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Paige, Stephen R.

SLOW BRAIN POTENTIAL MANIFESTATIONS OF THE ORIENTING REFLEX: EFFECTS OF INTENSITY, PROBABILITY, DEGREE AND DIRECTION OF CHANGE

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by

Stephen R. Paige

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TITLE

Slow brain potential manifestations of the orienting reflex:

Effects of intensity, probability, degree and direction of change

BY

Stephen R. Paige

APPROVED	DATE
John W. Rohrbaugh, Ph.D.	
Shelton E. Hendricks, Ph.D.	
Evan L. Brown, Ph.D.	
Donald Jensen, Ph.D.	
Jorge Rodriguez-Sierra, Ph.D.	

SUPERVISORY COMMITTEE

GRADUATE COLLEGE **UNIVERSITY OF NEBRASKA**

SLOW BRAIN POTENTIAL MANIFESTATIONS OF THE ORIENTING REFLEX: EFFECTS OF INTENSITY, PROBABILITY, DEGREE AND DIRECTION OF CHANGE

Stephen R. Paige, Ph.D.

University of Nebraska, 1985

Adviser: John W. Rohrbaugh, Ph.D.

Slow wave components of the event-related brain potential (ERP) were investigated as possible indicators of the brief, transient period of involuntary attention known as the orienting reflex (OR). Convergent information was also derived from concomitant heart rate (HR) changes. Subjects were asked to count 10 series of 200 ms, 1000 Hz tone pips at 20, 40, or 60 dB SL. In some series the intensity was held constant and in other series the intensity varied unpredictably. Responses were studied as functions of stimulus intensity, probability, degree and direction of intensity change between different stimuli within a series.

Since a within-subjects design was used and responses were averaged over trials, it was not possible to assess for habituation effects. However, the averaged HR responses consistently showed a brief initial deceleration that has traditionally been interpreted as an indicator of the OR. HR deceleration was greater for an intensity increase than a decrease, but was not significantly related to the degree

of change.

The ERP responses over the various conditions showed a consistent structure, including P300 and early and late O wave components. P300 amplitude was significantly responsive to the effects of stimulus intensity. P300 amplitude was also greater for an intensity increase than a decrease, but was not reliably related to the degree of intensity change. However, P300 did reflect stimulus processing, in that significantly larger P300 amplitudes were elicited by rare than by frequent stimuli.

O wave amplitudes were consistent with Sokolov's (1963) stimulus comparator theory of OR elicitation. The O waves were elicited by decreases as well as increases in stimulus intensity in proportion to the degree of intensity change. These results are discussed in terms of their implications for the existence of a neuronal model consisting of expected stimulations. An interpretation of the O waves as reflecting the detection of stimulus change is proposed.

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List of Acronyms

BPM	beats per minute
CNS	central nervous system
CNV	contingent negative variation
CS	conditional stimulus
DR	defensive reflex
EEG	electroencephalogram
EKG	electrocardiogram
EOG	electrooculogram
EP	evoked potential
ERP	event-related potential
GSR	galvanic skin response
HR	heart rate
ISI	interstimulus interval
LNC	late negative component
LPC	late positive component
MRF	mesencephalic reticular formation
MTFCS	mediothalamic frontocortical system
OR	orienting reflex
SCR	skin conductance response
SNW	slow negative wave
SP	slow potential
SPL	sound pressure level
SPW	slow positive wave
UCS	unconditional stimulus

Introduction and Literature Review

The orienting reflex (OR) as described by Pavlov (1927) has maintained an honored place in the study of learning and cognitive functioning. Pavlov discovered the OR within the context of his classical conditioning experiments with dogs, where he found the stimuli he chose:

> The bells, lights, metronomes, rotating discs, rattles, whirligigs, vibrators, and so forth--all tended to elicit an observable attentional reaction in his animals even before the conditioning procedure began; indeed, Pavlov found quite early in his investigations that only stimuli that evoked these initial reactions would serve effectively as conditional stimuli (although the reactions had to cease--that is, habituate--before a conditional reflex could be expected). (Kimmel, 1979, pp. xi-xii)

Pavlov described the OR as the "what is it?" reflex. In so doing, he stressed the importance of the OR as an innate response of the organism to some common feature of diverse stimuli.

The influence of Russian investigators has largely dominated conceptualizations of the OR. Sokolov (1955, 1960, 1963a, 1963b, 1965, 1969, 1975) has provided the most comprehensive characterization of the OR. He describes the OR as "an unspecific reflex . . . independent of the

modality of the stimulating agent" (1960, p. 189). The OR is manifested in terms of specific changes in a variety of physiological systems including changes in heart rate (HR), respiration, skin potential, skin conductance responses (SCRs), vascular responses, muscle activity, desynchronization of brain rhythms, and changes in spinal and eye blink reflexes. The functional significance of these responses is emphasized by Sokolov (1963b), all "aiming at an increased state of preparedness of the whole body, and at better perception of the stimulus" (p. 118). Thus, Sokolov (1955) considers the OR as "a complex reaction of the whole organism" (p. 134). The unity of the OR is stressed by Sokolov as "an integrated reaction" (1963a, p. 547) of the visceral, somatic, and central nervous system (CNS) in order to bring about "the enhancement of analyser sensitivity" (1963b, p. 13).

Sokolov also specifies the conditions responsible for the elicitation of the OR. This aspect of his theory has been variously characterized as a "stimulus comparator theory" (Siddle, Kuiack, & Stenfert Kroese, 1983, p. 153), "two-stage model of habituation" (Siddle & Spinks, 1979, p. 474), and "model-comparator theory" (Thompson, Berry, Rinaldi, & Berger, 1979, p. 35). A critical element is the concept of a neuronal model which consists of stored characteristics of previous stimulations in the form of cortical representations of these stimuli. Afferent input

is compared in the first stage with the neuronal model. An OR is generated to a mismatch between a current stimulus and available models. More recent formulations (Sokolov, 1975) have implicated the hippocampus in the model-comparison process. The second stage is designated as an amplifying system thought to involve nonspecific reticular arousal elicited by the stimulus and by signals of discrepancy from the comparator. If a match occurs between current input and the neuronal model, the nonspecific input to the amplifying system is blocked by inhibitory impulses from the comparator system. If the amplifying system is stimulated by signals of discrepancy, nonspecific reticular arousal is not blocked, and an OR occurs.

Habituation of the OR takes place as stimulus properties are incorporated into the neuronal model through repeated presentation of the stimulus. According to Sokolov (1963b), the degree of change between a new stimulus and previously presented stimuli is reflected in the strength and rate of habituation of the OR. A more intense and slowly habituating OR will be elicited by a greater degree of mismatch between a stimulus and previously established internal representations of the stimulus.

The theoretical underpinnings of the present work derive from stimulus-model comparator theory, although broadly construed so as to minimize the traditional

emphasis on habituation. This is in keeping with suggestions that the OR may be viewed as "a persistent response when elicited by salient stimuli, and [one] thus likely to accompany a great variety of experimental situations" (Rohrbaugh, 1984, p. 324). In the context of the present experiment, the OR is viewed as a mechanism controlling involuntary alerting or arousal to bring about better processing of the eliciting stimuli or future stimuli. The eliciting stimuli are auditory tones that are relevant to a judgment task assigned to the subjects. The magnitude of the psychophysiological responses are studied as functions of the experimental variables of intensity, probability, degree, and direction of change.

Although a number of excellent and comprehensive reviews of the extensive OR literature are available (e.g., Siddle, Stephenson, & Spinks, 1983), in the following selective review particular emphasis is placed on the stimulus factors under investigation here as well as on the use of event-related cortical potentials (ERPs) as an indicator of the OR. A convergent measure of orienting is provided by analyses of cardiac responses as an index of stimulus registration and evaluation (e.g., Graham, 1973, 1979; Lacey & Lacey, 1980, 1970). Although responses are measured in two psychophysiological systems, the major emphasis here is on the measurement of endogenous cortical ERPs. The promise offered by ERPs as a CNS correlate of

the OR has been emphasized by a number of authors (e.g., Loveless, 1983; Roth, 1983). The link between some of these ERP waveforms and the OR derives primarily from observations that they habituate over repeated stimulus presentations with a time course comparable to the OR (Lutzenberger, Schandry, & Birbaumer, 1979; Megela & Teyler, 1979; Rust, 1977). Other components, however, may be linked with the OR by the additional virtues of showing relationships with some of the autonomic expressions of the OR and by their relationships to the cognitive and behavioral processes involved in OR generation and manifestation.

Novelty

A major concern of the OR literature has been the investigation of the effects of stimulus novelty, considered in terms of recovery of one or more signs of the OR to change in repetitive stimulation. The relevant literature has been extensively reviewed in terms of "the repetition-change paradigm" (Siddle, Stephenson, & Spinks, 1983, p. 63) where a stimulus or set of stimulus conditions is presented for a number of (training) trials while recording one or more surface physiological components of the OR. On a subsequent (test) trial, the variations in stimulus condition are introduced, and the magnitude of the physiological responses to the test stimuli are then compared with each other and to the response level on the

last training trial. Some studies have included comparisons with no-change control conditions.

There seems to be clear evidence that changes in the modality of stimulus presentation produce OR recovery in terms of electrodermal measures (O'Gorman, 1973). For example, Houck and Mefford (1969) reported that subjects who habituated to a mild light or tone stimulus exhibited large galvanic skin responses (GSRs) to an intruding intermodal stimulus as compared with no-change controls.

However, as noted by O'Gorman (1973), increased responsiveness to change in stimulus modality does not necessarily require a comparator model. Differential output from a single-stage amplifying (reticular) system could reflect the "fact that the analysers are connected with the reticular system in different degrees" (Sokolov, 1965, p. 142). Response to a change in modality would therefore be expected "without recourse to a hypothetical matching process" (O'Gorman, 1973, p. 468).

Sokolov and Paramonova (1961) presented data on the extinction (habituation) and re-elicitation of various OR components to frequency changes in an acoustic tone independent of manipulations in the intensity and duration. Their results, reported as a "reactivity curve of the skin-galvanic component" (p. 3), showed a generalization gradient of decreased responsiveness as frequency approached the habituated tone (training frequency) of