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The effects of serial position and frequency of presentation of common stimulus features on orienting response reinstatement

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Abstract

Two factors that might affect the novelty value of a test stimulus (the frequency of appearance of features common to the test stimulus and the set of preceding stimuli, and the serial position of these features) were systematically manipulated, and their effects on the electrodermal component of the orienting response (OR) were examined. We presented 256 participants with both verbal and pictorial stimulus sequences. Following 12 presentations of control stimuli, a test stimulus, which shared two common components with some of the control stimuli, was presented, followed by two additional presentations of control stimuli. The results revealed that recent presentations of the common components significantly reduced OR magnitude to the test stimulus, whereas the presentation frequency of common components had no significant effect. The implications of these findings for the feature-matching theory are discussed and a modification of the theory is proposed.

Descriptors: Orienting response, Habituation, Stimulus novelty, Feature-matching theory, Skin conductance response

A great deal of research effort has been devoted to the study of orienting and habituation processes since the early work of Sokolov (1963, 1966). The concept of the orienting reflex was introduced originally by Pavlov (1927) to describe the reflex that brings about an immediate response (both behavioral and physiological) to the slightest change in the environment. The definition of the orienting response (OR) as a response to a change in stimulation implies that repeated presentations of the same stimulus would yield a gradual decline in response magnitude, a process which is termed "habituation."

Siddle (1991) classified the theoretical approaches proposed to account for orientation and habituation into two broad categories: comparator, or two-stage theories, which postulate that the OR is a product of a comparison between stimulus input and expectations (e.g., Sokolov, 1966), and noncomparator, or one-stage theories suggesting that habituation reflects the changes occurring in the elements that intervene between stimulus input and response output (e.g., Groves & Thompson, 1970). After reviewing the results of many studies that dealt with various aspects of orientation and habituation, Siddle (1991) concluded that the noncomparator approaches can be ruled out. The comparator theory, which dominated OR literature, was proposed by Sokolov (1963), who postulated that repeated presentations of a given stimulus result in an internal representation of that stimulus input. This representation, termed by Sokolov the "neuronal model," contains the parameters of the stimulus. All input information is compared with the existing neuronal models, and a mismatch between stimulus input and the models results in an orienting reaction. If the input matches an existing model, the OR will be inhibited. Sokolov's approach led to extensive research, which, in general, confirmed his theory (e.g., Corman, 1967; Zimny & Schwabe, 1965).

However, several crucial issues were not resolved by Sokolov's (1963) theory, and some theoretical questions remain unanswered. Sokolov proposed that ORs are determined by a comparator (match–mismatch) mechanism, but no attempt was made by him and his followers to specify the nature of this mechanism. This lack of specification led to some confusion in the literature regarding the necessary and sufficient conditions for OR elicitation (e.g., Bernstein, 1979; Maltzman, 1979; O'Gorman, 1979).

The conventional interpretation of Pavlov (1927) and Sokolov (1963) suggests that any perceived change in stimulation is sufficient to produce an OR. However, this does not seem plausible because a mechanism that produces an OR to the slightest change in stimulation would not be functional. Indeed, with the accumulation of research data, more and more instances were reported in which a change in stimulation failed to evoke an OR (e.g., Bernstein, 1969; Furedy, 1968; Houck & Mefferd, 1969; Zimny, Pawlick, & Saur, 1969). It is difficult to determine whether these instances should be interpreted as refutation of Sokolov's theory because the comparator mechanism was not specified. Consequently, it is unclear whether a given change in

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stimulation is insufficient to trigger an OR (a stimulus change below threshold), or whether the fact that it did not produce a response is an indication that the whole comparator approach is invalid.

A possible reason for the fact that a stimulus change does not necessarily lead to an OR is based on the concept of "generalization of habituation." Some researchers used this term to indicate that habituation processes may generalize across a whole set of stimuli belonging to a given category (e.g., Ben-Shakhar & Lieblich, 1982; Connolly & Frith, 1978a, 1978b; Houck & Mefferd, 1969; Mino & Miyata, 1975). The concept of generalization of habituation implies that neuronal models may represent stimulus categories rather than individual stimuli; thus, a stimulus change within a given category is not expected to produce an OR. However, the term generalization of habituation is problematic from an explanatory perspective because no clear theory specifying the conditions for generalization of habituation has been formulated. Therefore, this concept may be used as a post hoc explanation whenever a change in stimulation fails to elicit an OR.

A theoretical approach that may resolve some of these issues was proposed by Ben-Shakhar and Gati (e.g., Ben-Shakhar & Gati, 1987, 1992; Ben-Shakhar, Gati, & Salamon, 1995; Gati & Ben-Shakhar (1990) Gati, Ben-Shakhar, & Avni Liberty, 1996; Gati, Ben-Shakhar, & Oren, 1986). This theory, which was not designed to replace Sokolov's theory, but rather to supplement it, accounts for OR elicitation by introducing feature-matching definitions of both stimulus significance and stimulus novelty. These definitions are based on the contrast model proposed by Tversky (1977) to account for judgments of similarity. The adaptation of the contrast model to describe OR processes rests on the assumption that both stimulus inputs and stimulus representations (neuronal models) can be characterized by sets of features. This approach departs from Sokolov's theory by proposing two separate comparator mechanisms, one for assessing stimulus significance, and one for assessing stimulus novelty. In addition, it attempts to specify the comparator mechanisms by proposing that they are based on feature-matching algorithms.

The Feature-Matching Theory for OR Elicitation

The present theory applies to a situation in which a stimulus sequence is presented to the subjects while one or more psychophysiological measures are recorded. Let us denote the stimulus sequence as: c_1, c_2, c_3, ... c_n, t, c_{n+1} …, where each c_i represents a control stimulus, and t represents a test stimulus. Prior to the stimulus sequence presentation, a certain stimulus (or stimuli) is defined as relevant (r) by the context. For example, a stimulus may become relevant through a conditioning process, or by instructing the subject to pay a special attention to it. The theory describes the OR elicited by t, as a function of its level of significance ($S(t)$), and novelty ($N(t)$). More specifically, it is postulated that $\mathrm{OR} = F(S,N)$, where F is a nonnegative monotonic function, S refers to the degree of significance, and N refers to the degree of novelty.

It is assumed that each stimulus can be characterized by a set of measurable features. The significance factor (S) is based on matching the features of the test stimulus (t) with those of the relevant one (r). The degree of match is derived from the contrast model proposed by Tversky (1977). According to this model, the match between two stimuli is a function of three arguments: the set of their common features (i.e., features shared by both stimuli), and two sets of distinctive features (i.e., features of one stimulus that do not belong to the other, and vice versa). More specifically, applying the contrast model to the present paradigm results in the following formula for $S(t)$ (the significance level of the test stimulus, t), which is defined by the degree of similarity (or match) between t and r:

$$S(t) = \theta f(T \cap R) - \alpha f(T - R) - \beta f(R - T), \ (\theta, \alpha, \beta, 0), \tag{1}$$

where T and R denote the feature sets of stimuli t and r, respectively, and θ, α, and β are nonnegative constants reflecting the relative weights of the common versus the two sets of distinctive features. Thus, according to this model, the significance level of t is a function of the similarity of t to r, which is a linear combination, or contrast, of their common and distinctive features. Specifically, similarity (and hence significance) increases with the measure of common features and decreases with the measure of distinctive features. Note that this formulation of significance within the framework of the contrast model incorporates the concept of OR generalization into the definition of significance, because the significance value of a given stimulus is a direct function of its similarity to r.

Whereas the significance factor is derived directly from the contrast model by comparing the features of the test stimulus with those of the relevant one, the novelty factor ($N(t)$) is more complex because it involves a comparison of the test stimulus with a whole set of stimuli—the set of all stimuli that precede it in the sequence. Gati and Ben-Shakhar (1990) proposed that the degree of novelty of stimulus t is positively related to the measure of its unique features, and negatively related to the common features it shares with at least one of the preceding stimuli. More specifically, Gati and Ben-Shakhar assumed that the novelty factor is determined by the following linear function:

$$N(t) = \gamma g(T - C) - \delta g(T \cap C) \ (\gamma, \delta > 0), \tag{2}$$

where C represents the feature set of all c_i, $i = 1, 2, \ldots, n$ (the set of all features included in at least one of the stimuli preceding t in the sequence); g is a nonnegative scale defined on the relevant collection of features, and γ and δ are nonnegative constants.

A number of studies have been conducted to examine several aspects of the feature matching theory of OR elicitation (Ben-Shakhar & Gati, 1987, 1992; Ben-Shakhar et al., 1995; Gati & Ben-Shakhar (1990) Gati et al., 1986, 1996). Ben-Shakhar and Gati (1987) focused on the significance factor by using a paradigm based on the Guilty Knowledge Test (GKT). They manipulated the similarity between the relevant stimulus (memorized by the subjects in the first stage of the experiment) and the test stimulus by substituting, adding, or deleting components, and demonstrated that the electrodermal component of the OR to the test stimulus was positively related to the number of components common to the test and the relevant stimulus, and negatively related to the number of distinctive components included in the relevant, but not in the test stimulus. This monotonic relation was robust across four experiments that used verbal and pictorial stimuli, and different manipulations of similarity. Gati and Ben-Shakhar (1990) examined the novelty factor of the feature-matching theory by manipulating the contrast between a test stimulus and the set of preceding stimuli. They demonstrated that an OR elicited by a test stimulus decreased as a function of previous presentations of some of its components. Furthermore, they showed that ORs are determined additively by the two factors of stimulus significance and stimulus novelty. More recently, Ben-Shakhar, Gati, Ben-Bassat, and Sniper (2000) demonstrated that substituting, adding, and deleting components of nonsignificant stimuli affect OR reinstatement, as predicted by the feature-matching theory.

Although the feature-matching theory seems promising in light of previous research, several of its aspects have not been critically examined yet. More specifically, the current formulation of this theory (e.g., Ben-Shakhar et al., 2000; Gati & Ben-Shakhar, 1990) leaves some questions open, and in particular it does not take into account two factors that might affect the novelty value of the stimulus, and the magnitude of the OR elicited by it: (a) The theory considers the number of features common to the test stimulus and the set of preceding stimuli, but it does not take into account the frequency of appearances of these features. In other words, no distinction has been made between a common feature that was included in just a single stimulus prior to the test stimulus and a common feature that was included in several (or even possibly all) stimuli preceding the test stimulus. (b) The current formulation of the theory does not take into account the serial position of these common features. In other words, no distinction has been made between a common feature included in the stimulus that appeared just before the test stimulus and a common feature included in a stimulus located much earlier in the stimulus sequence.

The goal of the present study is to examine the effects of these two factors on OR reinstatement. An experiment was designed in which the frequency and the serial position of stimulus components common to the test stimulus and the stimuli preceding it in the sequence were systematically manipulated. It is hypothesized that: (a) OR magnitude elicited by the test stimulus will be negatively related to the number of appearances of stimulus components common to the test stimulus and the preceding control stimuli, and (b) OR magnitude will be negatively related to the recency of appearance of these common stimulus components.

The experiment, which was designed to examine the two hypotheses formulated above, was based on the modified version of the GKT employed in previous studies (e.g., Ben-Shakhar & Gati, 1987, 1992). In the first stage of the experiment, a particular stimulus was made relevant to the participants, in some of the experimental conditions, by associating it with a victim of an imaginary crime and instructing participants to memorize it. In the second stage, a stimulus sequence, which included a total of 15 stimuli, each composed of five components, was presented. The structure of the stimulus sequence was constant across all experimental conditions and included a test stimulus, which was preceded by 12 control stimuli and followed by 2 additional control stimuli. The test stimulus was composed of three novel components and two components that were included in some of the control stimuli. In some experimental conditions, the three novel components of the test stimulus were included in the relevant stimulus memorized by the participants in the first stage of the experiment.

Method

Participants

Two hundred fifty-six undergraduate students (208 women and 48 men) with a mean age of 22.17 ($SD = 3.40$) participated in the experiment for either course credit or payment.

Instruments

Skin conductance was measured by a constant voltage system (0.5 V ASR Atlas Researches), and two Ag/AgCl electrodes (0.8 cm diameter), with electrode paste that consisted of one part physiological saline mixed with two parts of Unibase creme, following the recipe provided by Fowles et al. (1981). The experiment was conducted in an air-conditioned laboratory, and was monitored from a control room separated from the laboratory by a one-way mirror. A Macintosh II computer was used to control the stimulus presentation and compute skin conductance changes. The stimuli were displayed on a Macintosh 13-in. color monitor, placed about 50 cm from the participant's eyes. Responses were transmitted in real time to the Macintosh II computer, and the skin conductance responses (SCRs) were computed using an A/D (NB–MIO–16) converter with a sampling rate of 1000/s.

Stimuli

Both verbal and pictorial stimuli were used in this experiment. The verbal stimuli were descriptions of persons consisting of the following five components: occupation (e.g., lawyer), city of residence (e.g., Haifa), personality trait (e.g., introvert), hobby (e.g., sailing), and appearance (e.g., tall). The pictorial stimuli were schematic faces, which included the following five separable components: The basic frame (including eyes, nose, and mouth), glasses, a hat with an ornament, a beard and mustache, a pipe with smoke. Examples of these schematic faces were presented in various previous articles (e.g., Ben-Shakhar et al., 2000).

Each stimulus used in this experiment belonged to one of the following four categories: (a) The relevant stimulus memorized during the first stage of the experiment; (b) The test stimulus, which was presented at the 13th trial of each stimulus sequence, and was preceeded by 12 presentations of control stimuli and followed by 2 additional presentations of control stimuli; (c) A control stimulus (C_0) that shared no common components with any of the other stimuli used in this experiment, and was fixed across all experimental conditions; and (d) A second type of control stimulus (C_2) that shared two components with the test stimulus, but none with the relevant stimulus. The test stimulus was composed of three novel components that were not included in any of the control stimuli and two components that were included in C_2. In some experimental conditions (the ''significant'' conditions), the three novel components of the test stimulus were included in the relevant stimulus, whereas in the other conditions (the ''neutral'' conditions), the test stimulus did not share any common components with the relevant stimulus.

Procedure

At the first stage of the experiment, participants were seated facing the computer monitor and were told that the aim of the experiment was to examine the accuracy of the polygraph in detecting criminals. The participants were then told to pretend that they were suspected of taking part in a murder. For participants in either the significance (S) condition or in one of the neutral (N_1) conditions, the face of the ''murder victim'' or his verbal description was displayed on the computer monitor. After the participants assured the experimenter that they had memorized the face or the verbal description of the victim, the general principles of the Guilty Knowledge Technique were explained to them, and they were instructed to try to appear innocent of the murder charge. Participants in the second neutral condition (N_0) were not presented with any face or verbal description at this stage.

At the second stage of the experiment, all participants were told that they would be presented with a sequence of verbal and a sequence of pictorial stimuli, and that an attempt would be made to infer from their physiological responses whether or not they were familiar with the victim of the crime. They were reminded that they should try to appear innocent of the murder charge by acting as if they were unfamiliar with the victim's face or verbal description. All participants were presented with a sequence of either 15 verbal or 15 pictorial stimuli, and were requested to sit quietly and pay close attention to all stimuli. For half of the participants in each experimental condition, the verbal sequence was presented first, whereas for the other participants, the pictorial sequence was presented first. Stimuli were presented for 5 s, with random interstimulus intervals (ISI), ranging from 16 to 24 s, with a mean ISI of 20 s. After a 2-min rest period, the second relevant stimulus was displayed on the computer monitor, for participants in the S and N_1 conditions, and they were asked to memorize its details. The second stimulus sequence, which had the same structure as the first sequence, was then presented to all participants. At the end of the experiment, participants in the S and N_1 conditions were asked to identify the face of the victim and to recall the verbal description. The data from the few subjects (less than 3%) who failed to identify the relevant face were discarded and they were replaced by other subjects. Finally, participants were debriefed and paid.

Design

A mixed design was used, with stimulus modality (verbal vs. pictorial) serving as a within-subjects factor. In addition, the following three between-subjects factors were manipulated:

1. Nature of the test stimulus: significant (which shared three components with the relevant stimulus memorized in the first stage of the experiment) versus neutral (which shared no common components with with the relevant stimulus). Two procedures for creating neutral test stimuli were used: (a) Participants were presented, during the first stage of the experiment, with a relevant stimulus that did not share any components with the test stimulus (N_1); and (b) participants were not required to memorize any information at the first stage (N_0). The purpose of this manipulation was to examine whether instructing participants to memorize a certain stimulus will affect their responses, even when the relevant components were not presented.
2. Frequency of exposure of components of the test stimulus prior to its initial presentation (low vs. high). This factor was manipulated by varying the frequency of the control stimulus, which shared two components with the test stimulus (C_2), in the sequence preceding the test stimulus. Thus, in the low frequency condition, the stimulus sequence was comprised of 2 presentations of C_2, and 10 presentations of C_0, which shared no components with the test stimulus; whereas in the high frequency condition, the two types of control stimuli (C_0 and C_2) appear six times each.
3. Serial position of the control stimuli (C_2), which shared two common components with the test stimulus in the sequence preceding it (early vs. late). In the low frequency condition, C_2 was presented either on the 2nd and 4th trials (early), or on the 9th and 11th trials (late). In the high frequency condition, C_2 was presented either on trials 2, 3, 4, 6, 7, and 9 (early), or on trials 4, 6, 7, 8, 10, and 11 (late).

These three between-subject factors created eight independent cells and 32 participants were randomly assigned to each cell. Sixteen of the participants in each of the NEUTRAL cells (i.e., where the test stimulus was neutral), were not presented with the relevant stimulus at the first stage of the experiment (N_0). The other 16 participants were presented with the relevant stimulus, but none of its components was included in the test stimulus during the second stage of the experiment (N_1). Each participant was presented with a pictorial and a verbal stimulus sequence, with their order counterbalanced across participants within each cell. Thus 16 participants within each cell were presented with the verbal stimuli first whereas the other participants were presented with the pictorial stimuli first.

Response Scoring and Analysis

The SCR was defined as the maximal conductance change beginning from 1 s to 5 s after stimulus onset. To eliminate individual differences in responsivity and allow a meaningful summation of responses of different individuals, each participant's conductance changes to the test stimuli were transformed into within-participant relative scores, defined as the SCR to the test stimulus minus the mean SCR to all preceding control stimuli.[1] These relative scores to the test stimuli served as the dependent variables in most of the statistical analyses, and a rejection region of $p < .05$ was used in all statistical tests.

Results

Before testing the main hypotheses, using the relative responses to the test stimuli, we examined whether the raw SCRs to the control stimuli displayed habituation and were affected by stimulus modality. The SCRs elicited by the 12 control stimuli preceding the test stimulus were subjected to a 2 (stimulus modality: verbal vs. pictorial) × 12 (habituation trials) repeated measures ANOVA conducted across experimental conditions. Only the habituation trials factor produced a statistically significant effect, $F(11,2508) = 32.37$, $MSE = 0.25$, $\varepsilon = .48$, whereas stimulus modality produced neither a statistically significant main effect, $F(1,228) = 0.02$, $MSE = 0.50$, nor an interaction effect with trials, $F(11, 2508) = 1.59$, $MSE = 0.20$, $\varepsilon = .66$. The linear trend for the habituation trials factor was statistically significant, $F(1,228) = 76.64$, with the expected negative slope. However, a power function produced the best fit to the mean SCRs across the 12 trials for both the verbal and the pictorial stimuli. The habituation functions for the verbal and pictorial stimuli were $0.624 * x^{-0.302}$ and $0.563 * x^{-0.265}$, and these functions accounted for 66% and 68% of the variance, respectively.

An initial comparison of the two procedures for creating neutral stimuli (N_0 vs. N_1) was conducted by analyzing the data

[1]In most of our previous studies, we transformed the raw SCRs into within-individuals standard scores. When this transformation was applied to the present data, it produced an extremely skewed distribution of the transformed scores, which was due to small standard deviations of some participants' raw SCR distributions. Consequently, we used a transformation in which the within-participant mean SCR is subtracted from the SCR elicited by the test stimulus, without dividing by the standard deviation. The efficiency of this transformation, as well as the standardization transformation, was demonstrated by Ben-Shakhar (1985).

of 128 participants who were presented with a neutral test stimulus. A four-way mixed ANOVA, with stimulus modality serving as a within-subjects factor and nature of the test stimulus (N_0 vs. N_1), frequency of common components (two vs. six), and their serial position (early vs. late) serving as between-subjects factors, was conducted on the mean relative scores to the test stimuli. This analysis revealed that memorizing the relevant stimulus had no statistically significant effects on the responses to the test stimulus (neither the main effect nor the interactions of memorizing the relevant stimulus with the other factors produced statistically significant outcomes). Consequently, the data were collapsed across the two procedures for creating neutral test stimuli.

A four-way ANOVA, with one within-subjects factor (stimulus modality) and three between-subjects factors (significance of the test stimulus, frequency, and serial position of common components) was conducted on these data. Serial position of the components common to the test and preceding stimuli emerged as the only between-subjects factor producing a statistically significant effect, $F(1{,}248) = 11.07$, $MSE = 0.54$, in the predicted direction (smaller ORs with more recent presentations of common components). Surprisingly, neither frequency of common components nor significance level of the test stimulus affected OR magnitude. Stimulus modality produced a statistically significant main effect, $F(1{,}248) = 5.56$, $MSE = 0.42$, with the verbal stimuli producing larger relative responses. The two-way interaction between stimulus modality and frequency of common components produced a statistically significant effect, $F(1{,}248) = 3.96$, reflecting a stronger modality effect under the high presentation frequency condition (mean relative responses of 0.37 vs. 0.12 for the verbal and pictorial stimuli, respectively) than under the low frequency condition (means of 0.19 and 0.16 for the verbal and pictorial stimuli, respectively).

The main outcomes of the ANOVA are displayed in Table 1, which presents the means and standard deviations of the relative scores to the verbal and pictorial test stimuli as a function of presentation frequency of components common to the test and preceding stimuli (two vs. six) and the serial position of these components (early vs. late).

To examine more closely whether the frequency manipulation may have different effects for the verbal and pictorial stimuli, a $2 \times 2 \times 2$ between-subjects ANOVA was conducted for each stimulus modality. For the verbal stimuli, serial position was the only factor producing a statistically significant effect, $F(1{,}248) = 11.04$, $MSE = 1.28$. A somewhat different pattern emerged in the analysis conducted for the pictorial stimuli. Although the serial position factor still produced a statistically significant main effect, $F(1{,}248) = 4.50$, $MSE = 0.51$, it also produced a statistically significant interaction with the presentation frequency factor. An inspection of this interaction (see Table 1) indicates that the effect of serial position holds only under the low frequency condition (mean relative response 0.31 vs. 0.02 for the early and late conditions, respectively). Under the high frequency condition, however, there is no serial position effect (means of 0.11 vs. 0.13 for the early and late conditions, respectively). Two-way ANOVAs conducted on the relative responses to the pictorial test stimuli within each frequency condition revealed a statistically significant serial position effect only under the low frequency condition, $F(1{,}124) = 8.48$, $MSE = 0.31$. Similar analyses conducted within each serial position condition revealed that presentation frequency did not produce a statistically significant effect, neither under the early nor under the late condition.

To examine whether OR reinstatement to the test stimulus occurred within each experimental condition, the SCRs elicited by the test stimulus were compared with the those produced by the immediately preceding stimulus. These comparisons that were conducted within each experimental condition, using matched-groups t tests, revealed that although in all cases the test stimulus produced larger SCR than the preceding stimulus, the differences were not always statistically significant. The t values were statistically significant in seven out of the eight early conditions, but in only three out of the eight late conditions. This is consistent with the outcomes of the ANOVA, and suggests that the serial position of common components is an important factor determining OR, and that when these components are presented just one or two trials before the test stimulus, OR magnitude to the test stimulus may be attenuated.

Finally, to examine dishabituation effects, the SCRs elicited by the stimulus subsequent to the test stimulus were compared with the SCRs produced by the stimulus immediately preceding it. Within-subjects t tests conducted within each experimental condition revealed that no statistically significant dishabituation effects were observed.

Discussion

This study was conducted to test the effects of two factors, which were disregarded by the original formulation of the feature-matching theory for OR reinstatement (Gati & Ben-Shakhar, 1990). These factors (presentation frequency of components common to the test and preceding stimuli, and their serial position) were chosen because they seem to be associated with the novelty value of the test stimulus. But prior to examining the effects of these factors on OR reinstatement to a change in

Table 1. *Means and Standard Deviations of the Relative Scores to the Verbal and Pictorial Test Stimuli as a Function of Presentation Frequency and Serial Position, across Levels of Significance*

	Verbal stimuli			Pictorial stimuli		
	Early	Late	Total	Early	Late	Total
Low frequency	0.34 (0.80)	0.03 (0.46)	0.19 (0.67)	0.31 (0.65)	0.02 (0.43)	0.16 (0.57)
High frequency	0.51 (1.09)	0.23 (0.75)	0.37 (0.94)	0.11 (0.53)	0.13 (0.58)	0.12 (0.56)
Total	0.43 (0.96)	0.13 (0.63)	0.28 (0.82)	0.21 (0.60)	0.08 (0.51)	0.14 (0.56)

stimulation, it was important to establish that the SCRs showed habituation across the 12 trials preceding the test stimulus. Response habituation is an important feature of OR theory, which has been observed in many studies, with some exceptions (e.g., Furedy, 1968; Furedy, Davis, & Gurevich, 1988; Furedy, Gigliotti, & Ben-Shakhar, 1994; Furedy, Posner, & Vincent, 1991; Vincent & Furedy, 1992). The present data showed clear habituation (best described by decreasing power functions), which was independent of stimulus modality.

An examination of the main hypotheses of this study revealed that only the serial position of the components common to the test stimulus and the preceding control stimuli affects OR reinstatement. Specifically, relatively smaller ORs were obtained when these common components were included in the stimulus presented just one or two trials before the test stimulus. For the verbal stimuli, this effect was obtained under all experimental conditions, but for the pictorial stimuli it was observed only under the low frequency condition (see Table 1). The fact that no serial position effect was observed with pictorial stimuli under the high frequency condition might limit the generality of our findings, and this should be further explored in future research.

The serial position effect may have important theoretical implications for the nature of the neuronal models and the comparator mechanism underlying OR reinstatement. It seems that neuronal models (or representations of recently occurring events) decay relatively quickly, and this decay function should be taken into account in any attempt to specify the process of comparing stimulus input with previously presented stimuli.

One approach to this issue is to incorporate additional parameters to the novelty component of the feature-matching algorithm, which weigh the effect of common features by their "distance" from the test stimulus. For example, a common component included in the stimulus just preceding the test stimulus will have a maximum impact on OR reinstatement, whereas the same component included in stimuli presented earlier in the sequence will have a gradually decreasing effect on OR magnitude. Specifically, the formula (2) presented above for deriving the novelty value of t ($N(t)$) can be reformulated as follows:

$$N(t) = \gamma g(T\ ;\mathrm{ms}\ C)\ ;\mathrm{ms}\ \Sigma[\delta_j g(T \cap C_j)]\ (\gamma, \delta_j \geq 0), \qquad (3)$$

where C_j represents the set of all features included in stimulus c_j, and δ_j represents the weight of the common features of t and c_j ($j = 1,2,\ldots, n$). As j increases from 1 to n, the corresponding weight, $\delta_{j,}$ increases. Of course, for stimuli presented many trials prior to t, δ_j may be 0, which would mean that they have no effect on OR elicitation by t. Clearly, further research is required before a revision of the feature-matching theory is undertaken. Particularly, careful parametric studies should be conducted to estimate the decay function of common features. In addition, the question of whether this decay is a function of the intervening stimuli, which do not have features common with the input, as suggested by Equation 3, or whether it is a function of the time elapsed between the input and previously presented common features should be resolved in future research.

In most experimental conditions, the test stimulus elicited enhanced responses relative to the preceding stimulus. In particular, it is important to note that a statistically significant OR reinstatement was obtained in seven out of the eight early conditions, but only three out of the eight late conditions. This further supports our conclusion that representations of previously presented stimulus features may decay relatively quickly.

From a theoretical perspective, it is particularly interesting to examine OR reinstatement in the experimental conditions in which nonsignificant test stimuli were used. The present results indicate that in the early conditions, OR reinstatement was observed even when the test stimuli included no significant components. This means that, in contrast to arguments made by Bernstein (1979) and others, nonsignificant stimulus change is capable of eliciting an OR reinstatement. In other words, stimulus significance does not seem to be a necessary condition for OR elicitation by a change in stimulation. Similar findings were reported by Ben-Shakhar, Asher, Poznansky-Levy, Asherowitz, and Lieblich (1989) and by Ben-Shakhar et al. (2000).

The fact that presentation frequency of common components did not affect OR reinstatement can also be accounted for by the notion of a neuronal model decay function. If this decay process is relatively fast, and only the few (e.g., two or three) stimuli preceding the test stimulus should be considered in the matching process, then it follows that extending the presentation frequency of common components beyond two or three should not make a difference, as far as OR reinstatement is concerned.

The finding that no statistically significant effect was obtained for the stimulus-significance factor is rather surprising and inconsistent with previous findings (e.g., Ben-Shakhar & Gati, 1987; Gati & Ben-Shakhar, 1990). However, it should be noted that the significance manipulation employed in this study was relatively weak because a partially significant test stimulus (which included three out of the five significant components) was compared to a neutral test stimulus (which did not include any significant component). In contrast, all our previous studies included the original relevant stimulus memorized by the subjects in one of the experimental conditions.

Larger relative responses were obtained in this experiment for the verbal than for the pictorial stimuli. This result is consistent with findings reported by Ben-Shakhar and Gati (1987) and by Gati and Ben-Shakhar (1990), who used very similar verbal and pictorial stimuli. They suggested that this finding may be attributed to the fact that verbal stimuli are easier to store and retrieve than pictorial stimuli. However, this modality effect is probably not robust, as it was not demonstrated in other studies that used similar stimulus material (Ben-Shakhar & Gati, 1992; Ben-Shakhar et al., 2000). In addition to its main effect, stimulus modality interacted with the presentation frequency factor. This interaction implies that the modality effect was stronger under the high frequency condition. Indeed, an inspection of the four low frequency cells in Table 1 reveals that very similar mean relative responses were obtained for the verbal and pictorial stimuli. We have no explanation for this interaction, which may be another indication that the modality effect is not robust.

Finally, the results of this study, like the results of previous studies that used a similar paradigm (e.g., Ben-Shakhar et al., 2000) did not demonstrate dishabituation effects. Dishabituation is predicted by Sokolov's theory because presentation of the test stimulus must change the neuronal model, and therefore when the subsequent control stimulus is reintroduced, the stimulus input no longer matches the existing neuronal model. However, it is possible that dishabituation depends on a much stronger and more pronounced change in stimulation than the one employed in this study (which consisted of substituting only some stimulus components).

REFERENCES

Ben-Shakhar, G. (1985). Standardization within individuals: A simple method to neutralize individual differences in psychophysiological responsivity. *Psychophysiology*, *22*, 292–299.

Ben-Shakhar, G., Asher, T., Poznansky-Levy, A., Asherowitz, R., & Lieblich, I. (1989). Stimulus novelty and significance as determinants of electrodermal responsivity: The serial position effect. *Psychophysiology*, *26*, 29–38.

Ben-Shakhar, G., & Gati, I. (1987). Common and distinctive features of verbal and pictorial stimuli as determinants of psychophysiological responsivity. *Journal of Experimental Psychology: General*, *116*, 91–105.

Ben-Shakhar, G., & Gati, I. (1992). The effect of common versus distinctive stimulus features on electrodermal orientation to significant stimuli. *Psychophysiology*, *29*, 306–314.

Ben-Shakhar, G., Gati, I., Ben-Bassat, N., & Sniper, G. (2000). Orienting response reinstatement and dishabituation: The effects of substituting, adding and deleting components of nonsignificant stimuli. *Psychophysiology*, *37*, 102–110.

Ben-Shakhar, G., Gati, I., & Salamon, N. (1995). Generalization of the orienting response to significant stimuli: The roles of common and distinctive stimulus components. *Psychophysiology*, *32*, 36–42.

Ben-Shakhar, G., & Lieblich, I. (1982). Similarity of auditory stimuli and generalization of skin conductance response (SCR) habituation. *Physiological Psychology*, *10*, 331–335.

Bernstein, A. (1969). To what does the orienting response respond? *Psychophysiology*, *6*, 338–350.

Bernstein, A. (1979). The orienting response as a novelty and significance detector: Reply to O'Gorman. *Psychophysiology*, *16*, 263–273.

Connolly, J. F., & Frith, C. D. (1978a). Effects of stimulus variability on the amplitude and habituation of the electrodermal orienting response. *Psychophysiology*, *15*, 550–555.

Connolly, J. F., & Frith, C. D. (1978b). Effects of varying stimulus context on habituation and sensitization of the O.R. *Physiology & Behavior*, *21*, 511–514.

Corman, C. D. (1967). Stimulus generalization of habituation of the galvanic skin response. *Journal of Experimental Psychology*, *74*, 236–240.

Fowles, D. C., Christie, M. J., Edelberg, R., Grings, W. W., Lykken, D. T., & Venables, P. H. (1981). Publication recommendations for electrodermal measurements. *Psychophysiology*, *18*, 232–239.

Furedy, J. J. (1968). Human orienting reactions as a function of electrodermal versus plethysmographic response modes and single versus alternating stimulus series. *Journal of Experimental Psychology*, *77*, 70–78.

Furedy, J. J., Davis, C., & Gurevich, M. (1988). Differentiation of deception as a psychological process: A psychophysiological approach. *Psychophysiology*, *25*, 683–688.

Furedy, J. J., Gigliotti, F., & Ben-Shakhar, G. (1994). Electrodermal differentiation of deception: The effect of choice vs. no choice of deceptive items. *International Journal of Psychophysiology*, *18*, 13–22.

Furedy, J. J., Posner, R., & Vincent, A. (1991). Electrodermal differentiation of deception: Memory-difficulty and perceived-accuracy manipulations. *Psychophysiology*, *28*, 163–171.

Gati, I., & Ben-Shakhar, G. (1990). Novelty and significance in orientation and habituation: A feature-matching approach. *Journal of Experimental Psychology: General*, *119*, 251–263.

Gati, I., Ben-Shakhar, G., & Avni-Liberty, S. (1996). Stimulus novelty and significance in electrodermal orienting responses: The effects of adding versus deleting stimulus components. *Psychophysiology*, *33*, 637–643.

Gati, I., Ben-Shakhar, G., & Oren, C. (1986). The relationship between similarity judgments and psychophysiological responsivity. *Acta*, *62*, 123–139.

Groves, P. M., & Thompson, R. F. (1970). Habituation: A dual process theory. *Psychological Review*, *77*, 419–450.

Houck, R. L., & Mefferd, R. B. (1969). Generalization of GSR habituation to mild intramodal stimuli. *Psychophysiology*, *6*, 202–206.

Maltzman, I. (1979). Orienting reflexes and significance: A reply to O'Gorman. *Psychophysiology*, *16*, 274–281.

Mino, T., & Miyata, Y. (1975). Effects of the range of stimulus variation upon habituation of the orienting response. *Psychophysiology*, *12*, 136–140.

O'Gorman, J. G. (1979). The orienting reflex: Novelty or significance? *Psychophysiology*, *16*, 253–262.

Pavlov, I. P. (1927). *Conditioned reflex*. Oxford, England: Clarendon Press.

Siddle, D. A. T. (1991). Orienting, habituation, and resource allocation: An associative analysis. *Psychophysiology*, *28*, 245–259.

Sokolov, E. N. (1963). *Perception and the conditioned reflex*. New York: Macmillan.

Sokolov, E. N. (1966). Orienting reflex as information regulator. In:–A. Leontyev, A. Luria, & A Smirnov, (Eds.). *Psychological research in U.S.S.R.* (pp. 334–360). Moscow: Progress Publishers.

Tversky, A. (1977). Features of similarity. *Psychological Review*, *84*, 327–352.

Vincent, A., & Furedy, J. J. (1992). Electrodermal differentiation of deception: Potentially confounding and influencing factors. *International Journal of Psychophysiology*, *13*, 129–136.

Zimny, G. H., Pawlick, G. F., & Saur, D. F. (1969). Effects of stimulus order and novelty on orienting responses. *Psychophysiology*, *5*, 166–173.

Zimny, G. H., & Schwabe, L. W. (1965). Stimulus change and habituation of the orienting response. *Psychophysiology*, *2*, 103–114.

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