Validity, Reliability, and Applicability of Psychophysiological Techniques in Marketing Research

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ABSTRACT

A variety of psychophysiological techniques have been used in the measurement of consumer reactions to marketing stimuli since the 60s. The objectives of this paper are: (1) to present a descriptive review of the psychophysiological techniques and (2) to discuss critical concerns about validity, reliability, and applicability of these psychophysiological techniques raised by previous research. The strengths and weaknesses of ten major psychophysiological techniques are analyzed on the basis of the summaries of 67 marketing studies that have employed psychophysiological techniques. This study shows a need for marketing research to establish validity and reliability and to emphasize applicability when psychophysiological techniques are to be used. Meeting such a need requires an understanding of the nuanced psychophysiological process that links particular psychological antecedents and the physiological consequences being measured. A framework for analyzing this psychophysiological process in marketing research is provided.

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In marketing research, a variety of measurement techniques have been used to measure consumers' reaction to stimuli. These measures include: (1) behavioral measures, such as actual purchase, amount of time and money spent, or store patronage; (2) verbal measures, such as self-reported assessments of intentions, attitudes, recalls, or emotions; and (3) psychophysiological measures, such as pupil dilation, eye movement, or heart rate (Green & Tull, 1978; Stewart & Furse, 1982; Wiles & Cornwell, 1990; Poels & Dewitte, 2006).

Marketing researchers have been skeptical about using behavioral and verbal measures because of their limitations in providing an effective measure of internal reaction to external stimuli. Behavioral measures of responses to stimuli are problematic because they cannot reflect the process occurring between affect and behavioral consequence (Wiles & Cornwell, 1990). The affect that consumers receive also cannot be adequately measured by self-reported verbal indicators, due to the complexity of thought (Wiles & Cornwell, 1990). Respondents using self-reported verbal measures are also more likely to give so-called lip service responses, such as socially acceptable answers or uncontemplated feedback (Nighswonger & Martin, 1981). Furthermore, from a psychology perspective, the unconscious minds of consumers have not been fully emphasized in psychological and behavioral measurement (Liu, 1986; Zaltman, 2000, 2003). Consumers may still have a "feeling of knowing" experience even though they cannot trace a clear memory by verbal measures, but researchers have not aimed to "realize that the results of unconscious processing can be brought into consciousness" (Liu, 1986, p. 42). Zaltman (2003) employed neurology and psychology to understand how consumers process information. He found that, in most cases, consumers cannot clearly explain the reason for buying a specific product by the use of verbal measures.

On the other hand, psychophysiological measures can "provide a very basic, unbiased, and sensitive measure of an individual's reaction to a stimulus" because "autonomic reactions are not under voluntary control" and "it is not possible for individuals to mask their 'true' reactions to a product or advertisement" (Stewart & Furse, 1982, p. 2). Marketing research needs to pursue more precise, comprehensive, and unbiased measurements of the psychological processes to reflect a broader and deeper intellectual understanding of the human mind's mechanism. In order to meet such a need in marketing research, the use of psychophysiological techniques in measuring consumer reactions to external stimuli is an important area worthy of further examination.

Psychophysiology is an interdisciplinary subject that combines physiology, biology, and psychology research (Kroeber-Riel, 1979). It has been defined as "the study of relations between psychological manipulations and resulting physiological responses, measured in the living organism, to promote understanding of the relation between mental and bodily processes" (Andreassi, 2000, p. 1). Consequently, marketing researchers

are able to use physiological indicators to monitor covert psychological processes.

In this study, the objectives are to present a descriptive review of psychophysiological techniques that have been employed in marketing research, and to discuss some critical concerns that can benefit future research in this area. This study is organized using the following structure: first, a review of ten psychophysiological techniques is offered, along with the summaries of sixty-seven previous studies using such techniques in marketing research; second, the strengths and weaknesses of each psychophysiological technique are discussed on the basis of the review; and last, conclusions and recommendations for future research are provided.

REVIEW OF MARKETING RESEARCH USING PSYCHOPHYSIOLOGY

Ten psychophysiological techniques have appeared in published marketing research. These techniques include three central nervous system (CNS) measures (non hemispheric brain wave analysis, hemispheric lateralization, and brain imaging analysis); five autonomic nervous system (ANS) measures (pupillary response, electrodermal analysis, voice pitch analysis, heart rate response, and vascular activity); and two somatic nervous system (SNS) measures (facial muscle activity and eye movement analysis) (cf. Bagozzi, 1991).[1] Sixty-seven marketing studies published between 1960 and 2006 that have empirically applied these psychophysiological techniques are summarized in the Appendix.

It can be found that, along with the progress of psychophysiological research and the growing interest of marketing researchers in psychophysiology, the number of marketing publications using psychophysiological techniques increased from the 60s to the 80s. Later, the popularity of certain techniques waxed and waned. In the 60s, pupillary response and electrodermal analysis began in marketing-related experiments. Since the 70s, non hemispheric brain wave analysis, hemispheric lateralization, voice pitch analysis, and eye movement analysis have been used in marketing research. In the late 80s, cardiovascular activity (including both heart rate and blood pressure) and facial muscle activity were further explored by marketing researchers. However, in the 90s, the number of publications that employed psychophysiological measures decreased. An underlying reason may be that the validity, reliability, and applicability issues of some techniques—such as voice pitch analysis and brain wave analysis (both hemispheric and non hemispheric)—were brought into question by a number of research findings and critiques. Lack of reliability and validity as well as restrictions in applicability discouraged further application of some psychophysiological techniques.

[1] Eye movement is considered both voluntary (somatic) and involuntary (autonomic) (Stewart & Furse, 1982).

Table 1. Chronological Classification of Marketing Studies Using Psychophysiological Techniques.

Measure	60s (7)	70s (10)	80s (21)	90s (16)	2000–present (22)
Non hemispheric brain wave analysis (5)		1	3		1
Hemispheric lateralization (8)		1	5	1	1
Pupillary response (8)	6	2			
Electrodermal analysis (16)	1		5	5	5
Voice pitch analysis (4)		2	2		
Heart rate response (5)				1	4
Vascular activity (2)			2		
Facial muscle activity (4)			1	1	2
Eye movement analysis (19)		4	3	8	4
Brain imaging analysis (5)					5

Note: Numbers in parentheses are numbers of publications.
Studies using two or more psychophysiological techniques are counted by each of the techniques.

This decrease of the 90s has not continued. From 2000 to the present, the number of marketing publications using psychophysiological techniques has become larger than that for the entire 90s. Between 2000 and the present, non hemispheric brain wave analysis, hemispheric lateralization, electrodermal analysis, facial muscle activity, and eye movement analysis were still being used, while heart rate analysis and brain imaging analysis were adopted and used by a growing number of marketing studies. A chronological classification of published marketing studies using psychophysiological measures is provided in Table 1.

REVIEW OF PSYCHOPHYSIOLOGICAL TECHNIQUES

Psychophysiological techniques use a number of physiological indicators to keep track of different psychological responses to stimuli. These psychological responses can be represented by cognitive and affective processes in the mind. The cognitive process is involved with "everything that goes in the consumers' minds concerning the acquisition, processing, retention, and retrieval of information" (Eroglu, Machleit, & Davis, 2001, p. 181). Quantitative measures of the cognitive process usually include measures of beliefs, knowledge, attitudes, attention, memory, and recall (Eroglu, Machleit, & Davis, 2001).[2] On the other hand, the affective process is a mental state that develops spontaneously without cognitive effort, and is involved with a set of emotional reactions that are usually represented by Mehrabian and Russell's (1974) pleasure (pleasant vs. unpleasant), arousal (excited vs. calm), and dominance (dominant vs. submissive) dimensions (Eroglu, Machleit, & Davis, 2001). Some researchers have adopted a two-dimensional model, which includes

[2] The structure of the attitude construct includes both cognitive and affective aspects (Ajzen, 2001).

valence (i.e., pleasure; pleasant vs. unpleasant) and arousal (excited vs. calm), to describe the affective process (e.g., Russell, 1980). Researchers in social psychology posited that, based on the combinations of the basic affective dimensions (pleasure, arousal, and dominance), a broader sense of human emotions can be divided into fifteen primary categories, including amusement, anger, contempt, contentment, disgust, distress, embarrassment, excitement, fear, guilt, pride, relief, satisfaction, sensory pleasure, and shame; and a variety of secondary emotions can be derived from each of the primary categories (Ekman, 1999).

Experts in psychophysiology suggested that appropriate application of a psychophysiological technique depends on fully understanding its working mechanism and how different cognitive and affective processes are being measured (Kroeber-Riel, 1979; Stewart & Furse, 1982). As Stewart and Furse (1982) contended, the application of any psychophysiological measure "should be based on three additional sources of information: (1) an understanding of the stimulus context in which the measurements were taken; (2) a knowledge of the physiology of the system measured, and (3) an assessment of other response events that may be occurring simultaneously" (p. 30). Based on the philosophy of science, Bagozzi (1991) suggested different patterns of inference relations between psychological antecedents and physiological consequences. So that these inference relation patterns can be understood, the process of bodily response to cognitive and affective activities in the mind must be illustrated before the psychophysiological measure is taken (Jennings, 1986a, b).

Plummer (1972) suggested seven criteria to determine the application of a measurement technique for consumer reaction to stimuli in marketing research. They include reliability, validity, sensitivity, independence of measures, comprehensiveness, relationship to other tests, and acceptability. Among the seven criteria, validity, independence of measures, and relationship to other tests are related to validity issues in terms of construct validity, discriminant validity, and convergent validity, whereas sensitivity, comprehensiveness, and acceptability are related to the applicability of a measure in marketing research. Therefore, marketing researchers need to examine the reliability, validity, and applicability of psychophysiological techniques before investigating consumers' cognitive and/or affective responses to marketing or advertising stimuli. In this study, each of the ten psychophysiological techniques is to be evaluated in terms of its validity, reliability, and applicability in marketing research.

1. Non hemispheric Brain Wave Analysis

Brain wave analysis examines different types of waves in the human brain (e.g., alpha waves vs. beta waves) to measure variations in the frequency of electrical brain activities (Young, 2002). The electroencephalograph (EEG) is the most frequently used measurement device for brain wave analysis in marketing research (see Appendix). Non hemispheric brain

wave analysis, which is a branch of brain wave analysis, may be applied to connect brain activity to consumers' cognitive (e.g., attention, memory) and affective (e.g., arousal, pleasure) changes in the brain (Klebba, 1985). In advertising research, nonhemispheric brain wave analysis was first used by Krugman (1971) in the investigation of consumers' responses to different advertisements. Since then, considerable effort has been made to further the study of consumer responses to advertisements by using EEG to measure brain activities (e.g., Alwitt, 1989; Young, 2002). Previous marketing studies using non hemispheric brain wave analysis have mainly focused on the investigation of consumers' immediate responses to variations in advertising, packaging, and branding (see Appendix).

Previous marketing studies found that cognitive information processing can indicate brain wave peaks (Young, 2002), but the concurrent validity of using brain waves to measure a particular affective response, such as arousal, was hardly established in non hemispheric brain wave analysis (see Appendix). Stewart and Furse (1982) considered nonhemispheric brain wave analysis a "straightforward indication of response to marketing stimuli" but a "less reliable measure of how the individual is responding to a specific stimulus than are measurements of more peripheral responses" (p. 21). Therefore, despite its easy applicability, non hemispheric brain wave analysis still remains somewhat unclear in terms of its validity and reliability. To address the validity and reliability issues in using this technique, the combination of brain wave measurement with peripheral response measurement (e.g., ANS and SNS measures) in marketing research was recommended (Stewart & Furse, 1982; Rossiter et al., 2001b).

2. Hemispheric Lateralization

Another branch of brain wave analysis is hemispheric lateralization. It does not examine the process of brain activity; instead, it examines the differences in the two brain hemispheres (left brain vs. right brain) when they respond to external stimuli (Young, 2002). Hansen (1981) and Weinstein (1982) applied the findings of hemispheric lateralization in psychophysiology research to the understanding of consumers in marketing research and suggested that the differences in hemispheric lateralization (e.g., information processing depending on right or left brain) influence the patterns of an individual's information acquisition and decision making.

Previous marketing studies have used EEG to measure hemispheric differences that are related to arousal and interest (e.g., Weinstein, Weinstein, & Drozdenko, 1984), pleasure (e.g., Cacioppo & Petty, 1982), memory (e.g., Appel, Weinstein, & Weinstein, 1979; Rothschild & Hyun, 1990), and information processing (e.g., Weinstein, Appel, & Weinstein, 1980; Rothschild et al., 1988). Rossiter et al. (2001a) used an evolutionary version of EEG, steady-state probe topography (SSPT), as the measurement device for brain activity. Using SSPT, which can offer fast and

accurate measurement of cortical activity in response to a visual stimuli sequence, Rossiter et al. (2001a) established that dynamic visual scenes are encoded into long-term memory in the left hemisphere.

It can be observed from the number of publications that research efforts on brain activity analysis have been invested somewhat more on hemispheric lateralization than non hemispheric brain wave analysis. In the meanwhile, inquiries about the validity and reliability of hemispheric lateralization in marketing and advertising research have never ceased. Skeptics asserted that Sperry's (1973) findings on hemispheric specialization, which were the cornerstones for hemispheric lateralization in marketing research, were not generalizable.[3] For example, Sperry's (1973) findings were not applicable to individuals with normal brain activity (Katz, 1983) or to left-handed individuals (Klebba, 1985). The explanatory power of hemispheric lateralization was also low because only less than 15 percent of hemispheric dominance could be explained (Klebba, 1985). In addition, it has not been found whether brain wave variations correspond to any particular psychological process (e.g., pleasure, arousal, or information processing), either cognitive or affective, in response to external stimuli (Stewart, 1985).

Another aspect of skepticism over validity and reliability lies in the measurement device. First, EEG and the SSPT can only monitor general brain activity in response to external stimuli as a whole. Previous research using these measurement techniques has not investigated which part of complex stimuli, such as a television commercial, induces the brain activity (Klebba, 1985; Crites & Aikman-Eckenrode, 2001). Second, experimental settings have significant influences on the results produced by an EEG. The results of hemispheric lateralization differ depending on the placement of electrodes (Klebba, 1985). Therefore, the validity and reliability of hemispheric lateralization are subject to experimental conditions, significantly restricting its applicability. These critics urge caution in future use of the hemispheric lateralization technique, and emphasize the need for the reinforcement of reliability and validity of the measure as well as more careful application of this technique in experiments.

3. Pupillary Response

Pupillary response measures physiological changes in an individual's pupil size (Blackwell, Hensel, & Sternthal, 1970). Early psychophysiological research on pupillary response focused on the temporary dilation of pupils in response to visual stimuli as an indicator of affective responses such as pleasure and arousal (Hess & Polt, 1960; Hess, 1965). Previous

[3] Researchers in support of hemispheric lateralization claimed that the EEG has sufficient psychophysiological basis to be applied in marketing research. For example, Weinstein, Drozdenko, and Weinstein (1984b) argued that, regardless of the percentage of brain activity explained, hemispheric lateralization research could document the fundamental differences between the hemispheres, and such differences exist in the normal brain.

marketing studies using the pupillary response technique were conducted, mostly in the 60s and early 70s, to evaluate the effectiveness of advertisements. Pupillary response has shown significant discriminatory power on the effectiveness of different advertising stimuli (e.g., Krugman, 1965; Van Bortel, 1968; Hess, 1968; Stafford, Birdwell, & Van Tassel, 1970).

Although pupillary response was considered useful and practical in terms of its applicability in measuring affective responses to advertising stimuli (Stewart & Furse, 1982), researchers have presented empirical challenges to the concurrent validity of the physiological measure in relation to the psychological mechanism. For example, there were questions about which psychological process was demonstrated by pupil dilation (e.g., Blackwell, Hensel, & Sternthal, 1970; Janisse, 1974; see Stewart & Furse, 1982, for a detailed review). Although pupillary response has been used as a measure of valence (i.e., pleasure), changes in an individual's pupil size can be a result of a number of psychological processes, including attention, arousal, pleasure, memory and information processing, and so on (Watson & Gatchel, 1979; Stewart & Furse, 1982). Thus, pupillary response does not merely indicate valence. Besides the validity problem, the reliability of pupillary response has not been examined in previous marketing research (see Appendix). This technique has not appeared in marketing publications after the 70s. However, the use of pupillary response in marketing research has great potential, such as the ability to measure mental activity associated with cognitive information processing or with responses to successive stimuli (Arch, 1979). For future research using pupillary response, it is necessary to specify the causal relationship between psychological processes (e.g., attention, pleasure, or information processing) and physiological indicators (pupil size) (Blackwell, Hensel, & Sternthal, 1970; Watson & Gatchel, 1979).

4. Electrodermal Analysis

Electrodermal activities can be measured by the amount of resistance or conductance of human skin to passing current (Watson & Gatchel, 1979). Psychophysiologists established that physiological arousal occurring in the sweat glands can reflect psychological activity, and thus changes in electrodermal activities in the sympathetic nervous system may be a result of interest, arousal, or pleasure (Klebba, 1985). Electrodermal activities can be monitored through either galvanic skin response (GSR) or skin conductance response (SCR). Galvanic skin response, which can be recorded by a galvanometer to assess the ability of the skin to conduct electricity, is more frequently used in published marketing studies (see Appendix). Skin conductance response can also be employed to monitor skin conductance (the reciprocal of skin resistance) by polygraphic recording (Klebba, 1985; Wiles & Cornwell, 1990). In marketing research, electrodermal activity has been intensively used to measure attention

(e.g., Vanden Abeele & MacLachlan, 1994a; Bolls, Muehling, & Yoon, 2003) and arousal (e.g., Groeppel-Klein & Baun, 2001; Bolls, Lang, & Potter, 2001), and also linked to anxiety and warmth as affective processes (e.g., Aaker, Stayman, & Hagerty, 1986; Stem & Bozman, 1988; Vanden Abeele & MacLachlan, 1994b).

Electrodermal response has been considered a reliable and valid measure of arousal (e.g., Kroeber-Riel, 1979; Klebba, 1985) and it can allow researchers to identify the magnitude of a response with considerable accuracy (Klebba, 1985). However, Vanden Abeele and MacLachlan (1994a) reported that electrodermal response was not valid in measuring attention. Electrodermal response is also not a valid indicator of warmth as an affective response to stimuli (Vanden Abeele & MacLachlan, 1994b). In addition, previous research has provided a number of caveats in applying the electrodermal technique. For example, electrode placement is critical to the accuracy of results because the results tend to be biased when the placement sites and environment are not carefully chosen, cleaned, and controlled (Stewart & Furse, 1982). Sensitivity to external influences needs to be better understood in order to make this psychophysiological technique applicable in experimental conditions. In addition, Cacioppo and Petty (1983) suggested that electrodermal activity should be measured at different times to address reliability issues.

5. Voice Pitch Analysis

Voice pitch analysis examines the fluctuations generated by vocal cords in human speech, which can indicate an individual's affective responses to external stimuli independent of the volume, content, and speed of the speech (Klebba, 1985). Relying on the findings from attitudinal research, voice pitch analysis (VOPAN) was developed by Brickman (1976, 1980) in the field of advertising research. Brickman (1980) claimed that voice pitch analysis is more valid, reliable, and sensitive than verbal measures in measuring consumers' attitude change. Beyond that, it has also demonstrated superior discriminatory power in actual purchase and advertising effectiveness studies (Brickman, 1976, 1980; Nelson & Schwartz, 1979). Another experimental study found that voice pitch level and range indicate a specific affective dimension—arousal (i.e., activation) (Backhaus, Meyer, & Stockert, 1985).

As noted by Klebba (1985), voice pitch analysis has at least two practical advantages over other psychophysiological techniques in marketing research. First, instead of using cumbersome equipment, the experimental procedure only requires oral responses and audio recording apparatus. Second, participants are least likely to be influenced by controlled and unnatural experimental settings because the recording apparatus is not apparent or interfering. However, Nighswonger and Martin (1981) questioned the validity of the technique in measuring affective changes,

especially arousal. They pointed out that affective changes may be reflected by voice pitch change, but the process of these simultaneous changes is unfounded from a psychophysiological perspective. Therefore, future studies using voice pitch analysis must establish evidence of concurrent validity. Nighswonger and Martin (1981) also suggested that voice pitch analysis combined with the response latency technique (measurement of the amount of time for deliberation) can be a more accurate and reliable measure of affective responses. Although marketing studies using voice pitch analysis can hardly be found since the 80s, Nighswonger and Martin's (1981) recommendations still provide useful guidelines for future research using this technique. Further, the ability to capture voice digitally and apply computerized analysis should revive this technique. For example, a computer-based software program, the Multi-Dimensional Voice Program (MDVP), can be used to generate a database consisting of tens of acoustic parameters, after respondents' voices are digitally recorded. Graphic comparisons on voice parameters can also be produced by computer.

6. Heart Rate Response

As a branch of cardiovascular analysis, heart rate response is usually measured by electrocardiogram (EKG), which monitors the electrical discharges associated with the muscle contraction of the heart (Wiles & Cornwell, 1990). Previous studies employed heart rate response to measure pleasant or unpleasant responses to external stimuli (e.g., Israel, 1969; Bolls, Lang, & Potter, 2001). However, Watson and Gatchel (1979) contended that, rather than being just a measurement of the directions of affect, heart rate response is also a valid and sensitive measure of one of the cognitive processes, attention, because heart rate is an important component of the psychophysiological attention mechanism. Watson and Gatchel's (1979) argument was supported by recent findings of Lang et al. (2002) and Bolls, Muehling, and Yoon (2003). Previous research also found that heart rate response is capable of predicting recall and memory (Lang et al., 2002; Bolls, Muehling, & Yoon, 2003). Besides its validity, heart rate response demonstrated high reliability over time (Lang et al., 2002). In addition, heart rate response is not influenced by environmental disturbances, showing its applicability in non-laboratory experimental settings (Watson & Gatchel, 1979).

Although heart rate response is a valid, reliable, and sensitive measure of several psychological processes, Watson and Gatchel (1979) noted that "it is difficult to formulate with any certainty generalizations about this physiological response during a number of psychological processes" (p. 22). This reveals a potential threat to concurrent validity. Researchers must be meticulous when explaining a particular psychological process by interpreting heart rate changes, because the changes may be evoked by multiple psychological processes.

7. Vascular Activity

Vascular activity, another branch of cardiovascular analysis, records changes in blood pressure, blood volume, or pulse volume (Bagozzi, 1991). Previous studies in the 80s used vascular activity to measure arousal in response to external stimuli (Frost & Stauffer, 1987; Sanbonmatsu & Kardes, 1988). Frost and Stauffer (1987) found that blood pulse volume and skin conductance response highly correlated with each other in measuring arousal. However, the validity and reliability of vascular activity in measuring arousal have not been assessed by previous studies. Like heart rate response, vascular activity may be a result of a number of psychological processes, including pleasure, arousal, and memory (Bagozzi, 1991; Brownley, Hurwitz, & Schneiderman, 2000). Future marketing research needs to address validity and reliability issues when using vascular activity to measure arousal and/or other psychological processes.

Compared with other psychophysiological techniques, vascular activity can be easily monitored and reported. For example, Sanbonmatsu and Kardes (1988) used a Pollenex blood pressure monitor to measure vascular activity. The measurement device is much less complex to handle than those used in other psychophysiological techniques. However, the auscultatory method of determining blood pressure used in Sanbonmatsu and Kardes's (1988) study, which utilizes a blood pressure cuff placed around a subject's arm, requires a careful plan on cuff size and placement of the machine to obtain accurate and reliable blood pressure measurement (Brownley, Hurwitz, & Schneiderman, 2000). To obtain valid and reliable data, future experimental research needs to pay great attention to these handling skills.

8. Facial Muscle Activity

Different from other involuntary psychophysiological measures, facial muscle activity is a voluntary physiological indicator generated by the somatic nervous system. Facial muscle activity is measured by electrical signals caused by the contraction of facial muscle fibers when the voltage is active from two electrodes placed on the face (Wiles & Cornwell, 1990). The electromyography (EMG) has been the most frequently used measurement device for facial muscle activity in marketing research (see Appendix). Wiles and Cornwell (1990) suggested that facial muscle activity be used to identify the directions of affective responses (i.e., pleasure vs. displeasure) to external stimuli.

Bolls, Lang, and Potter (2001) demonstrated the validity, reliability, and applicability of using facial muscle activity to measure the directions of affective responses (i.e., valence/ pleasure) to complex stimuli, such as radio advertisements. Documented by facial EMG data, the physiological reaction accompanied by positive affective response was robust across different stimuli (Bolls, Lang, & Potter, 2001). Facial muscle activity can

also allow researchers to precisely examine the effects of those complex stimuli that can result in non exclusively positive or negative affective responses (Bolls, Lang, & Potter, 2001). However, Bolls, Lang, and Potter (2001) warned that, in experiments using facial muscle activity, the electric signal produced by an EMG device can be influenced by participants' physical movements or bodily sensitivity. Accordingly, they suggested that future research using facial muscle activity in measuring the directions of affect should well disguise the experiment process and distract the participant during electrode placement.

9. Eye Movement Analysis

Eye movement is measured by recording either the number of fixations or dwell time of the eyes during an individual's exposure to external stimuli (Stewart & Furse, 1982). By examining the eye patterns on pickup and retention of information, researchers can identify the elements of a complex stimulus that receive voluntary (somatic) or involuntary (autonomic) attention (Stewart & Furse, 1982).

Eye movement analysis has been widely used in marketing studies from the early 70s to the present (see Appendix). In previous marketing research findings, eye movement has found to be related to attention (e.g., Bogard & Trolley, 1988; Lohse, 1997; Pieters, Rosbergen, & Wedel, 1999; Pieters & Wedel, 2004), memory (e.g. Krugman, 1971; Morrison & Dainhoff, 1972; Krugman et al., 1994; Wedel & Pieters, 2000), and information processing (e.g., King, 1972; Kroeber-Riel & Barton, 1980; Kroeber-Riel, 1984). However, as Kroeber-Riel (1979) pointed out, most previous studies using eye movement as a physiological measure have not established a psychological basis for the meaning of eye movements. Therefore, concurrent validity of the eye movement measure is questioned. Although some studies demonstrated high predictive power on recall and memory based on either dwell time (Krugman et al., 1994) or the number of fixations (Wedel & Pieters, 2000), Kroeber-Riel and Barton (1980) argued that the validity of eye movement as a predictor of recall and memory depends on the mediating role of cognitive learning. Pieters, Rosbergen, and Wedel (1999) also questioned the reliability of eye movement measures. They held that, although external disturbances to the experiment can be controlled, eye movement measures are not highly reliable because eye movement patterns can be influenced by subjects' excessive blinking or tear fluid. This restricts the opportunity of recruiting certain individuals with various eye problems for eye movement experiments in marketing research.

10. Brain Imaging Analysis

Brain imagining analysis has been intensively used in neuromarketing research, which relies on neuroscience technologies to investigate

individuals' brain activities in response to marketing and advertising stimuli. Neuroscience technologies that can be employed by brain imaging analysis in marketing research include Functional Magnetic Resonance Imaging (fMRI), Positron Emission Tomography (PET), and Magnetoencephalography (MEG) (Zaltman, 1997; Ambler et al., 2004). These relatively new techniques in marketing research monitor magnetic activity or radioactive patterns in the medial prefrontal cortex of the brain, and are able to provide high spatial resolution as well as temporal resolution that can document an individual's brain activities in response to non static stimuli (Rossiter et al., 2001a; Berthoz et al., 2002). Thus, these brain imaging techniques complement less precise brain activity measurement techniques, such as EEG (Rossiter et al., 2001a). Using the fMRI technique, marketing research has identified some of the cognitive activities in the brain, with implications for marketing. The left hemisphere of the brain is mainly involved with sequential ordering abilities and analytical abilities, whereas the right hemisphere is involved with the determination of meaning, nonverbal communications, and visual-spatial perceptions (Morgan & Reichert, 1999). Previous research suggested that brain imaging analysis can be used to investigate the presence or absence of pleasure and arousal (Novemsky & Kahneman, 2005), information processing patterns (Zaltman, 1997), and memory (Percy, 2004).

Brain imaging analysis techniques, such as fMRI, have been intensively used by marketing researchers and practitioners since the 90s in field investigations on product preferences, advertising effectiveness, brand loyalty, and so on (Carmichael, 2004; Helliker, 2006). It was considered more accurate in practice than the use of focus groups and surveys in explaining consumers' experiences and feelings (Kelly, 2002). It was also considered more effective than other psychophysiological techniques because the experimental process is not influenced by external disturbances and participant bias (Kelly, 2002). Although suspicions have been raised as to whether increased brain activity necessarily indicates affective changes as well as product preferences (Carmichael, 2004), recent research has provided some illuminative findings. By using fMRI to investigate respondents' brain reactions to brands, it was found that certain brain areas indicating pleasure, self-identification, and rewards were evoked by a well-known brand, whereas the parts in the brain indicating displeasure and memory were evoked by an unfamiliar brand (Helliker, 2006).

In neuroeconomics research that investigates the mechanism of the brain in economics-related decision-making process, the validity and reliability of brain imaging analysis has been demonstrated in measuring both cognitive and affective responses to stimuli (e.g., Montague & Berns, 2002; McClure et al., 2004). Based on brain activity in the prefrontal cortex monitored by brain imaging analysis, cognitive and affective responses to the economic environment can be depicted and then used to predict

economic decision-making and behavioral consequences (McClure et al., 2004). Using fMRI, McClure et al. (2004) found that the hippocampus and dorsolateral prefrontal cortex are the main brain areas that indicate affective brain activities, which, together with cognitive brain activities indicated in other brain areas, helped to explain subjects' brand preferences. Recent research conducted by Knutson and Peterson (2005) found that the anticipation of increasing monetary gains activates a subcortical region of the ventral striaum, accompanied by increased arousal and pleasure. Therefore, the brain imaging analysis technique in marketing research has sufficient psychophysiological basis for the interpretation of both cognitive and affective responses to marketing stimuli.

Nonetheless, brain imaging analysis has been increasingly challenged from an ethical perspective, with reasons such as invasion of privacy and the potential for mind control (Thompson, 2003; Wahlberg, 2004). Current neuromarketing research focuses on the use of the Zaltman Metaphor Elicitation Technique (ZMET) to investigate the unconscious of consumers (e.g., Coulter, Zaltman, & Coulter, 2001; Christensen & Olson, 2002; Lee et al., 2003). ZMET is not a psyshophysiological technique. This survey technique is more naturalistic than experimental brain imaging analysis, and thus ethical problems restricting the applicability of brain imaging analysis can be avoided. However, the use of experimental brain imaging analysis should not be discouraged. When brain imaging analysis is used in future marketing research, necessary steps must be taken to ensure that human subjects are well protected and potential ethical issues are resolved.

CONCLUSION

On the basis of the discussion above, a summary of the ten psychophysiological techniques used in marketing research is provided in Table 2.

Based on the summary, a psychophysiology framework in marketing research is given in Figure 1. This psychophysiology framework can be used for the purpose of analyzing different psychological antecedents and corresponding physiological consequences. The framework is presented in a Stimulus-Organism-Response (S-O-R) model from environmental psychology to explain the impact of external stimuli on consumer response (Mehrabian & Russell, 1974; Eroglu, Machleit, & Davis, 2001). According to the S-O-R paradigm, the environment contains stimuli that can influence consumers' internal organism, which in turn influences consumers' behavioral outcomes. In marketing research, the psychophysiological process can be better understood by analyzing consumers' internal organism. The relationship between psychological antecedents and physiological consequences presented in the internal organism extends Bagozzi's (1991) psychophysiological relationship model and depicts the detailed patterns of the psychological processes and

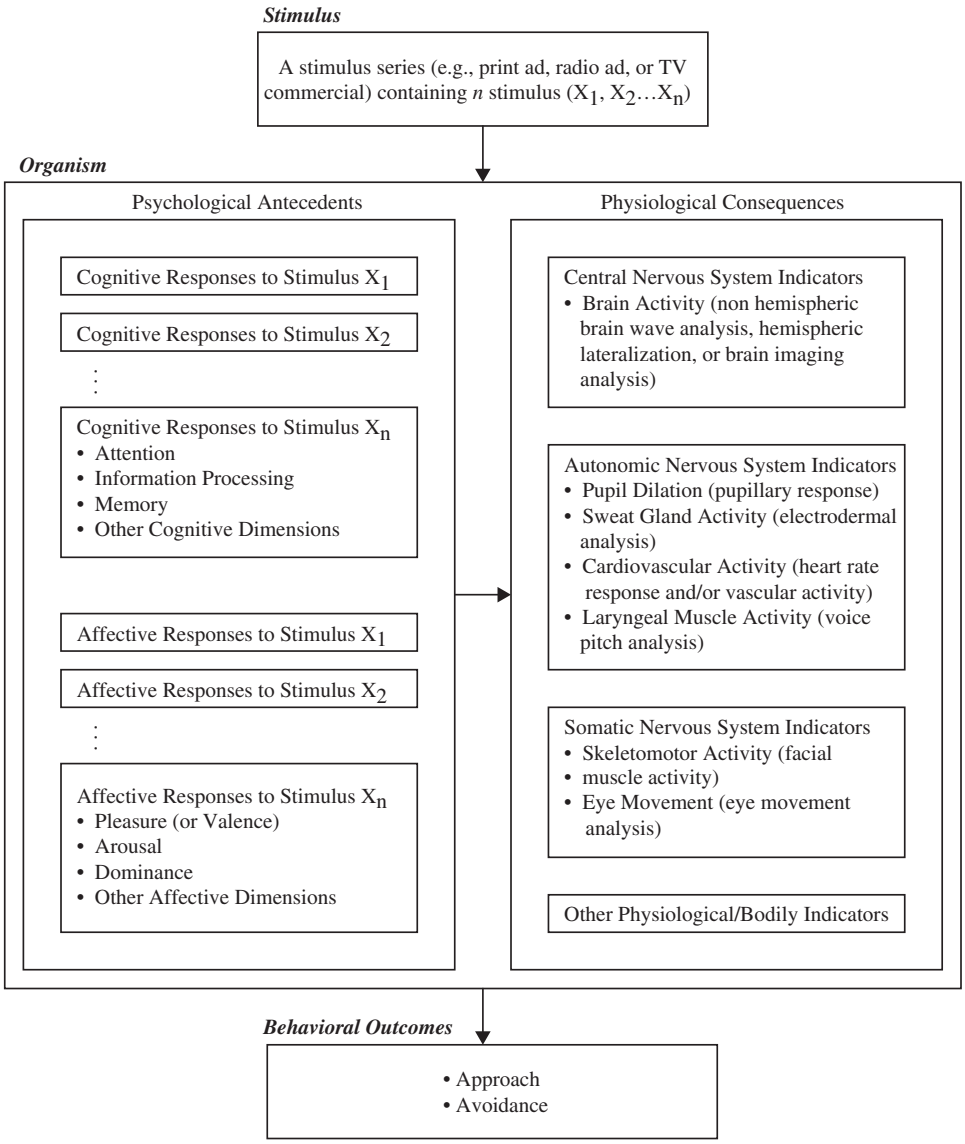
Table 2. Summary of Psychophysiological Techniques in Marketing Research.

Measure	Physiological Indicator [Measurement Device]	Suggested Psychological Antecedents	Validity	Reliability	Applicability
Non- hemispheric Brain Wave Analysis	Variations in the frequency of electrical activity in the brain [EEG or SSPT]	• Pleasure • Arousal • Attention • Memory • Information Processing	• Valid measure for cognitive information processing	• Less reliable than ANS and SNS measures	• Not applicable to complex stimuli • Results influenced by experimental settings
Hemispheric Lateralization	Differences of electrical activity in two brain hemispheres [EEG or SSPT]	• Pleasure • Arousal • Memory • Information Processing	• Lack generalizability • Low explanatory power	• Reliability influenced by experimental conditions	• Not applicable to complex stimuli • Results influenced by experimental settings
Pupillary Response	Temporary changes in pupil size [Pupillometrics]	• Pleasure • Arousal • Attention • Memory • Information Processing	• Lack of validity because of multiple psychological antecedents	• Not assessed	• Robust to environmental disturbances
Electrodermal Analysis	Amount of resistance or conductance to passing current in human skin [Galvanometer or Polygraphic Recorder]	• Arousal	• Valid measure for arousal and pleasure • Not valid in measuring attention or warmth	• Reliable measure for arousal and pleasure	• Results influenced by experimental settings
Voice Pitch Analysis	Fluctuations in speech patterns [Audio-Adapted Computer Equipment]	• Arousal	• Lack of concurrent validity	• Not assessed	• Easy procedure and simple device • Results not influenced by experimental settings

(*Continued*)

Table 2. (continued)

Measure	Physiological Indicator [Measurement Device]	Suggested Psychological Antecedents	Validity	Reliability	Applicability
Heart Rate Response	Electrical discharges associated with heart muscle contraction [EKG]	• Pleasure • Attention • Memory	• Valid measure for attention	• Reliable measure for attention	• Results not influenced by external disturbances
Vascular Activity	Variations in blood pressure or blood volume [Blood Pressure Monitor, Ultrasonography, or Plethymo-graphy]	• Pleasure • Arousal • Memory	• Lack of validity because of multiple psychological antecedents	• Not assessed	• Results influenced by experimental settings
Facial Muscle Activity	Electrical contraction of facial muscle fibers [EMG]	• Pleasure	• Valid measure for valence (pleasure)	• Reliable measure for valence (pleasure)	• Results influenced by participants' sensitivity
Eye Movement Analysis	Number of eye fixations and/or dwell time [Eye-Tracking Equipment]	• Attention • Memory • Information Processing	• Validity in measuring memory depends on cognitive learning	• Not reliable	• Results depending on participants' eye conditions
Brain Imaging Analysis	Changes in chemical composition or changes in the flow of fluids in the brain [fMRI, PET, or MEG]	• Pleasure • Arousal • Memory • Information Processing	• Valid measure for cognitive and affective responses	• Reliable measure for cognitive and affective responses	• Ethical barriers such as invasion of privacy • High cost



The psychophysiology framework is based on Bagozzi's (1991) psychophysiology relationship framework and Mehrabian and Russell's (1974) Stimuli-Organism-Response paradigm.

Figure 1. Psychophysiology framework in marketing research.

physiological indicators. The psychophysiology framework reflects the unity of body and mind (Zaltman, 2003) and the complex nature of the psychophysiological mechanism (Bagozzi, 1991; Cacioppo, Tassinary, & Berntson, 2000).

An experimental study in marketing using psychophysiological techniques usually starts with an intention to examine consumers' cognitive and/or affective processes in response to prefabricated marketing stimuli. In experimental studies, these cognitive and/or affective processes,

separately or jointly, serve as psychological antecedents to a variety of physiological consequences produced by the human nervous system. The physiological consequences may include CNS indicators and peripheral nervous system (ANS and SNS) indicators. The ANS indicators, which regulate organ functions, are under involuntary control, whereas the SNS indicators, which regulate muscle functions, are under voluntary control. Ideally, by measuring one or a number of physiological change(s), researchers are able to identify the changes in an individual's cognitive and/or affective processes.

However, as described in the framework, the psychophysiological process is more complex than a one-to-one inference relationship between a single psychological antecedent and a single physiological consequence (Bagozzi, 1991). Several noteworthy findings can be disclosed. First, a physiological change can be accompanied by a number of simultaneous or sequential cognitive and/or affective processes. These psychological processes usually co-exist when an individual reacts to certain stimuli. As noted previously (e.g., Klebba, 1985; Wiles & Cornwell, 1990), it is crucial for researchers to establish that a physiological measure indicates the particular psychological process that it is supposed to indicate. Second, a particular psychological antecedent can result in a number of physiological consequences. A combination of different physiological measures, such as CNS with peripheral ANS or SNS measures, can offer cross-validation for the effects of external stimuli on consumers' psychological responses (Stewart & Furse, 1982). Third, marketing and advertising research usually investigate a stimulus series, such as media ads or TV commercials, that consist of an unknown number of elements in the stimuli (Crites & Aikman-Echenrode, 2001). The particular stimulus or portion of stimuli to which the psychological processes respond was usually not identified in previous studies. The explanatory or discriminatory power of psychophysiological measures on the effectiveness of media or stimuli demonstrated is questionable if researchers cannot identify the particular stimulus in a stimuli set to which a psychological process corresponds.

FUTURE RESEARCH RECOMMENDATIONS

This study provides a descriptive review of major psychophysiological techniques used in marketing research and offers some insights in appropriately applying these techniques in future marketing research. In addition to the recommendation of careful examination of the validity and reliability issues of psychophysiological measures, future research recommendations are made in the following areas.

Dimensionality of Particular Psychological Response. Future research in investigating the relationships between psychological

antecedents and physiological consequences may focus on exploring the dimensionality of a particular psychological process and using a number of physiological measures to measure different dimensions of the psychological process. For example, arousal was suggested to be a multidimensional affective state (Thayer, 1978; Stewart & Furse, 1982; LaTour, 1990). Thayer (1978) suggested that physiological measures, such as brain activity, pupil dilation, and heart rate, reflect different aspects of arousal. Thus, a single physiological measure may not be valid to measure arousal because of other unmeasured dimensions. The theoretical framework between the multiple dimensions of a psychological response and the corresponding multiple physiological measures needs to be explored in future research.

Sequential Issues in Cognitive and Affective Responses. Further investigation of the relationships between psychological antecedents and physiological consequences may also focus on exploring the complex sequence of the effects of external stimuli. An individual's cognitive and affective responses to stimuli may occur in sequence. DeVoe's (1956) hierarchy of effects model for advertising effectiveness described such a sequence: attention → interest → desire → action. Lavidge and Steiner's (1961) hierarchy of effects model in examining advertising effectiveness contended that consumers follow four stages in response to stimuli: attention → cognition → affect → conation. Bagozzi (1991) suggested that psychophysiological measures can be used to investigate such a sequential process in response to marketing stimuli: cogniton → arousal → attitude change → behavior. However, the hierarchy of effects may vary because of high or low involvement (Petty, Cacioppo, & Schumann, 1983). Therefore, future research combining temporal variations of different physiological indicators during an individual's exposure to marketing stimuli may offer great value in assessing the sequence of an individual's psychological process in response to marketing stimuli in different situations.

Triangulation of Verbal and Psychophysiological Measures. Although psychophysiological measures have several advantages over verbal measures, researchers should be aware that experimental studies in marketing using psychophysiological techniques may involve various validity, reliability, and applicability problems. For example, participant characteristics or external disturbances can bias the physiological data. In certain situations, threats to validity and reliability cannot be well controlled. For validation purposes, researchers may combine a verbal measure and psychophysiological measure(s) to examine a particular response to stimuli. Psychophysiological measures combined with verbal measures can also help to control the bias caused by participant characteristics or environmental disturbances (Wiles & Cornwell, 1990). Future research may also examine the differences in consumers' responses obtained from verbal and psychophysiological measures in the study of the unconscious of consumers.

Application of New Equipment and Technologies. Rapid technological evolution enables marketing researchers to use more advanced equipment to conduct psychophysiological measurements. For example, researchers usually have to visually examine brain wave patterns taken by EEG, but an extension of EEG, which is called Quantitative EEG (qEEG), is able to help researchers conduct brain wave mapping and statistical analyses by computer. Using computer-aided qEEG, future marketing research in non hemispheric brain wave analysis or hemispheric lateralization may aim to identify the relationships between psychological processes and unseen patterns of brain waves.

New Psychophysiological Techniques in Marketing Research. In this study, ten psychophysiological techniques that have been used in marketing research are discussed. Future research may incorporate other psychophysiological techniques into marketing research. For example, in the gastrointestinal system, the gastric tract, which is monitored by the electrogastrogram (EGG), can be linked to emotions such as stress and disgust (Stern, Koch, & Muth, 2000). In the respiratory system, breathing patterns documented by oxygen consumption (ml/min) or alveolar ventilation (l/min) can indicate a number of affective processes, such as arousal, anger, or stress (Harver & Lorig, 2000). Previous research also suggested that the reactions in the sexual response system indicate sexual arousal in the mind, and these reactions can be measured by a number of psychophysiological techniques (Zuckerman, 1972; Geer & Janssen, 2000).

In closing, despite certain difficulties, psychophysiological techniques offer a number of advantages over behavioral and verbal measures. With new technologies being made available, the potential of psychophysiological techniques for further research is vast.

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Appendix: Summaries of Marketing Studies Using Psychophysiological Techniques.

Article Name	Research Question(s)	Reliability of Measure	Validity of Measure	Findings
Non hemispheric Brain Wave Analysis				
Krugman, 1971	Effects of TV ads and print ads on consumers' brain activity	Not discussed	Predictive validity established	TV ads are more effective than print ads because consumers' mode of brain wave response differs more between print and television than it does to content differences within the ads.
Weinstein, Drozdenko, & Weinstein, 1984a	Relationship between brain response and purchase behavior	Not discussed	Convergent and predictive validity established	Brain response is positively associated with the propensity of purchase.
Rothschild et al., 1986	Relationship between EEG activities and learning/affect	Not discussed	Not discussed	EEG patterns are correlated with learning and affect at different stages of a commercial.
Alwitt, 1989	TV commercial and brain waves in different periods	Not discussed	Not discussed	Certain elements in the TV commercial and brain waves are first negatively related and then positive related.
Young, 2002	Identification of potential branding moments in TV commercials	Not discussed	Content, convergent, and concurrent validity established	Peak moments of brain activity are identified with semantic information content, whereas the visuals in commercials are associated with aesthetic content.
Hemispheric Lateralization				
Appel, Weinstein, & Weinstein, 1979	Recall of ads by left and right hemispheres	Not discussed	Content and concurrent validity established	Recall is positively associated with brain activity in both left and right hemispheres.
Weinstein, Appel, & Weinstein, 1980	Brain activities in left and right hemispheres in response to ads	Not discussed	Content validity established	Print ads are positively associated with left-brain activity and TV ads are positively associated with right-brain activity. Print ads create greater brain activity than TV ads.

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Appendix: (continued)

Article Name	Research Question(s)	Reliability of Measure	Validity of Measure	Findings
Cacioppo & Petty, 1982	Hemispheric differences in affective responses	Not discussed	Content and concurrent validity established	Subjects with more right hemispheric activity have more affective response to stimuli.
Weinstein, Weinstein, & Drozdenko, 1984	Hemispheric differences in interest and arousal	Not discussed	Content and concurrent validity established	Commercials classified as emotional are associated with right hemisphere, whereas commercials classified as logical are associated with left hemisphere.
Bogart & Tolley, 1988	Patterns of brain activity and contents of ads	Not discussed	Content and concurrent validity established	The arousal patterns produced by the ad in the left and right hemispheres are congruent, showing thinking and feeling at the same time.
Rothschild et al., 1988	Hemispheric differences of information processing on TV commercials	Robust across participants; Test-retest reliability demonstrated	Content and predictive validity established	Right hemisphere is more related to visual/music/abstract cues, and left hemisphere is more related to verbal/concrete cues.
Rothschild & Hyun, 1990	Hemispheric laterality and memory of simple stimuli	Not discussed	Content validity established	Hemispheric laterality covaries with memory of the stimuli. Right hemisphere dominates the initial period of exposure and left hemisphere dominates the following periods.
Rossiter et al., 2001a	Visual recognition patterns on TV commercials	Not discussed	Content, concurrent, and predictive validity established	Encoding of dynamic visual scenes into long-term memory takes place in the left hemisphere.
Pupillary Response				
Krugman, 1964	Pupillary response, verbal response, and volume of sales in measuring advertising effectiveness	Reliability questioned because of small magnitude of changes	Content and predictive validity established	The correlation between pupillary response and sales is larger than that between verbal response and sales.

Krugman, 1965	Pupillary response and verbal response in measuring advertising effectiveness	Not discussed	Predictive validity established	Pupillary response has significant discriminatory power between different commercials, but verbal response does not.
Krugman, 1966	Consumer responses to package designs	Not discussed	Content validity established	Whites and blacks differ in their preferences of package designs.
Halpern 1967	Pupillary response patterns before and after explanation of the stimuli	Not discussed	Content and predictive validity established	Pupillary response has significant discriminatory power in before-and-after experiments.
Van Bortel, 1968	Pupil dilation under initial impact, persuasion, and sales leads	Not discussed	Content and predictive validity established	Pupillary response has significant discriminatory power in the differences of sales leads, but not in the amount of differences in sales.
Hess, 1968	Pupillary response to designs, types of ads, and products	Not discussed	Content and predictive validity established	Pupillary response is positively associated with actual sale. Pupillary response has significant discriminatory power between print and TV ads.
Stafford, Birdwell, & Van Tassel, 1970	Pupillary response in measuring affect	Not discussed	Content and predictive validity established	Pupillary response has significant discriminatory power between stimulus ads.
King, 1972	Relationship between pupil dilation and message appeal	Not discussed	Content and predictive validity established	Enlarged pupil size indicates favorable attitudes and consumers' interests.
Electrodermal Analysis				
Kohan, 1968	Galvanic skin response and verbal response in measuring advertising effectiveness	Not discussed	Convergent and predictive validity established	Differences between galvanic skin response and verbal response are not significant.
Belch et al., 1982	Psychological and physiological responses to sex in ads	Not discussed	Predictive validity established	Nudity and suggestiveness elicit skin reactions, and the cognitive and affective responses associated with these reactions vary by gender.
Kilbourne, Painton, & Ridley, 1985	Effectiveness of sexual embedding in advertising	Not discussed	Predictive validity established	Sexual embedding is effective in increasing electrodermal activities in response to ads.

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Appendix: (continued)

Article Name	Research Question(s)	Reliability of Measure	Validity of Measure	Findings
Aaker, Stayman, & Hagerty, 1986	Galvanic skin response and warmth in advertising	Test-retest reliability demonstrated	Content, convergent, and predictive validity established	Galvanic skin response is positively associated with warmth level in advertising.
Frost & Stauffer, 1987	Arousal in response to media violence	Not discussed	Content, convergent, and concurrent validity established	Skin conductance response and blood pulse volume are both positively associated with arousal levels.
Stem and Bozman 1988	Methods in reducing respondent anxiety	Not discussed	Content validity established	Significant differences in anxiety exist between question methods.
Stayman & Aaker, 1993	Warmth, liking, humor, irritation, and galvanic skin response	Test-retest reliability demonstrated	Content, convergent, and predictive validity established	Galvanic skin response is positively associated with warmth level and humor.
Vanden Abeele & MacLachlan, 1994a	Reliability and validity of galvanic skin response to dynamic stimuli	Low reliability based on split sample correlations	Content validity established; convergent validity suspected	Galvanic skin response is reliable to measure attention when adequate sample size was used, but its validity in measuring attention is questioned.
Vanden Abeele & MacLachlan, 1994b	Emotional warmth in response to TV commercials	Low reliability based on split sample correlations	Content and discriminant validity established	Galvanic skin response and the warmth measure are correlated, but they measure different affective responses.
LaBarbera & Tucciarone, 1995	Galvanic skin response as a measure of affect	Test-retest reliability demonstrated	Content and predictive validity established	Galvanic skin response has higher predictive validity for sales than verbal measures.
Bagozzi, 1996	Influence of arousal on the halo effect for beliefs	Not discussed	Not discussed	Arousal increases the halo effect for positive beliefs, and decreases the halo effect for negative beliefs.
Groeppel-Klein & Baun, 2001	Visual merchandising, store design, and consumer arousal	Not discussed	Content and concurrent validity established	Electrodermal response is a valid and sensitive indicator of arousal.
Bolls, Lang, & Potter, 2001	Validity of facial muscle activity in measuring valence	Not discussed	Content and concurrent validity established	Consumers are significantly more aroused during positive ads than during negative ads.

Bolls, Muehling, & Yoon, 2003	Effects of visual cuts in a commercial on attention and recall	Not discussed	Content and predictive validity established	Fast-paced ads have a positive effect on viewers' involuntary attention. Enhanced involuntary attention is directed towards the non-claim elements of an ad.
Sundar & Kalyanaraman, 2004	Effects of animation speed on arousal, recall, and intention	Not discussed	Not discussed	Fast animation speeds attract attention and elicit greater arousal, whereas slow animation speeds enhance the overall appeal of a Web site.
Porter et al., 2006	Programming context and processing of fear-appeal message	Not discussed	Content, discriminant, convergent, and predictive validity established	Positive programming context activates a viewer's appetitive motivational system, whereas negative programming context activates a viewer's aversive motivational system.
Voice Pitch Analysis				
Brickman, 1976	Consumers' affective responses to product attributes	Not discussed	Predictive validity established	Voice pitch is positively associated with consumers' actual purchase after commercials are watched.
Nelson & Schwartz, 1979	Consumers' attitudes toward TV commercials	High reliability coefficient	Predictive validity established	Voice pitch analysis predicts brand usage more accurately than verbal measures.
Brickman, 1980	Consumers' attitudes toward brands and purchase	Test-retest reliability demonstrated	Content, convergent, and predictive validity established	Voice pitch analysis is a more reliable, valid, and sensitive measure than verbal measures in predicting actual purchase.
Backhaus, Meyer, & Stockert, 1985	Voice pitch patterns and arousal	Not discussed	Concurrent validity established	Voice pitch level and voice pitch range indicate arousal level.
Heart Rate Response				
Lang, 1990	Effects of structural features and emotional content in commercials on attention and arousal	Not discussed	Content validity established	Structural features in commercials elicit involuntary physiological attention. Emotional content in commercials intensifies involuntary physiological attention through the mediation of arousal.
Bolls, Lang, & Potter, 2001	Validity of facial muscle activity in measuring valence	Not discussed	Content and predictive validity established	Negative messages receive more attention than positive messages.

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Article Name	Research Question(s)	Reliability of Measure	Validity of Measure	Findings
Lang et al., 2002	Effects of Web structural features on attention and memory	Test-retest reliability demonstrated	Content and predictive validity established	Plain text, boxed text, and non animated banner ads do not elicit cardia orienting, but warnings and animated banner ads elicit orienting.
Bolls, Muehling, & Yoon, 2003	Effects of visual cuts in a commercial on attention and recall	Not discussed	Content and predictive validity established	Fast-paced ads have a positive effect on viewers' involuntary attention. Enhanced involuntary attention is directed towards the non-claim elements of an ad.
Smith & Dickhaut, 2005	Effects of emotion on price setting behavior	Not discussed	Not discussed	Emotional intensity affects price setting behavior. The cardiac system is involved with processing economic events.
Vascular Activity				
Frost & Stauffer, 1987	Arousal level in response to media violence	Not discussed	Content and convergent validity established	Skin conductance response and blood pulse volume are both positively associated with arousal level.
Sanbonmatsu & Kardes, 1988	Effects of arousal on information processing and persuasion	Not discussed	Content and predictive validity established	Peripheral cue has a stronger influence on brand attitudes under high than under moderate arousal, whereas central cue has a greater impact under moderate than under high arousal.
Facial Muscle Activity				
Cacioppo & Petty, 1989	Affective responses to products	Not discussed	Content and concurrent validity established	Facial muscle activity indicates positive or negative emotions of an individual toward a product.
Hazlett & Hazlett, 1999	Affective responses to TV commercials using self-report and facial muscle activity measures	Not discussed	Concurrent and predictive validity established	Facial muscle activity is a more sensitive discriminator between commercials than self-report, and is more strongly related to recall.

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Bolls, Lang, & Potter, 2001	Validity of facial muscle activity in measuring valence	Not discussed	Content, convergent, and predictive validity established	The validity of facial muscle activity in measuring valence resulted from media messages is demonstrated.
Porter et al., 2006	Programming context and processing of fear-appeal message	Not discussed	Content, discriminant, convergent, and predictive validity established	Positive programming context activates a viewer's appetitive motivational system, whereas negative programming context activates a viewer's aversive motivational system.
Eye Movement Analysis				
Krugman, 1971	Effects of advertising stimuli on recall	Not discussed	Content, concurrent, and predictive validity established	Recall is positively associated with eye movements. Less-scanned ads are better recalled.
Morrison & Dainoff, 1972	Recall of ads and individuals' time looking at magazines	Not discussed	Content and predictive validity established	Recall of ads is positively associated with individuals' looking time on magazines.
King, 1972	Eye movement and message appeal	Not discussed	Content and concurrent validity established	Rational and objective thoughts are reinforced when eye direction is right, whereas emotional and subjective thoughts are reinforced when eye direction is left.
Treistman & Gregg, 1979	Eye movements, verbal measures, and sales in measuring advertising effectiveness	Not discussed	Content, convergent, and predictive validity established	Eye movement has superior discriminatory power in consumers' reactions to different ads.
Kroeber-Riel & Barton, 1980	Eye movement and recognition data in measuring	Not discussed advertising effectiveness	Validity of eye movement depending on cognitive learning	Information acquisition is better for textual elements positioned in the upper half of an ad. Memory performance is positively associated with the number of eye fixations.
Kroeber-Riel, 1984	Effects of emotional pictorial elements in the ad on information processing	Not discussed	Content and concurrent validity established	Eye movement indicates the extent of the cognitive activities as well as the selective information acquisition and processing.
Bogart & Tolley, 1988	Patterns of brain activity and contents of ads	Not discussed	Content validity established	Ads larger than half a page receive more fixations and multiple fixations.

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Appendix: (continued)

Article Name	Research Question(s)	Reliability of Measure	Validity of Measure	Findings
Krugman et al., 1994	Effects of cautionary notices in ads on recall	Not discussed	Content, concurrent, and predictive validity established	Dwell time is positively associated with content recall. The time spent looking at the warning is positively related to recall of the message.
Russo & Leclerc, 1994	Consumers' choice process by using eye fixations	Not discussed	Content validity established	The choice process has several distinctive stages due to eye fixations for different purposes.
Lohse, 1997	Factors influencing consumer attention to yellow pages ads	Not discussed	Content validity established	Subjects are more likely to notice larger ads and ads near the heading. Color and graphics have significant effects on viewing time.
Rosbergen, Pieters, & Wedel, 1997	Effects of physical ad properties on attention	Test-retest reliability demonstrated	Content validity established	Consumers exhibit distinct patterns of visual attention, product involvement, brand attitude, and advertising recall.
Janiszewski, 1998	Information gathering and retention during exploratory search	Not discussed	Not discussed	Consumers engaged in exploratory search spend less attention on areas surrounded by material generating a strong demand for attention.
Fox et al., 1998	Effects of product warnings on attention	Not discussed	Content validity established	Similar warnings can produce different lengths of dwell time, depending on the product and message.
Pieters, Rosbergen, & Wedel, 1999	Consumers' visual attention during repeated exposures to print ads	Reliability was questioned because of excessive blinking or tear	Content validity established	Attention duration decreases significantly across advertising repetitions. Attentional scanpaths remain constant across advertising repetitions.
Pieters & Warlop, 1999	Effects of time pressure and task motivation on consumers' visual attention	Not discussed	Content and predictive validity established	Increased time pressure leads to acceleration, more filtration, and more information acquisition, whereas increased task motivation leads to deceleration, less filtration, and less information acquisition.

Wedel & Pieters, 2000	Eye fixations on print ads and memory of advertised brands	Not discussed	Content and predictive validity established	Eye fixations to the pictorial and the brand are positively associated with brand memory.
Garcia, Ponsoda, & Estebaranz, 2000	Effects of involvement and position of illustration on attention	Not discussed	Content validity established	Position of the illustration has no effect on attention when involvement is high, but it does when involvement is low. Interaction effect exists between position of the illustration and involvement.
Dreze & Hussherr, 2003	Attention, recall, and cognition of banner advertising	Not discussed	Content validity established	Viewers intend to avoid banners, but location, size, and zone content predict whether a banner attracts attention.
Pieters & Wedel, 2004	Effects of brand, pictorial, and text on attention of ads	Not discussed	Content and predictive validity established	Pictorial element is superior in capturing attention, independent of its size. Text element best captures attention in direct proportion to its surface size. Brand element most effectively transfers attention to the other elements.
Brain Imaging Analysis				
Ambler et al., 2004	Brain activation differences in brand choice and height discrimination	Not discussed	Not discussed	Brain activation in brand choice differs from that for height discrimination, and choice times are faster when one brand is more familiar.
Rustichini et al., 2005	Consumer choices between certain, risky, and ambiguous lotteries	Not discussed	Content validity established	Brain activation in certain regions differs when subjects have different choices. Subjects estimate the value of the lotteries and the difficulty to make a choice during lotteries.
Knutson & Peterson, 2005	Brain activation during anticipation of gain	Not discussed	Content and concurrent validity established	Anticipation of increasing monetary gains activates a subcortical region of the ventral striatum, whereas anticipation of monetary losses does not.

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Article Name	Research Question(s)	Reliability of Measure	Validity of Measure	Findings
Bhatt & Camerer, 2005	Brain activity during decision making and belief expression	Not discussed	Content validity established	Little difference is found in brain activity across choice and belief tasks. Actual earnings from choices and beliefs are negatively correlated with activity in the insula, suggesting poor strategic thinkers are self-focused.
Yoon et al., 2006	Semantic judgments about products and persons processed in the brain	Not discussed	Content validity established	Judgment about persons causes greater activation in the medial prefrontal cortex regions, whereas judgment about products causes greater activation in the left inferi or prefrontal cortex, an area for object processing.