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# Dissociations of Personally Significant and Task-Relevant Distractors Inside and Outside the Focus of Attention: A Combined Behavioral and Psychophysiological Study

Nurit Gronau, Asher Cohen, and Gershon Ben-Shakhar
Hebrew University of Jerusalem

Studies of attentional capture by personally significant stimuli have reached inconsistent results, possibly because of improper control of the participants' attention. In the present study, the authors controlled visual attention by using a Stroop-like task. Participants responded to a central color and ignored a word presented either centrally (i.e., at the focus of attention) or peripherally (i.e., outside the focus of attention). Central words led to slower reaction times and larger orienting responses for significant items than for neutral items. These effects largely disappeared when the words appeared in a peripheral location. The peripheral words interfered with performance when they were relevant to task demands. These results indicate that there is a fundamental difference between task-relevant words and personally significant words: The former capture attention even when presented peripherally, whereas the latter do not.



Human beings are constantly bombarded with a vast amount of information, generated by external sources as well as internally by the cognitive system. Clearly, it is impossible to deal successfully with all this information (see, e.g., Shiffrin, 1988). Attention is a selection mechanism that allows people to focus on high-priority stimuli and to filter out or attenuate material of secondary importance (e.g., Pashler, 1998). The nature of this selection has been extensively investigated for decades. A long-lasting question in the literature concerns the extent to which unattended stimuli are processed. Theories on this issue differ widely (e.g., Broadbent, 1958; Deutch & Deutch, 1963; Lavie, 1995; Treisman, 1960; Yantis & Johnston, 1990), and numerous studies using a variety of paradigms have explored it (see Driver, 2001, for a recent review). One popular approach to this issue, used in our study, is to examine whether stimuli outside the focus of attention interfere with task performance, presumably by capturing attention in some way.

Although the earliest modern studies on attention suggested that very little information is processed outside the focus of attention (e.g., Broadbent, 1958), the next wave of studies indicated that at least some types of information may actually be processed outside the focus of attention. One such type is task-relevant information (i.e., stimuli that are related in some fashion to the task in which the subject is engaged). For example, in the well-known Stroop task (Stroop, 1935), words denoting color names are considered task relevant because their content is related to the task in which the subject is engaged. A study by Treisman (1960) may have been the first to show that task-relevant information is processed outside the focus of attention. Many subsequent studies using a variety of paradigms have confirmed this finding (e.g., Eriksen & Eriksen, 1974; Folk, Remington, & Johnston, 1992).

A second type of information concerns stimuli that are personally significant to the individual but are not specifically relevant for the task at hand (e.g., the participant's own personal name; such stimuli are hereafter termed *significant* in this article). A well-known study by Moray (1959) suggested that unattended significant stimuli are also processed. However, as extensively reviewed below, the results of subsequent studies (e.g., Bundesen, Kyllinsbaek, Houmann, & Jensen, 1997; Harris, Pashler, & Coburn, in press; Wood & Cowan, 1995) were not consistent, and most of them suffered from an insufficient control over the locus of the participants' focus of attention. Thus, whereas it seems clear that task-relevant information captures attention at least to some extent, the status of significant but task-irrelevant information is unclear.

The question of whether unattended personally significant stimuli are processed is fundamental for understanding the operation of selective attention. On the one hand, as originally suggested by Treisman (1960), these stimuli can be considered relevant across all contexts because of their general significance and as such may function like task-relevant or "endogenous" stimuli. Several studies have shown that endogenous stimuli, which comprise properties that are relevant to task demands, involuntarily capture attention (e.g., Folk et al., 1992). If significant stimuli are indeed relevant across all contexts, attention capture cannot rely on transient stores such as working memory, because the amount of significant information a person normally has does not allow it to be stored in transient, limited-capacity stores. On the other hand, significant stimuli may behave like any other task-irrelevant or

Nurit Gronau, Asher Cohen, and Gershon Ben-Shakhar, Department of Psychology, Hebrew University of Jerusalem, Jerusalem, Israel.

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Correspondence concerning this article should be addressed to either Nurit Gronau or Asher Cohen, Department of Psychology, Hebrew University of Jerusalem, Jerusalem 91905, Israel. E-mail: msgron@mscc.huji.ac.il or msasher@mscc.huji.ac.il

"exogenous" stimuli, capturing attention only if they comprise particularly salient perceptual features (e.g., Theeuwes, 1992, 1994; Yantis & Jonides, 1984, 1990). If so, attention capture by task-relevant information should be related to the operation of transient mechanisms such as working memory. The primary goal of our study was to tightly control the participants' visual attention and examine whether personally significant visual stimuli affect performance when presented inside and outside the focus of attention.

Note that we refer to visual (and auditory) attention as a mechanism that selects regions or objects in space for subsequent processing. Unlike other possible attentional mechanisms (see, e.g., Posner & Boies, 1971), this attentional mechanism is not necessarily associated with conscious awareness (cf. Kahneman & Treisman, 1984). Although our perspective follows a rich and popular tradition in attention research (e.g., Eriksen & Eriksen, 1974; Posner, 1980), another tradition, mostly associated with Garner (e.g., 1974), uses attention in a different sense. According to this tradition, attention is a device that distinguishes between relevant and irrelevant stimuli. Typically, all the stimuli in the Garner tradition are presented in a single location and no spatial selection is involved. Recent evidence from Shalev and Algom (2000) suggests that these two types of attentional mechanisms are distinct and operate independently. Given this independence, we reserve the use of the word *attention* in this article exclusively for the mechanism responsible for the selection of regions and objects.

A secondary goal of our study was to investigate whether the capture of visual attention by personally significant stimuli is reflected by an orienting response (OR) elicited by these stimuli. The OR is a set of nonspecific physiological and behavioral responses (e.g., an increase in the sensory organs' sensitivity, an increase in electrodermal activity, and a sudden slowing of heart rate) to changes in the environment (Sokolov, 1963). It has been suggested that the OR reflects a shift of attention toward novel stimuli (e.g., Dawson, Filion, & Schell, 1989; Ohman, 1979; Siddle & Packer, 1987). Because our study includes a systematic manipulation of the locus of visual attention, it would provide an excellent opportunity to examine the relation between attentional shifts and the OR. Moreover, the OR may be particularly useful as a dependent measure in studies examining personally significant stimuli because it is well-known that such stimuli consistently elicit enhanced ORs (e.g., Ben-Shakhar & Elaad, 2002; Ben-Shakhar, Lieblich, & Kugelmass, 1970). In this study, the electrodermal component of the OR (defined as an increase in skin conductance, or the skin conductance response [SCR]) is used to examine whether enhanced ORs are elicited by personally significant stimuli under different conditions of visual attention.

## Processing of Unattended Personally Significant Stimuli

In early studies, researchers using the dichotic listening paradigm (e.g., Broadbent, 1958) examined the ability of participants to directly report the identity of unattended stimuli. Participants in these studies had to attend to one auditory message (e.g., a message presented to the right ear) by shadowing it (i.e., they repeated the message verbatim) and ignore another unattended message (e.g., a message presented to the left ear). These studies revealed that participants are generally unaware of the unattended stimuli. This finding was the basis for the early selection model of Broadbent (1958), which assumed that only gross physical properties of the unattended stimuli are processed, whereas the content of these stimuli is not processed at all.

A first important exception to these findings was reported by Moray (1959). He used a similar dichotic-listening task and found that although participants were generally unable to report the content of the ignored message, about one third of them identified their own name when it was presented in the unattended message. This result implies, as pointed out by Treisman (1960) in her attenuation theory, that certain highly important stimuli are semantically processed and may therefore capture attention. As mentioned earlier, Treisman (1960) proposed that personally significant stimuli function like task-relevant stimuli in that both types of stimuli may need relatively little input to penetrate consciousness and be available for direct report.

However, Moray's (1959) study suffered from two basic shortcomings typical to the early attentional studies that used the dichotic listening paradigm. First, this paradigm did not provide sufficient control over the temporal locus of attention. Although it is clear that most of the time participants focused their attention on the shadowed message, their attention may have been shifted from time to time to the unattended message. Thus, knowledge of information presented in the unattended message may have resulted from the occasional wandering of attention to the unattended message, making it, in effect, attended rather than processed without attention. This problem reinforces the early selection view (e.g., Broadbent, 1958), according to which the content of messages is recovered primarily and perhaps even solely by attentional processes. A more recent study (Wood & Cowan, 1995) used a more stringent methodology to control for temporal lapses of attention, utilizing digitized speech (to synchronize the time of the two messages) and on-line measures of attention. The results of this study replicated Moray's (1959) original findings concerning the detection of significant stimuli in the unattended channel. Nevertheless, as will be discussed later, it is not clear whether these measures blocked occasional lapses of attention. Thus, it is possible that this paradigm overestimates the degree of processing without attention.

A second problem concerns the reliance of the dichotic listening methodology on the participants' ability to directly report the content of unattended stimuli. As a number of studies have demonstrated, participants may be unable to report the content of unattended stimuli in situations where there is clear, indirect evidence that it was processed (e.g., Corteen & Wood, 1972). From this perspective, direct report by participants underestimates the degree of processing without attention.

A large number of paradigms were developed over the years to overcome these problems, mainly in the visual domain. The general approach adopted by researchers in many of these studies was to examine whether the presence of certain unattended stimuli affects performance, which would indicate that these stimuli are processed and capable of capturing attention (for reviews, see Driver, 2001; Theeuwes & Godijn, 2001). We focus primarily on studies examining whether the presence of personally significant stimuli affects performance.

Welford and Morrison (1980) conducted a discrimination task in which participants were asked to rapidly judge whether two briefly presented digits were of the same parity (both odd or both even) or of a different parity. In one condition, a central word was inserted between the digits and participants were instructed to ignore it. In the second condition, the digits appeared at the same locations but with no central word between them. Welford and Morrison found that when the participant's name appeared as a central word, it produced a significant disruption of the primary task, reflected by an increased reaction time to the parity judgment. In addition, participants in the first condition tended to remember the appearance of their names more often than the appearance of other control words (80% vs. 68%, respectively). The authors concluded that the names captured attention despite their appearance in an irrelevant location.

Shapiro, Caldwell, and Sorensen (1997) conducted an experiment in which participants were required to identify a target word and then detect the presence or absence of a second probe word among a stream of words presented in rapid serial visual presentation (RSVP). Normally, participants show an *attentional blink*, namely, a significant deficit in detecting the secondary probe item when it appears immediately after the target item (e.g., Raymond, Shapiro, & Arnell, 1992; Shapiro, Raymond, & Arnell, 1994). However, detection rates of the probe word were nearly perfect when the probe consisted of the participant's own name. Shapiro et al. (1997) suggested that one's own name was distinguished from other probe words by virtue of its semantic saliency, which enabled its conscious identification despite the attentional competition with the target item (see also Arnell, Shapiro, & Sorensen, 1999).

Mack and Rock (1998) reached a similar conclusion through the use of the inattentional blindness paradigm, in which participants are instructed to judge the relative lengths of two briefly presented lines that bisect each other to form a cross. After a few length judgments, a critical trial appears in which an unexpected stimulus (e.g., a small shape) is presented near the cross. Typically, a relatively high percentage of participants (between 20% to 60%) report seeing nothing other than the cross, a phenomenon termed *inattentional blindness* (Mack & Rock, 1998; Mack, Tang, Tuma, Kahn, & Rock, 1992). Mack and Rock (1998) found that when the unexpected stimulus was the participant's own written name, nearly all participants (87%) correctly identified it. Control conditions in which someone else's name or a control word was presented yielded significantly lower frequencies of detection (65% and 50%, respectively).

A common feature of the studies mentioned above is that the so-called unattended word was actually presented at the observers' fixation point. In the Welford and Morrison (1980) study, the word was presented between the two more peripheral digits, and in the Shapiro et al. (1997) study, the stream of RSVP was presented to fixation. Similarly, in the Mack and Rock (1998) study, the word was presented at fixation and the target (cross) was presented more peripherally. It is possible that in all of these cases, the participants' focus of attention included the fixation area and that the enhanced effect of the names on task performance was due to the fact that the words were, in fact, at least partially attended.

Some support for this argument comes from two additional studies, in which the personally significant distractors appeared in a more peripheral location, resulting in contradictory findings. Bundesen et al. (1997) conducted a partial report study in which four written names were briefly presented around a fixation point. Two of the names were shown in red and two were shown in white. The participants' task was to report the red names (targets) and to ignore the white ones (distractors). On some trials, the participant's own name appeared as a display item. Bundesen et al. (1997) found that when the participant's own name appeared as a target, the proportion of accurately reported targets was higher than when other names appeared as targets (67% vs. 57%, respectively). However, when the participant's name served as an irrelevant distractor, no interference in performance was observed (56% when the participant's name was a distractor vs. 57% otherwise). This study suggests that the appearance of one's name in a task-irrelevant location does not capture attention automatically and does not impair task performance.

More recently, Harris et al. (in press) conducted a series of visual search experiments. In this paradigm, participants are typically required to detect the presence of a target whose location is unknown among a variable number of distractors. It has been shown (e.g., Yantis & Jonides, 1984, 1990) that some types of stimuli, such as an abrupt appearance of a new object (termed *onset*) or highly salient visual stimuli (known as *singletons*, which differ from all other stimuli in the visual scene by their color or basic shape; e.g., see Theeuwes, 1992), can involuntarily capture attention. Harris et al. (in press) found that when the participant's name appeared as a target, it was detected more quickly than other targets were. However, when it appeared as a distractor and another stimulus was used as a target, search time was not affected by the presence versus absence of the participant's name. These findings, like those of Bundesen et al. (1997), imply that participants might be more efficient in processing personally significant stimuli when these stimuli are relevant for the task. However, it seems that participants are not distracted by the presence of task-irrelevant stimuli, even when these stimuli are personally significant, suggesting that the latter do not capture attention when they are exogenous to the task at hand.

The review so far suggests that although some studies demonstrated that task-irrelevant personally significant stimuli grab attention involuntarily (Mack & Rock, 1998; Shapiro et al., 1997; Welford & Morrison, 1980), others provided contradicting evidence (Bundesen et al., 1997; Harris et al., in press). All of these studies are characterized by an insufficient control over the participants' locus of visual attention. In particular, no study to date has systematically compared the influence of personally significant but task-irrelevant stimuli inside and outside the focus of attention. When significant stimuli were presented inside the focus of attention (e.g., Bundesen et al., 1997), they were always task relevant. And, as mentioned previously, studies that attempted to present significant but task-irrelevant stimuli outside the focus of attention may have been unsuccessful in this manipulation. Therefore, it is possible that the discrepancy between the findings relates to the extent to which the exogenous significant stimuli truly appeared in an unattended location. The primary goal of our study was to overcome these shortcomings by controlling the locus of visual attention and examining how exogenous but personally significant stimuli affect performance when presented inside versus outside the focus of attention.

## The OR

The concept of the OR was originally introduced by Pavlov (1927) to describe the reflex that brings about an immediate physiological and behavioral response to changes in the environment. Sokolov (1963) elaborated on Pavlov's ideas and described the physiological responses triggered by stimulus change (e.g., an increase in electrodermal activity and a sudden slowing of heart rate). According to Sokolov (1963), these changes prepare the organism to deal more efficiently with novel stimuli. Indeed, studies conducted by Sokolov as well as by subsequent researchers (e.g., Corman, 1967; Zimny & Schwabe, 1965) showed that the OR is elicited by novel stimuli and habituates with repetitions.

However, ORs are triggered not only by novel stimuli but also by stimuli that are significant for the individual. Although in the present study, we use the term *significant* for stimuli that are personally important for the participant but irrelevant for task requirements, the OR literature has referred to the concept of significance in a much broader sense. For instance, Sokolov (1963) introduced the term *signal value* to describe any stimulus perceived by the participants as a signal for future actions and postulated that such stimuli are associated with enhanced orientation and slower habituation as compared with nonsignal (neutral) stimuli. Subsequent studies demonstrated that stimuli defined by task requirements as target items to be detected elicit an enhanced OR (e.g., Bernstein, 1979; Maltzman, 1979; Maltzman & Langdon, 1982). In these studies, significance was defined on the basis of task-relevant properties, because a specific response to a selected stimulus was required. However, other studies have shown that meaningful stimuli elicit enhanced ORs, even when they do not require a distinct response or when they are irrelevant to task demands. In the guilty knowledge technique (GKT), for example, participants consistently show enhanced ORs to meaningful stimuli, relative to neutral stimuli, although both types of items require the very same monotonic response (Lykken, 1959, 1960).[1] Furthermore, enhanced physiological responsivity to the significant items is achieved even when participants passively view these items and no explicit response is required whatsoever (e.g., Elaad & Ben-Shakhar, 1989). Thus, mere knowledge of the critical information is sufficient for eliciting an OR independent of the specific task demands. Typically, the significant information in the GKT consists of either crime-related details (e.g., Ben-Shakhar, Gronau, & Elaad, 1999) or personally relevant information (e.g., Ben-Shakhar & Elaad, 2002; Ben-Shakhar et al., 1970). In this study, we focus on the latter type of significant stimuli: task-irrelevant but personally significant stimuli.

Several studies have shown that the OR may be viewed as an indication of an attentional shift toward external stimuli. For example, Siddle and Packer (1987) demonstrated that the presentation of an unexpected stimulus prior to the appearance of a probe item caused an increase in the OR combined with a slowed reaction time to the probe. OR elicitation was interpreted as a marker of allocation of attentional resources toward the unexpected stimulus, which caused the longer reaction time to the probe. Dawson et al. (1989) reported similar findings and showed that habituation of the OR (due to stimulus repetition) was associated with a reduction in probe reaction times. In general, a positive correlation was found between OR magnitude and probe latency. Other studies have supported these findings (Siddle, 1991; Siddle & Jordan, 1993), although some researchers have argued that there is a more complex relationship between attentional allocation and the OR (Dawson et al., 1989; Siddle, Lipp, & Dall, 1996).

As pointed out by some investigators (e.g., Pashler, 1991; Posner & Boies, 1971), orienting of visual attention may be distinct from attentional processes concerned with probe interference. Nevertheless, some properties of the OR and visual attention appear similar. As just mentioned, the OR is triggered by novelty and by significance (albeit significance in a broad sense, including both task-relevant and task-irrelevant stimuli; e.g., Gati & Ben-Shakhar, 1990; Siddle, 1991). In a similar manner, visual attention is captured by the onset of new objects (Yantis & Jonides, 1984) and by task-relevant stimuli (e.g., Eriksen & Eriksen, 1974; Folk et al., 1992). However, the relation between the OR and visual attention has never been directly examined when the locus of visual attention has been properly controlled. One of our goals in this study was to systematically examine this relation.

## Overview of the Experiments

In all of the experiments reported in this study, we used a Stroop-like task in which participants were instructed to respond to a color as fast as possible and to ignore a word. We manipulated visual attention by presenting the word and the color at the same location in some experiments and by spatially separating the color and the word in others. We assume throughout this article, as is standard in the visual attention literature (e.g., A. Cohen & Ivry, 1989; Duncan, 1984; Posner, 1980), that when the target and distractors are located at the same location and are both part of a single object, visual attention is focused on both. We further assume that when the color and the word are properly spatially separated and the focus of attention is on the color, the word is outside the central focus of attention (cf. Eriksen & Eriksen, 1974). In all of our experiments, we also manipulated the content of the distracting words. The majority of trials in all the experiments included neutral words that were neither task relevant nor significant. In Experiments 1–2 and 4–7, we included on some trials personally significant but task-irrelevant words. In Experiments 4–5, we also included words that were task relevant but not personally significant. In Experiment 3, we used words that were both task relevant and significant. These manipulations allowed us to compare across experiments the effect of significant but task-irrelevant stimuli inside versus outside the focus of attention. In addition, we compared the effect of irrelevant significant distractors within each attentional condition to that exerted by task-relevant distracting words. In all of our experiments, we measured reaction time (RT) and proportion of accuracy. In Experiments

[1] The GKT is a psychophysiological method of information detection, which has been developed for purposes of polygraph investigation. It is based on the phenomenon of enhanced ORs to significant items from which guilt is circumstantially inferred. The GKT uses a series of multiple-choice questions, each having one significant alternative (e.g., a feature of the crime under investigation) and several neutral alternatives (e.g., other features irrelevant to the crime under investigation), chosen so that an innocent suspect would not be able to discriminate them from the significant alternative (Lykken, 1959, 1960). If the suspect's physiological responses to the significant alternatives are consistently larger than they are to the neutral alternatives, knowledge about the event (i.e., the crime) is inferred. The GKT has been extensively researched during the past three decades, and the results have demonstrated high levels of validity (see a review in Ben-Shakhar & Elaad, 2003).

1–5, we also included the electrodermal component of the OR, measured by SCRs. The use of SCRs necessitated an unusually long intertrial interval (ITI) to allow for a recovery of the SCRs to baseline level. Therefore, the ITI in all of our experiments (except for Experiments 6 and 7, in which we did not measure the SCR) averaged 20 s.

## Experiment 1

In Experiment 1, we examined the extent to which personally significant but task-irrelevant words influence behavior and elicit an OR when presented in a task-relevant location. A colored word was presented centrally at fixation, and the participants responded by naming its color. The words denoted either significant concepts (e.g., the participant's name) or neutral concepts (e.g., other names). Although it could, in principle, be sufficient for the participants to focus on just a small segment of the word for the color identification (thereby making the whole word outside the central focus of attention), it is well established that visual attention generally selects whole objects rather than specific features (e.g., Duncan, 1984). Therefore, we assumed that the words were presented within the focus of visual attention. We used two different experimental versions. Whereas in Experiment 1A, the target stimulus remained on the screen until a response was recorded, in Experiment 1B, it was masked after 150 ms, forcing the participants to focus on its location ahead of time.

The task used in Experiment 1 is reminiscent of the emotional Stroop paradigm (see Williams, Mathews, & MacLeod, 1996, for a review). In this paradigm, like in our study, participants are engaged in a color-naming task. We compare the effect of irrelevant but personally significant words and irrelevant neutral words. In the emotional Stroop paradigm, irrelevant emotional words are compared with irrelevant neutral words. Despite these similarities, fundamental differences between the two methods may exist and thus an analogy between the results obtained with these two paradigms may be premature. We discuss this issue extensively in the General Discussion section.

### *Method*

*Participants.* Thirty-two undergraduate students, with normal or corrected-to-normal sight, participated in each experimental group for either course credit or payment (25 NIS, or approximately U.S.$6). All participants were native Hebrew speakers.

*Apparatus.* All stimuli were presented on a color monitor connected to a Pentium computer. Participants responded vocally, and their responses were recorded by a small microphone attached to the collar of their shirt and connected to the computer. SCRs were measured by a constant voltage system (0.5-V ASR Atlas Researches). Two Ag/AgCl electrodes (0.8-cm diameter) were used with an electrode paste, which was prepared according to the recipe provided by Fowles et al. (1981). The SCRs were defined as the maximal conductance change obtained from 1 s to 5 s after stimulus onset. The SCRs were computed using an A/D (NB-MIO-16) converter with a sampling rate of 1,000 per second.

*Stimuli and design.* Participants were required to name the color of centrally presented Hebrew words as fast as possible. The words appeared in one of four colors: red, yellow, blue, or green. The background luminance was dark. The size of the letters was 0.7 cm in height by approximately 0.6 cm in width, corresponding to a visual angle of approximately $0.5° \times 0.43°$ from a viewing distance of 80 cm.

The words denoted either significant or neutral concepts, forming the significant-word and neutral-word conditions. The significant words denoted personal items that were collected prior to the experiment and were incorporated into the computer program without notifying the participants. Each personal item was adjusted specifically to each participant (e.g., his or her own name). The neutral stimuli denoted nonpersonal items belonging to the same category (e.g., other names), which were matched in length to the personally significant items. The words were chosen from four categories: first names, family names, mothers' names, and area of major study.[2] Each category included five stimuli consisting of a single significant item (i.e., the participant's first name in the first-name category) and four neutral items (i.e., four neutral names in the first-name category). The significant concepts were presented in just one fifth of the trials to prevent habituation, known to occur with OR measurements (e.g., Sokolov, 1963). All in all there were four categories by five items, for a total of 20 experimental stimuli in a block. The participants in Experiment 1A were tested on one experimental block, and those in Experiment 1B were tested on two experimental blocks.

The experimental block was composed of a buffer stimulus followed by the 20 experimental stimuli. The buffer stimulus was used because the first experimental stimulus is known to cause enhanced OR. It consisted of a fixed word (*TABLE*) in a fixed color (red). Each of the four neutral words in each category appeared in a different color, which was randomly determined. The four significant stimuli for each participant appeared in the four different colors, counterbalanced across participants so that each color was presented equally often in each category. The stimuli (excluding the buffer) were presented in a random order, with the constraint that at least one neutral item must be presented between any two significant items. The experimental block was preceded by a practice block of eight trials. These trials consisted of words denoting various nonpersonal object names (e.g., *APPLE*, *PEN*).

*Procedure.* Participants were seated at a table facing the screen, and a microphone was attached to the collar of their shirt. Two electrodes were attached with masking tape to the volar side of the index and fourth fingers of the participants' left hand. The experimenter instructed the participants to name the color of the words appearing on the screen as fast as possible and to ignore their content. After the practice block, participants were requested to sit at ease for a rest period of 2 min, in which a baseline recording of the SCR was conducted. After this recording, the experiment began. Twenty-one words were presented at a random ITI ranging from 16 s to 24 s, with a mean of 20 s. In Experiment 1A, the word in each trial remained on the screen until the participant responded. In Experiment 1B, the word was masked after 150 ms by a white pattern mask (*####*), which covered the area of the word for another 100 ms. The experimenter sat beside the participant during the experiment and keyed the participant's vocal response into the computer to keep track of errors.

### *Results and Discussion*

To eliminate individual differences in SCRs and permit a meaningful summation of the responses for the different participants, we transformed each participant's conductance changes into within-participant standard scores (e.g., Ben-Shakhar, 1985). The standard scores were calculated on the basis of all trials in the experiment, including the buffer. We then calculated for each participant the mean standard scores for the significant-word trials and for the

[2] To eliminate possibly significant names from the neutral items, we also collected the names of family members and friends of each participant prior to the experiment. These names were excluded from the list of neutral items. A previous study that used the same classification scheme showed that the four categories used in the experiment elicit significant ORs relative to the neutral list (Ben-Shakhar & Elaad, 2002).

neutral-word trials. Finally, we calculated the mean standard score for each condition across participants. Table 1 presents the mean standardized SCRs and the mean RTs, as well as their standard deviations, for the significant- and neutral-word conditions. Trials in which RTs were below 300 ms or exceeded 2,000 ms were discarded (less than 1% in both Experiments 1A and 1B). Trials on which participants made errors in the color-naming task were excluded from the calculations as well (less than 2% and 6% in Experiments 1A and 1B, respectively).

In these, as well as the remaining experiments, the proportion of errors was small and did not differ between the two word conditions. In addition, there was no hint of a possible speed–accuracy tradeoff. Therefore, we focus only on the RT and the SCR in all subsequent analyses. Inspection of Table 1 reveals a similar pattern of results for both Experiments 1A and 1B: slower RTs and larger SCRs in the significant-word condition relative to the neutral-word condition, $t(31) = 2.75$, $p < .01$, effect size (ES) = 0.49, and $t(31) = 6.27$, $p < .01$, ES = 1.11, for RTs and SCRs, respectively, in Experiment 1A, and $t(31) = 2.86$, $p < .01$, ES = 0.51, and $t(31) = 3.72$, $p < .01$, ES = 0.66, for RTs and SCRs, respectively, in Experiment 1B. The ES was defined as the standardized mean difference between the significant and neutral word conditions. We use a standard norm of ES equaling 0.2, 0.5, and 0.8 for small, medium, and large effects, respectively (see J. E. Cohen, 1988). These results demonstrate that the exogenous significant items impaired performance and elicited an OR when they were presented within the focus of attention. This occurred despite the fact that the content of the words was irrelevant to task requirements.

In Experiment 2, we examined whether the exogenous significant words capture attention when they are presented outside the focus of visual attention. If the significant words indeed capture attention, we should observe an interference effect in task performance as well as larger ORs, similar to those found in Experiment 1.

## Experiment 2

In this experiment, we used a Stroop-like task similar to the one used in Experiment 1, except that the distracting words were spatially separated from the target colors. On each trial, a color square was presented in the center of the screen, and participants were required to name its color. Two strings of letters were presented simultaneously with the color patch, one above and one below it. One of these letter strings consisted of a repeated single letter, and the other one consisted of a word. The word was either significant or neutral, as in the conditions used in Experiment 1. The goal of the experiment was to explore whether significant words affect performance and elicit an OR when they are presented outside the focus of attention. As in Experiment 1, we used two experimental versions. In Experiment 2A, the target stimulus remained on the screen until the participant responded. The target stimulus was presented for a short duration (150 ms) and masked in Experiment 2B.

### Method

*Participants.* Thirty-two undergraduate students, with normal or corrected-to-normal sight, participated in each experimental group for either course credit or payment (25 NIS, or approximately U.S.$6). All participants were native Hebrew speakers.

*Stimuli and design.* All aspects of the experiment were identical to Experiment 1, except for the following: Each display consisted of a small colored square with two strings of white letters above and below it. One of the two strings was a word from the same list used in Experiment 1 (i.e., either significant or neutral, with a ratio of 1:4, respectively), and the second string was a nonword. The nonword was composed of repetitions of a single letter randomly chosen by the computer from all the Hebrew letters (e.g., *XXXXX*). On each trial, the length of the nonword was matched to that of the word. The location of the word and nonword was determined randomly on each trial, with the constraint that half of the words appeared above the colored square and the remaining half appeared below it. The inclusion of a nonword in the display was intended to dilute the amount of spatial attention allocated to the word (cf. Kahneman & Chajczyk, 1983). The size of the letters was identical to that in Experiment 1, and the size of the square was 0.7 cm $\times$ 0.7 cm (corresponding to a visual angle of approximately 0.5° $\times$ 0.5° from a viewing distance of 80 cm). The center-to-center distance between the square and each of the two strings was 1.4 cm (1° of visual angle).

In this experiment, both groups were tested on two experimental blocks of 21 trials each. Stimuli in the two blocks were identical, differing only in the order of presentation that was randomly determined by the computer. In all other respects, the structure of the blocks was identical to that in Experiment 1.

*Procedure.* Participants were instructed to respond as fast as possible to the color of the square by naming the color aloud and were told that any letters or words surrounding the square were irrelevant for the task. In all other respects, this experiment was similar to Experiment 1.

### Results and Discussion

The SCRs were transformed into *Z* scores separately within each block. Extreme RTs (less than 1% and 0.5% for Experiments 2A and 2B, respectively) and erroneous trials (less than 2% and 3% for Experiments 2A and 2B, respectively) were defined by the same criteria as they were in Experiment 1 and were discarded. Mean responses for the different conditions (significant vs. neutral words) were calculated within each block and across blocks. Because the block factor produced neither a main effect nor an interaction with the word condition, we report only the means collapsed across the two blocks. Table 2 presents the means of the standardized SCRs and RTs, along with the proportion of errors for the significant- and neutral-word conditions and standard deviations for all measures.

Table 1
*Mean Reaction Times (RTs), Mean Standardized Skin Conductance Responses (SCRs), and Proportion of Errors for the Significant and Neutral Words in the Color-Naming Task in Experiments 1A and 1B*

| | Significant words | | Neutral words | |
|---|---|---|---|---|
| Experiment and measure | *M* | *SD* | *M* | *SD* |
| Experiment 1A | | | | |
| RT (in ms) | 895 | 220 | 831 | 159 |
| Standardized SCR | 0.48 | 0.47 | −0.11 | 0.11 |
| Proportion of errors | .03 | .11 | .01 | .03 |
| Experiment 1B | | | | |
| RT (in ms) | 880 | 175 | 840 | 134 |
| Standardized SCR | 0.28 | 0.47 | −0.10 | 0.13 |
| Proportion of errors | .07 | .09 | .06 | .06 |

Table 2
*Mean Reaction Times (RTs), Mean Standardized Skin Conductance Responses (SCRs), and Proportion of Errors for the Significant and Neutral Words in the Color-Naming Task in Experiments 2A and 2B*

| | Significant words | | Neutral words | |
|---|---|---|---|---|
| Experiment and measure | *M* | *SD* | *M* | *SD* |
| Experiment 2A | | | | |
| RT (in ms) | 728 | 104 | 723 | 86 |
| Standardized SCR | 0.26 | 0.36 | −0.07 | 0.09 |
| Proportion of errors | .03 | .05 | .01 | .02 |
| Experiment 2B | | | | |
| RT (in ms) | 736 | 120 | 715 | 112 |
| Standardized SCR | 0.03 | 0.31 | −0.02 | 0.08 |
| Proportion of errors | .03 | .05 | .03 | .03 |

The pattern of the RT results was roughly similar in Experiments 2A and 2B. In Experiment 2A, RTs for the significant items were not different from the RTs for the neutral items, $t(31) = 0.51$, $p = .62$, ES $= 0.09$.[3] The difference between these two conditions in Experiment 2B was numerically larger but still not significant, $t(31) = 1.80$, $p = .08$, ES $= 0.31$. Thus, the behavioral interference by the significant words that was observed in Experiment 1 was eliminated by physically separating the words from the colors.

However, the pattern of the OR measurement differed between the experiments. In Experiment 2A, the OR measurement continued to show significantly larger SCRs for the personally related items than for the neutral ones, $t(31) = 4.36$, $p < .01$, ES $= 0.77$. In contrast, there was no difference in the SCRs between the significant and the neutral items in Experiment 2B, $t(31) = 0.75$, $p = .46$, ES $= 0.13$. These results are puzzling. The RT results, combined across Experiments 1 and 2, suggest that exogenous significant words affect performance inside the focus of visual attention but are unable to capture attention when presented outside the focus of attention. However, the SCR results appear inconclusive, and whereas in Experiment 2B they are in accord with the RT results, in Experiment 2A they suggest that exogenous significant words trigger an OR and therefore must be processed both inside and outside the focus of attention.

One may suggest that the OR is a more sensitive index than RT for attentional capture by significant stimuli. However, the only difference between Experiments 2A and 2B is that the stimuli were masked in the latter but not in the former, and this same masking manipulation did not produce a difference between Experiments 1A and 1B. Thus, there is no apparent reason that the presumed added sensitivity of the SCR will be observed in Experiment 2A and not in Experiment 2B. We propose that the OR effect in Experiment 2A may reflect the fact that SCRs are measured over a period of 4 s (i.e., they are the maximal change in skin conductance obtained from 1 s to 5 s after stimulus onset). The stimulus display in Experiments 1A and 2A was removed only after the execution of the participant's response. Although there is no agreement concerning the specific involvement of attentional processes in responding to a color target, it is widely agreed that this involvement ends well before the actual execution of the overt response (see, e.g., Pashler, 1998). Thus, it is possible that participants first focused their attention on the central target. During this period, the peripheral word did not elicit any OR. After this period, however, and prior to the actual execution of the overt response, participants may have been able to shift their attention to the peripheral word. The OR may have resulted from this latter attentional processing of the word. Put differently, the OR effect in Experiment 2A may reflect a late, endogenous shift of attention toward the significant items rather than an early, exogenous one.

To further support our conclusions regarding the influence of attended and nonattended significant stimuli on behavior, we performed two additional statistical analyses across Experiments 1–2. A 2 (experiments: 1A, 1B) × 2 (stimulus significance: significant, neutral) mixed analysis of variance (ANOVA) was performed on each measure (RT and the SCR). The significance effect was statistically significant for both measures, $F(1, 62) = 14.68$, $p < .001$, for RT, and $F(1, 62) = 48.84$, $p < .001$, for SCR. No other effects were statistically significant, all $F$s $< 2$, all $p$s $> .1$. Similar ANOVAs were conducted for Experiments 2A and 2B. In accord with our conclusions, none of the effects were statistically significant for the RT, all $F$s $< 3$, all $p$s $> .09$, but the Experiment × Stimulus Significance interaction was statistically significant for the SCR, $F(1, 62) = 8.3$, $p < .01$.

The combined results of Experiments 1 and 2 suggest a straightforward picture concerning the impact of exogenous significant items on task performance and the OR. When these items are presented inside the focus of visual attention, performance is disrupted and the OR is triggered. This generalization holds when the display remains present until the participants' overt response (Experiment 1A) or when it is presented for a short exposure time (Experiment 1B). When the significant word is presented outside the main focus of attention, however, the behavioral effects disappear or are at least largely attenuated (Experiments 2A and 2B). The OR is not triggered when the display is presented for a short exposure duration (Experiment 2B) but is elicited when the display is presented for a long duration (Experiment 2A). We hypothesize that the latter OR arousal is due to attentional processes that occur after the participant has completed all of the processes involving visual attention for the central target and shifted his or her attention to the peripheral word. In essence, then, there appears to be an agreement between the RT and the OR measurements, except that, because of its long measurement window, the OR can also be triggered by additional processes that take place after the completion of the target-related processes.

Our results question the view raised by Treisman (1960) that personally significant stimuli function like task-relevant stimuli. We found a dramatic attenuation in the impact of peripherally presented exogenous significant words on central targets. In contrast, numerous studies showed that task-relevant peripheral stimuli might strongly affect performance on central targets. Indeed, this is the hallmark of the well-studied flanker paradigm (e.g., Eriksen & Eriksen, 1974; Miller, 1991; see A. Cohen & Shoup, 1997, for a review), where flanking task-relevant distractors interfere with the response to central targets. Likewise, researchers in a number of studies used a spatial separation version of the Stroop

[3] In Experiments 1–3, the statistical power for detecting a medium effect size of 0.5 was 0.78. In Experiments 4–5, the statistical power for detecting the same effect size was 0.57, and in Experiments 6–7, it was 0.75.

task in which the color patch was separated from the word (e.g., Gatti & Egeth, 1978; Kahneman & Henik, 1981), and they still obtained a robust Stroop effect. This latter Stroop task, in which participants name a color patch flanked by words, is very similar to the task used in our study. The only difference is that we used exogenous significant words instead of words denoting colors (that are therefore task relevant), which are routinely used in the Stroop task. The fact that a robust effect is typically obtained in the Stroop version but a very small effect was shown in our experiments suggests that there may be a fundamental difference between endogenous task-relevant stimuli and exogenous personally significant stimuli.

However, peripheral task-relevant distractors do not always exert strong effects (e.g., Yantis & Johnston, 1990). Furthermore, it is possible that the specific conditions used in our study, such as the size of the words, their distance from the target, the use of a nonword as one of the two flanking stimuli, and possibly other factors prevent semantic processing of words altogether. In the next three experiments, we examined the relation between task-relevant distractors and significant but task-irrelevant distractors. In Experiment 3, we used a stimulus display similar to that of Experiment 2B (in which no effect was obtained), but, via task instructions, we made the significant words relevant for the task. This manipulation allowed us to examine whether a personally significant distractor that normally does not affect performance (as in Experiment 2) would now affect performance by virtue of being task relevant.

## Experiment 3

Experiment 3 was modeled after Experiment 2B in terms of the stimulus display and the experimental design. We turned the personally significant words into task-relevant words by altering the task instructions. Participants were required to respond to the color squares by uttering the significant words instead of the actual colors of the squares. For instance, a participant was instructed to utter his first name ("David") in response to a red square, his family name ("Levi") in response to a yellow square, his mother's name ("Rachel") in response to a blue square, and his field of major study ("psychology") in response to a green square. The peripheral words denoted either these significant items or neutral items, just as in Experiments 1 and 2. Note that like in the original Stroop task, these conditions create three types of trials: congruent, incongruent, and neutral. In the congruent trials, a significant word that matched the required response was presented in the periphery (e.g., in the example given above, the word *DAVID* coupled with a central red square). In the incongruent trials, a significant word that matched an alternative response was presented (e.g., the word *LEVI* coupled with a red square). In the neutral trials, a neutral word irrelevant to the participant's responses appeared in the periphery (e.g., a neutral name coupled with a red square). As in standard Stroop tasks (see MacLeod, 1991, for a review), we measured the difference between congruent and incongruent trials as an index of word processing and of attentional selection. A congruency effect (i.e., slower latencies for the incongruent trials than for the congruent trials) would indicate that, in contrast to the results of Experiment 2, the peripheral words were processed. Theoretically, it would also indicate that there is a fundamental difference between the selection of personally significant stimuli that are endogenous to task requirements and the selection of the very same stimuli when they are exogenous to the task.

### Method

*Participants.* Thirty-two undergraduate students, all native Hebrew speakers with normal sight, participated in the experiment for course credit or payment (25 NIS, or approximately U.S.$6).

*Stimuli and design.* The stimulus display was similar to that of Experiment 2B, with the exception that three blocks of 21 stimuli were used instead of two. Each block consisted of a buffer stimulus, 16 neutral items, and four repetitions of a single significant item. The neutral stimuli, which were identical in all three blocks, were similar to those used in Experiment 2 and consisted of nonpersonal items from the four categories used in previous experiments. Each block included one significant item (first name, family name, mother's name, or major), which appeared four times, once with each of the four color squares. Thus, the four significant trials in each block consisted of a single congruent trial (e.g., the word *DAVID* with a red square) and three incongruent trials (e.g., the word *DAVID* with the other three colors). Note that each participant was presented with just three of the four significant items, one in each block. The three significant items were chosen randomly for each participant, such that their frequency was counterbalanced across participants. All together, the experiment consisted of 48 neutral trials, 3 congruent trials, and 9 incongruent trials. In all other aspects, the experimental procedure was identical to that used in Experiment 2. The experiment began with three practice blocks, which were identical to the experimental blocks, but because SCR was not measured during practice, stimuli were presented at a relatively fast rate (a word every 3 s). The experiment lasted approximately 50 min.

### Results and Discussion

The same data trimming used in previous experiments was applied (less than 2% of trials were discarded because of errors and 1% were omitted as outliers). Table 3 presents the means of the two measures (RT and standardized SCR), as well as the proportion of errors for the incongruent, neutral, and congruent words and the standard deviations for all measures.

Table 3 reveals clear RT differences between the three congruency conditions. These differences were statistically significant, $F(2, 62) = 9.77$, $p < .001$. A planned comparison analysis revealed a significant RT difference between the incongruent condition and the congruent condition, $F(1, 31) = 12.05$, $p < .001$, ES $= 0.61$. It is interesting to note that a different pattern of results emerged for the SCR measure, with no statistically significant differences between these two conditions, $F(1, 31) = 0.67$, $p = .42$, ES $= 0.14$.

Two important findings emerged from Experiments 2 and 3. First, there appears to be a clear difference between endogenous and exogenous personally significant stimuli. Whereas peripherally presented task-relevant distractors affect performance (Experiment 3), peripherally presented but exogenous words have very little effect (Experiment 2). Because physically identical stimuli were used, these findings suggest a possible qualitative difference between exogenous and endogenous stimuli regardless of their personal significance.

Second, a clear dissociation was obtained between RT and the electrodermal component of the OR. Whereas task performance was strongly affected by the content of the endogenous distractors, SCR differences were not found either between the congruent and incongruent conditions or between the endogenous words and the

Table 3
*Mean Reaction Times (RTs), Mean Standardized Skin Conductance Responses (SCRs), and Proportion of Errors for the Incongruent, Neutral, and Congruent Words in the Naming Task in Experiment 3*

| | Incongruent significant words | | Neutral words | | Congruent significant words | |
|---|---|---|---|---|---|---|
| Measure | *M* | *SD* | *M* | *SD* | *M* | *SD* |
| RT (in ms) | 1,072 | 182 | 1,049 | 143 | 980 | 185 |
| Standardized SCR | 0.08 | 0.51 | −0.02 | 0.09 | −0.04 | 0.56 |
| Proportion of errors | .02 | .08 | .01 | .02 | .03 | .05 |



neutral words. It is commonly assumed that visual attention processes are involved in the conflict between the incongruent distractors and the target when they are spatially separable (e.g., J. D. Cohen, Dunbar, & McClelland, 1990; LaBerge, Brown, Carter, Bash, & Hartley, 1991). The present result, in turn, suggests that the OR is not affected by visual attention processes, an issue that is further discussed in the General Discussion section.

The fact that personally significant words captured attention only when they were relevant to task requirements suggests, in accord with previous studies, that task-relevant stimuli might be unique in their ability to influence behavior (e.g., Atchley, Kramer, & Hillstrom, 2000; Bacon & Egeth, 1994; Folk et al., 1992). However, although Experiment 3 certainly documented the importance of task-relevant distractors, the design of Experiments 2 and 3 does not allow for a direct comparison of task-relevant and significant task-irrelevant distractors. In particular, on the basis of the RT results, it is still possible that the difference between the two types of distractors is quantitative rather than qualitative. Experiment 3 showed that task-relevant stimuli affect performance outside the focus of attention. Experiments 1 and 2 showed that significant exogenous stimuli affect performance inside but not outside the focus of attention. It is possible that both types of stimuli have similar effects, but the effect of task-relevant distractors is stronger both inside and outside the focus of attention. In other words, the null results obtained in Experiment 2 may reflect a floor effect.

Experiments 4 and 5 were designed to make a direct comparison between significant exogenous and task-relevant distractors. Two types of distractors were compared within the focus of visual attention (Experiment 4) and outside the focus of attention (Experiment 5). As in previous experiments, most distracting words were neutral, and personally significant irrelevant words were used as exogenous stimuli in some trials. Most important, we also added in some other trials words denoting color names. These color words are not personally significant, but they are task relevant because the task involved naming the color of the central targets. The presentation of exogenous and endogenous stimuli in the same experimental block and within the same task allows for a direct comparison of the impact of the two types of stimuli under central and peripheral presentation conditions.

## Experiment 4

Our main goal in Experiment 4 was to directly compare exogenous personally significant distractors and task-relevant distractors. For this purpose, the two types of distractors were presented in different trials of each block. This manipulation allows for a comparison of the effects of the two types of distractors while participants are engaged in the same task and presumably use a similar strategy with both.

Experiment 4 differed from the previous experiments in several other respects. First, although we did not find a statistically significant RT effect of personally significant distractors outside the focus of attention in two different experiments (Experiments 2A and 2B), the difference between significant and neutral distractors approached statistical significance in Experiment 2B. This weak tendency may be explained by an insufficient control over visual attention, which relied on the participants' knowledge that the target would be presented in the center of the computer screen. Therefore, we added a central fixation point that appeared prior to the presentation of the target display, allowing the participants to focus more precisely on the target location. In addition, to further encourage the participants to focus on the target location ahead of time, we shortened the exposure duration of the target display to 100 ms. Finally, the four significant categories used in the present experiment included the participant's own first name, family name, mother's name, and father's name.[4]

### Method

*Participants.* Twenty undergraduate students, all native Hebrew speakers with normal sight, participated in the experiment for course credit or payment (25 NIS, or approximately U.S.$6).

*Stimuli and design.* All aspects of this experiment were identical to those of Experiment 1B (in which the distracting words were presented centrally), except for the following: In addition to the 21 stimuli (consisting of a buffer stimulus, 4 personally significant items, and 16 neutral items from the four name categories), 8 color words were included in each of the two blocks. These consisted of 4 color words (*RED*, *YELLOW*, *GREEN*, and *BLUE*), each repeated twice in each block. Overall, there were 29 stimuli in each block.

The coupling of a specific color with a specific significant or neutral word was identical to that done in Experiment 1B. In addition, each color word (across the two blocks) appeared once with each print color, resulting in 16 combinations (4 color words × 4 print colors). Thus, each block

[4] The significant categories used in the previous experiments included the participant's field of major study. Because the effect of this category was considerably weaker than that of the remaining categories, it was replaced with the category of fathers' names.

consisted of two congruent trials (e.g., the word *RED* printed in red) and six incongruent trials (e.g., the word *RED* printed in yellow). The pairing of a specific congruent or incongruent trial with a particular block was counterbalanced across participants to eliminate any possible order effects.

Prior to the presentation of each word, a fixation point appeared for 500 ms, indicating the location of the word. The word itself appeared for 100 ms and was subsequently masked, as in Experiment 1B. The stimuli (excluding the buffer) were presented in a random order, with the constraint that at least one neutral or color word was presented between any two significant words. All other aspects of the stimulus design and the experimental procedure were identical to those in Experiment 1B.

### Results and Discussion

Trials in which participants made errors (less than 3%) or in which RTs were either below 300 ms or above 1,500 ms (0.5%) were discarded from the calculations. Table 4 presents the means of the two measures (RT and standardized SCR), as well as the proportion of errors for the incongruent, significant, neutral, and congruent words and the standard deviations for all measures.

Table 4 reveals robust RT differences between the significant and neutral words, as well as between the incongruent and congruent conditions. Planned comparisons conducted on these data revealed that both contrasts produced statistically significant effects, $t(19) = 5.87$, $p < .001$, ES = 1.31, and $t(19) = 6.42$, $p < .001$, ES = 1.43, respectively. However, the SCR measure produced different results for the two conditions: A statistically significant difference was found for the significance effect, $t(19) = 5.59$, $p < .001$, ES = 1.25, but not for the congruency effect, $t(19) = 1.23$, $p = .23$, ES = 0.27.

The results for the significant-word condition were similar to those obtained in previous experiments, demonstrating once again that personally significant distracting words affect performance and increase the SCR when they are presented inside the focus of attention. In addition, in accord with numerous other studies (see MacLeod, 1991, for a review), we obtained a robust congruency effect on RTs with distracting color words. It is interesting to note that this effect was not reflected by notable changes in the SCR measure, just like the results of Experiment 3.

The relative effects of personally significant and task-relevant distracting words are most relevant for the present purpose. Because these two types of words were mixed within each block, we assumed that the participants used a similar strategy in working with both. Consequently, we used the neutral-word trials as a common baseline condition. The mean absolute latency for the incongruent words (793 ms) was slightly higher than the latency for the personally significant words (778 ms), and the resulting amount of interference caused by an incongruent and a significant word relative to the baseline condition was similar (108 ms vs. 93 ms, respectively), $t(19) = 0.73$, $p = .47$, for the difference between the two. In fact, the effect size of this interference was identical in both cases (ES = 1.31). The SCR measure led to different results, with a higher SCR for the personally significant words (0.52) than for the task-relevant distractors (0.15). The amount of interference relative to the baseline condition was larger in the former (0.69, ES = 1.25) than in the latter (0.32, ES = 0.69), and this difference was statistically significant, $t(19) = 2.79$, $p < .01$. This finding emphasizes once again the sensitivity of the OR to personally significant stimuli and its relative insensitivity to incongruent task-relevant stimuli.

Experiment 5 was similar to Experiment 4, with one crucial difference: The distracting words were presented peripherally, outside the main focus of visual attention. Given that central distractors led to similar RT effects for personally significant and task-relevant words, we can now examine whether the same effects will be observed for unattended distractors. Likewise, we can examine whether the higher SCR effect for attended personally significant distractors than for task-relevant distractors holds for peripheral words as well.

## Experiment 5

### Method

*Participants.* Twenty undergraduate students, all native Hebrew speakers with normal sight, participated in the experiment for course credit or payment (25 NIS, or approximately U.S.$6).

*Stimuli and design.* All aspects of the experiment were identical to those of Experiment 4 with one exception. The stimulus display consisted of a central color patch, with a word and a nonword appearing above and below it. The spatial arrangement of the word and nonword was identical to that in Experiment 2B. Participants were instructed to name the color of the central patch as fast as possible and to ignore all stimuli above or below the target.

### Results and Discussion

Data trimming was similar to that of Experiment 4 (0.5% of the trials were excluded from computations because of errors and 0.5% were omitted as outliers). Table 5 presents the means of the

Table 4
*Mean Reaction Times (RTs), Mean Standardized Skin Conductance Responses (SCRs), and Proportion of Errors for the Incongruent, Significant, Neutral, and Congruent Words in the Color-Naming Task in Experiment 4*

| | Incongruent color words | | Significant words | | Neutral words | | Congruent color words | |
|---|---|---|---|---|---|---|---|---|
| Measure | *M* | *SD* | *M* | *SD* | *M* | *SD* | *M* | *SD* |
| RT (in ms) | 793 | 166 | 778 | 136 | 685 | 108 | 600 | 83 |
| Standardized SCR | 0.15 | 0.36 | 0.52 | 0.46 | −0.17 | 0.14 | 0.00 | 0.38 |
| Proportion of errors | .05 | .08 | .05 | .09 | .02 | .03 | .00 | .00 |

Table 5
*Mean Reaction Times (RTs), Mean Standardized Skin Conductance Responses (SCRs), and Proportion of Errors for the Incongruent, Significant, Neutral, and Congruent Words in the Color-Naming Task in Experiment 5*

| | Incongruent color words | | Significant words | | Neutral words | | Congruent color words | |
|---|---|---|---|---|---|---|---|---|
| Measure | *M* | *SD* | *M* | *SD* | *M* | *SD* | *M* | *SD* |
| RT (in ms) | 645 | 61 | 609 | 53 | 607 | 56 | 565 | 56 |
| Standardized SCR | 0.02 | 0.23 | −0.04 | 0.43 | −0.03 | 0.13 | 0.03 | 0.59 |
| Proportion of errors | .01 | .03 | .01 | .04 | .00 | .01 | .00 | .00 |



two measures (RT and standardized SCR), as well as the proportion of errors for the incongruent, personally significant, neutral, and congruent words and the standard deviations for all measures.

Table 5 reveals that unlike the results of Experiment 4, the significance effect completely disappeared in both the RT and the SCR measures. Planned comparisons for the differences between personally significant and neutral words were nonsignificant with both measures, $t(19) = 0.29$, ES = 0.06, and $t(19) = -0.09$, ES = −0.02, respectively. In contrast, the RT measure for the task-relevant words revealed a clear congruency effect, $t(19) = 7.33$, $p < .001$, ES = 1.64. It is interesting to note that similar to the previous experiment, no congruency effect was obtained with the SCR measure, $t(19) = -0.07$, ES = −0.02.

As in Experiment 4, we compared the RT interference effect of the task-relevant words and the personally significant words relative to the neutral, baseline condition. The interference was much larger for the task-relevant words (38 ms) than for the personally significant words (2 ms), and this difference was statistically significant, $t(19) = 5.02$, $p < .001$. The ES for the former and latter were 1.09 and 0.06, respectively, further demonstrating the difference between the two effects, which is in sharp contrast to the virtually identical effect sizes obtained for central words. These results demonstrate a clear dissociation between personally significant exogenous stimuli and endogenous stimuli, and they reflect a fundamental difference between these two types of stimuli when the stimuli are presented outside the focus of attention.

The dissociation between exogenous personally significant stimuli and endogenous stimuli is further reflected by the SCR measure, which reveals a stronger interference effect for personally significant distractors than for task-relevant distractors inside the focus of attention (Experiment 4). However, this interference effect was completely eliminated when the significant distractors were presented outside the central focus of attention (−0.01, ES = −0.02). Thus, we can now firmly conclude that the differences between the results of Experiments 2 and 3 were not a mere consequence of differences in basic effect sizes and/or dilution processes. Rather, they reflect the fact that task-relevant stimuli, in contrast to irrelevant personally significant items, are unique in their ability to capture attention when they are presented in an unattended location.

The final two experiments address several methodological issues that may be raised regarding the previous experiments and our interpretation of their results. First, although our classification of the words into significant and neutral categories is valid, if the significant concepts are also more frequent than the neutral ones (although frequency estimates for these words are not available), the obtained effects with these words can be accounted for in terms of frequency rather than significance. Second, because the significant concepts were presented in just one fifth of the trials, it is possible that the interference effect reflects the infrequent appearance of the significant categories rather than their significance. Third, an unusually long ITI was used in the previous experiments, and it is important to demonstrate that the dissociation between significant exogenous and task-relevant distractors would be also obtained with more standard ITIs.

We conducted Experiments 6 and 7, which used central and peripheral presentations of the distracting words, respectively, to address these concerns. These experiments were similar to Experiments 1B and 2B, but SCRs were not measured and therefore the ITI was shortened to 3 s. In addition, we replaced one neutral concept from each category with a highly frequent word (as determined by Hebrew word-frequency norms based on questionnaire ratings of 100 participants; see explanation below) not belonging to any of the categories (e.g., *BREAD*, *HOUSE*). As a result, the words included 4 significant names (as in Experiments 4 and 5), 12 neutral names, and 4 highly frequent words. If the difference between significant and neutral words was caused by either the relative rarity of their presentation or their high frequency, we should observe the same effect for the frequent words.

## Experiment 6

### Method

*Participants.* Thirty undergraduate students, all native Hebrew speakers with normal sight, participated in the experiment for course credit or payment (25 NIS, or approximately U.S.$6).

*Stimuli and design.* The experimental paradigm resembled that of Experiment 1, in which significant and neutral words were presented centrally. However, each of the four categories comprised one significant item (e.g., the participant's first name) and only three neutral items (e.g., other participants' first names). Following a procedure similar to the one we used in Experiments 4 and 5, we used first names, family names, fathers' names, and mothers' names as categories. In addition, a novel category was inserted in each block, consisting of 4 three-letter object names rated as highly frequent by Hebrew-speaking participants. In English, the frequent words were *BREAD*, *HOUSE*, *BOOK*, and *DOG*. All four words were taken from Hebrew word-frequency norms based on questionnaire ratings of 100 participants. These words received a mean score higher than 6 on a frequency scale of 1–7 (in which a higher score

Table 6
*Mean Reaction Times (RTs) and Proportion of Errors for the Significant, Frequent, and Neutral Words in the Color-Naming Task in Experiment 6*

| | Significant words | | Frequent words | | Neutral words | |
|---|---|---|---|---|---|---|
| Measure | *M* | *SD* | *M* | *SD* | *M* | *SD* |
| RT (in ms) | 658 | 155 | 591 | 94 | 619 | 112 |
| Proportion of errors | .04 | .07 | .03 | .05 | .03 | .03 |



indicated higher frequency).[5] Thus, there were three types of stimuli in the experiment: neutral, significant, and frequent words. In each block there were 20 experimental stimuli consisting of 12 neutral names, 4 significant names, and 4 frequent words. Because the ITI was short, we added two more experimental blocks. Thus, there were 4 experimental blocks.

The temporal stimulus sequence was the same as that in Experiments 4 and 5: A white fixation point, presented for 500 ms, preceded the appearance of a colored word on each trial. Words were presented for 100 ms and followed by a white mask of 100 ms. In contrast to previous experiments, only RTs were measured, allowing a relatively short ITI of 3 s. In all other aspects, the experimental design and stimulus presentation were similar to those in previous experiments.

*Procedure.* The experimental procedure we used was the same as that used in previous experiments, except for the fact that only response latencies were measured.

## Results and Discussion

Trials in which participants made errors (less than 3%) or in which RTs were below 300 ms or exceeded 1,500 ms (0.5%) were discarded from the calculations. Table 6 presents the mean RTs and the proportion of errors for the significant, frequent, and neutral words, as well as the standard deviations for all measures, for the first two blocks (the results for the first two blocks are presented first because they can be compared with the results of previous experiments). A one-way ANOVA revealed a statistically significant effect for the three types of words, $F(2, 58) = 8.96$, $p < .001$, and a planned contrast showed that the participants in the significant-word condition were slower than those in the neutral-word condition, $t(29) = 2.37$, $p < .05$, ES = 0.43. This significance effect was similar to the one obtained in previous experiments. Surprisingly, faster RTs were obtained in the frequent-word condition than in the neutral-word condition. Thus, the appearance of rare, frequent words appears to facilitate rather than hinder performance relative to the neutral condition. In other words, the slower RTs for the significant words cannot be explained by these factors.

Interestingly, the results for the additional two blocks (Blocks 3 and 4) were somewhat different. Mean RTs for the significant-, frequent-, and neutral-word conditions were 594 ms, 582 ms, and 588 ms, respectively, revealing a significance effect of only 6 ms. A two-way ANOVA of Block (1–2 vs. 3–4) × Word Category (significant, neutral, or frequent) revealed statistically significant main effects, $F(1, 29) = 9.86$, $p < .01$, for blocks and $F(2, 58) = 8.84$, $p < .001$, for the word category condition, as well as an interaction effect, $F(2, 58) = 4.34$, $p < .05$. The attenuation of the significance effect in the last two blocks was unexpected but is in accord with a recent article by Harris and Pashler (in press). These authors followed up on the paradigm of Welford and Morrison (1980) described earlier and showed that the name effect obtained by Welford and Morrison virtually disappears with practice. Thus, it seems that the effect of significant distractors on behavior is robust only on the first blocks and attenuates with further repetitions.

We showed repeatedly that there is a significance effect with both RT and SCR measures when significant distractors are present inside the focus of attention. This effect disappears when the distractors are positioned outside the focus of attention. The results by Harris and Pashler (in press) and those obtained in the last two blocks of the present experiment suggest that the attentional effect occurs under limited conditions. In fact, this finding reinforces the dissociation between significant and task-relevant distractors obtained in our study. Numerous studies (e.g., MacLeod, 1991) have shown that the interference by task-relevant distractors, despite becoming somewhat weaker, does not habituate with practice, suggesting again that the task-relevant distractors exert a fundamentally different effect than that of significant distractors.

Our previous findings suggest that there should be no significance effect when the personally significant distractors are presented outside the focus of attention. In Experiment 7, we examined whether this generalization holds under the same conditions as those of Experiment 6.

# Experiment 7

## Method

*Participants.* Thirty undergraduate students, all native Hebrew speakers with normal sight, participated in the experiment for course credit or payment (25 NIS, or approximately U.S.$6).

*Stimuli and design.* The experimental design and stimulus presentation were identical to those of Experiment 6, except that a word and a nonword were presented above and below a central color patch.

*Procedure.* The experimental procedure was identical to that of Experiment 6.

## Results and Discussion

Data trimming was similar to previous experiments (less than 1% of the trials were discarded because of errors and 1% were dropped as outliers). Table 7 presents mean RTs and proportion of errors for the significant, frequent, and neutral words, as well as standard deviations for all measures, for the first two blocks.

[5] See word-frequency norms at http://micro5.mscc.huji.ac.il/~frost.

Table 7
*Mean Reaction Times (RTs) and Proportion of Errors for the Significant, Frequent, and Neutral Words in the Color-Naming Task in Experiment 7*

| Measure | Significant words *M* | Significant words *SD* | Frequent words *M* | Frequent words *SD* | Neutral words *M* | Neutral words *SD* |
|---|---|---|---|---|---|---|
| RT (in ms) | 524 | 95 | 522 | 70 | 517 | 63 |
| Proportion of errors | .01 | .04 | .00 | .02 | .01 | .02 |

As can be seen in Table 7, differences between the conditions were very small, and, indeed, a one-way ANOVA did not yield a statistically significant effect, $F(2, 58) = 0.26$, $p = .77$. Similarly, a planned comparison contrasting the significant and neutral distractors was not statistically significant, $t(29) = 0.58$, $p = .57$, ES = 0.11. The results for the last two blocks were similar and showed no difference between the three conditions. These results confirmed our previous observations that the presence of significant distractors outside the focus of attention does not affect behavior, even under the very same conditions where attended significant distractors do affect performance.

## General Discussion

The relative influence of personally significant and task-relevant distractors on visual-task performance and on the OR was investigated in a series of experiments. Our results revealed a fundamental difference between the effects of significant distractors inside and outside the focus of attention. Experiments 1, 4, and 6 showed that centrally presented, personally significant distractors hinder performance. This effect was robust and consistent across three experiments that varied in several features, such as exposure duration of the display, ITI, and the presence or absence of masking. Experiments 1 and 4 also showed that attended personally significant distractors lead to enhanced ORs. Experiments 2, 5, and 7, which also differed in several features, showed that when personally significant distractors are positioned outside the focus of attention, performance is minimally affected. The difference between peripheral significant and neutral distractors was not statistically significant in any of the experiments and, with the exception of Experiment 2B, was never greater than 6 ms. Experiments 2B and 5 also showed that the OR is not affected at all by unattended significant distractors when the stimulus display is available for a short time. The enhanced SCRs observed in Experiment 2A, with the long exposure duration, seem to reflect a late shift of attention toward the distractors.

By contrast, Experiments 4 and 5 showed that task-relevant distractors affect performance both inside and outside the focus of attention, facilitating and hindering response latencies when they are congruent and incongruent, respectively, with the target. Experiment 3 further showed that when the significant distractors become relevant to the task (when the instructions are changed), they affect performance even when presented outside the focus of attention. This further demonstrates the unique role of unattended task-relevant stimuli. However, Experiments 3, 4, and 5 demonstrated that task-relevant stimuli have very little effect on the OR, both inside and outside the focus of attention.

These results document two distinct dissociations between task-relevant and personally significant stimuli. First, task-relevant stimuli capture visual attention, whereas personally significant stimuli do not. Second, attended personally significant stimuli affect the OR, whereas task-relevant stimuli have minimal effect on the OR both inside and outside the focus of attention. These findings have implications for the two issues explored in our study: (a) the influence of personally significant distractors, located either inside or outside the focus of visual attention, on responses to central targets, and (b) the relation between the OR and shifts in visual attention. We discuss these two issues in turn.

### *The Effect of Personally Significant Distractors and Its Broader Implications: Relation to Previous Studies*

Previous studies that used personally significant stimuli as distractors led to contradictory conclusions. Whereas some (Mack & Rock, 1998; Shapiro et al., 1997; Welford & Morrison, 1980) suggested that significant distractors affect performance even when they are unattended, others (Bundesen et al., 1997; Harris et al., in press) concluded that they do not. Our findings may shed light on this issue and resolve these inconsistencies. We suggest that the lack of interference in the studies by Bundesen et al. (1997) and Harris et al. (in press) reflects the fact that the significant distractors were located outside the focus of attention. The results of Shapiro et al. (1997), Mack and Rock (1998), and Welford and Morrison (1980) are also consistent with our findings, assuming that the manipulations used in these studies did not prevent visual attention from focusing on the significant distractors. Consider first the study by Welford and Morrison (1980). Participants were required to make a parity judgment on two peripheral digits while the participant's name was presented in between the two digits. It is quite likely that the participants' focus of attention spanned the entire visual display, including the distractor (see, e.g., A. Cohen & Ivry, 1989; Treisman & Schmidt, 1982). Likewise, participants in the Shapiro et al. (1997) study focused their attention at the RSVP stream, which included the significant probe item. The interpretation of the study by Mack and Rock (1998) is similar. In their study, the target stimulus (a cross) appeared in the periphery, and the unexpected significant distractor appeared at fixation. Moreover, assuming that the entire area of the cross was task relevant, the distractor was actually presented inside the area of the attended object. From this perspective, the significant distractors may have been attended, leading to their identification, as in our experiments in which words were presented centrally. In fact, when Mack and Rock reduced the size of the cross such that its location no longer overlapped with that of the significant distractor, detection rates of the distractor significantly dropped.

Our study focused on visual distractors. The effect of auditory significant distractors on task performance is less clear. As reviewed earlier, Wood and Cowan (1995) demonstrated that about one third of their participants noticed the presence of their names when they were presented in an unattended channel. Wood and Cowan made several methodological improvements on the earlier study by Moray (1959) to prevent participants from occasionally shifting their attention to the unattended channel. According to these researchers, their findings support the notion that attention was not incidentally diverted to the significant words (because RTs to the words appearing simultaneously with the significant words were not affected by it), and therefore the ability of some participants to notice the significant word is an indication of processing without attention.

Our findings give rise to a different interpretation. In Experiment 2A, we found enhanced ORs with no increase in RTs to the peripherally presented significant words. The SCR increase was eliminated when the exposure duration of the display was shortened in Experiment 2B, suggesting that the OR effect in Experiment 2A was due to a late, endogenous shift of attention. The study by Wood and Cowan (1995) is conceptually similar to Experiment 2A: Two messages were played simultaneously without an immediate auditory masking. It is possible that the participants first completed the processing required for the shadowing of the attended word and then shifted (in some of the trials) their attention to the unattended message. As in our Experiment 2A, this late shift of attention did not affect RT to the shadowing, but it might have led to processing of the unattended word. Recognition of a significant word, in turn, may have disrupted the participant's regular processing, affecting the shadowing of subsequent items. Thus, the processing of the significant words in the ignored message was carried out with attention rather than without attention.

An interesting follow-up study by Conway, Cowan, and Bunting (2001) showed that there are systematic individual differences in the ability to notice significant information in the unattended auditory channel. In particular, this ability was negatively correlated with working memory capacity. If working memory capacity is positively correlated with the ability to focus attention, these findings are consistent with our interpretation that auditory significant distractors, like visual ones, do not capture attention when they are truly outside the focus of attention. If so, participants with a higher working memory capacity also focus better on the attended channel and therefore notice less information in the unattended channel (because their attention is shifted less often to this channel). Alternatively, there might be a fundamental difference between auditory and visual distractors in their ability to capture attention. Further research is required to resolve this issue.

### *The Emotional Stroop Phenomenon and Its Relation to Our Study*

As mentioned earlier, our findings, particularly with central attended targets, resemble, at least at a superficial level, the emotional Stroop phenomenon. In this paradigm, like ours, participants are instructed to name the color of centrally presented words and to ignore the words' content. In some trials the central words denote emotionally charged concepts (e.g., *anxiety*), and in others they denote neutral concepts (e.g., *house*). A large number of studies have reported longer latencies for the former words than for the latter words (see Williams et al., 1996, for a review), results resembling the behavioral effect obtained in the present study.

However, the emotional Stroop paradigm and the results derived from it differ from the present study in several important aspects. First, the emotional Stroop effect has been found mainly among clinical populations with emotional disorders such as anxiety, posttraumatic stress disorder, panic disorder, phobia, and depression (e.g., Mogg, Bradley, Williams, & Mathews, 1993; Watts, McKenna, Sharrock, & Trezise, 1986; Williams et al., 1996). The findings for nonclinical populations were not always consistent. For example, in several studies, researchers that investigated nonclinical populations found the effect only for a subgroup of individuals who had a high level of anxiety (e.g., Dawkins & Furnham, 1989; Mogg & Marden, 1990; Richards & French, 1990). Second, the emotional Stroop studies typically used stimuli that involved negative, threat-related words (e.g., *scream*, *tense*) and only rarely positive, emotionally charged concepts (e.g., *happiness*, *success*; see, e.g., MacLeod & Hagan, 1992; McKenna & Sharma, 1995; Mogg & Marden, 1990; Riemann & McNally, 1995). Only very few studies used personally relevant words, irrespective of their emotional valence, like the stimuli used in the present study. Unfortunately, these studies produced conflicting results. For instance, Riemann and McNally (1995) demonstrated an interference effect of words related to participants' positive and negative current concerns, as assessed by personal-concern questionnaires. Similarly, Dalgeish (1995) found that ornithology experts show color-naming interference for names of rare birds relative to names of musical instruments or other neutral concepts. In contrast, however, Mogg and Marden (1990) found no emotional Stroop effect for words related to rowing relative to neutral words among members of a boat club. Similarly, Nortje, Westhuizen, Moller, and Oellermann (1999) showed no interference effect of social-related threat words among individuals with high interest in interpersonal relationships, and Segerstrom (2001) found no effect of academic words among undergraduate students.

In addition, our study focused on the comparison between attended and unattended distractors, and, to the best of our knowledge, there is not a single published study with the emotional Stroop paradigm that manipulated this factor. In fact, all distractors used in the emotional Stroop studies were positioned inside the focus of attention. A few studies manipulated factors that may appear on the surface to be similar to ours, but a closer inspection shows that the locus of visual attention was not controlled in these studies. For example, Richards and French (1990) presented emotional words both centrally and peripherally, but the color and the word were always integrated in this study (i.e., the combined location of the target and distractor was manipulated in their study). Numerous studies (e.g., A. Cohen & Rafal, 1991; Duncan, 1980) have shown that visual attention must be focused on the target for the production of the response. Thus, participants in the peripheral condition of the Richards and French (1990) study had to shift their attention to the color (and consequently to the distracting word as well) and then respond. Therefore, both peripheral and central conditions of this study were, in fact, attended. A few other studies used the visual probe task in addition to the emotional Stroop task to assess attentional allocation to emotional words (Brosschot, de Ruiter, & Kindt, 1999; Mogg, Mathews, & Eysenck, 1992). However, the use of the visual probe task in these studies lacked adequate temporal control over the participants' visual attention (i.e., stimuli with long exposure durations were used).

This brief review shows that the relation between the personally significant concepts and the stimuli used in the emotional Stroop paradigm is unclear, and further research is required to clarify this issue. It is possible that the consistent results obtained in our study and the lack of consistent results in the emotional Stroop studies is due to the fact that our stimuli may be of a higher personal value than those used in the emotional Stroop paradigm. Alternatively, there may be qualitative, as yet unknown differences between the two types of stimuli. A third possibility, related to the recent findings reported by Harris and Pashler (in press) as well as to the results of Experiment 7 of this study, is that the effect of attended significant distractors habituates with time, a factor that has not been explored in the emotional Stroop studies.

Most important, our study shows that whereas personally significant stimuli presented outside the focus of attention do not capture attention, stimuli denoting task-relevant semantic content do capture attention. Given that the results with the emotional Stroop stimuli positioned inside the focus of attention are less consistent, there is no reason to assume that these stimuli would capture attention when positioned outside the focus of attention. The lack of interference by unattended significant but exogenous stimuli has important implications for theories of attention, as further discussed below.

### *Do Other Special Distractors Capture Attention?*

Although our study suggests that exogenous significant stimuli do not affect performance, there may be other special types of exogenous stimuli that do capture attention. In a number of studies, researchers examined whether visually salient stimuli are efficient in capturing attention. Yantis and Jonides (1984, 1990; see also Remington, Johnston, & Yantis, 1992), using the visual search paradigm, showed that the appearance of new stimuli, known as *onsets*, captures attention. A number of other studies (e.g., Theeuwes, 1992, 1994; see Theeuwes & Godijn, 2001, for a review) suggested that singleton distractors, differing from all other stimuli in a particular primitive feature, such as color or basic shape, also capture attention. However, the interpretation of these results is controversial. Some investigators claim that onsets and singletons capture attention only when they are part of the task set (e.g., Bacon & Egeth, 1994; Folk et al., 1992). That is, perceptually salient stimuli such as onsets and singletons may capture attention only when they are seen as task relevant.

In addition, Yantis and Jonides (1990) showed that when participants focused on a particular location, onsets presented at other locations did not affect performance. However, task-relevant stimuli presented at these same locations did affect performance. This dissociation between onsets and task-relevant stimuli resembles the dissociation we obtained between exogenous, personally significant, and task-relevant stimuli.

### *The Special Status of Task-Relevant Stimuli*

Our study, like many previous studies (e.g., Atchley et al., 2000; Bacon & Egeth, 1994; Eriksen & Eriksen, 1974; Folk et al., 1992), documents the ability of task-relevant stimuli to affect performance. Our findings further reinforce the importance of task-relevant distractors in showing that personally significant stimuli presented under identical perceptual conditions affect performance only when they are relevant for the task.

These results provide a clear dissociation between exogenous and endogenous factors in attention capture and question the suggestion made by Treisman (1960) that the same mechanism operates for both significant and endogenous stimuli and makes both more available for preattentive processing. Our findings suggest that the mechanism that causes endogenous stimuli to affect performance is specific to these types of stimuli. Although the nature of this mechanism is yet to be specified, the present results set strong constraints on it by limiting its operation to transient, context-related processes such as those associated with working memory (e.g., Baddeley, 1992). Finally, a reservation is in order concerning unattended processing of task-relevant stimuli. Some studies have used highly stringent methods for narrowing the focus of attention (e.g., Besner, Stolz, & Boutilier, 1997; LaBerge et al., 1991; Shiffrin, Diller, & Cohen, 1996) and have strongly reduced performance interference even by task-relevant distractors. Thus, the ability of unattended task-relevant stimuli to affect performance may also be restricted by a particularly stringent control of attention.

### *The OR and Visual Attention*

A unique aspect of the present research is the use of the OR in addition to RTs as a measure of attentional capture. As reviewed earlier, several studies suggested that the OR is associated with the allocation of attentional resources toward external stimuli (Dawson et al., 1989; Siddle & Jordan, 1993; Siddle & Packer, 1987). Our method enabled us to examine more closely whether the OR is related to the capture of visual attention by distractors.

Experiments 3–5 of our study suggest that the OR is not an indication of visual attention capture. In these experiments, the task-relevant distractors were either congruent or incongruent with respect to the participant's response. Although the different conditions affected RTs, indicating that attention was captured by the distractors (cf. Yantis & Jonides, 1990), the RT effects were not mirrored by similar differences in the OR. Moreover, the task-relevant distractors were not associated with enhanced ORs, even when presented inside the central focus of attention (Experiment 4), further emphasizing that visual attention per se is not related to the OR.

In contrast, Experiments 1 and 4 revealed that the OR is triggered by exogenous significant stimuli when these stimuli are positioned inside the attentional focus. The combined results of Experiments 2 and 5 are also consistent with this observation. ORs were triggered by peripheral significant distractors (Experiment 2A), but this effect was abolished when the exposure duration of the stimulus display was limited (Experiments 2B and 5). Thus, the effect observed in Experiment 2A was due to a late shift of visual attention to the distractor's location that, in turn, triggered the OR. Our results demonstrate that the OR is triggered by significant stimuli located inside the attentional beam but not by stimuli appearing in an unattended location. In addition, there is a dissociation between the OR and visual attention, as observed in the experiments using task-relevant stimuli.

How can our findings be reconciled with those showing a positive relation between the OR and attention? An immediate implication is that the visual attention processes manipulated in our study differ from the attentional mechanisms required for shifting attention to a probe task (e.g., Siddle & Packer, 1987). Indeed, there is good evidence from both neuropsychological (e.g., Posner & Petersen, 1990) and behavioral studies (e.g., Pashler, 1991; Posner & Boies, 1971; see A. Cohen & Magen, in press, for a review) that the two types of attentional mechanisms are distinct. In particular, visual attention should be distinguished from high-level attentional mechanisms in charge of executive functions (e.g., Pashler, 1991). The latter attentional mechanisms may be associated with conscious awareness (Posner & Boies, 1971), whereas visual attention is not necessarily associated with conscious awareness. From this perspective, visual attention processes may be involved even when task-relevant stimuli affect performance without being consciously perceived (e.g., Greenwald, Abrams, Naccache, & Dehaene, 2003). Our results suggest that the OR is not related to visual attention, and the studies by Siddle and colleagues may indicate that the OR is related to the higher levels of executive functions.

Many types of executive functions have been identified (see A. Cohen & Magen, in press, for a review). The available studies to date do not allow us to determine which, if any, of these processes is distinctly associated with the OR. One plausible account may be that the appearance of a significant stimulus causes the participant to shift from his or her current task set to that of dealing with the significant stimulus. The probe technique is also focused on a quick shift from the previous set to that involving the probe. Processes of task switching, known to be related to executive functions, have been investigated extensively in recent years (e.g., Rogers & Monsell, 1995). The OR, then, may be triggered by task-switching processes. Alternatively, a few studies have suggested that the OR does not necessarily reflect a call for attentional resources but rather a detection and an evaluation of stimuli as task-relevant or important events after the attentional shift (e.g., Dawson et al., 1989). Thus, OR elicitation may be a consequence of attentional allocation to stimuli that are judged to be significant. This may explain why significant stimuli in our study elicit an OR only when presented inside the focus of visual attention but not when presented in an unattended location (to which there is no attentional shift). However, it still remains to be explained why task-relevant stimuli (whether inside or outside the focus of visual attention) affect performance and yet do not elicit an OR. Thus, further research is required to determine the precise attentional processes associated with the OR. In either case, our study demonstrates that visual attention processes are not necessarily associated with the OR.

In summary, our findings suggest that the OR is triggered by exogenous significant stimuli positioned inside the visual focus of attention. Attention may be necessary either for processing these significant stimuli or for associating them with the task set. However, ORs are not elicited by peripheral distractors, even when they affect performance, suggesting that the OR is dissociated from visual attention capture per se.

## *Conclusions*

Our study investigated the influence of personally significant stimuli on performance when these stimuli were presented inside and outside the focus of visual attention. Our results illustrated a clear picture, according to which exogenous significant stimuli elicit an OR and interfere with task performance when presented inside the focus of attention. However, there was no attentional capture when the significant stimuli appeared in an unattended peripheral location. By contrast, task-relevant stimuli captured attention even when presented in an unattended location, outside the attentional beam. This capture of attention was reflected by an interference with task performance but not by the OR, indicating a dissociation between OR and visual attention processes. Our results suggest that task-relevant stimuli may be unique in their ability to capture attention. Although the exact mechanism by which these unattended endogenous stimuli affect performance requires further research, our study implicates its involvement with transient, context-dependent representations.

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