicated at $p < 0.1$
Relation of alpha to stimulus changes	Changes in alpha can be explained due to changes in stimulus	Same finding (power as dependent variable)	Same finding (dominance as dependent variable)
Hemispheric lateralization	Right hemisphere more responsive to visual/music/abstract cues	No data	Same finding as basic literature
	Left hemisphere more responsive to verbal/concrete cues	No data	Same finding as basic literature
	Bilateral processing across hemispheres	No data	Same finding as basic literature
Changes in alpha due to rational/emotional messages	No data	No data	No significant findings
Autocorrelation in EEG	No data	After responding to a stimulus, there is a period during which attentuation occurs (power as dependent variable)	No significant findings (dominance as dependent variable)
Lags between stimulus onset and drop in alpha	No data	1100 millisecond delay (power as dependent variable)	1280 millisecond delay (dominance as dependent variable)
Reliability	Reliability of EEG is robust in response to simple stimuli	No data	Reliability of EEG is robust in response to complex stimuli

study but not in the other. Other researchers have found weak or no relations between these variables (Rust et al. 1985; Rockey et al. 1980).

Perhaps the difference in the success rate of replicability between the two linkages is a function of whether the linkage considers what precedes or follows the observation of EEG. We feel that there is a better explanation. The data reported in this study that examined STIMULUS → EEG used half-second increments of time as the unit of measurement, and captured the importance of EEG in describing micro information processing. However, the EEG → MEMORY linkage was examined across an aggregation of thirty seconds of EEG and across memory responses to the entire commercial.

To clearly observe the relation between EEG and memory, it may be necessary to consider short time periods of EEG and memory tests for component parts of the overall commercial stimulus. There is a less theoretical reason to believe the aggregate EEG should correlate with aggregate memory than that short periods of EEG should correlate with memory tests of appropriate message components. Because each component generates its own variance, it is natural that pooling these variances would lead to less clear results. It is this issue that we feel is most likely to have led to a lack of replicability in the EEG → MEMORY linkage.

Method Differences Between This Study and Other Research Concerning EEG and Advertising

Advertisers have become interested in considering EEG measures as a set of responses to commercial stimuli. This interest has been piqued by a psychophysiology literature that indicates a strong relation between certain types of stimuli and certain types of EEG responses.

However, these EEG findings will only transfer with difficulty to the relation between commercial advertising stimuli and learning response measures. As noted in the psychophysiology literature, effects become more difficult to observe as stimui become more complex. This complexity has been overlooked in many of the earlier advertising-related studies and may have been a major contributor to a lack of positive findings. In the current work, the clearest findings have emerged when the complex stimulus was broken down into simpler parts; using the complex stimulus in its entirety has been more likely to result in insignificant findings.

Another advantage of the half-second time increment appears in studying lag effects. As noted, longer time periods smooth over patterns in the data; the Alwitt (1985) data discussed previously show that longer periods also miss lagged effects. Alwitt, using a similar method to ours, aggregated all data to the nearest two seconds and was unable to observe as many differences in lags; in her analysis, nine of 17 cases were lagged zero periods and another five were lagged one period (two seconds).

In addition to the problems of analyzing complex stimuli, there are other complexities that need to be avoided. These include concern for a homogenous sample of respondents that controls for gender, handedness and age, and concern for homogeneity in the stimuli that controls for involvedness of the products and prior exposure to the messages. In Rothschild et al. (1986), we discussed these issues in more depth and recommended showing previously unseen commercials for low involvement products to right-handed women between the ages of 20 and 50. Although these constraints are desirable for reducing variance, they limit the generalizability of results and external validity.

By being concerned with homogeneity of subjects and stimuli, by creating an experimental situation that minimizes unnecessary variance, by considering lag effects, and by transforming data to control for individual variance, analysis of the two data sets collected to date have been able to show that relations exist between advertising stimuli and EEG responses. Furthermore, the studies have shown that these relations, which previously had been shown to exist for simpler stimuli, also exist for complex stimuli.

Implications for Information Processing Theory and Research

The word "processing" implies something that is dynamic, proceeding, marked by change. Although the field of information processing examines changes that occur over long periods of time or over the repetition of messages, there is very little work that considers this process within the scope of a 30-second commercial. People continually process, but researchers evaluate in terms of large discrete time periods. Evaluating in the same continuous manner in which people process may provide more information.

Indeed, the data reported in this study indicate that there is a dynamic process occurring over short periods of time, which can be seen in the lagged effects and autocorrelations that differ across stimuli and across hemispheres. Perhaps messages need to be constructed with an eye to what precedes and follows each stimulus component. Will information be processed more effectively if key ideas follow components, such as edits, by a certain period of time? Should a verbal idea follow a verbal or nonverbal component? These questions need to be pursued.

A trend exists among advertisers toward more visual and emotional messages, yet much of the information processing literature is based on verbal and rational messages. This study has shown differences in processing for different message components.

At least three types of variance can be considered in assessing message impact; these types of variance are due to the medium, the overall message, and the message components. Past information processing work has considered primarily the first two; this stream of research has examined the last two.

Future Research

In studies to date, the examination of EEG was an end unto itself; it was necessary to learn how EEG would respond to complex stimuli before researchers could use it as a reliable tool. This task has progressed greatly, and EEG now becomes a means to pursue a different end. Future work needs to study micro levels of information processing.

For example, EEG can be used to examine order effects on information processing. Will memory or persuasion be enhanced if key message points are preceded by elements that enhance learning? Can an experimental design paradigm be used to observe a commercial constructed with several different orderings? In a more macro environment, the issue of context effects has become important in information processing research; similarly, scene by scene context effects may prove to be equally important.

Another important area of information processing is that of cognitive versus affective processing. EEG can contribute in this area as well. By examining alpha at the frontal and parietal lobes, one may be able to learn what type of processing is occurring at any instant during the message. (It is felt that frontal alpha shows affect [Davidson 1984], and parietal activity best indicates higher level cognitive processing [Moscovitch 1979].)

A third issue to be studied might consider the question of central versus peripheral processing (Petty and Cacioppo 1986). If central processing is higher order and peripheral is a response to basic changes in stimuli, then parietal versus occipital differences might be insightful as EEG measures of these respective levels of processing.

Finally, a weak link in the STIMULUS → AROUSAL → MEMORY / PERSUASION relation is the one that ties EEG to self-reported measures of learning and affect. To improve this work, the self-report measures will need to test what has happened at the scene or epoch level of the message. Little research has been done in this area, although Young and Robinson (1987) and Thorson et al. (1988) have made interesting moves in this direction.

Whether EEG is a viable research tool for consumer researchers is no longer a legitimate debate. The next step is to set a research agenda to use this tool in the study of information processing at a micro level. In this way, we will give a richer meaning to the word *process*.

APPENDIX

List of Independent Stimulus Variables

VERBAUD: verbal audio—any words on the audio track
VERBVIS: verbal visual—any superimposed words on the visual track
PKG: appearance of the words on the product or package
BODY: any below-the-neck movement of a person
HEAD: any above-the-neck movement of a person
STARE: staring at the camera by the spokesperson
NONVERB: nonverbal audio—any other sound on the audio track
EDIT: edits, scene changes, dissolves
ZOOMS: zooms, pans

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