Journal of Personality and Social Psychology
2003, Vol. 85, No. 2, 231–248

Copyright 2003 by the American Psychological Association, Inc.
0022-3514/03/$12.00 DOI: 10.1037/0022-3514.85.2.231

Selective Attention Improves Under Stress: Implications for Theories of Social Cognition

Eran Chajut
Tel-Aviv University and the Open University of Israel

Daniel Algom
Tel-Aviv University

Three influential perspectives of social cognition entail conflicting predictions regarding the selectivity of performance under stress. According to the attention view, selectivity to the task-relevant attribute improves under stress because of reduced utilization of task-irrelevant attributes. According to the capacity–resource approach, stress depletes attentional resources wherefore selectivity fails for all but chronically accessible information. A third perspective, ironic process theory, similarly holds that selective attention fails under stress but adds that task-irrelevant information is rendered hyperaccessible. The theoretical derivations were tested in a series of experiments using 2 classes of selectivity measures, with special care taken to control for hitherto neglected factors of context. The results showed that the selectivity of attention improved under stress, consistent with the prediction of the attention view.

Following instructions, a flight controller monitors solely the altitude of an approaching airplane, ignoring other data such as its speed, direction, or position with respect to other planes. The controller performs the job with his superintendent watching in close proximity. Does he respond to the changes in altitude faster and in a more accurate fashion than he would without the stressful presence of the superintendent? Do changes in the task-irrelevant dimensions of speed and azimuth intrude on his performance with the target dimension of altitude? Are such intrusions more numerous under high stress than under low stress? Daily life is replete with situations where people must respond to selected attributes of stimuli. All too often, performing the tasks is fraught with stress. The question posed in this study therefore concerns the effect of stress on selective attention. Does stress lead to a narrowing of attention to the task-relevant attribute, hence improving selectivity? Alternatively, does stress precipitate the broadening of attention, rendering the person vulnerable to intrusions from irrelevant attributes? Both possibilities have been argued in the literature. In an attempt to resolve this question, we borrowed state-of-the-art tools of gauging selectivity from the cognitive laboratory (MacLeod, 1991; Melara & Algom, 2003). We measured selectivity under conditions of high and low stress for a range of stimulus attributes, eschewing various biases identified in recent cognitive research. To foreshadow the results, we found interference from irrelevant variation to be smaller under high stress than under low stress. Performance under high stress was almost free of intrusions from task-irrelevant dimensions. We concluded that selective attention improves under high stress. Our results carry theoretical as well as practical ramifications.

It is difficult to overstate the practical significance of resolving the question of performance under stress. It may signal the difference between erratic and skillful performance, between losing and keeping one's job, between depression and normal functioning, or, indeed, between demise and survival. Attention under stress has also accrued vivid theoretical interest because three influential theories of social cognition entail conflicting outcomes. In what follows, we review the various perspectives and derive the pertinent hypotheses regarding selectivity under stress. We then perform a triple dissociation of the conflicting hypotheses by means of a diagnostic design. Two classes of rigorous measures serve to assess selectivity. We report three experiments that demonstrate that selective attention shows marked improvement under stress. Our findings have implications for general models of social cognition.

Three Theories of Selectivity Under Stress

The Attention Approach

The logic of the attention approach is simple and compelling. Stress depletes one's available attentional resources. The scarce resources left are necessarily committed to processing the task-relevant dimension at hand. The paradoxical result is that the deficits on the task-irrelevant dimensions render the processing of the relevant dimension intrusion free. Under the threatening presence of his superintendent, our flight controller will narrowly focus on the target attribute of altitude without suffering intrusions from speed or relative position simply because he has no resources left for processing those irrelevant attributes. The controller's perfor-

Eran Chajut, Department of Psychology, Tel-Aviv University, Tel-Aviv, Israel, and Department of Psychology, the Open University of Israel, Ramat-Aviv, Israel; Daniel Algom, Department of Psychology, Tel-Aviv University.

Portions of this research are based on a doctoral dissertation at the Department of Psychology, Tel-Aviv University, completed by Eran Chajut under the supervision of Daniel Algom. We thank Ran Hassin, Giora Keinan, and Nira Liberman for helpful comments on earlier versions of the article.

Correspondence concerning this article should be addressed to either Daniel Algom, Department of Psychology, Tel-Aviv University, Ramat-Aviv 69978, Israel, or Eran Chajut, Department of Psychology, the Open University of Israel, Ramat-Aviv 61392, Israel. E-mail: algomd@freud.tau.ac.il or eranch@openu.ac.il

mance thus improves under the stressful presence of his superior, a phenomenon dubbed *social facilitation* (Baron, 1986; S. Cohen, 1978, 1980; Huguet, Galvaing, Monteil, & Dumas, 1999). The term *narrowing of attention* was coined in the early 1950s by Callaway and colleagues (Callaway, 1959; Callaway & Dembo, 1958; Callaway & Thompson, 1953) to characterize cognition under stress. However, it was the theoretical treatment of Easterbrook (1959) that opened the floodgates for numerous studies of how stress improves the selectivity of attention. According to Easterbrook's influential notion, stress progressively reduces the range of cues utilized in a task. Tasks of selective attention benefit from stress because of the growing exclusion of irrelevant cues. Reviewing the voluminous research, Wells and Matthews (1994) concluded that "one of the few consistent effects of arousing stressors which generalizes across different sources of stress is narrowing of attention" (p. 187).

Easterbrook's (1959) notion has been extended by subsequent investigators to apply to a variety of procedures and stressors (Broadbent, 1971; Eysenck, 1982; Hockey, 1970a, 1970b, 1978; Hockey & Hamilton, 1983; A. P. Smith, 1991; Wachtel, 1967; Warburton, 1988). Baron (1986) extended the notion to socially induced stress (see also S. Cohen, 1978; Huguet et al., 1999; MacKinnon, Geiselman, & Woodward, 1985; Sanders, Baron, & Moore, 1978). In situations of social facilitation or inhibition, the same phenomenon of enhanced focusing and reduction in cue utilization occurs. According to Baron, a threatening (hence distracting) social presence overloads the cognitive system, leading in turn to narrow focusing. Enhanced focusing under stress readily generalizes to other cognitive tasks, including premature closure in decision making (Keinan, 1987), disproportional primacy effect in impression formation (Webster, Richter, & Kruglanski, 1996), loss of distance cues in perception (Callaway & Thompson, 1953; Singer, 1952), enhanced stereotyping (Keinan, Friedland, & Even-Haim, 2000), and peripheral narrowing of vision conducive to athletic injury (Williams, Tonymon, & Andersen, 1991).

This theory also comprises the one approach that is fully and explicitly devoted to characterizing performance under stress. Following the recent research and review by Huguet et al. (1999), we dub this approach the *attention view*. The major distinction drawn in the theory is that between to-be-responded-to attributes and to-be-ignored attributes. Stress affects the two classes of attributes differentially. The diminished resources available are fully engaged by the former with the net result of better selectivity in responding. This differential deployment of attention occurs regardless of the composition of the two classes of dimensions. The to-be-responded-to dimension always commands priority, if not exclusivity, in attentional processing. It is precisely the composition of the stimulus dimensions that forms the cornerstone of another approach to selectivity under stress, to which we turn next.

Capacity–Resource Theory

According to capacity–resource theory, too, attention narrows under stress. However, the narrowing is directional, with efficient processing confined to chronically accessible, automatically activated dimensions. Attention fails for all of the other dimensions, regardless of the task demands. If the more accessible dimension happens to be one that is irrelevant to the task at hand, then selective attention to the task-relevant dimension will fail. Suppose that because of past experience, our flight controller is more facile at detecting changes in speed than detecting changes in altitude, his current responsibility. Under the stressful presence of his supervisor, the controller is bound to suffer growing intrusions from the more accessible dimension of speed. Failure of selectivity to the vital attribute of altitude ensues. The logic is easily discerned. Attention is an effortful activity. Stress takes a toll on this activity, seriously compromising its serviceability. Automatically accessed dimensions are dominant under stress precisely because they are easily activated in the absence of attention. Their salience under stress in turn undermines selectivity to other dimensions, including those relevant to responding.

Kahneman (1973; see also Keinan, Friedland, Kahneman, & Roth, 1999) proposed that arousal and stress influence the allocation of attentional resources in a cognitive system constrained by limited information-processing capacity. Stress and arousal use up resources needed for effective attentional segregation (Keinan et al., 1999, 2000; Wells & Matthews, 1994). Because automatic processes are relatively effort free, they are largely saved from the adverse influences of stress. As a result, unintended automatic processes (Bargh, 1989, 1992) are often activated under stress, again regardless of the task demands or instructions.

In a series of elegant studies, Bargh and his associates identified several sets of automatically activated information in the social realm (Bargh, 1982; Bargh & Thein, 1985; Bargh & Tota, 1988; Pratto & Oliver, 1991). They include self-relevant personality traits, trait categories that the person characteristically applies to the environment in order to understand and anticipate it (Higgins, King, & Mavin, 1982; Kelly, 1955), and global stereotypes. Bargh and Thein (1985) postulated that those "chronically accessible categories . . . do not require much in way of attentional resources" (p. 1132), so activation of such categories should survive strains on capacity. The investigators applied an extreme form of stress, time pressure (Corr & Kumari, 1998; Garst, Frese, & Molenaar, 2000; Revelle, Amaral, & Turriff, 1976) to test for the dominance of chronically accessible information under stress. Under conditions of time pressure, the participants had to process information about a target person at a rate of 1.5 s per sentence compared with indefinitely long exposures (Bargh & Thein, 1985) or 5–10 times longer exposures (Pratto & Oliver, 1991) in the stress-free conditions. It was found that automatically activated stimuli (chronically accessible categories, stereotypic impressions) were processed on a par under stressful and stress-free conditions, but that the processing of other stimuli (inaccessible constructs, individuating information) was severely compromised under stress. The differential effects of stress occurred in the face of invariant experimental instructions to recover all information. Increased reliance on automatically processed stimuli has been reported under further conditions of time pressure, information overload, noise, or the (threatening) presence of others (Cottrell, 1968, 1972; Hockey & Hamilton, 1983; Huguet et al., 1999; Pratto & Oliver, 1991; Wentura, Rothermund, & Bak, 2000; Zajonc, 1965, 1980).

Commensurate with its title, capacity–resource theory stresses the nature of attention as a mental resource cumulated through effortful selection and bounded by limited capacity. Stress consumes much of this resource, thereby undermining the processing of all attention-dependent dimensions. The scarce amounts of attentional resources left cannot sustain efficient processing of those dimensions. In contrast, dimensions that require relatively low amounts of attentional resources, namely automatically processed dimensions, remain intact under stress. Therefore, the major distinction drawn in this approach is that between dimensions processed in an automatic fashion, on the one hand, and dimensions that require controlled and effortful processing, on the other hand. Stress affects only the latter. The fact that the person is required to respond to a selected dimension of the environment does not ipso facto salvage that dimension from the adverse effects of stress (provided that the relevant dimension is not chronically accessible itself). Under stress, selectivity will be undermined by intrusions from automatically accessible irrelevant dimensions. In other words, this approach is indifferent to the experimental role of the stimulus attributes (relevant, to-be-responded-to attributes vs. irrelevant, to-be-ignored attributes). What counts for selectivity is the type of the constituent dimensions.

The distinction between controlled and automatic processing figures prominently in another theory of attention under stress, albeit in a fundamentally different fashion. We examine that theory next.

The Thought Suppression Approach

The third prevalent explanation of selective attention under stress is rooted in the recent work by Wegner and his associates on mental control and thought suppression (Wegner, 1994; Wenzlaff & Bates, 2000; Wenzlaff & Wegner, 2000). Like the capacity–resource view, the thought suppression account conceives attention to be a conscious, voluntary effort focusing on the target attribute. However, this intentional process is only part of the act of attending. An equally consequential process is devoted to suppressing the task-irrelevant attribute. This second process is not conscious and is performed in an automatic fashion. An ironic property of the automatic search for to-be-suppressed information is that it makes the person sensitive to that very information. Selective attention is bound to fail, but it is most apt to do so under stress. Stress depletes attentional resources. Because the act of focusing draws heavily on such resources, stress exacts a toll on the quality of selective attention. Because automatic processes do not require attention, stress exerts little effect on the monitoring of the to-be-ignored dimension. Selectivity thus is disrupted under stress, with performance fraught by numerous intrusions from the task-irrelevant dimension. These notions form the base of ironic process theory (Wegner, 1994; Wenzlaff & Wegner, 2000). Regarding performance under stress in particular, stress "disturbs the operation of controlled, resource-dependent processes while interfering only little with the operation of automatic processes" (Wegner & Erber, 1992, p. 905). As a result, the task-irrelevant dimension is rendered highly accessible under stress, a phenomenon dubbed "hyperaccessibility of suppressed thoughts" (Wegner & Erber, 1992, p. 903).

Consider yet again performance by the flight controller. He is instructed to ignore speed and attend solely to altitude. According to ironic process theory, two processes are initiated, one conscious and volitional, the other implicit and automatic. The controller focuses intentionally on the target attribute of altitude, but unconsciously, he is also engaged in an automatic monitoring of changes in irrelevant speed. Ultimately, the changes in speed will intrude on his responding to changes in altitude. However, the stressful presence of the supervisor expedites and exacerbates these unwanted intrusions. Selective attention to target altitude is impaired under stress.

A variety of studies have tested the prediction of ironic process theory that stress has the effect of not merely impairing attention to the target dimension but also of rendering the task-irrelevant dimension more accessible than it would have been without watchful suppression (Macrae, Bodenhausen, Milne, & Ford, 1997; Muraven, Tice, & Baumeister, 1998; Wegner & Erber, 1992; Wegner, Erber, & Zanakos, 1993; Wenzlaff & Bates, 2000). The preferred forms of stress used were time pressure and concurrent information overload (Keinan et al., 2000; Wells & Matthews, 1994). The results supported the idea of stress-induced hyperaccessibility of the to-be-ignored dimension; inevitably, selective attention to the to-be-responded-to dimension was seriously compromised. Thus, Wegner and Erber (1992) recorded a tendency under stress of time pressure to respond to word prompts with to-be-ignored words. In other experiments, the investigators (see also Wegner et al., 1993) found increased latencies of naming the print color of to-be-ignored words (not color words) when under stress of increased mental load.

Like the capacity–resource approach, the thought suppression approach lays great emphasis on the distinction between controlled and automatic functioning. However, there is a difference between the two approaches that is as subtle as it is important. In the former approach, it is the *stimuli* that are processed in a controlled or automatic fashion. For instance, some individual traits are processed in a controlled, attention-dependent fashion, whereas certain stereotypic impressions are processed in an automatic fashion. In other instances, all of the pertinent attributes are processed in a controlled fashion or all are processed in an automatic fashion. Moreover, automatic activation is subject to training and experience. The same stimuli (say, personal traits) may be processed in an automatic fashion on one occasion but in a controlled fashion on another occasion (Higgins et al., 1982). In the thought suppression approach, by contrast, the distinction applies to processes, not to stimuli. The task-relevant dimension is always processed in a controlled fashion, whereas the irrelevant dimension is always processed in an automatic fashion. The theory is indifferent to the composition of the stimuli. The critical role of the target–distractor division becomes apparent when one reverses the roles of the pertinent dimensions. Consider the flight controller for a final time. Altitude is the target dimension and speed the distractor dimension, wherefore the former is processed in a controlled fashion, the latter in an automatic fashion. Suppose that the instructions are subsequently changed so that speed is prescribed the target dimension, altitude the distractor dimension. According to ironic process theory, it is speed that is processed in a controlled fashion now, altitude in an automatic fashion. Again, the distinction between controlled and automatic processing is a contingent one, depending critically on whatever dimension is selected for responding. The effect of stress is similarly contingent: It disrupts performance with the dimension that is selected for responding by the experimenter or by nature.

Experimental Resolution of Conflicting Predictions

It is clear that each of the three approaches boasts an impressive amount of supporting evidence. Less readily apparent is the fact that the respective hypotheses of performing under stress are incompatible. In the literature, each body of experimental studies has been confined to its own camp. A principled comparison of the various implications for selectivity under stress has not previously been accomplished. We performed such a comparison in this study.

The great bulk of studies performed within the framework of the attention view have entailed attributes that are typically processed in a controlled manner. Consequently, the distinction stressed by the capacity–resource view between automatic and controlled action did not apply. The tasks used were fairly easy and routine, such that considerations of capacity did not apply either. The studies performed under the rubric of the capacity–resource theory did include sets of automatically processed stimuli. However, the typical experimental tasks entailed memory and full report. The quality of selective attention to the various sets of stimuli (i.e., those processed in an automatic fashion vs. those processed in a controlled fashion) could be inferred from the data, but often selectivity was not tested directly. Selectivity has been tested directly within the framework of ironic process theory. However, the tests used were selective, designating dimensions processed in a controlled manner to be target dimensions and dimensions processed in an automatic fashion to serve as distractor dimensions. This policy of allocation itself could have precipitated the observed failure of selectivity to the target dimension. Following the capacity–resource view, chronically available information always intrudes on information processed in a controlled manner. Also, the studies lacked any measure of the baseline difficulty of the two dimensions. An easier to process dimension that is irrelevant to the task at hand will nonetheless interfere with performance on a relevant dimension that is more difficult to process (Algom, Dekel, & Pansky, 1996; Arieh & Algom, 2002; Melara & Algom, 2003; Pansky & Algom, 1999, 2002; Shalev & Algom, 2000).The upshot is that failures of selectivity could have been precipitated by a variety of reasons other than watchful suppression.

In this study, we performed a systematic comparison of the theoretical predictions by testing performance in the Stroop task (Stroop, 1935), psychology's classic means of gauging selectivity. In the Stroop experiment, color words printed in color are presented for view, and the participant's task is to name the print color (and ignore the carrying word). The stimuli divide naturally into congruent (the word names its print color) and incongruent (word and color mismatch) combinations. The difference in color-naming performance between congruent and incongruent stimuli defines the Stroop effect. A nonzero Stroop effect indicates the failure of exclusive attention to the target dimension of print color. It shows that the conflicting or corresponding words, irrelevant to the task of classifying color, were noticed and intruded on task performance. In a complementary experiment, the participant's task changes to that of naming (reading) the words and ignoring the print color. The difference in word-naming performance between congruent and incongruent stimuli defines the reverse Stroop effect. A reverse Stroop effect similarly shows the failure of exclusive attention to the target dimension of word. Typically, selectivity fails for color more than for word. The asymmetry has motivated the practice of eschewing testing for word reading altogether (for a review, see MacLeod, 1991). However, the pattern of interference is malleable. For instance, one can engender a larger reverse Stroop effect by rendering the print colors more salient to perception than the color words (Algom et al., 1996; Melara & Algom, 2003; Melara & Mounts, 1993; Sabri, Melara, & Algom, 2001).

In the following experiments, the participants performed the Stroop task under conditions of high and low stress. Notably, we used both color and word in turn as target dimensions. We could thus derive both Stroop and reverse Stroop effects. We also monitored the discriminability of the colors and the words used. *Discriminability* refers to the aforementioned baseline difficulty or salience of the tested dimensions. Discriminability at baseline is matched if the speed of classifying color (with word held constant) is the same as that of classifying word (with color held constant). Relative baseline discriminability thus specifies the relative salience, ease, or difficulty of the constituent dimensions. Monitoring discriminability is important because the more discriminable dimension usually intrudes on the less discriminable dimension more than vice versa. It is difficult to ignore a salient dimension even when that dimension is irrelevant to the task at hand. In the realm of Stroop studies, words might have intruded on colors simply because they were more salient at baseline. In the realm of stress studies, it is important to monitor discriminability under high and low stress. If discriminability remains invariant, then any effects of stress on performance must emanate from central modulation of attention. Specifying relative baseline discriminability thus is important for isolating the locus of the effect of stress on attention. We monitored (in all of the present experiments) and manipulated (in Experiments 1A and 1B) the salience of the tested dimensions.

Deploying the complete Stroop design, we accomplished a triple dissociation of the conflicting theoretical prediction as shown in Table 1. Note that examination of both color and word is needed for a fully diagnostic resolution. For color as the target dimension, the capacity–resource perspective and the thought suppression perspective predict impaired selectivity under stress. According to the former view, color naming draws on attentional resources much more than word reading. Under stress, selectivity to color naming collapses because of the scarce resources available, but the automatically activated words are still processed in an intact manner. According to the latter view, selectivity to print color is impaired because attentional segregation is disabled by stress. Moreover, increased intrusions of the to-be-ignored words are expected because these words are subject to automatic search that remains intact under stress. In sharp contrast, the attention perspective predicts better color naming performance (i.e., improved selectivity) under stress. According to this perspective, the scarce resources available under stress are devoted in full to the task-relevant dimension of color. The task-irrelevant dimension of word is not processed, saving the target dimension from unwanted intrusions. For word as the relevant dimension, the capacity–

Table 1
Stroop Effects Under Stress Predicted by Three Theories

Theory	Dimension: Word	Dimension: Color
Attention	Decreases	Decreases
Capacity–resource	Unchanged	Increases
Thought suppression	Increases	Increases

resource theory predicts the absence of an effect of stress on performance. Words are processed in an automatic manner and do not draw on attentional resources, so they are saved from the adverse effects of stress on performance. In contrast, the attention view predicts improved performance under stress for words, too. In yet another contrast, the thought suppression view predicts impaired word performance under stress. According to the perspective of thought suppression, it is the search for to-be-suppressed information, not any type of information, that is automatic. Hence, stress is expected to take a toll on the quality of focusing on the target attribute, whether word or color.

The Stroop task has been used in past research to probe performance under stress with notoriously variable results. Several studies reported a decrease in the Stroop effect (i.e., improved selectivity) under stress (Agnew & Agnew, 1963; Callaway, 1959; Folkard & Greeman, 1974; Glass & Singer, 1972; Houston, 1969; Houston & Jones, 1967; Huguet et al., 1999; O'Malley & Poplawsky, 1971; Tecce & Happ, 1964; see also Baron, 1986). Other studies reported an increase of the Stroop effect under stress (Brand, Schneider, & Arntz, 1995; Hartley & Shirley, 1976; Hochman, 1967, 1969; Pallack, Pittman, Heller, & Munson, 1975; Woodfield, Jones, & Martin, 1995). In yet a third class of studies, no effect or equivocal effects of stress on the Stroop effect were found (Hartley & Adams, 1974; Keinan et al., 1999; O'Malley & Gallas, 1977; A. P. Smith & Broadbent, 1981, 1985). In the face of such inconsistency, Loeb (1986) was forced to conclude that (noise-induced) stress "may . . . increase, decrease, or leave unchanged the magnitude of the Stroop effect" (p. 187).

We attribute the inconsistency to three sources. First, the great bulk of the pertinent studies have not been guided by a theoretical perspective. Obviously, no resolution of the different conceptual approaches has been attempted. Another unfortunate consequence of the lack of theoretical perspective has been the unsystematic selection of dimensions, stimuli, procedures, and analyses. Second, virtually all of the pertinent studies have entailed a truncated procedure, testing selective attention only to color. However, one must examine both color and word for theoretical diagnosis. For instance, a symmetric design is critical for testing ironic process theory. For a given pair of dimensions, A and B, the pattern of interference with A as the target dimension must be the mirror image of that with B as the target dimension (A and B are processed in controlled and automatic fashion, respectively, in the first case, but the processes reverse in the second case). Again, this critical test has not been performed. Third, the studies lacked adequate controls. For one, the relative salience of the colors and the words presented was neither measured nor appreciated. As we mentioned, if the colors are less salient than the words (as we suspect has been the case in most studies), this fact alone might suffice to engender a modicum of Stroop effect. For the effect of stress, it may alter the perception of the constituent stimuli (in which case discriminability should change under stress) or stress may exert its influence centrally (in which case discriminability should remain unchanged under stress). Additional factors of context have been neglected in extant research (Melara & Algom, 2003), notably a hidden correlation between word and color over the experimental trials (Dishon-Berkovits & Algom, 2000). In all of the cited studies, the color words appeared in their matching colors more often than in the other colors, thus engendering a correlation between color and word. The irrelevant words were noticed and processed in part because they were predictive of the relevant colors. Inevitably, selective attention to the target colors failed, and a Stroop effect ensued.

In this study, we addressed these problems. We derived the pertinent theoretical predictions explicitly to contrast them within the framework of a single comprehensive experimental design. To attain the theoretical resolution, we measured selective attention to both colors and words. Finally, we monitored and manipulated the relative salience of the colors and words used. This enabled better experimental control and, most important, enabled the identification of the locus of the effect of stress on selective attention. We also derived the Stroop effect in the absence of a correlation between the colors and words presented. A hallmark of the present study is the meticulous controls used, controls that had hitherto been confined to the cognitive laboratory. To reap the full gains from those controls, the following experiments were conducted within the framework of Garner's speeded classification paradigm (Garner, 1974). An extra bonus was the derivation of yet another measure of the selectivity of attention, Garner interference (Pomerantz, 1983).

The Present Study: Stroop and Garner Effects Under High and Low Stress

Deploying the Garner paradigm, we compared classification performance across four separate blocks of trials: baseline, filtering, positively correlated dimensions, and negatively correlated dimensions. A single color word in color was shown on a trial. In the *baseline* condition, the participant classified, while timed, values on one dimension—say, whether the print color was *red* or *green*—with values on the second, irrelevant dimension held constant (e.g., all of the words presented were RED). In the *filtering* condition, the participant again classified values on the criterial dimension (whether the color was *red* or *green*), but the values on the irrelevant dimension also varied from trial to trial in a random fashion. In the *correlated dimensions* conditions, the task, again, was to classify the stimuli on the criterial dimension of color. However, the components varied in a perfectly correlated manner throughout the sequence of presentations. Thus, all stimuli either matched (RED printed in *red* and GREEN printed in *green*) or mismatched, respectively, for positively and negatively correlated sets of stimuli. The same four blocks of trials were presented a second time with word as the relevant dimension.

The ability to attend selectively was measured by comparing performance in the baseline condition, in which the irrelevant dimension was held constant, with performance in the filtering condition, in which the two dimensions varied in an orthogonal fashion. If performance in filtering equals that at baseline, then selective attention is perfect. The parity implies that the participant was able to focus on the criterial dimension (say, color) and ignore irrelevant variation on another dimension (word). Conversely, if the participant's performance is worse in filtering than at baseline, then selective attention has failed. The difference in performance between filtering and baseline is called *Garner interference* (Pomerantz, 1983), and it reflects an inability to focus exclusively on the relevant dimension.

We derived the Stroop effects by calculating the difference in performance between congruent trials (in which the word named the print color) and incongruent trials (in which the word and the color conflicted). Two measures of Stroop congruity commensurate with this definition ensue. First, in the filtering condition the relevant and the irrelevant dimensions varied in an orthogonal fashion. Hence, on half the trials word and color corresponded, and on half they conflicted. The difference in classification performance between the congruent and incongruent trials provided the first and most decisive measure of the Stroop effect. Another measure derived from the difference in performance between the positively and negatively correlated conditions. In the former condition, all of the stimuli are congruent; in the latter, all are incongruent. This index is a between-conditions measure, whereas the former is a within-conditions measure. A Stroop effect can actually be derived in the baseline task as well; however, its value is questionable because only unidimensional variation exists in that task.

Like Garner interference, the Stroop effect reflects the failure of selective attention. The two are separate indices of selective attention (indeed, of its failure), yet, as just outlined, both can be gauged under the same experimental context. The former is a between-tasks effect, whereas the latter is a between-trials effect (whether or not the congruent and incongruent stimuli are presented in the same block of trials or in different blocks of trials). The two effects are gauged independently, although a possible logical relationship has been suggested (Pomerantz, Pristach, & Carlson, 1989). Garner interference indexes the toll exacted by the mere presence of task-irrelevant variation. Stroop interference indexes the effect of the kind of irrelevant variation: It is sensitive to the semantic relation (conflicting or agreeing) between the momentary values on the relevant and irrelevant dimensions. Because one cannot notice the kind of variation without noticing the variation, the presence of Stroop effect implies the presence of Garner effect, although the reverse is not true.

Therefore, in the present study, we tested performance with the original Stroop stimuli within the framework of Garner's (1974) speeded classification paradigm. We derived genuine Stroop and Garner effects under conditions of high and low stress. Dimensional correlation was monitored and manipulated within each experiment by comparing performance in the filtering task (zero) with that in the correlated-dimensions tasks (perfect). In Experiment 1, we tested performance with both color and word using time pressure, threat to the ego, and task difficulty as stressors. We also tested further semantic (picture–picture) and nonsemantic (form and color) dimensions with the same stressors. In Experiment 2, we tested Stroop and Garner effects with color using noise, another potent means of inducing stress. In Experiment 3, we excluded an alternative explanation of the results, demonstrating that it was stress alone that precipitated the narrowing of attention.

Experiment 1

Stress affects various ongoing activities in everyday life; you may feel stressed while reading a book, watching television, or riding the bus. Some of these activities are processed in an automatic fashion, whereas other activities are volitional and effortful. Some of the tasks require semantic processing, whereas other tasks merely require perceiving the physical stimulus at hand. To emulate the variety of everyday functioning, we tested a range of dimensions in Experiment 1. In Experiments 1A and 1B, we tested the original Stroop dimensions of color and word. The first dimension is physical and processed in a controlled fashion, whereas the second dimension is semantic and presumably processed in an automatic fashion. In Experiment 1A, words were more salient than colors at baseline (the situation prevailing in the vast majority of Stroop studies), an asymmetry that resulted in larger amounts of interference to color than to word. In Experiment 1B, we partially redressed the imbalance favoring word by rendering color to be as salient as word. Despite the overall advantage of words in Experiments 1A and 1B, resulting in larger amounts of interference to color than to word, stress affected both target dimensions in a similar fashion. In Experiment 1C, we tested picture–picture compounds, stimulus combinations entailing only semantic dimensions. Discriminability dictated the pattern of interference (larger values of interference with the less discriminable small pictures) in this experiment, too, yet stress affected both dimensions in a similar manner. Finally, in Experiment 1D we tested attention to colored shapes, stimuli composed of nonsemantic physical dimensions. Stress affected performance in a similar fashion with both dimensions as targets. Therefore, the contextual factor of discriminability (and correlation) shaped the pattern of interference in each experiment, yet stress affected both dimensions in exactly the same fashion. To anticipate the predominant result, high stress reduced the amount of interference recorded with a given dimension under low stress, regardless of the composition (semantic, nonsemantic, automatic, effortful) of the tested dimension. What was most revealing about the results of Experiment 1 was the absence of interaction of stress with target dimension.

Method

Participants

One hundred sixty young men and women performed in four separate experiments, 40 participants in each. They were freshmen from the Department of Psychology, Tel-Aviv University, Tel-Aviv, Israel, participating in the experiment in partial fulfillment of the requirements in introductory psychology. All had normal or corrected-to-normal vision and intact color vision. Their ages ranged between 20 and 25 years. The 40 participants in each experiment were randomly assigned into the high-stress or the low-stress condition.

The design, the assessment of selectivity, and the means of stress induction were common to all four experiments. The experiments differed only with respect to the stimulus dimensions used, and these are described separately for each experiment.

Design: Assessing Selective Attention

Each of two dimensions, A (say, color) and B (word), were binary valued to form four stimulus combinations. From these stimuli, we created 10 experimental tasks (5 involving classification of A, 5 involving classification of B) of 64 trials each. Each task was preceded by 16 trials for training (unbeknownst to the participant, because the training trials were contiguous with the experimental ones). For classification of A, the participants performed in two baseline tasks (with B held constant at either $B_{1\ (\mathrm{RED})}$ or $B_{2\ (\mathrm{PINK})}$), in two correlated dimensions tasks (with A and B correlated either positively or negatively), and in a filtering task (with A and B varying in an orthogonal fashion). The participants also performed in the same 5 tasks, classifying B. A brief description of each task follows.

Baseline. The participants responded to values on Dimension A (print color), whereas Dimension B remained invariant from trial to trial. In the complementary task of baseline classification of B, the participants responded to values of B (word), with A held constant from trial to trial.

Filtering. The participant was presented with all four stimulus combinations in a random fashion. Again, the task was to classify the values of A and ignore those of B, which also varied from trial to trial. In the complementary task, the participant classified B, ignoring trial-to-trial variation in irrelevant A.

Positively correlated dimensions. The stimulus set contained only congruent stimuli, with the participant's task unchanged: She or he classified values of A in one task, values of B in the complementary task.

Negatively correlated dimensions. The stimulus set contained only conflicting stimuli. The task again was to classify A and ignore B, or in the complementary task, to classify B and ignore A.

Each participant performed the five A tasks and the five B tasks together as a set, with half of the participants first performing the A tasks and half first performing the B tasks. Within each set, order of the tasks was semirandom (the two blocks of baseline and the two blocks of correlation tasks were always performed next to one another; apart from this proviso the order of blocks was strictly random).

Experiment 1A. The stimuli were color words (RED, PINK) appearing printed in each color (*red*, *pink*) to form four stimulus combinations. The stimuli were generated in Microsoft Word (Hebrew font Sinai, size 64) by a Macintosh G3 300 computer and displayed on a 17-inch color monitor set at a resolution of 1,024 $\times$ 768 pixels. Mixing standard palettes R-100, G-9, and B-13 created the red color, and mixing R-100, B-100, and G-50 created the pink color. The color words in color appeared within the invisible frame of a rectangle of 118 $\times$ 40 pixels; viewed from a distance of approximately 60 cm, they subtended 4.48° of visual angle in width and 1.52° in height. The stimuli appeared over the light gray background of the screen, approximately at its center. To avoid strategic responding (e.g., with participants focusing on a constant small portion of the print to avoid reading the words), we introduced a trial-to-trial spatial uncertainty of 50 pixels around the target location.

Experiment 1B. We replaced the word PINK and the color *pink* with the word GREEN and the color *green* (created by mixing the computer hues of R-0, G-55, and B-46). We reduced font size to 60. The rectangular frame (invisible) encasing the stimuli was reduced as well to 103 $\times$ 36 pixels, subtending 3.91° of visual angle in width and 1.37° in height. In all other respects, Experiment 1B duplicated Experiment 1A.

Experiment 1C. The stimuli were picture–picture compounds of cow and bird. A professional artist prepared the two line drawings, modeling them after prototypical exemplars taken from children's books. They were instantly recognized as pictures of a cow and a bird. Each picture was presented in two sizes demarcated by the following invisible rectangles: 300 $\times$ 220 pixels for the large size and 130 $\times$ 95 pixels for the small size. On a trial, a small picture of an animal embedded in a large picture of an animal appeared around the center of the screen. The compound subtended 11.70° of visual angle in width and 8.65° in height. The picture–picture compounds appeared black (Color 256 in the standard palette) on a gray background (Color 249 in the standard palette).

The combinations of the small and large pictures divided into congruent stimuli in which the same animal was presented in the two sizes and incongruent stimuli in which the large and small pictures depicted different animals. In one set of tasks, the large picture was defined as the target dimension; in the complementary set of tasks, the small pictures comprised the relevant dimension. The participants were instructed to attend to the relevant dimension and ignore irrelevant variation. In all other respects, Experiment 1C duplicated the tasks and procedures of Experiments 1A and 1B.

Experiment 1D. We used all four combinations of color (*red*, *green*) and form (circle, triangle) to create the experimental stimuli. For color, we used the colors *red* and *green* from Experiment 1B. For form, the diameter of the circle was 81 pixels, equal to the base of the isosceles triangle, whose sides spanned 87 pixels each. Hence, the area of the circle (4.4 cm^2) was approximately equal to that of the triangle (3.8 cm^2). These shapes in color appeared within the framework of (an invisible) square of 81 $\times$ 81 pixels, subtending a visual angle of 3.2° in both width and height.

Conjoining color and form does not create Stroop stimuli (the set of stimuli does not divide onto congruent and incongruent stimuli); hence, the term "positive and negative correlation" no longer carries psychological significance. Consequently, we omitted the tasks of correlation from this experiment. The participants performed in the baseline and the filtering tasks, with color and form as the relevant dimensions in turn. In all other respects, the procedure followed that of Experiments 1A–1C.

Design: Manipulation of Stress

We largely followed the procedures used by Keinan et al. (1999; cf. Chajut, 1996; McGrath, 1970). The participants performed in three tasks of 10 items each tailored after standard psychometric tests: (a) an estimation task, (b) a number series task, and (c) an analogies task. In the first task, the participant indicated the percentage of target stimuli in briefly presented displays (e.g., the person estimated the relative frequency of smiling faces of all the faces in the display). The second task required discovery of the underlying function generating the five numbers on a display in order to add two numbers to the series (e.g., 3, 8, 13, 18, 23, ?, ?). The third task required identification of analogies—for example, "Refrigerator relates to cold as oven to (1) baking, (2) cake, (3) electricity, (4) heat."

Stress was induced by a variety of means, including task difficulty, time pressure, and threat to the ego. The items included in the number series and analogies tasks were more difficult in the high-stress condition than in the low-stress condition. Moreover, four of the items in each of the latter tests were insoluble (in principle) in the high-stress condition (random selection of numbers for the series, presentation of no true analogies). No such items were included in the low-stress condition. Time pressure was induced by limiting performance to 20 s per item in all tests in the high-stress condition compared with 50 s per item in the low-stress condition. In the former condition, a clock displayed on the monitor indicated the time remaining. The instructions in the high-stress condition described the to-be-performed tasks as measures of cognitive ability. The participants were told that they would be able, should they desired to do so, to compare performance to normative data. Finally, to enhance personal relevance, participants were asked to log their names and personal identification numbers on the computer before performing each task (this information was not saved and was duly discarded by the experimenter). In the low-stress condition, by contrast, the tasks were described as means to develop computerized versions of certain tests, assessing psychometric properties (rather than individual skills). The participants performed their easy, pressure-free tasks anonymously.

At the end of the entire experiment, participants filled out a very brief self-report questionnaire to assess the level of stress they experienced during the session and the difficulty they encountered while performing the tasks. Each question was rated on a 5-point scale.

Procedure

The participants were tested individually in a dimly lit room. The three "psychometric" tests comprised the first part of the experiment. The tests were fully computerized, with item difficulty, time constraints, and the instructions regarding personal relevance differing for participants in the high-stress and the low-stress conditions. The participant entered responses to all of the items in all of the tests by pressing the appropriate key on the computer keyboard. After conclusion of the three tasks, the selectivity of attention was gauged through the Garner paradigm.

In the different tasks of the Garner paradigm, the participant initiated the first trial by pressing any key on the computer board. The stimuli followed 0.5 s after each response. Classifications of A or of B were made by pressing either a right- or left-hand key on the keyboard. Stimulus displays were response terminated. Reaction time (RT) was measured in milliseconds using a software timer. The participants were instructed to attend to the relevant dimension and ignore irrelevant variation. They were encouraged to respond quickly but accurately.

The entire experimental session lasted about 50 min. At its conclusion, the participants answered the two questions in the self-report questionnaire and then were given full disclosure on the nature of the experiment, its aims, and their role as participants.

Data Analysis

Trials in which the participant's RT was either below or above two standard deviations of the mean for that participant were excluded from the analyses. The average error rates were very low and did not exceed 2.5% in any of the conditions of this study. Given this low rate, we did not analyze the error data further (cf. Wentura et al., 2000). We elucidate the RT data (for correct responses) in our analyses and discussions. Regarding the general RT performance, it was fairly speedy, averaging at 502.91 ms in the entire Experiment 1.

The data from all of the self-report questionnaires confirmed the effectiveness of the stress manipulation (Keinan, 1987; Keinan et al., 1999, 2000). In Experiment 1A, the participants in the high-stress condition perceived the tasks to be more difficult than did their cohorts in the low-stress condition (*M*s = 3.7 and 2.2, respectively); $F(1, 38) = 22.5$, $p < .005$. The former also reported higher levels of stress than the latter (*M*s = 3.35 and 2.15, respectively); $F(1, 28) = 14.4$, $p < .01$. In Experiment 1B, the average ratings of stress in the low-stress and high-stress conditions (*M*s = 2.0 and 3.15, respectively), $F(1, 38) = 7.78$, $p < .01$, and difficulty (*M*s = 2.15 and 3.35), $F(1, 38) = 6.28$, $p < .05$, duplicated the pattern of Experiment 1A. In Experiment 1C, the participants in the high-stress condition reported the tasks to be more difficult than participants in the low-stress condition (*M*s = 3.6 and 2.5), $F(1, 38) = 11.02$, $p < .05$. The former also experienced more stress than the latter (*M*s = 3.0 and 2.1); $F(1, 38) = 8.1$, $p < .05$. Finally, in Experiment 1D, the participants in the high-stress condition felt the tasks to be more difficult than those in the low-stress condition (*M*s = 3.3 and 1.9); $F(1, 38) = 9.96$, $p < .005$. The participants in the former group also experienced more stress than those in the latter group (*M*s = 3.4 and 2.1); $F(1, 38) = 6.36$, $p < .05$.

Results

Omnibus Analyses

Garner interference under high and low stress. We performed an overall analysis of variance (ANOVA) on the size of Garner interference ($RT_{baseline} - RT_{filtering}$) with stress (high, low), experiment (1–4), and target dimension (first, second) as the independent variables. The last variable is a within-subject factor, whereas the first two are between-subjects factors. The main effect of stress was found to be highly significant, $F(1, 158) = 12.17$, $p = .0006$, but neither experiment, $F(3, 158) = 1.96$, $p > .10$, nor target dimension ($F < 1$) were statistically significant. Stress interacted neither with experiment, $F(3, 158) = 2.04$, $p > .10$, nor target dimension ($F < 1$). The absence of the last interaction is as notable as the presence of the main effect for stress: It shows that stress reduced interference by the same amount regardless of whether the distractor dimension was word, color, picture, or geometric form.

Given these results, we averaged RT classification performance across the various dimensions of the four experiments in the baseline and filtering tasks to derive mean values of Garner interference under conditions of high and low stress. Pooled over the 160 participants, Garner interference amounted to 19 ms under low stress but to a mere 4 ms under high stress. Performing under low stress, the participants could not ignore task-irrelevant variation: They performed better with the irrelevant dimension held constant (baseline) than with the irrelevant dimension varying in a random fashion (filtering). Irrelevant variation thus took a noticeable toll, 19 ms, on performance with the target dimension. Under high stress, by contrast, the participants successfully withstood possible interference from irrelevant variation: They performed on a par in the presence and absence of irrelevant variation. Under high stress, performance was virtually free of intrusions from the task-irrelevant dimension (the Garner interference of 4 ms did not differ statistically from zero, $F < 1$). Therefore, our participants could focus exclusively on the target dimension when performing under high stress but were unable to do so when performing under low stress.

Stroop effects under high and low stress. Of the four experiments, the first three only contained Stroop dimensions (the fourth experiment included the dimensions of color and form that do not generate congruent and incongruent combinations, hence a Stroop effect does not apply). We performed an overall ANOVA with stress (high, low), experiment (1–3), target dimension (first, second), and measure of selectivity (Stroop effects in filtering and in correlation tasks) as the variables. Again, the main effect of stress was highly significant, $F(1, 118) = 13.92$, $p = .0003$, as was target dimension, $F(1, 114) = 37.44$, $p < .0001$, with colors and small pictures sustaining more Stroop interference than words and large pictures. The measure of selectivity was also significant, $F(1, 118) = 10.04$, $p < .0001$, with larger Stroop effects in the correlation tasks than in the filtering tasks. Most important, stress interacted with neither experiment, $F(2, 118) = 1.44$, $p > .10$, nor target dimension ($F < 1$). The absence of this last interaction is extremely important: It shows that stress reduced Stroop interference just as much when the distractor dimension was processed in an automatic or semantic fashion as when it was processed in a controlled or nonsemantic fashion. Initial interference (i.e., one under low stress) varied across dimensions, yet the size of the reduction precipitated by stress was uniform.

Given the symmetry in the reduction of the Stroop effect, we averaged RT classification performance across the various dimensions of the first three experiments for congruent and incongruent stimuli to derive the mean Stroop effects under conditions of high and low stress. Pooled over the 120 participants, the average Stroop effect amounted to 24 ms under low stress but to 12 ms under high stress. The results show that the momentary value of the task-irrelevant dimension, corresponding or conflicting with the target, was noticed and facilitated or hindered performance. However, the ensuing Stroop effects differed under low and high stress: The Stroop effect under low stress was twice its value under high stress. The interference and facilitation to target performance was much more pronounced under low stress than under high stress. Gauged by the Stroop effect, our participants also were better able to withstand interference from the task-irrelevant dimension when performing under high stress than when performing under low stress.

Stroop and Garner effects for individual dimensions under high and low stress. Garner interference and the pair of Stroop effects (from the filtering and the correlation tasks) were calculated separately for each of the eight target dimensions included in the four experiments (see the results of the individual experiments below).

In Table 2, we list these effects for each of the individual dimensions calculated under conditions of low and high stress. Consider first the effects of selectivity derived under low stress. Of the 20 effects, 14 differed significantly from zero ($p = .058$ in the binomial test). Clearly, performance was fraught with unwanted intrusions in the majority of the cases. The pattern obtained under high stress was the mirror image of that obtained under low stress: Of the 20 effects, only 4 differed statistically from zero ($p = .006$ in the binomial test). Under high stress, performance was free of interference in the great majority of the cases. Finally, consider direct comparisons of the individual effects under low and high stress. Of the 20 contrasts, 17 documented a reduction in the magnitude of interference under high stress ($p = .001$). Collectively, the summary of results with respect to the individual dimensions again displays a pervasive improvement of selective attention under high stress.

Table 2
Stroop and Garner Effects (in Milliseconds) Under High and Low Stress for Each of the Individual Dimensions in Experiments 1A–1D

Target dimension and effect	Stress: Low	Stress: High	Difference
Experiment 1A			
Word			
Garner	9	−4	(+)
Filter Stroop	−4	3	(−)
Correlation Stroop	18*	7	(+)
Color			
Garner	9	−1	(+)
Filter Stroop	26**	4	+
Correlation Stroop	39**	26**	(+)
Experiment 1B			
Word			
Garner	18*	4	+
Filter Stroop	20**	4	+
Correlation Stroop	−4	0	(+)
Color			
Garner	19*	21**	(−)
Filter Stroop	14*	−1	+
Correlation Stroop	13	7	(+)
Experiment 1C			
Large picture			
Garner	18*	−5	+
Filter Stroop	9	10	(−)
Correlation Stroop	29*	−2	+
Small picture			
Garner	34*	6	+
Filter Stroop	42**	25**	(+)
Correlation Stroop	74**	62**	(+)
Experiment 1D			
Shape			
Garner	14*	5	(+)
Color			
Garner	19**	9	(+)

Note. + = significant difference in favor of narrowing attention under high stress; (+) = nonsignificant difference in favor of narrowing attention under high stress; (−) = nonsignificant difference against narrowing attention under high stress.
* $p < .05$. ** $p < .01$.

Analysis by Experiments

Experiments 1A and 1B. In Experiments 1A and 1B, we used color words and print colors as dimensions: the words RED and PINK in colors *red* and *pink* in Experiment 1A and the words RED and GREEN in colors *red* and *green* in Experiment 1B. We performed a combined ANOVA with stress (low, high), relevant dimension (color, word) and measure of selectivity (Garner interference, Stroop effect in the filtering condition, Stroop effect in the correlation conditions) as main effects and with the three effects of selectivity serving as the dependent variable. We found an effect of target dimension, $F(1, 78) = 7.067$, $p < .001$, with interference to color exceeding that to word. This pattern derives at least partially from the superior salience of words in Experiments 1A and 1B. Stress exerted a significant effect, $F(1, 78) = 6.037$, $p = .016$, with mean interference decreasing from 14.5 ms under low stress to 5.8 ms under high stress. Clearly, selectivity was better under high stress than under low stress. Most important, stress did not interact with relevant dimension (word or color). In summary, the Stroop effect (registering the failure of selectivity for color) was larger than the reverse Stroop effect (registering the failure of selectivity for word). Nevertheless, the absence of an interaction between dimension and stress showed that both color and word were better focused under high stress. Stress thus reduced interference by approximately the same amount to color and word.

The mean RTs for classifying words and colors in the various tasks under conditions of high and low stress appear in Table 3. The main point to note apart from the vanishing values of Garner interference under high stress (for both color and word) is that words were more discriminable than colors at baseline in Experiment 1A. The advantage of words amounted to 72 ms under low stress and 73 ms under high stress; for both conditions, $F(1, 19) = 18.5$, $p < .0005$. A mismatched salience of the constituent dimensions favoring word is characteristic of much of the existing literature. The mean RTs for classifying congruent and incongruent stimuli in the filtering and correlation tasks under low and high stress appear in Table 4. Note the trend for diminished values of the Stroop effect under high stress for both word and color.

The baseline asymmetry in salience between the words and the colors rendered the words hard to ignore but rendered the colors relatively easy to ignore. Words intruded on performance with colors to a greater extent than did colors on performance with words. We recorded larger and more numerous instances of Stroop effects than reverse Stroop effects. For the contextual factor of dimensional correlation, the largest Stroop effects were recorded in the correlation tasks. In these tasks, the participants noticed the predictive relation established between word and color, compromising, in turn, selectivity to both dimensions.

In Experiment 1B, we attempted to redress the dimensional imbalance of Experiment 1A. Extensive pilot testing preceded that experiment in an attempt to eliminate the mismatch in discriminability. Table 3, which presents the average performance in the various tasks under low and high stress, shows that the advantage of words was eliminated. In Experiment 1B, the colors were

Table 3
Mean Reaction Times (in Milliseconds) for Classification of Words and Colors Across Tasks (Garner Interference) Under Conditions of Low and High Stress (Experiments 1A–1D)

Task	Exp. 1A Word	Exp. 1A Color	Exp. 1B Word	Exp. 1B Color	Exp. 1C Large picture	Exp. 1C Small picture	Exp. 1D Shape	Exp. 1D Color
Low stress								
Baseline	512	584	484	459	512	558	448	463
Filtering	521	593	502	478	531	592	463	482
Garner interference	9	9	18*	19*	18*	34*	15	19**
Positive correlation	468	534	474	449	516	523		
Negative correlation	486	573	470	462	545	597		
High stress								
Baseline	490	563	498	459	535	568	466	478
Filtering	486	562	502	480	530	574	471	487
Garner interference	−4	−1	4	21**	−5	6	5	9
Positive correlation	476	509	476	449	510	531		
Negative correlation	483	535	476	456	508	593		

Note. Experiment 1D did not include the correlation tasks or stimuli associated with the Stroop effect; hence, the empty cells. Exp. = experiment.
* $p < .05$. ** $p < .01$.

slightly more discriminable than the words by 25 ms, $F(1, 19) = 1.58$, $p > .10$, under low stress, and by 39 ms $F(1, 19) = 4.29$, $p < .05$, under high stress. The change rendered the pattern of interference largely symmetrical across word and color (see Table 4). However, the most noticeable trend in the data of Experiment 1B again is the collapse of interference under high stress.

Experiment 1C. The picture–picture compounds used in this experiment are a special species of Stroop stimuli: Both constituent dimensions are semantic. With the original Stroop stimuli of color words printed in color (Experiments 1A and 1B), only the former is semantic. Moreover, it is moot whether word naming itself is accomplished by engaging the semantic system. Pictures, by contrast, must engage the semantic system (Glaser, 1992). The

Table 4
Mean Reaction Times (in Milliseconds) for Classification of Dimensions Across Congruent and Incongruent Stimuli (Stroop Effect) Under Conditions of Low and High Stress (Experiments 1A–1C)

Condition and task	Experiment 1A IC	Experiment 1A C	Experiment 1A Stroop effect	Experiment 1B IC	Experiment 1B C	Experiment 1B Stroop effect	Experiment 1C IC	Experiment 1C C	Experiment 1C Stroop effect
Low stress									
Dimension 1									
Filtering	519	523	−4	512	492	20*	536	527	9
Correlation	486	468	18*	470	474	−4	545	516	29*
Dimension 2									
Filtering	606	580	26**	485	471	14*	613	571	42**
Correlation	573	534	39**	462	449	13	597	523	74**
High stress									
Dimension 1									
Filtering	487	484	3	504	500	4	535	525	10
Correlation	483	476	7	476	476	0	508	510	−2
Dimension 2									
Filtering	564	560	4	480	481	−1	586	561	25**
Correlation	535	509	26**	456	449	7	593	531	62**

Note. IC = incongruent stimuli; C = congruent stimuli.
* $p < .05$. ** $p < .01$.

present stimuli and their processing were thus semantic through and through.

An overall ANOVA yielded a highly significant effect of stress, $F(1, 38) = 19.1$, $p < .0001$, with interference effects amounting to 14 ms and 39 ms, respectively, under high and low stress. Target dimension was also consequential, $F(1, 38) = 30.33$, $p < .0001$, with interference affecting the less discriminable dimension of the small animal (41 ms) more than that of the big animal (12 ms). Measures of selectivity differed too, with the Stroop effect derived in the correlation tasks (42.25 ms) larger than that derived in the filtering task (22 ms) which in turn was larger than Garner interference (15.25 ms), $F(1, 38) = 13.0$, $p < .0001$. Finally, we found an interaction of relevant dimension with measure of selectivity, $F(2, 76) = 6.11$, $p = .0035$, with the Stroop effects obtained in the correlation conditions diverging most across the two dimensions (68.5 ms and 16 ms, 34 ms and 10 ms, and 21.5 ms and 9 ms, for small and big animal, respectively: for Stroop effects in the correlation and the filtering conditions and for Garner interference). The performance in Experiment 1C is depicted in detail in Tables 3 and 4. Notable again are the reduced amounts of interference, whether of Stroop or Garner species, under high stress. Therefore, for these Stroop dimensions also, selective attention improved substantially under high stress. In fact, what is most revealing about the present results is how similarly stress affects attentional processing with semantic and nonsemantic stimuli alike.

The contextual factors of dimensional imbalance and correlation shaped the pattern of interference in this experiment, too. For the first factor, the more discriminable dimension of large picture intruded on performance with the less discriminable dimension of small picture much more than vice versa. For the second factor of dimensional correlation, the largest values of interference were recorded under the context of correlated dimensions. The predictive relationship established compromised the nominal goal of exclusive focus on the target dimension.

Experiment 1D. In Experiment 1D, we tested the effect of stress on attention with non-Stroop stimuli. We elected to test the prototypical example of separable dimensions (Garner, 1974), color and form. Note that no Stroop effects can be defined for stimuli constructed by conjoining values from these dimensions (there exist neither congruent nor incongruent combinations). Therefore, in Experiment 1D we gauged selectivity under stress through Garner interference.

None of the main effects or interactions turned out statistically significant in an overall ANOVA. As shown in Table 3, the values of Garner interference recorded under high stress were approximately half the corresponding values observed under low stress for both shape and color. Moreover, both of the Garner effects (for color and form) vanished under high stress. However, neither of the differences was significant statistically in direct comparison because of the large variability. To put the current results in perspective, minuscule amounts of Garner interference are expected with separable dimensions under all circumstances (Melara & Mounts, 1993).

Discussion

The purpose of the preceding experiments was to address the question of selectivity under stress. The examination was rigorous, gauging selectivity by two classes of measures and controlling for hitherto neglected factors of context. The results showed that the selectivity of attention improved under stress. Stress enabled narrow focusing on the task attribute at hand. Under low stress, task performance was affected by appreciable amounts of Stroop and Garner effects: Irrelevant variation intruded pervasively on performance with the target attribute. Under high stress, these effects diminished noticeably, with attention focused squarely on the target attribute. Performing under high stress, our participants withstood successfully intrusions from task-irrelevant attributes. These results enable a clear decision among the theoretical alternatives.

Consider first ironic process theory. This theory predicts the collapse of selectivity under stress. According to the thought suppression account, performance with the dimension of interest should suffer enhanced intrusions from task-irrelevant information under conditions of high stress. To the contrary, we found selective attention to the target attribute to be better under high stress. The pattern of enhanced selectivity held for both constituent dimensions of a stimulus (e.g., word and color) serving in turn as the to-be-responded-to attribute. The results of the symmetrical testing are incompatible with the prediction of ironic process theory. The findings of improved selectivity under stress actually stand in direct opposition to the theoretical prediction.

Consider next the capacity–resource account. According to this account, selectivity under stress should remain intact for chronically accessible, automatically processed attributes but should be compromised for other attributes. The results disagree with this prediction. The narrowing of attention under stress applied to colors, words, pictures, and geometrical shapes alike. Whether the stimuli were semantic (word, picture) or physical (color, shape) mattered little to performance under stress. In other words, the semantic nature of words and pictures did not exempt them from the salutary effects of stress on selectivity. Attention to words and to pictures also improved under stress. Whether the pertinent processes were automatic (as is often claimed to be the case for words and pictures) or not (for colors and shapes) mattered little as well. The uniformity of the effect of stress on attention is captured by the graphical depiction in Figure 1. These features of the results are incompatible with the predictions of the capacity–resource approach.

Our results support the attention view by showing that people are able to focus on the target attribute better under high stress than under low stress. This effect of stress applies regardless of which dimension is selected to be the target dimension and regardless of the composition of the pertinent dimensions. The most revealing feature of the present results is the uniformity of the stress effect: Selective attention always narrows under stress. Taken together, the results are difficult to reconcile with ironic process theory or with the capacity–resource view of selectivity under stress. The attention view offers the best account of the present findings; indeed, it is the only account compatible with the results.

In Experiment 1, we generated a combination of several of the most powerful stressors identified in the literature (Contrada, 1989; Davidson & Henderson, 2000; Dolan & Tziner, 1988; Janis, 1993; Levine, Krass, & Padawer, 1993; cf. Svenson & Maule, 1993). Time pressure, task difficulty, and threat to the ego have often been used in the studies conducted under the rubric of ironic process theory and the capacity–resource perspective. Notably, all

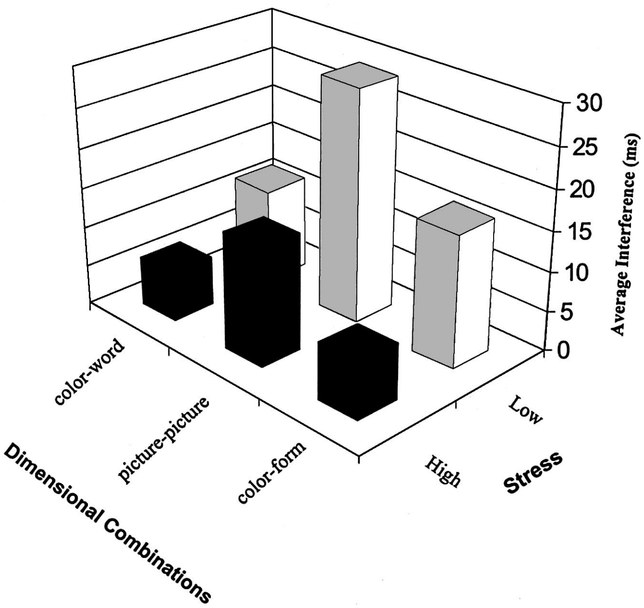

Figure 1. Average interference under conditions of high and low stress for speeded classification of various target dimensions in Experiments 1A–1D. Note the uniformity of the stress effect across the different types of dimensions.

of the stressors are psychological ones, exerting their influence by depleting available cognitive resources (Wells & Matthews, 1994).

We have recounted the seemingly incompatible outcome of studies conducted within the capacity–resource perspective (e.g., Bargh, 1982) and within the thought suppression perspective (e.g., Wegner & Erber, 1992), similarly applying time pressure and cognitive overload as stressors. For the former, the tasks often tapped divided attention, not selective attention. Tasks of divided attention are compromised under stress for the very same reason that tasks of selective attention are facilitated, namely the progressive narrowing of attention under stress. For the latter, Wegner and Erber (1992) as well as other investigators of the thought suppression approach tested (a) color but never word as the relevant dimension, without (b) manipulating or garnering information on the salience of the colors and words (not color words) presented. The asymmetric examination did not allow for a truly critical testing of ironic process theory; arguably, the words intruded on performance with the colors because of their superior facility and discriminability (especially because the task was verbal), not because of automatic search under stress. Indeed, Macrae, Bodenhausen, Milne, and Jetten (1994) challenged the results and interpretations of Wegner and Erber (1992) on similar grounds. These investigators argued that stress was not a decisive factor in engendering Wegner and Erber's results. The same results can often be observed in the absence of stress: "There seems to be no compelling theoretical or empirical reason to assume that hyperaccessibility can only occur under conditions of mental load" (Macrae et al., 1994, p. 814). We used the same stressors but were careful to test both color and word while monitoring discriminability. The application of stress in this study resulted in massive improvement in selective attention to the target component.

The question arises regarding the locus of the stress effect. Does stress exert its influence perceptually by rendering the task-irrelevant information less salient? Alternatively, does stress exert its influence centrally by fine-tuning attentional selectivity? The present data permit a clear answer to this question by observing possible changes in dimensional discriminability under low and high stress. Notably, elevated stress did not change the perceptual salience of the tested dimensions. For instance, if word was the more discriminable dimension under low stress, then it remained so under high stress as well. Moreover, a correlation usually emerged between the sizes of the same effects under low and high stress. For instance, the Pearson correlation between the respective effects under high and low stress in Experiment 1C amounted to .8(7), $p < .05$ (with the redundancy effects, baseline-correlation tasks, included). Therefore, heightened stress altered neither the nature of the tasks at hand nor the discriminability of the pertinent stimuli. Stress enabled the performer to better focus on the target attribute, yet the improved selectivity was not the result of a change in baseline discriminability. Likely, the improvement in selectivity under stress is effected by centrally controlled mechanisms of attention.

The contextual factors of dimensional imbalance and correlation shaped the patterns of interference observed. For the first factor, the more discriminable dimension in each experiment intruded on performance with the less discriminable dimension more than vice versa. As a result, larger effects of Stroop and Garner affected performance with the latter than with the former. For the second factor of dimensional correlation, the largest values of interference were recorded under the context of correlated dimensions. The predictive relationship established in the correlation tasks compromised the nominal goal of exclusive focus on the target dimension.

Despite the clear theoretical resolution, the procedures and outcomes of Experiment 1 can be challenged on several grounds. First, the manipulation of stress used is a potent and accepted procedure (e.g., Keinan, 1987; Keinan et al., 1999), yet it can be argued that motivational factors were also involved. Thus, the high-stress manipulation could have been read as a failure condition, and participants in those conditions might just have been motivated to try harder to avoid the unwelcome effects of another failure. Also, the high-stress manipulation may have signaled to participants that the Stroop task would also be difficult, so they tried harder, accepting it as a challenge. Second, the timing of the stress manipulation may be of some concern. The stress manipulation did not occur during the Stroop procedure. It is possible that once the stressful manipulation was completed, the participants' cognitive resources were restored to normal levels (but see S. Cohen, 1980). Third, applying another stimulus to induce stress is desirable on counts of cross-validation and as a means to alleviate some of the concerns mentioned.

Therefore, in Experiment 2, we used noise to induce stress in the participants. Noise is the most commonly used manipulation in the burgeoning literature on stress (e.g., Broadbent, 1971; Evans & Johnson, 2000; Glass & Singer, 1972; Goldberger & Breznitz, 1993; A. P. Smith, 1991; J. C. Smith, 1993). Noise is also coextensive with the Stroop procedure. We applied a within-subjects design in Experiment 2 to increase statistical power. In Experiment 3, we showed that it was stress rather than motivation that precipitated the observed narrowing of attention.

Experiment 2

Method

Participants

An independent sample of 20 undergraduates was recruited from the Tel-Aviv University community to participate in a single experimental session.

Stimuli, Apparatus, and Procedure

The assessment of selectivity, the stimuli, the design, and the procedure were those of Experiment 1A with two notable exceptions: The same persons participated in the low-stress and the high-stress conditions, performing only in tasks of speeded classification of print color. A random half of the participants first performed under low stress; the other half first performed under high stress. A break of 5 min separated the two conditions. The participants performed twice in the baseline, filtering positively correlated and negatively correlated dimension tasks, once under high stress and once under low stress. In the various tasks, they classified, while timed, the print color of the color words presented. We decided to jettison word naming in this experiment to avoid exposing participants to excessive stress because of the within-subjects design used.

To induce stress, we used the noise stimuli of A. P. Smith (1985; see also A. P. Smith & Broadbent, 1981; A. P. Smith, Jones, & Broadbent, 1981). Continuous noise at sound pressure level (SPL) of 84 dB (calibrated on the A scale of a Bruel & Kjaer 2235 [Copenhagen, Denmark] sound level meter) with equal levels per octave (+1 dB) between 200 and 4,000 Hz was applied in the high-stress condition. The SPL in the low-stress condition was 55 dB with the same spectrum. The noise was presented over two Sound Blaster SBS20 speakers (Creative, Singapore) positioned at distances of 24 cm to the left and to the right of the vertical midline of the computer screen facing the participant.

The average ratings of stress (*M*s = 2.0 and 3.15), $F(1, 38) = 7.78$, $p < .01$, and difficulty (*M*s = 2.15 and 3.35), $F(1, 38) = 6.28$, $p < .05$, in the low-stress and high-stress conditions confirmed the effectiveness of the stress manipulation.

Results

An ANOVA with stress (high, low) and measure of selectivity (Garner interference and the two Stroop effects) revealed a significant effect of noise stress, $F(1, 38) = 10.25$, $p = .005$, with mean interference values of 3 ms and 27 ms, respectively, under high and low stress. Notably, the effect of stress was not confined to any one of the measures of selectivity used, $F(2, 38) = 1.65$, $p > .10$, nor qualified by an interaction of stress and measure of selectivity ($F < 1$). For the two species of selectivity, both Garner interference (Table 5) and the Stroop effects (Table 6) diminished markedly under high stress, with none of the effects differing statistically from zero in this condition. Performance under low stress, in contrast, was plagued by fairly large amounts of interference (see Tables 5 and 6).

Table 5
Mean Reaction Times (in Milliseconds) for Classification of Colors Across Tasks (Garner Interference) Under Conditions of High and Low Stress (Experiment 2)

Task	Reaction time
Low stress	
Baseline	598
Filtering	620
Garner interference	22*
Positive correlation	560
Negative correlation	579
High stress	
Baseline	583
Filtering	593
Garner interference	10
Positive correlation	545
Negative correlation	551

* $p < .05$.

Discussion

Noise is a “common and important source of stress” to the extent that “much of the laboratory research on stress and performance used a variety of sources of noise” (J. C. Smith, 1993, p. 211; see also Arnsten & Goldman-Rakic, 1998, Evans, Hygge, & Bullinger, 1995; Holt, 1993). Applying this powerful stressor in Experiment 2, the pattern of results obtained throughout Experiment 1 was fully replicated. The Stroop and Garner effects that plagued performance under low stress all but vanished under high stress.

It is difficult to reconcile the results of Experiment 2 with the capacity–resource view and with ironic process theory. The task of color classification performed in the current experiment was an effortful activity that drew on attentional resources and was subject to voluntary control. The task-irrelevant dimension of word was one that does not draw on resources in processing and one that is activated in an automatic fashion. The prediction of the capacity–resource view under such circumstances is clear. Under stress, words are expected to intrude on colors with increased force. The prediction of ironic process theory is equally clear: Under stress, words are expected to be hyperaccessible and highly intrusive. The results showed instead better selectivity of color classification under stress. Attention theory alone predicts improved selectivity under stress. The theory is supported using a powerful stressor applied concurrently with the Stroop procedure.

In Experiment 3, we demonstrated that it was stress alone that was responsible for the observed narrowing of attention. We replaced the stress manipulation by a motivation manipulation and detected no effect on selective attention.

Experiment 3

Method

Participants

An independent sample of 40 undergraduates was recruited from the Department of Psychology, Tel-Aviv University, to participate in a single experimental session.

Stimuli, Apparatus, and Procedure

The stimuli, design, and procedure were the same as those of Experiment 2 with the following major exception: The stress manipulation was

Table 6
Mean Reaction Times (in Milliseconds) for Classification of Colors Across Congruent and Incongruent Stimuli (Stroop Effect) Under Conditions of High and Low Stress (Experiment 2)

Task	Incongruent	Congruent	Stroop effect
Low stress			
Filtering	641	600	41**
Correlation	579	560	19
High stress			
Filtering	595	592	3
Correlation	545	551	−6

** $p < .01$.

replaced by that of motivation within the framework of a between-subjects design.

Motivation was augmented by the following two means (for the same manipulation of motivation, see MacKinnon et al., 1985). Participants in the high-motivation group were promised a bonus of 20 Israeli shekels (IS; approximately $5 US) if their RT and accuracy of performance exceeded the "norm" measured in "a general student population" for their task (while keeping errors at minimum). They were further promised extra credit, reducing course requirement for participation in additional experiments, if they surpassed the norm. Neither reward nor any other information was mentioned for the participants in the low (or "usual") motivation group. At the end of the experiment, all participants were awarded both rewards regardless of performance.

Testing the effectiveness of the manipulation of motivation is not as straightforward as testing the manipulation of stress. Unlike self-reports about stress, self-reports about states of motivation are notoriously unstable and subject to bias. It is socially undesirable to report that one was poorly motivated to perform a task. Collecting data before task presentation may bias performance. To garner information on the validity of our procedure, we asked accidental samples of students gathering next to the board that advertises experiments in the Department of Psychology (prospective participants in the various experiments) to fill out a short questionnaire of eight items. The items related to various aspects of participation, but one critical item described an experiment entailing monetary rewards of 20 IS and exemption from a number of the required experiments (our actual manipulation of high motivation). We asked, "How strongly motivated would you be to participate in such an experiment in terms of the speed and accuracy of your performance?" The students responded on a 1 (*not particularly motivated*) to 7 (*highly motivated*) scale. A second critical item described an experiment that instead of the prescribed 30 min merely lasted 20 min (the mean duration of Experiment 3). The same scale was used for this as well as for the rest of the items. The sample of students (42 freshmen and sophomores who did not participate in any of the experiments of this study) was collected on a daily basis over a 3-week period. The results revealed surprisingly high levels of motivation, with means of 6.25 ($SD = 0.64$) and 5.35 ($SD = 0.88$), respectively, for the first and the second items. The significant difference, $t(41) = 3.45$, $p = .001$, conferred support on the validity of our manipulation of motivation.

Results

None of the main or the interaction effects were significant in an ANOVA with stress (high, low) and motivation (high, low) performed on the data of Experiment 3. In particular, level of motivation had absolutely no effect on the quality of selective attention ($F < 1$). Interference was comparable under low and high motivation with overall mean values of 22 ms and 19 ms, respectively. The lack of an effect for measure of selectivity confirmed that selectivity was on a par under the two levels of motivation whether gauged by Garner interference (Table 7) or by Stroop effects (Table 8).

Discussion

The results are easily summarized: Motivation did not exert an effect on the selectivity of attention. Most important for the present concerns, participants performing under high motivation were not free of intrusions from irrelevant information more than those performing under low motivation. Motivation per se was not conducive to refined selectivity. This null effect contrasts with the appreciable changes in selectivity observed in Experiments 1–2. We conclude that stress alone is conducive to enhanced selectivity of attention.

We note that using the same manipulation of motivation, MacKinnon et al. (1985) similarly found a null effect in their study. Motivation per se did not alter the magnitude of the Stroop effect (see their pilot experiments). However, when stress was introduced through the presence of a competitor, the Stroop effect was reduced (i.e., the selectivity of attention improved). In MacKinnon et al.'s main experiments, stress and motivation were confounded (both a reward and a competitor were present); hence, the source of the observed improvement in selectivity was moot. Our findings show that motivation per se does not engender a reduction in the Stroop effect. A review of voluminous Stroop literature (MacLeod, 1991; Melara & Algom, 2003) indicates that this finding is not really surprising. The skilled readers performing in the Stroop experiment are eager to conform with the instructions to ignore the words, yet they nonetheless succumb to the tendency to read the words. In contrast, stress does precipitate a reduction in intrusions from the irrelevant words. Our results are consistent with those of Huguet et al. (1999), who found that coaction, social comparison,

Table 7
Mean Reaction Times (in Milliseconds) for Classification of Colors Across Tasks (Garner Interference) Under Conditions of High and Low Motivation (Experiment 3)

Task	Reaction time
Low motivation	
Baseline	575
Filtering	593
Garner interference	18
Positive correlation	543
Negative correlation	574
High motivation	
Baseline	580
Filtering	607
Garner interference	27*
Positive correlation	551
Negative correlation	565

* $p < .05$.

Table 8
Mean Reaction Times (in Milliseconds) for Classification of Words and Colors Across Congruent and Incongruent Stimuli (Stroop Effect) Under Conditions of High and Low Motivation (Experiment 3)

Task	Incongruent	Congruent	Stroop effect
Low motivation			
Filtering	602	584	18*
Correlation	574	543	31*
High motivation			
Filtering	615	599	16*
Correlation	565	551	14

* $p < .05$.

and competition affect the selectivity of attention in the Stroop task. Stress mediates the salutary effects of coaction and competition on the selectivity of attention.

To recap, stress and motivation exert qualitatively different influences on cognitive processes of selectivity. Selective attention improves under heightened stress but remains unchanged under heightened motivation.

Conclusions

Throughout the present experiments, we observed substantial, systematic, and readily interpretable reductions in interference to performance under stress. Interference was gauged by Stroop and Garner effects. The effects were present under conditions of low stress, but they diminished considerably under conditions of high stress. We demonstrated the narrowing of attention with a variety of stressors and showed that it is stress rather than motivation that is conductive to improved selectivity. A collateral conclusion of the present research is the endorsement of the attention view for explaining selective attention under stress. According to this theory, improved selectivity under stress is a ubiquitous phenomenon independent of type of processing (automatic or controlled) or of the selection of target information (allocation of the constituent dimensions for selective processing). Our results are incompatible with the alternative perspectives of capacity–resource and thought suppression that hold selectivity under stress to be a contingent phenomenon (depending on type of processing and on target and distractor information, respectively). The present results and conclusions reinforce those reported recently by Huguet et al. (1999), who used social stresses as stimuli.

The methodological caution exercised in the present research may help resolve a lingering indecision in theory and data on selectivity under stress. In a recent Stroop study of the effect of stress on attention, Keinan et al. (1999) characterized the major theoretical notions in the field as "controversial" and "not entirely consistent" and existing data as "inconsistent," and stated that the pertinent effects "appear contradictory" (p. 473). Our study addressed these concerns by applying comprehensive testing with both dimensions of authentic Stroop stimuli. In addition, we monitored and manipulated critical factors of context. With the improved methodology applied, we derived a coherent set of results showing better focusing on target information under stress.

The present research helps to identify the locus of the stress effect. It is not perceptual, because the salience of the pertinent dimensions remains unchanged under high and low stress. Stress does not act by rendering the target attribute salient to perception and the distractor attribute less salient to perception. The stress effect is not spatial, because the relevant and irrelevant attributes inhere in the same spatial location (color and word occupy the same location in space). This point needs clarification because restricted focusing has often been interpreted in the spatial sense as a more narrowly concentrated beam (Chajut, 1996; Tsal & Shalev, 1996; Urbach & Spitzer; 1995; cf. Posner, Snyder, & Davidson, 1980), as enhanced processing of central stimuli (Baddeley, 1972), as the relative neglect of low-probability stimuli (Hockey & Hamilton 1983), or as the actual shrinkage of the effective visual field (Williams et al., 1991; Williams, Tonymon, & Andersen, 1990). Again, these notions do not apply in the present case, because the two dimensions inhered in the same spatial location. The stress effect is not one of motivation, because the latter does not itself improve selectivity. Therefore, we conclude that stress exerts its salutary effects on attention through centrally controlled acuity. Stress improves the ability of people to decompose the stimulus onto its constituent dimensions. This central mechanism is not subject to strategic influences (note again the lack of a motivation effect) and is probably activated in an unconscious and default fashion on the appearance of stress.

Finally, consider the role of the contextual factors treated in the present study. In much social research, mismatched discriminability and correlation conspired to produce Stroop effects whenever the effects were sought. Their apparent robustness served in turn to bias criteria for theoretical resolution. Manipulating and controlling those factors of context in the present study, we were able to resolve an inconsistent literature on the impact of stress on attention. In the present study, we show that the perceiver is sensitive to context, including covariation of the components (dimensional correlation) and their relative saliency (dimensional discriminability). Often, performance and interference depend on these factors of context. On the basis of manipulating other factors of context, Besner and Stolz (1999) concluded that "the Stroop effect is reduced in magnitude or eliminated, depending on details of context" (p. 99). Applying social means to induce stress, Huguet et al. (1999) similarly concluded that their findings "are inconsistent with the widespread view . . . that . . . semantic analyses of . . . words are uncontrollable in the sense that they cannot be prevented" (p. 1023). The present findings and conclusions are consistent with those of Besner and Stolz and Huguet et al., challenging the alleged robustness of the Stroop effect.

We conclude with a caveat to be contemplated in daily life. From a pragmatic point of view, the effects of stress are not uniformly unsavory and harmful. They are actually beneficial when the task requires exclusive focusing on target information. In such cases, the watchful presence of your supervisor can render your performance immune to distraction. On the other hand, tasks that require integration of information from several sources are vulnerable to the adverse effects of stress. Notably, however, these differential effects of stress are not qualified by the nature of the task components at hand.

References

Agnew, N., & Agnew, M. (1963). Drive level effects on tasks of narrow and broad attention. *Quarterly Journal of Experimental Psychology, 15,* 58–62.

Algom, D., Dekel, A., & Pansky, A. (1996). The perception of number from the separability of the stimulus: The Stroop effect revisited. *Memory and Cognition, 24,* 557–572.

Arieh, Y., & Algom, D. (2002). Processing picture–word stimuli: The contingent nature of picture and of word superiority. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 28,* 221–232.

Arnsten, A. F., & Goldman-Rakic, P. S. (1998). Noise stress impairs prefrontal cortical cognitive function in monkeys: Evidence for a hyperdopaminergic mechanism. *Archives of General Psychiatry, 55,* 362–368.

Baddeley, A. D. (1972). Selective attention and performance in dangerous environments. *British Journal of Psychology, 63,* 537–546.

Bargh, J. A. (1982). Attention and automaticity in the processing of self-relevant information. *Journal of Personality and Social Psychology, 43,* 425–436.

Bargh, J. A. (1989). Conditional automaticity: Varieties of automatic influence in social perception and cognition. In U. James & J. A. Bargh (Eds.), *Unintended thought* (pp. 3–51). New York: Guilford Press.

Bargh, J. A. (1992). The ecology of automaticity: Toward establishing the conditions needed to produce automatic processing effects. *American Journal of Psychology, 105,* 181–199.

Bargh, J. A., & Thein, R. D. (1985). Individual construct accessibility, person memory, and the recall–judgment link: The case of information overload. *Journal of Personality and Social Psychology, 49,* 1129–1146.

Bargh, J. A., & Tota, M. E. (1988). Context-dependent automatic processing in depression: Accessibility of negative constructs with regard to self but not others. *Journal of Personality and Social Psychology, 54,* 925–939.

Baron, R. S. (1986). Distraction–conflict theory: Progress and problems. In L. Berkowitz (Ed.), *Advances in experimental social psychology* (Vol. 19, pp. 1–40). New York: Academic Press.

Besner, D., & Stolz, J. A. (1999). What kind of attention modulates the Stroop effect? *Psychonomic Bulletin and Review, 6,* 99–104.

Brand, N., Schneider, N., & Arntz, P. (1995). Information processing efficiency and noise: Interactions with personal rigidity. *Personality and Individual Differences, 18,* 571–579.

Broadbent, D. E. (1971). *Decision and stress.* New York: Academic Press.

Callaway, E. L. (1959). The influence of amobarbital (amylobarbitone) and methamphetamine on the focus of attention. *Journal of Mental Science, 105,* 382–392.

Callaway, E. L., & Dembo, D. D. (1958). Narrowed attention: A psychological phenomenon that accompanies a certain physiological change. *Archives of Neurology and Psychiatry (Chicago), 79,* 74–90.

Callaway, E. L., & Thompson, S. (1953). Sympathetic activity and perception: An approach to the relationships between autonomic activity and personality. *Psychosomatic Medicine, 15,* 443–455.

Chajut, E. (1996). *Narrowing of visual attention under stress conditions.* Unpublished master's thesis, Tel-Aviv University, Tel-Aviv, Israel.

Cohen, S. (1978). Environment load and the allocation of attention. In A. Baum, J. E. Singer, & S. Valins (Eds.), *Advances in environmental psychology* (pp. 1–29). Hillsdale, NJ: Erlbaum.

Cohen, S. (1980). Aftereffects of stress on human performance and social behavior: A review of research and theory. *Psychological Bulletin, 88,* 82–108.

Contrada, R. J. (1989). Type A behavior, personality hardiness, and cardiovascular responses to stress. *Journal of Personality and Social Psychology, 57,* 895–903.

Corr, P. J., & Kumari, V. (1998). Impulsivity, time of day, and stress: Effects on intelligence test performance. *Journal of Research in Personality, 32,* 1–12.

Cottrell, N. B. (1968). Performance in the presence of other human beings: Mere presence, audience, and affiliation effect. In E. C. Simmel, R. A. Hoppe, & G. A. Milton (Eds.), *Social facilitation and imitative behavior* (pp. 91–110). Boston: Allyn & Bacon.

Cottrell, N. B. (1972). Social facilitation. In C. G. McClintock (Ed.), *Experimental social psychology* (pp. 185–236). New York: Holt, Rinehart & Winston.

Davidson, R., & Henderson, R. (2000). Electronic performance monitoring: A laboratory investigation of the influence of monitoring and difficulty on task performance, mood state, and self-reported stress levels. *Journal of Applied Social Psychology, 30,* 906–920.

Dishon-Berkovits, M., & Algom, D. (2000). The Stroop effect: It is not the robust phenomenon that you have thought it to be. *Memory and Cognition, 28,* 1437–1449.

Dolan, S., & Tziner, A. (1988). Implementing computer-based automation in the office: A study of experienced stress. *Journal of Organizational Behavior, 9,* 183–187.

Easterbrook, J. A. (1959). The effect of emotion on cue utilization and the organization of behavior. *Psychological Review, 74,* 16–28.

Evans, G. W., Hygge, S., & Bullinger, M. (1995). Chronic noise and psychological stress. *Psychological Science, 6,* 333–338.

Evans, G. W., & Johnson, D. (2000). Stress and open-office noise. *Journal of Applied Psychology, 85,* 779–783.

Eysenck, M. W. (1982). *Attention and arousal: Cognition and performance.* New York: Springer-Verlag.

Folkard, S., & Greeman, A. L. (1974). Salience, induced muscle tension, and the ability to ignore irrelevant information. *Quarterly Journal of Experimental Psychology, 26,* 360–367.

Garner, W. R. (1974). *The processing of information and structure.* Hillsdale, NJ: Erlbaum.

Garst, H., Frese, M., & Molenaar, P. C. (2000). The temporal factor of change in stressor–strain relationship: A growth curve model on a longitudinal study in East Germany. *Journal of Applied Psychology, 85,* 417–438.

Glaser, W. R. (1992). Picture naming. *Cognition, 42,* 61–105.

Glass, D. C., & Singer, J. E. (1972). *Urban stress: Experiments on noise and social stressors.* New York: Academic Press.

Goldberger, L., & Breznitz, S. (1993). *Handbook of stress: Theoretical and clinical aspects.* New York: Free Press.

Hartley, L. R., & Adams, R. G. (1974). Effect of noise on the Stroop test. *Journal of Experimental Psychology, 102,* 62–66.

Hartley, L. R., & Shirley, E. (1976). Color-name interference at different times of day. *Journal of Applied Psychology, 61,* 119–122.

Higgins, E. T., King, G. A., & Marvin, G. H. (1982). Individual construct accessibility and subjective impressions and recall. *Journal of Personality and Social Psychology, 43,* 35–47.

Hochman, S. H. (1967). The effects of stress on Stroop color-word performance. *Psychonomic Science, 9,* 475–476.

Hochman, S. H. (1969). Stress and response competition in children's color-word performance. *Perceptual and Motor Skills, 28,* 115–118.

Hockey, G. R. (1970a). Effect of loud noise on attentional selectivity. *Quarterly Journal of Experimental Psychology, 22,* 28–36.

Hockey, G. R. (1970b). Signal probability and spatial location as possible bases for increased selectivity in noise. *Quarterly Journal of Experimental Psychology, 22,* 37–42.

Hockey, G. R. (1978). Attentional selectivity and the problems of replication: A reply to Forster & Grierson. *British Journal of Psychology, 69,* 499–503.

Hockey, G. R. J., & Hamilton, P. (1983). The cognitive patterning of stress states. In G. R. J. Hockey (Ed.), *Stress and fatigue in human performance* (pp. 331–362). Chichester, England: Wiley.

Holt, R. R. (1993). Occupational stress. In L. Goldberger & S. Breznitz (Eds.), *Handbook of stress: Theoretical and clinical aspects* (pp. 342–367). New York: Free Press.

Houston, B. K. (1969). Noise, task difficulty, and Stroop color-word performance. *Journal of Experimental Psychology, 82,* 403–404.
Houston, B. K., & Jones, T. M. (1967). Distraction and Stroop color-word performance. *Journal of Experimental Psychology, 74,* 54–56.
Huguet, P., Galvaing, M. P., Monteil, J. M., & Dumas, F. (1999). Social presence effects in the Stroop task: Further evidence for an attentional view of social facilitation. *Journal of Personality and Social Psychology, 77,* 1011–1025.
Janis, I. L. (1993). Decision making under stress. In L. Goldberger & S. Breznitz (Eds.), *Handbook of stress: Theoretical and clinical aspects* (pp. 69–80). New York: Free Press.
Kahneman, D. (1973). *Attention and effort.* Englewood Cliffs, NJ: Prentice Hall.
Keinan, G. (1987). Decision making under stress: Scanning of alternatives under controllable and uncontrollable threats. *Journal of Personality and Social Psychology, 52,* 639–644.
Keinan, G., Friedland, N., & Even-Haim, G. (2000). The effect of stress and self-esteem on social stereotyping. *Journal of Social and Clinical Psychology, 19,* 206–219.
Keinan, G., Friedland, N., Kahneman, D., & Roth, D. (1999). The effect of stress on the suppression of erroneous competing responses. *Anxiety, Stress, and Coping, 12,* 455–476.
Kelly, G. A. (1955). *The psychology of personal constructs.* New York: Norton.
Levine, F. M., Krass, S. M., & Padawer, W. J. (1993). Failure hurts: The effects of stress due to difficult tasks and failure feedback on pain report. *Pain, 54,* 335–340.
Loeb, M. (1986). *Noise and human efficiency.* New York: Wiley.
MacKinnon, D. P., Geiselman, R. E., & Woodward, J. A. (1985). The effects of effort on Stroop interference. *Acta Psychologica, 58,* 225–235.
MacLeod, C. M. (1991). Half a century of research on the Stroop effect: An integrative review. *Psychological Bulletin, 109,* 163–203.
Macrae, C. N., Bodenhausen, G. V., Milne, A. B., & Ford, R. L. (1997). On regulation of recollection: The intentional forgetting of stereotypical memories. *Journal of Personality and Social Psychology, 72,* 709–719.
Macrae, C. N., Bodenhausen, G. V., Milne, A. B. & Jetten, J. (1994). Out of mind but back in sight: Stereotypes on the rebound. *Journal of Personality and Social Psychology, 67,* 808–817.
McGrath, J. E. (1970). *Social and psychological factors in stress.* New York: Holt, Rinehart & Winston.
Melara, R. D., & Algom, D. (2003). Driven by information: A tectonic theory of Stroop effects. *Psychological Review, 110,* 422–471.
Melara, R. D., & Mounts, J. R. (1993). Selective attention to Stroop dimensions: Effects of baseline discriminability, response mode, and practice. *Memory and Cognition, 21,* 627–645.
Muraven, M., Tice, D. M., & Baumeister, R. F. (1998). Self-control as a limited resource: Regulatory depletion patterns. *Journal of Personality and Social Psychology, 74,* 774–789.
O'Malley, J. J., & Gallas, J. (1977). Noise and attention span. *Perceptual and Motor Skills, 44,* 919–922.
O'Malley, J. J., & Poplawsky, A. (1971). Noise-induced arousal and breadth of attention. *Perceptual and Motor Skills, 33,* 887–890.
Pallack, M. S., Pittman, T. S., Heller, J. F., & Munson, P. (1975). The effect of arousal on Stroop color-word task performance. *Bulletin of the Psychonomic Society, 6,* 248–250.
Pansky, A., & Algom, D. (1999). Stroop and Garner effects in comparative judgment of numerals: The role of attention. *Journal of Experimental Psychology: Human Perception and Performance, 25,* 39–58.
Pansky, A., & Algom, D. (2002). Comparative judgment of numerosity and numerical magnitude: Attention preempts automaticity. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 28,* 259–274.
Pomerantz, J. R. (1983). Global and local precedence: Selective attention in form and motion perception. *Journal of Experimental Psychology: General, 112,* 516–540.
Pomerantz, J. R., Pristach, E. A., & Carlson, C. E. (1989). Attention and object perception. In E. S. Bryan & E. S. Ballesteros (Eds.), *Object perception: Structure and process* (pp. 53–89). Hillsdale, NJ: Erlbaum.
Posner, M. I., Snyder, R. R., & Davidson, D. J. (1980). Attention and the detection of signals. *Journal of Experimental Psychology: General, 109,* 160–174.
Pratto, F., & Oliver, J. P. (1991). Automatic vigilance: The attention-grabbing power of negative social information. *Journal of Personality and Social Psychology, 61,* 380–391.
Revelle, W., Amaral, P., & Turriff, S. (1976, April 9). Introversion/extroversion, time stress, and caffeine: Effect on verbal performance. *Science, 192,* 149–150.
Sabri, M., Melara, R. D., & Algom, D. (2001). A confluence of contexts: Asymmetric versus global failures of selective attention to Stroop dimensions. *Journal of Experimental Psychology: Human Perception and Performance, 27,* 515–537.
Sanders, G. S., Baron, R. S., & Moore, D. L. (1978). Distraction and social comparison as mediators of social facilitation effects. *Journal of Experimental Social Psychology, 14,* 291–303.
Shalev, L., & Algom, D. (2000). Stroop and Garner effects in and out of Posner's beam: Reconciling two conceptions of selective attention. *Journal of Experimental Psychology: Human Perception and Performance, 26,* 997–1017.
Singer, J. L. (1952). Personal and environmental determinants of perception in a size constancy experiment. *Journal of Experimental Psychology, 43,* 420–427.
Smith, A. P. (1985). The effects of noise on the processing of global shape and local detail. *Psychological Research, 47,* 103–108.
Smith, A. P. (1991). Noise and aspects of attention. *British Journal of Psychology, 82,* 313–324.
Smith, A. P., & Broadbent, D. E. (1981). Noise and levels of processing. *Acta Psychologica, 47,* 129–142.
Smith, A. P., & Broadbent, D. E. (1985). The effects of noise on the naming of colours and reading of colour names. *Acta Psychologica, 58,* 275–285.
Smith, A. P., Jones, D. M., & Broadbent, D. E. (1981). The effects of noise on recall of categorized lists. *British Journal of Psychology, 72,* 299–316.
Smith, J. C. (1993). *Understanding stress and coping.* New York: Macmillan.
Stroop, J. R. (1935). Studies of interference in serial–verbal reaction. *Journal of Experimental Psychology, 18,* 643–662.
Svenson, O., & Maule, A. J. (Eds.). (1993). *Time pressure and stress in human judgment and decision making.* New York: Plenum Press.
Tecce, J. J., & Happ, S. J. (1964). Effects of shock-arousal on a card-sorting test of color-word interference. *Perceptual and Motor Skills, 19,* 905–906.
Tsal, Y., & Shalev, L. (1996). Inattention magnifies perceived length: The attentional receptive field hypothesis. *Journal of Experimental Psychology: Human Perception and Performance, 22,* 233–243.
Urbach, D., & Spitzer, H. (1995). Attentional effort modulated by task difficulty. *Vision Research, 35,* 2169–2177.
Wachtel, P. L. (1967). Conceptions of broad and narrow attention. *Psychological Bulletin, 6,* 417–429.
Warburton, D. M. (1988). Emotional and motivational determinants of attention and memory. In V. Hamilton & G. H. Bower (Eds.), *Cognitive perspectives on emotion and motivation* (pp. 195–219). Norwell, MA: Kluwer.
Webster, D. M., Richter, L., & Kruglanski, A. W. (1996). On leaping to conclusions when feeling tired: Mental fatigue effects on impressional primacy. *Journal of Experimental Social Psychology, 32,* 181–195.

Wegner, D. M. (1994). Ironic processes of mental control. *Psychological Review, 101,* 34–52.

Wegner, D. M., & Erber, R. (1992). The hyperaccessibility of suppressed thoughts. *Journal of Personality and Social Psychology, 63,* 903–912.

Wegner, D. M., Erber, R., & Zanakos, S. (1993). Ironic processes in the mental control of mood and mood-related thought. *Journal of Personality and Social Psychology, 65,* 1093–1104.

Wells, A., & Matthews, G. (1994). *Attention and emotion: A clinical perspective.* Hillsdale, NJ: Erlbaum.

Wentura, D., Rothermund, K., & Bak, P. (2000). Automatic vigilance: The attention-grabbing power of approach- and avoidance-related social information. *Journal of Personality and Social Psychology, 78,* 1024–1037.

Wenzlaff, R. M., & Bates, D. E. (2000). The relative efficacy of concentration and suppression strategies of mental control. *Personality and Social Psychology Bulletin, 26,* 1200–1212.

Wenzlaff, R. M., & Wegner, D. M. (2000). Thought suppression. *Annual Review of Psychology, 51,* 59–91.

Williams, J. M., Tonymon, P., & Andersen, M. B. (1990). Effects of life-event stress on anxiety and peripheral narrowing. *Behavioral Medicine, 16,* 174–181.

Williams, J. M., Tonymon, P., & Andersen, M. B. (1991). The effects of stressors and coping resources on anxiety and peripheral narrowing. *Journal of Applied Sport Psychology, 3,* 126–141.

Woodfield, E., Jones, G. V., & Martin, M. (1995). Selective processing of stress-related words in colour naming. *Personality and Individual Differences, 19,* 385–387.

Zajonc, R. B. (1965). Social facilitation. *Science, 149,* 269–274.

Zajonc, R. B. (1980). Compresence. In P. B. Paulus (Ed.), *Psychology of group influence* (pp. 35–60). Hillsdale, NJ: Erlbaum.

Received August 16, 2002
Revision received March 19, 2003
Accepted March 29, 2003 ■

Correction to Hobfoll et al. (2003)

The article "Resource Loss, Resource Gain, and Emotional Outcomes Among Inner City Women," by Stevan E. Hobfoll, Robert J. Johnson, Nicole Ennis, and Anita P. Jackson (*Journal of Personality and Social Psychology*, 2003, Vol. 84, No. 3, pp. 632–643), contained several errors.

On page 643, in the tables for Appendixes B and C, the variables labeled with "T3" should all read "T2." In Appendix C, the column headings "Nonlinear model" should read "Nonlinear model T1"; the column headings "Linear model" should read "Nonlinear model T2." These changes do not affect the findings, interpretations, or conclusions.