The visual search analogue of latent inhibition: Implications for theories of irrelevant stimulus processing in normal and schizophrenic groups

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Latent inhibition (LI) is a robust phenomenon that is demonstrated when a previously inconsequential stimulus is less effective in a new learning situation than a novel stimulus. Despite LI's simplicity, there is considerable disagreement as to its theoretical basis. Attentional theories claim that unattended stimulus preexposures reduce stimulus associability. Alternatively, it has been asserted that associability is unaffected and that LI is a result of competition/retrieval processes. The present article reviews a series of visual search studies, some with normal subjects, both undifferentiated and divided into low and high schizotypals, and others with pathologies that entail dysfunctional attention, such as schizophrenia, Parkinson's disease, and anxiety. The visual search conditions were designed to model those of traditional LI experiments, while tapping attentional processes independently of the learning scores that index LI. A variety of evidence from these and other studies is used to support the involvement of attentional *and* retrieval processes in LI. A model of the mechanism of action of these processes in LI is presented, together with its application to schizophrenia.

There are some conditions that make it more difficult to acquire or to express a new association to a familiar stimulus than one to a novel stimulus, particularly when the familiar stimulus has been previously unattended. This situation is expressed in an apparently simple phenomenon, called *latent inhibition* (LI). LI occurs across a variety of species, including pigeons, rats, and humans, and in many different testing paradigms, from simple classical conditioning to rule learning (for a review, see Lubow, 1989). Given the generality and robustness of this stimulus preexposure effect, it is not surprising to find that LI has a significant place in the history of psychological research, beginning with issues in classical learning theory (for reviews, see Hall, 1991; Lubow, 1989) and extending through the study of the processing of irrelevant information associated with high schizotypality and schizophrenia (for reviews, see Braunstein-Bercovitz, Rammsayer, Gibbons, & Lubow, 2002; Escobar, Oberling, & Miller, 2002; Lubow, 2005; Lubow & Gewirtz, 1995) and even of creativity (Carson, Peterson, & Higgins, 2003).

Despite the overwhelming evidence that preexposure to a stimulus may have a negative impact on the demonstration of subsequent learning with that stimulus, ex-

tensive documentation indicates that such stimulus preexposure may also enhance performance on a learning task, as in perceptual-learning effects (for reviews, see Gibson, 1969; Hall, 1991). Whether one obtains poorer or better learning following stimulus preexposure depends on the conditions of stimulus preexposure, the relationship between the preexposure and the test contexts, including the time between them and where that time is spent, and the choice of a comparison (control) group. Briefly, LI in humans is favored when (1) the preexposed stimulus is not relevant to (is unattended in) the preexposure task (masking task) but is relevant to the test task. (2) the preexposure and test contexts are the same, and (3) the stimulus-preexposed (PE) group is compared with a group that is not preexposed (NPE) to the to-be-target stimulus but has spent the same amount of time in the preexposure context. In opposition to LI, perceptual learning is promoted when (1) the preexposed stimulus is relevant to (attended in) the preexposure task and continues to be relevant in the test task, (2) the PE stimulus is presented in one context but the test is conducted in a different context, and (3) the stimulus PE group is compared with a group that is tested with a novel stimulus in a novel context (NOV group).

In short, stimulus preexposure may produce different effects, some of which depend on the conditions of preexposure and others on those of test. Nor do such preexposures have consequences that are limited to impairment or enhancement of performance on tests of *learning*. For

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example, a novel item among familiar (preexposed) distractors can be localized more quickly than a novel item among novel distractors (novel pop-out [NPO] effect; see, e.g., Johnston & Hawley, 1994). Other examples include the once popular stimulus familiarization effect (Cantor, 1969), in which simple stimulus preexposure, as compared with no such preexposure, produces slower responding in a choice response time (RT) task. Indeed, any two-phase experimental design can be construed as involving preexposure and test stages—as for example, studies of extinction—in which a paired conditioned stimulus (CS) and unconditioned stimulus (US) are “preexposed” in the first phase and, in the second, test phase, the CS is presented by itself. Among the various animal-learning paradigms, blocking, overshadowing, sensory preconditioning, and many others also conform to a preexposure-and-test design.

Note that all of these paradigms employ multitrial preexposure and test stages, in which the trials that define each stage are *blocked*. As opposed to these designs, there are paradigms, typically used with human subjects, in which the preexposed stimuli and the test stimuli are presented in multitrial *pairs*, as in negative priming, Stroop tasks, flanker tasks, and cost-benefit procedures. The blocked and paired procedures have different historical roots, as well as different underlying assumptions. Curiously, there have been few attempts at a theoretical integration of the data generated from the two types of paradigms. For our purposes, it is sufficient to mention that the blocked trials procedures are commonly found in animal experiments that address theoretical issues centered on learning and that may or may not appeal to attentional explanations. On the other hand, the paired trial procedures are most commonly found in experiments with human subjects that center on problems of attention and that may or may not appeal to learning explanations.

However, as has long been recognized, attention and learning are intimately related. Indeed, any theory that posits that stimulus preexposure modulates attention will predict multiple preexposure effects, from perceptual to cognitive. A reduction of attention to a tone should affect the perceived intensity of the tone (salience) and, as a consequence, its subsequent associability. Similarly, a visual shape that has been presented as an irrelevant stimulus not only will be weakened in its ability to enter into, or reflect performance of, new associations (e.g., Braunstein-Bercovitz & Lubow, 1998a, 1998b), but also should be less effective as a target in a visual search task (Lubow & Kaplan, 1997). Just as modulations of attention can affect learning, learning can affect attention—as for example, in various interpretations of the research on perceptual learning (Gibson, 1969), the “acquired distinctiveness of cues” (e.g., Lawrence, 1949), and LI (Lubow, 1989; Lubow, Weiner, & Schnur, 1981).

Despite these intuitively obvious relationships, until recently there has been no study directed at showing that the LI effect is, in fact, based on a stimulus-specific loss of attention. Instead, the hypothetical decline of such attention during the preexposure period has been affirmed,

albeit circularly, by the LI effect itself (for exceptions, see Braunstein-Bercovitz, Hen, & Lubow, 2004; Braunstein-Bercovitz & Lubow, 1998a). However, this situation can be corrected, if one can demonstrate that the same set of stimulus PE conditions that produces degraded performance on a learning task (traditional LI) also leads to relatively poor performance on a task that assesses attention but is independent of the learning-based LI tests.

To this end, we have used visual search tasks that do not engage memory retrieval processes. The target is defined as a unique figure among a group of similar distractors, rather than as a function of historical experiential factors. By manipulating preexposure variables that normally produce LI and assessing performance on an attentionally modulated visual search task, one can attain a better comprehension of the processes governing LI, as well as of visual search itself. In order to understand the relationship between the visual search analogue of LI and standard learning-based LI, it is first necessary to describe a representative LI procedure of the latter type.

Eliciting Standard LI in Humans

Braunstein-Bercovitz and Lubow (1998a, 1998b) used a typical procedure for inducing LI in adult humans. The experiments were composed of two phases: preexposure and test. In Phase 1, the stimulus-preexposed subjects (PE group) were presented with 256 trials. Each trial contained the same pair of identical meaningless shapes. Concurrently, a pair of letters from the set TT, LL, TL, or LT was displayed in the space between the two shapes. The subjects were required to judge whether the letter pairs were identical (TT, LL) or different (TL, LT). This masking task served to divert attention from the shape that later, in the test phase, would be the stimulus to be learned. The nonpreexposed subjects (NPE group) received the same masking task, but without the shapes. In the test phase, the letter pairs from the masking task continued to be present in the same position as in the preexposure phase, but they were now irrelevant. On test trials, the shape that was preexposed was presented to both the PE and the NPE groups. The subjects had to learn that a change in the numerical value on a counter was associated with the presence of the shape pair that was previously irrelevant for the PE group (when the preexposed shape pair was present, a barpress decreased the number on the counter; a failure to press increased it). The PE group reached the learning criterion (five consecutive correct responses) more slowly than the NPE group did, thereby demonstrating the LI effect (for examples of recent similar findings, see Braunstein-Bercovitz, Hen, & Lubow, 2004; N. S. Gray et al., 2001).

The Basic Visual Search LI Procedure

The visual search procedure for generating LI-like effects differs from the standard learning-based LI procedures in that it uses a within-subjects, as opposed to a between-subjects, design. In addition, the primary dependent variable is RT, rather than correct responses

(CRs). As with the standard LI task, the LI-related visual search procedures have two stages: preexposure and test. In both stages, the subject has to detect a target that is a unique complex shape among a field of identical distractors. In some experiments, the subject is required to indicate whether the target is present or absent, and in others whether it is on the right or the left side of the display. The targets and distractors are meaningless five-line figures (Musen & Treisman, 1990).

The preexposure stage consists of 80–100 trials. Each trial consists of a display with the same set of common distractors. In the target present/absent experiments, some trials contain the target, and others do not. In the target right/left experiments, the target appears on every trial. In all cases, the positions of the target and the distractors vary from trial to trial. The test stage, also consisting of 80–100 trials, is initiated immediately after preexposure. For all experiments, the response requirements in the test phase are the same as those in the preexposure phase. On any given trial, the test phase target is congruent with its status during the preexposure phase (a target in both phases, $T \rightarrow T$), incongruent (a distractor during the preexposure phase becomes a target during the test, $D \rightarrow T$), or novel (N). Similarly, on any given trial, the test phase distractors are congruent ($D \rightarrow D$), incongruent ($T \rightarrow D$), or novel (N) in relationship to their status in the preexposure phase. The complete designation of a test phase trial, then, requires two expressions: one for the target and one for the distractor. For convenience, we will use a notational system in which the status of the test phase target is described by the first term in the expression and the status of the test phase distractor by the second term. Thus, for example, the notation $(D \rightarrow T):(T \rightarrow D)$ indicates that the test phase target was previously a distractor ($D \rightarrow T$) and the test phase distractor was previously a target ($T \rightarrow D$). Given the three possible states of test phase targets and of test phase distractors, seven test phase display types can be constructed,¹ although in practice we often use as few as three or four.

As an illustration of a typical procedure, in the preexposure phase, subjects are given multiple trials, each of which contains the same target and the same set of identical distractors. In the test phase, the subjects might receive four types of trials, intermixed in random order. In one type, the test trial is identical to the preexposure trials, $(T \rightarrow T):(D \rightarrow D)$; in another, the test trial represents a reversal of the preexposure trial $(D \rightarrow T):(T \rightarrow D)$; in another, the test trial might contain a completely novel target and novel distractors ($N:N$); and in a fourth trial type, there might be a *partial* reversal from the preexposure trial, as when the test phase target is novel but the target of the preexposure phase becomes the test phase distractor ($N):(T \rightarrow D)$.

The Formal Relation Between Standard and Visual Search LI Paradigms

The claim that the visual search paradigm described above provides an instance of independent attentional in-

volvement in standard LI is based on the premise that the $(D \rightarrow T):(T \rightarrow D)$ and the $(N):(T \rightarrow D)$ visual search conditions are analogous to the PE and the NPE conditions of the learning-based LI paradigm. From the previous description of a typical human learning-based LI procedure (Braunstein-Bercovitz & Lubow, 1998a, 1998b), it should be recalled that the preexposure phase contained masking task stimuli—the TT, LL, TL, and LT letter pairs of the similarity/difference judgment task. The masking task required the subject to allocate attention to the letter pairs. Concurrently, the visual shapes, which would become the targets in the test phase, were relatively unattended. In the test, the previous masking task stimuli continued to appear on the screen. Thus, in the standard LI test phase, the PE group is confronted with a reversal of the preexposure target and distractor conditions. The target in the preexposure phase becomes a distractor in the test, and the distractor in the preexposure phase becomes a target in test, as in the visual search procedure $(D \rightarrow T):(T \rightarrow D)$. On the other hand, the group that was not preexposed to the test phase target stimulus was presented with a novel target in the test phase, while at the same time receiving the same masking task stimuli in the preexposure and test phases as those of the PE group. Thus, the NPE group of standard LI is equivalent to the $(N):(T \rightarrow D)$ condition in visual search. In short, the PE and the NPE conditions of the traditional between-subjects LI experiment correspond, functionally, to the $(D \rightarrow T):(T \rightarrow D)$ and the $(N):(T \rightarrow D)$ within-subjects conditions of the visual search experiments. To make the notations similar to those used in the more traditional LI experiments, these two conditions, $(D \rightarrow T):(T \rightarrow D)$ and $(N):(T \rightarrow D)$, will now be referred to as PE and NPE, respectively.

The asserted similarities of conditions in the two paradigms, by themselves, do not validate the claim that they elicit behaviorally similar effects or that such effects, if present, are governed by the same underlying process, attentional or otherwise. This remains to be shown empirically, which we will do in a subsequent section.

The Locus of the LI Effect: PE or NPE?

In addition to providing information regarding the role of attention in the development of LI, the visual search design permits one to assess NPO effects. NPO is defined as faster responding to a novel target in a familiar array of distractors than to a novel target with novel distractors (Johnston & Hawley, 1994). The relationship between NPO and LI is of interest because the two paradigms share a common condition, NPE. The control or baseline condition in LI is the experimental one in the NPO paradigm. This suggests that the LI effect, poorer test performance of the PE than of the NPE group, which is attributed to a process occurring in the PE group, in fact may arise from two independent sources (Lubow, 1997). The *relatively* poor performance of the PE group may be a result of decreased attention to the preexposed stimulus at the time of test. On the other hand, it may be that the NPE group has relatively superior performance

because, at the time of test, the target is a novel stimulus presented on a background of familiar distractors, a condition for attracting attention and producing NPO. In the course of reviewing the LI-like visual search effects, the role of NPO in contributing to those effects will also be assessed.

Overview

The present article provides, for the first time, a review and appraisal of the LI visual search literature and its impact on theories of LI and the processing of irrelevant information, particularly in normal participants and schizophrenic patients. As such, it complements LI reviews that have focused on standard preparations (animal and human; e.g., Lubow, 1989), psychopharmacology (e.g., Weiner, 2003), schizotypality (Braunstein-Bercovitz et al., 2002), and schizophrenia (Escobar et al., 2002; Lubow, 2005; Lubow & Gewirtz, 1995). More specifically, the review makes the case for the involvement of selective attentional processes in LI in the devaluation of irrelevant stimuli and in the disruption of those processes in schizophrenia. In addition, the visual search LI data are used to reconcile two opposing views of LI, attentional and retrieval/competition.

Given the differences between traditional learning-based LI procedures that use between-subjects designs, with CR as the dependent variable, and the newer visual search procedures that use within-subjects designs, with RT as the dependent variable, as well as the gross dissimilarities of general procedures, it is first necessary to defend the contention that learning-based LI and visual-search-based LI are related phenomena—namely, that they are governed by the same attention-related processes. If traditional LI is modulated by attentional processes, as has been proposed by some (e.g., Lubow et al., 1981; Mackintosh, 1975; Pearce & Hall, 1980) but discounted by others (e.g., Bouton, 1993; Bouton, Nelson, & Rosas, 1999; Escobar et al., 2002; Miller, Kaspro, & Schachtman, 1986), then in the attentionally controlled visual search task, RT in the PE condition should be longer than that in the NPE condition. The next section will provide such data from a series of experiments with three related visual search procedures in which unique targets and common distractors were used.

Following this, evidence will be presented that the individual difference variables that modulate traditional LI—specifically, age, gender, and level of schizotypality—have comparable effects on performance in the visual search analogue of LI. Similarly, it will be shown that clinically diagnosed groups, including patients with schizophrenia and Parkinson's disease (PD) and children with anxiety disorders, provide the same pattern of data on traditional and visual search LI. The penultimate section will address a number of theoretical issues, including attentional and retrieval accounts of LI. The last section will offer a description of the attentional processes that underlies the stimulus preexposure effects that are reflected in learning-based and visual-search-based LI.

THE LI-RELATED VISUAL SEARCH PROCEDURES

Three sets of visual search procedures, all of which have a number of common features, are related to standard LI. As has already been noted, the preexposure and test phases are composed, with one exception (Lubow & Kaplan, 1997, Experiment 1), of identical visual search tasks. Although the similarities across experiments are fundamental to their purpose of providing a visual search analogue for LI, there are also a number of differences among them, primarily in regard to number of target trial types in the test phase and the kind of response required for target detection. When trials without a target are interspersed with trials that contain a target, target detection is indexed by a response of presence or absence. When targets are present on *all* trials, the subject is required to respond to whether the target is on the right or the left side of the screen. Experiments in which the different procedures have been used will be reviewed below. In addition to the response requirements, the experiments differ in terms of the number of within-subjects conditions in the test phase.

Seven Target/Distractor Test Conditions, Target Present or Absent

The first visual search LI analogue experiments presented subjects with all of the seven possible test phase conditions, with targets either present or absent. Table 1 (top) shows the mean RTs, for normal groups, for the three visual search conditions (PE, NPE, and NOV) from which LI and NPO effects are generated (Lubow, Dressler, & Kaplan, 1999; Lubow & Kaplan, 1997, Experiment 2; Lubow, Kaplan, Abramovich, Rudnick, & Laor, 2000; Lubow, Toren, Laor, & Kaplan, 2000). LI magnitude was computed by the formula $(PE - NPE)/NPE$, and NPO by $(NOV - NPE)/NPE$, in which the PE, NPE, and NOV values are mean RTs for those conditions. LI and NPO effects are indexed by positive ratios, where the higher the ratio is, the greater the effect will be. A negative ratio indicates a reversal of the effect.

From Table 1, it can be seen that the subjects in all four studies responded more slowly in the PE than in the NPE condition, thereby demonstrating the basic LI analogue effect. In addition, RTs in the PE condition were quite similar to those in the NOV condition. The difference in RTs between each of these and the NPE condition defines LI and NPO, respectively. Since the LI and NPO effects are both present, the data are ambiguous in regard to the source of the LI effect. In other words, the LI effect, the difference between PE and NPE, may derive from faster target-distractor processing in the NPE condition than in the PE condition *or*, as the accepted view of LI would have it, as a consequence of a difference in processing in the PE, as compared with the NPE, condition. However, as will be seen in a later section, LI also can be obtained in the absence of any NPO effect (e.g., Kaplan & Lubow, 2001).

Table 1
Mean Target Detection Response Times (RTs, in Seconds) for Three Visual Search Conditions—
Preexposed (PE), Nonpreexposed (NPE), and Novel (NOV)—and Magnitudes of Latent Inhibition
(LI) and Novel Pop-Out (NPO) Effects for Normal Groups in Experiments with Target/No-Target
Test With Seven Test Conditions and in Left-Right Procedure With Three Display Conditions

Source	RT			LI	NPO
	PE	NPE	NOV		
Seven Conditions: Target/No Target					
Lubow & Kaplan (1997, Experiment 2)	1.34	1.20	1.37	.12	.14
Lubow, Dressler, & Kaplan (1999)	2.55	1.90	2.35	.34	.24
Lubow, Kaplan, Abramovich, Rudnick, & Laor (2000)	2.10	1.90	2.03	.11	.07
Lubow, Toren, Laor, & Kaplan (2000)*	1.95	1.65	1.95	.18	.18
Three Conditions: Target, Left/Right					
Lubow, Kaplan, & De la Casa (2001)					
Experiment 1	1.90	1.58	1.68	.20	.06
Experiment 2	1.76	1.56	1.57	.13	.01

Note—LI = (PE - NPE)/NPE; NPO = (NOV - NPE)/NPE. *Children.

As has been noted, the four experiments shared the following characteristics: (1) Phases 1 and 2 consisted of identical visual search tasks, and (2) Phase 2 was composed of seven different target-distractor trial types (although only a subset of these will be reported). These properties raise two questions. First, the rationale for the experiments was based on the supposition that Phase 1 produces an attended target and an unattended distractor, as in the preexposure phases of standard LI experiments. Lubow and Kaplan (1997, Experiment 1) examined this assumption with a procedure developed by Rock and Gutman (1981). In Phase 1, instead of a visual search task, subjects viewed a figure-ground display consisting of two overlapping visual patterns of different colors. On each presentation, the subjects were required to rate, for example, a red figure on a scale of aesthetic preference. Thus, the red figure was attended, whereas a green figure, which lay behind the red one, was irrelevant and unattended. Rock and Gutman found that subjects could recall the shapes of the attended, but not the unattended, figures.

We used this procedure for the preexposure phase but followed it with a visual search task in which the previously attended and the unattended stimuli took on the roles of targets or distractors, as has previously been described. The results were similar to those in Lubow and Kaplan (1997, Experiment 2), where the Phase 2 visual search task was preceded by another visual search task. The fact that LI and NPO effects in the visual search task were generated with both preexposure procedures, one of which is generally accepted as producing unattended stimuli (Rock & Gutman, 1981), supports the position that the distractor stimuli in the subsequent experiments, in which visual search was used as the instrument of preexposure, were, indeed, unattended.

Three Target Trial Test Conditions, Target Present or Absent

By reducing the number of trial types in the test phase, the detection task is made easier, and the possibility of in-

terference from conditions that are not theoretically relevant is reduced. Table 2 presents the results of those studies, together with data related to block and context effects.

In general, Table 2 indicates that LI-like effects are evident even with a reduction of the number of trial types. In addition, generating the LI effect requires that the test stage contain some trials that are identical to that in the preexposure stage (reminder trials) and that the context is the same in preexposure and test. These results are

Table 2
Mean Target Detection Response Times (RTs, in Seconds) for
Three Visual Search Conditions—Preexposed (PE),
Nonpreexposed (NPE), and Novel (NOV)—and Latent
Inhibition (LI) and Novel Pop-Out (NPO)
Magnitudes for Normal Subjects

Source	RT			LI	NPO
	PE	NPE	NOV		
Kaplan & Lubow (2001)					
Experiment 1					
Reminder					
Block 1	2.40	2.00	2.20	.20	.10
Block 2	2.25	1.65	1.75	.36	.06
No reminder					
Block 1	1.97	1.65	1.80	.19	.09
Block 2	1.65	1.57	1.40	.05	−.11
Experiment 2					
Context same	2.10	1.50	1.57	.40	.05
Context different	1.70	1.50	1.57	.13	.05
Gibbons, Rammsayer, & Lubow (2001)*					
Experiment 1					
Block 1	1.55	1.50	—	.03 [†]	—
Block 2	1.34	1.37	—	−.02	—
Block 3	1.30	1.37	—	−.05 [†]	—
Experiment 2 [‡]					
Block 1	1.44	1.34	—	.07 [†]	—
Block 2	1.20	1.20	—	.00	—
Block 3	1.12	1.13	—	−.01	—

Note—LI = (PE - NPE)/NPE; NPO = (NOV - NPE)/NPE (from experiments with target/no-target test and three target trial conditions). [†]Data estimated from figures. [‡]PE vs. NPE, $p < .05$. [‡]Definitions of PE and NPE are different from those in other studies; PE = D→T:N; NPE = N:N.

congruent with those from the experiments with seven trial types, all of which contained reminder trials and had the same context in the preexposure and the test phases.

Three Target Trial Test Conditions, Target Present on All Trials

More recently, we have simplified the visual search task even further (Lubow, Kaplan, & De la Casa, 2001). Unlike the previously described procedures that required subjects to identify the presence or *absence* of a unique target, the new procedure displays the target on *every* trial, and the subject must indicate whether the target is on the left or the right side of the screen. Table 1 (bottom) displays the mean RTs for PE, NPE, and NOV conditions for Lubow et al.'s (2001) study. As can be seen, the left/right procedure also was effective in producing LI-like effects. Particularly noteworthy is the fact that variance of mean RTs in the left/right procedure is considerably smaller than that in the target/no-target procedure. However, as can be seen in Table 1, the NPO effect was severely compromised. In opposition to the four studies in which the seven-condition test procedure was used, all of which reported significant NPO effects, Experiment 1 with the new procedure provided only a marginally significant NPO effect ($p = .08$), and Experiment 2 none at all.

The difference in results between the two sets of studies suggests that the higher ratio of NOV and NPE trials to PE trials in the three-condition, as opposed to the seven-condition, procedure, together with the fact that a target appears on every trial, mitigated the influence of the preexposure phase. Indeed, one might expect that in the all-target, three-condition procedure, the novelty of the target and the distractor in the NOV condition would dissipate more rapidly than in the seven-condition procedure, in which there are both target and no-target trials. This hypothesis receives some support from a reanalysis of the data from Lubow et al., 2001 (Experiment 1). The NPO effect was obtained in the all-target, three-condition procedure, but only in the early blocks. When the test trials were divided into two blocks, the difference in RT between the NPE and the NOV conditions (NPO) was significant in the first block (23 msec), but not in the second

block (1 msec). A similar comparison of PE and NPE conditions indicated that the LI effect was significant in both the first and the second blocks (35 and 30 msec, respectively). In Experiment 2, the pattern of results was less clear. NPO effects were small in Blocks 1 and 2 (4 and 3 msec, respectively).

That the LI-like effect survives the demise of NPO undermines the suggestion that LI may be due to two different processes (Lubow, 1997), one residing in the PE condition/group and related to the stimulus-specific decline in attention, and one in the NPE condition/group, which represents an NPO effect—namely, the capture of attention by a novel stimulus among a field of familiar stimuli (Johnston & Hawley, 1994).

INDIVIDUAL DIFFERENCE VARIABLES

In this section, we will review the visual search LI data related to individual difference variables such as age and gender, as well as to differences, among normal subjects, in self-administered questionnaire test scores for schizotypality and anxiety. In addition, we will examine visual search LI data from clinically diagnosed pathological groups, including schizophrenic and PD patients and anxiety disorder and ADHD children. In each case, the visual search data will be related to that from matched normal controls and to comparable data from standard LI.

Age

Although age, as such, was not a variable in any of the experiments, there are enough differences in the ages of groups across experiments to allow for some tentative conclusions. Table 3 presents the visual search data from normal groups, whose ages varied from 12 to 59 years. As can be seen, there is no evidence of an age-related pattern.

As opposed to the absence of an age effect, Lubow (1989) concluded, mostly from the conditioned taste aversion studies with animals, that LI is present in young weanling, as well as in mature, rats but that it is weakened or abolished in senescent animals. With learning-based LI in humans, the situation is more complex, since a masking task is usually required to elicit LI in older children and adults, but not in children below the age of

Table 3
Mean Target Detection Response Times (RTs, in Seconds) of Normal Subjects for Three Visual Search Conditions—Preexposed (PE), Nonpreexposed (NPE), and Novel (NOV)—and Latent Inhibition (LI) and Novel Pop-Out (NPO) Effect Magnitudes as a Function of Age (in Years)

Top Out (NPO) Effect Magnitudes as a Function of Age (in Years)							
Source	Mean Age	Range	RT			LI	NPO
			PE	NPE	NOV		
Lubow, Toren, Laor, & Kaplan (2000)	12.0	6–17	1.95	1.65	1.95	.18	.18
E. Cohen et al. (2004)	16.0	14–18	1.51	1.34	1.47	.13	.10
Lubow, Kaplan, & De la Casa (2001, Experiment 2)	18.5	17–28	1.76	1.56	1.57	.13	.01
Lubow & Kaplan (1997, Experiment 2)	22.5	18–30	1.34	1.20	1.37	.12	.14
Kaplan & Lubow (2001, Experiment 2)	22.5	20–28	2.10	1.50	1.57	.40	.05
Lubow et al. (2001, Experiment 1)	22.8	20–30	1.90	1.58	1.68	.20	.06
Lubow, Kaplan, Abramovich, Rudnick, & Laor (2000)	34.1	22–58	2.10	1.90	2.03	.11	.07
Lubow, Dressler, & Kaplan (1999)	58.7	37–77	2.55	1.90	2.35	.34	.24

Note—LI = (PE – NPE)/NPE; NPO = (NOV – NPE)/NPE.

6 years (e.g., Lubow & Josman, 1993). Using an auditory LI task with masked preexposure, Swerdlow, Magulac, Filion, and Zinner (1996) compared older children (mean age of 11.5 years) and adults (mean age of 32.8 years). They found no differences in LI magnitude. Thornton et al. (1996) also concluded that for adults, LI was age independent.

Thus, the human LI literature is fairly consistent. Both standard and visual search LI procedures do not produce an effect of age, at least within the range of 12–59 years. In animal preparations, LI appears to decrease with age. The difference between the two sets of data may well be due to the restricted range of ages in the human studies.

Gender

Table 4 presents LI and NPO effects for the several visual search LI experiments that had male and female subgroups. As can be seen, there is a trend for more LI in males than in females. If true, this would be congruent with the data from standard human LI preparations (Golosheiken, Volf, & Razumnikova, 1997) and from a reanalysis of a large set of LI data from the Queensland and Giessen laboratories. In the latter, 60.6% of the male subjects, but only 37.2% of the female subjects, exhibited LI (Lipp, personal communication). Lower LI in women than in men may be due to higher experiment-induced anxiety levels in the former (Braunstein-Bercovitz, 2000). However, some experiments have not shown a gender effect for LI (Della Casa, Höfer, & Feldon, 1999; Swerdlow, Braff, Hartston, Perry, & Geyer, 1996; Swerdlow, Hartston, & Hartman, 1999; Swerdlow, Magulac, et al., 1996).²

The lack of clarity as to male–female differences in LI may be related to the findings that LI magnitude is a function of an interaction between gender and other individual difference variables. Thus, with *de novo* PD patients, female patients with right-side motor symptoms (left-hemisphere dopamine depletion) had elevated LI effects, as compared with female controls and with female PD patients with left-side motor impairment (Lubow et al., 1999). On the other hand, studies with schizo-

phrenic patients (Lubow, Kaplan, et al., 2000) and low and high schizotypals (Lubow et al., 2001, Experiment 2) indicate that LI magnitude is larger in normal females than in female schizophrenic patients (but see E. Cohen et al., 2004) and in low-schizotypal than in high-schizotypal females (Lubow et al., 2001, Experiment 2). Comparable male groups did not exhibit this pattern. A recent standard LI study (Lubow & De la Casa, 2002), in which a within-subjects design with RT as the dependent measure was used, also showed significant LI effects in low-schizotypal, but not high-schizotypal, females. In males, the pattern was reversed.

Relatedly, there is evidence of increased striatal dopamine in women, as compared with men (Pohjalainen, Rinne, Nagren, Syvalahti, & Hietala, 1998). Dopamine is associated with the positive symptoms of schizophrenia, and dopamine agonists, such as amphetamine, attenuate LI and produce mild positive symptoms in normal subjects (e.g., N.S. Gray, Pickering, Hemsley, Dawling, & Gray, 1992). The inverse relation between LI and positive symptoms, coupled with the fact that women tend to have more positive symptoms than do men, is congruent with the assumption of weaker LI in women than in men. These findings also are compatible with the LI schizotypy literature, in that females tend to score higher than males on schizotypy subscales that tap positive symptoms (Raine, 1992; see also J. A. Gray, Feldon, Rawlins, Hemsley, & Smith, 1991; N. S. Gray, Hemsley, & Gray, 1992), and high schizotypy is associated with reduced LI (see below).

In brief, women, both schizophrenic patients and high-schizotypal normals, tend to have more positive symptoms than do men, whereas men tend to have more negative symptoms than do women (Raine, 1992). This pattern fits with the suggestion that males should have more LI than females do.³

Although the animal literature does not provide evidence for basic LI differences between male and female rats, LI in male rats, as compared with female rats, is more vulnerable to loss by a variety of stress-related manipulations (e.g., Peters, Gray, & Joseph, 1991; Shalev,

Table 4
Mean Target Detection Response Times (RTs, in Seconds) of Normal Subjects for Three Visual Search Conditions—Preexposed (PE), Nonpreexposed (NPE), and Novel (NOV)—and Latent Inhibition (LI) and Novel Pop-Out (NPO) Effect Magnitudes as a Function of Gender

Source	Gender	RT			LI	NPO
		PE	NPE	NOV		
Lubow, Kaplan, & De la Casa (2001) Experiment 1	Male	2.00	1.60	1.65	.25	.03
	Female	1.80	1.55	1.70	.16	.10
	Male	1.57	1.31	1.36	.20	.04
	Female	1.75	1.60	1.61	.09	.01
Lubow, Dressler, & Kaplan (1999)	Male	2.93	2.12	2.44	.38	.15
	Female	2.48	1.95	2.41	.27	.24
Lubow, Kaplan, Abramovich, Rudnick, & Laor (2000)	Male	1.86	1.82	2.04	.02	.12
	Female	2.33	1.98	2.02	.18	.02

Note—LI = (PE–NPE)/NPE; NPO = (NOV–NPE)/NPE.

Feldon, & Weiner, 1998; Shalev & Weiner, 2001; Weiner, Feldon, & Ziv-Harris, 1987; Weiner, Schnabel, Lubow, & Feldon, 1985).

Schizophrenia and Schizotypality

LI is widely accepted as an index of the ability to ignore irrelevant stimuli. As such, it has been used as a tool to evaluate attentional dysfunction in schizophrenic patients (for reviews, see J. A. Gray, 1998; Lubow & Gewirtz, 1995). The rationale for this approach is based on dopamine-animal models of schizophrenia, particularly the fact that LI is mediated by mesolimbic dopaminergic activity (for reviews, see J. A. Gray, 1998; Moser, Hitchcock, Lister, & Moran, 2000; Weiner & Feldon, 1997), most likely impulse-dependent events in the nucleus accumbens that occur at the conditioning stage (Joseph et al., 2000; for a review, see Joseph, Datla, & Young, 2003).

The model is supported by the following additional empirical findings. (1) LI is attenuated by schizophrenia-related indirect dopamine receptor agonists, such as *d*-amphetamine, both in animals (e.g., Weiner, Lubow, & Feldon, 1984; for reviews, see Moser et al., 2000; Weiner & Feldon, 1997) and in healthy humans (N. S. Gray, Pickering, et al., 1992; Kumari et al., 1999; Swerdlow et al., 2003; Thornton et al., 1996). (2) LI is potentiated by nonselective dopamine receptor antagonists, such as haloperidol, which is an effective neuroleptic—again, both in animals (e.g., Weiner, Feldon, & Katz, 1987; for reviews, see Moser et al., 2000; Weiner & Feldon, 1997) and in healthy humans (Kumari et al., 1999; Williams et al., 1996; Williams et al., 1997).⁴ (3) As required by the model, LI is reduced or abolished in recently medicated, acute schizophrenic patients (Baruch, Hemsley, & Gray, 1988a; N. S. Gray, Hemsley, & J. A. Gray, 1992; N. S. Gray, Pilowsky, J. A. Gray, & Kerwin, 1995; Rascle et al., 2001; Sitskoorn, Salden, & Kahn 2001; but see Swerdlow, Braff, et al., 1996, and Williams et al., 1998). As opposed to this, chronic and medicated schizophrenic patients exhibit normal LI. Although most studies have reported no difference in LI between the latter two groups (e.g., Baruch et al., 1988a; Leumann, Feldon, Vollenweider, & Ludewig, 2002; Martins Serra, Jones, Toone, & Gray, 2001), Rascle et al. (2001) have described a super-LI effect in chronic schizophrenic patients, as compared with normals.⁵ (4) Finally, LI is attenuated in high-schizotypal, as compared with low schizotypal, normals (for reviews, see Braunstein-Bercovitz et al., 2002; Lubow & Gewirtz, 1995; also see below). The latter is consistent with a continuity model of psychopathology, which proposes that psychotic tendencies exist on a continuum, at one pole of which is a normal population and at the other a hospitalized patient group (e.g., Claridge, 1985; Eysenck & Eysenck, 1976; Zubin & Spring, 1977). In support of the continuity model, Vollema and van den Bosch's (1995) review of nine factor-analytic studies points to the striking similarities between schizotypal traits and schizophrenic symptoms (see also Gruzelić, 1996; Gruzelić & Doig, 1996).

As has been noted, low- and high-schizotypal normals, identified on the basis of scores on self-report questionnaires, such as the Schizotypal Personality Questionnaire (SPQ; Raine, 1991) and the Schizotypal Trait Questionnaire (Claridge & Broks, 1984), display significantly different levels of LI. Specifically, high schizotypals exhibit reduced standard LI, as compared with low schizotypals (e.g., Baruch, Hemsley, & Gray, 1988b; Braunstein-Bercovitz, 2000; Braunstein-Bercovitz & Lubow, 1998a; N. S. Gray, Fernandez, Williams, Ruddle, & Snowden, 2002; Lipp, Siddle, & Arnold, 1994; Lipp & Vaitl, 1992; but see Wuthrich & Bates, 2001, who found that LI was an inverted U-shaped function of schizotypy level). Relatedly, a recent study has reported the absence of a significant LI effect in both high and low schizotypals who were first-degree relatives of chronic schizophrenic patients, who themselves did not show LI (Martins Serra et al., 2001).

The reduced LI in schizophrenic patients and in high-schizotypal normals has been interpreted as reflecting dysfunctional attentional processing. More specifically, since normal LI is assumed to be the result of a stimulus-specific decline in attention with repeated presentations of an irrelevant stimulus, attenuated LI has been attributed to a failure to reduce the attentional response to the irrelevant stimulus (Lubow & Gewirtz, 1995). This hypothesis fits well with the many reports that the attentional dysfunction in schizophrenia is characterized by high distractibility and by a difficulty in switching from controlled to automatic processing of irrelevant stimuli (e.g., J. A. Gray et al., 1991; Hemsley, 1987; Nuechterlein & Dawson, 1984).

The attentional dysfunction explanation of LI deficits in schizophrenic patients and high-schizotypal normals in standard LI preparations is supported by the visual search LI data. In an unpublished study, Lubow et al. (2002) administered the SPQ to a large sample of undergraduate women, who were then divided into low-, mid-, and high-schizotypal groups. As was expected, the high-schizotypal group exhibited less LI than the low-schizotypal group did. Lubow et al. (2001) also found reduced visual search LI in high-schizotypal, as compared with low-schizotypal, females, although a similar pattern was not present for males. More recently, Tsakanikos, Sverdrup-Thygeson, and Reed (2003), using a different visual search procedure from that of Lubow and colleagues, and with approximately equal numbers of males and females, reported reduced LI in high-schizotypal, as compared with low-schizotypal, normal groups (the effect of gender was not examined).

Lubow, Kaplan, et al. (2000) also compared a mixed group of adult schizophrenic outpatients with matched normal controls. As was predicted, normal controls, but not schizophrenics, showed the LI-like effect. However, as with schizotypal subjects (Lubow et al., 2001), the latter finding was due exclusively to the absence of normal LI in female patients.

A more recent study by E. Cohen et al. (2004) suggests that the relationship between visual search LI and

schizophrenia may be more complex than was originally anticipated. Although healthy controls exhibited the usual LI effect, LI was *potentiated* in schizophrenics who simultaneously exhibited high levels of negative symptoms and low levels of positive symptoms, a pattern that may be related to length of hospitalization and/or chronicity (see also Rasclé et al., 2001). Schizophrenic groups with other combinations of positive and negative symptoms did not differ from controls, a pattern suggesting that past inconsistencies in the LI schizophrenia literature may be the result of opposing processes that are associated with positive and negative symptoms.

Parkinson's Disease Patients

Of particular interest for a dopamine model of schizophrenia is an apparent reciprocal relationship between schizophrenia and PD. PD, like schizophrenia, involves dopamine dysfunction. However, schizophrenia is associated with excessive dopamine activity or dopamine receptor sensitivity, perhaps in the nucleus accumbens (J. A. Gray, 1995; J. A. Gray et al., 1991), and PD is attributed to a loss of dopamine due to substantia nigra degeneration within the basal ganglia (Agid, 1991; Gibb, 1991; Roth & Elsworth, 1995). Despite the fact that different dopamine pathways are involved in the two diseases, mesolimbocortical and mesostriatal, there remains a general complementarity that may be related to surplus versus deficit dopamine states. Thus, treatment of schizophrenia with dopamine antagonists such as haloperidol may produce Parkinson's-like motor dysfunctions (tardive dyskinesia; Kane, 1995; Peacock, Solgaard, Lublin, & Gerlach, 1996), whereas treatment of PD with l-dopa may promote schizophrenia-like delusions and hallucinations (Marsden, 1994; Musser & Akil, 1996).

If the reciprocity hypothesis is valid, cognitive processing deficits in PD should, in general, show a pattern opposite to that found in schizophrenia. Since LI is attenuated in acute nonmedicated schizophrenics, as compared with normals, and, in healthy groups, dopamine agonists attenuate LI and dopamine antagonists produce a super-LI effect, *de novo* PD patients (nonmedicated), because of *decreased* dopaminergic activity, would be expected to show super-LI when compared with normal controls. Salzman, Hadar, Korczyn, and Lubow (1994) failed to find such an effect with a typical LI procedure, perhaps because of a ceiling on LI as a result of the fact that a large number of subjects from both groups failed to reach the learning criterion. However, Schugens, Topka, and Daum (1999, p. 199), using conditioned eyeblink, did report a larger than normal LI effect in PD patients.

To overcome the ceiling effects that are inherent in the traditional LI paradigm, we administered the visual search LI task to PD patients (Lubow et al., 1999). We predicted a greater LI-like effect in the PD group than in the control group. In addition, we were able to take advantage of the fact that the onset of PD typically is lateralized, with a predominance of overt motor symptoms on either the right or the left side. The lateralization is accounted for

by an asymmetric degeneration of dopaminergic nigrostriatal pathways. If LI is dopamine related, there might be some differences in LI due to differences in hemispheric dopamine activity. Indeed, there is some evidence that LI is mediated by the right hemisphere. Thus, when unattended preexposed auditory stimuli are presented to the left ear (right hemisphere), there is a significant LI effect, which is absent when the same stimuli are presented to the right ear (N. S. Gray, Pickering, et al., 1992). A similar pattern of LI has been reported for irrelevant visual stimuli presented to the right or the left visual field (Golosheiken et al., 1997). Consequently, one would expect that PD patients with primarily right- or left-hemisphere dopamine losses would exhibit different patterns of LI. Specifically, if, as the literature indicates, LI is attenuated by dopamine agonists and potentiated by dopamine antagonists and LI is mediated by the right hemisphere, PD patients with left-side motor symptoms (right-hemisphere dopamine depletion) should show the greatest enhancement of LI. On the other hand, if right-hemisphere integrity is essential for generating LI, PD patients with right-side motor symptoms (left-hemisphere dopamine depletion) should exhibit enhanced LI. Irrespective of the direction of the prediction, there should be differences in LI that are associated with side of damage. Indeed, female PD patients with right-side motor symptoms had elevated LI, as compared with female controls and female PD patients with left-side symptoms. On the other hand, male PD patients with right-side symptoms did not exhibit any LI (Lubow et al., 1999).

Anxiety Disorder Children

Although clinically diagnosed anxiety disorder children, in general, responded more slowly than normal children on the visual search task, there were differences neither in LI nor in NPO between the two groups (Lubow, Toren, et al., 2000). However, when the clinical diagnostic classification was disregarded, and the subjects were reclassified into low and high anxious on the basis of scores from the Revised Children's Manifest Anxiety Scale (RCMAS; Reynolds & Richmond, 1985), high-anxious children had less LI than low-anxious children did, although not significantly ($p = .12$). If proven to be reliable, the finding that a high anxiety level attenuates LI would be congruent with data from standard LI tests with ADHD children (Lubow & Josman, 1993), as well as with attenuated LI in normal adults who score high, as opposed to low, on the Spielberger, Gorsuch, and Lushene (1970) State Anxiety Questionnaire (Braunstein-Bercovitz, 2000). Relatedly, LI in adult humans is attenuated by stress (Braunstein-Bercovitz, Dimentman-Ashkenazi, & Lubow, 2001).

These studies, together with those that have shown that animal LI is reduced by stress (e.g., Hellman, Crider, & Solomon, 1983; Lehmann, Stöhr, & Feldon, 2000; Shalev et al., 1998) and by anxiogenic drugs (e.g., Feldon & Weiner, 1989; Lacroix, Spinelli, Broersen, & Feldon, 2000), indicate that LI may be impaired in any state that is

characterized by a high stress/anxiety level (Braunstein-Bercovitz et al., 2002). If true, this would undermine the suggestion that an LI deficit may be a specific marker for schizophrenia.

EVIDENCE FOR IDENTITY OF PROCESS IN VISUAL SEARCH AND STANDARD LI

As was stated in the introduction, the visual search LI experiments were initiated as a test of LI theories that implicate attentional processes. As such, the approach was based on the assumption that, irrespective of the nature of the underlying process in LI visual search, it is the same as that governing standard LI. Some evidence to support the similarity of process was presented in the section on individual differences. In the present section, we will continue to gather support for similarity of process, but now from the findings of similar effects of reminder and context variables on the two types of LI and from data describing a positive correlation between performance on the visual search and standard LI tasks.

Reminder Trials

In the case of LI, a reminder trial is defined as a pre-exposure stage event that is reproduced in the test stage. In general, it appears that LI is enhanced by any manipulation that increases the similarity of the preexposure and the test stages (see the next section on context effects). Thus, in the visual search analogue of LI, a test stage display that is identical to the target/distractor display of the preexposure phase ($T \rightarrow T$):($D \rightarrow D$) serves as a reminder trial. As such, most of our visual search experiments contained reminder trials. To determine whether the presence of these reminder trials does indeed enhance LI in visual search, Kaplan and Lubow (2001, Experiment 1) used groups with and without such trials. As can be seen in Table 2, the group with reminder trials showed a stronger LI effect than did the group without reminder trials, at least in the last trial block. However, significant visual search LI has also been obtained without any reminder trials (Gibbons, Rammsayer, & Lubow, 2001).

In standard paradigms, the LI-promoting effects of context stability from preexposure to test phases (e.g., Westbrook, Jones, Bailey, & Harris, 2000; Zalstein-Orda & Lubow, 1995), as well as the introduction of the test phase unconditioned stimulus into the preexposure phase (Killcross & Dickinson, 1996), have been interpreted in terms of reminder effects. Relatedly, preexposures of the to-be-CS and the to-be-US (but not paired) produce greater decrements in subsequent learning than does preexposing either one separately (Bennett, Maldonado, & Mackintosh, 1995; Bonardi & Hall, 1996; Matzel, Schachtman, & Miller, 1988). The addition of the to-be-US to the preexposure phase serves the same role as adding reminder trials to the test phase or increasing the similarity of the preexposure and the test stage contexts. On the other hand, reminder treatments aimed at retrieving the second-stage CS-US association are effective in disrupting LI (Kasprow, Catterson, Schachtman, & Miller, 1984).

In general, it is assumed that the various reminders of preexposure stage conditions provide cues for the retrieval of the CS-0 association. As such, LI would be potentiated in a two-stage procedure as a result of the relatively strong CS-0 association (stimulus-specific inattention) interfering with the acquisition of the new CS-US association. In a three-stage procedure, there may be two sources of LI enhancement: the LI already present from Stage 2 and an additional increase due to retrieval competition between the CS-0 and the CS-US associations.

Context Effects

Although the particular type of reminder trial effect reported by Kaplan and Lubow (2001, Experiment 1) has no direct parallel in the LI literature, the same cannot be said for context change. Numerous studies have demonstrated that a change of context from preexposure to test phase markedly disrupts LI, both in animals (e.g., Bouton & Brooks, 1993; McLaren, Bennett, Plaisted, Aitken, & Mackintosh, 1994) and in humans (De la Casa & Lubow, 2001; Escobar, Arcediano, & Miller, 2003; N. S. Gray et al., 2001; Zalstein-Orda & Lubow, 1995).

If the longer RTs in the PE than in the NPE condition obtained in the visual search procedure reflect an LI effect, a change of context from the preexposure to the test phase should abolish or reduce the RT difference between the PE and the NPE conditions. Indeed, Kaplan and Lubow (2001, Experiment 2) found that when the color of the background on which the visual search task was performed was the same in the preexposure and the test phases, the expected LI-like effect was obtained. However, when the context color was changed from the preexposure to the test phase, the LI-like effect was significantly attenuated (see Table 2).

A Direct Comparison Between Visual Search and Standard LI

The case for similarity of process in standard and visual search LI was further strengthened by Gibbons et al. (2001), who directly compared performance of the *same* subjects on the two tasks. If performance on the two tasks is governed by a common process, one would expect a significant positive correlation between RTs from a visual search LI index (PE minus NPE) and performance of the PE group in a standard LI learning task. Such a correlation (not reported in the original article) was obtained for the PE group (+.47; RT from Block 1 of visual search and number of CRs in the traditional rule-learning LI task). For the subjects in the NPE condition/group, the correlation was not significant and negative, -.20.

AN INTEGRATED THEORY OF LATENT INHIBITION

In the previous sections, we described the formal relationship between standard and visual search LI analogue procedures. It was shown that similar variables have similar effects on both types of tasks. Thus, low-

and high-schizotypal normals performed similarly on the visual search and standard LI tasks, as did schizophrenic patients and healthy controls. Furthermore, context change and reminder cues had the same effects in both preparations, and performance on the two tasks was significantly correlated. These data support the view that the visual search analogue of LI and standard LI are governed by equivalent processes. Since it is generally accepted that visual search engages attentional processes, it follows that standard LI, at least in part, also requires attentional processing, as has been proposed by several theories (e.g., conditioned attention theory; Lubow, 1989) but discounted by others (e.g., Bouton, 1994; Miller & Matzel, 1988). The next section will describe the attentional component of a model of target and distractor processing that integrates the data from standard and visual search LI and relates them to dysfunctional attentional processing in schizophrenia. Following this, an attempt will be made to resolve the apparently conflicting features of attentional and response competition theories of LI.

The Attentional Component of Latent Inhibition

The attentional component of the model is based on the distinction between two modes of information processing: automatic and controlled (Schneider & Shiffrin, 1977; Shiffrin & Schneider, 1977), but with an emphasis on the *relative* strengths of the two processes (cf. Duncan & Humphreys, 1989; Nakayama, 1990; Treisman, 1993; Wolfe, 1994). At the extremes, automatic processing is relatively rapid, effortless, involuntary, and not available to conscious awareness, whereas controlled processing is relatively slow, serial, effortful, voluntary, and available to conscious awareness. The model will be applied to the preexposure and test stages and to the process of switching from one stage to the other.

Preexposure stage. Figure 1, based on the data from Lubow and Kaplan (1997), presents the mean RTs for correct detection of target presence and target absence as a function of blocks of trials. As can be seen in the left panel, on initial presentations of visual search trials

(Block 1 of preexposure), target and nontarget displays are processed relatively slowly (controlled processing mode), as one would expect with multidimensional complex visual stimuli (e.g., Treisman & Gelade, 1980). That target search was operating primarily in the controlled mode is indicated by the fact that RTs for target-absent responses were significantly longer than those for target-present responses, signifying that target search was self-terminating and, therefore, serial.

The left panel of Figure 1 also indicates, as would be expected, that RTs became shorter with repeated presentations of the *same* targets and distractors. Although not seen in Figure 1, with a sufficiently large number of trials, the target-present and the target-absent RTs should converge, eventually approaching a common asymptotic level, with detection speeds that are close to those associated with pop-out phenomena. Indeed, such effects have been demonstrated for a variety of target/distractor displays (e.g., Ahissar & Hochstein, 1996; Sireteanu & Rettenbach, 2000; for a review, see Karni, 1996). Such a pattern would be congruent with a repetition-guided gradual transition from controlled to automatic processing, perhaps reflecting a process by which distractors are converted from individual attention-attracting elements to a coherent but relatively featureless background. This proposal is supported by the facts that target detection time decreases as a function of similarity of distractors to each other (Humphreys, Quinlan, & Riddoch, 1989; see also Duncan & Humphreys, 1989) and, under certain conditions, as a function of number of distractors (Bacon & Egeth, 1991; Banks & Prinzmetal, 1976; see also Bravo & Nakayama, 1992, where this effect was present for variable, but not for consistent, mapping conditions). Increasing the number of distractors increases the proximity of distractors. Both proximity and similarity are important factors in promoting grouping (Pomerantz, 1981). Consequently, increasing the number and similarity of distractors may perceptually homogenize these stimuli in such a way that they become a ground, relative to the novel figure. Indeed, the generally longer RTs in schiz-

Figure 1. Mean response times (RTs, in seconds) for the detection of the presence or the absence of a unique target among distractors as a function of blocks of trials during the preexposure stage (left panel) and the test stage (right panel). The data are from Lubow and Kaplan (1997).

ophrenic patients than in normal controls may reflect the former's inability to develop stable representations of context (J. Cohen, Barch, Carter, & Servan-Schreiber, 1999; J. Cohen & Servan-Schreiber, 1992; Silverstein, Kovacs, Corry, & Valone, 2000).

According to the above, the acquisition of efficient target detection depends, at least in part, on achieving automatic processing of the distractors. Indeed, if repeated exposure to the same distractors creates a background condition that supports rapid target detection, then target detection RTs should be considerably shorter with familiar distractors than with novel distractors. Although this perceptual-learning account is supported by a decrease in detection RTs across blocks of trials in the preexposure stage, those data are, of course, confounded with general practice effects. However, there is ample independent evidence that distractor familiarity per se enhances target search performance (e.g., Malinowski & Hübner, 2000; Reicher, Snyder, & Richards, 1976; Richards & Reicher, 1978; Shen & Reingold, 2001; Wang, Cavanagh, & Green, 1994). This evidence is supplemented by the data obtained from our own test stage.

Test stage. The test stage contains several sets of data that are relevant to evaluating whether the repeated presentations of the same distractors promote target detection. As has been noted, target detection should be faster in those conditions that contain familiar distractors than in those that contain novel distractors. Although Lubow and Kaplan (1997) found that familiar targets were detected just as quickly against a background of familiar distractors as with novel distractors, (T→T):(D→D) versus (T→T):(N), relatively rapid target detection also occurred when a novel target was presented against a background of familiar distractors (N):(D→D). In addition,

when the test stage target and the distractors were *both* novel (N:N), target detection was severely impaired. As is shown in Figure 1, these findings are consistent across the four 7-condition experiments. These data suggest that target familiarity can overcome the detrimental effects of novel distractors but that distractor familiarity supports efficient detection of novel targets.

Interestingly, if, as we suggested, schizophrenic patients are deficient in their ability to "create ground," as they would be if they are distracted by irrelevant stimuli, they should exhibit smaller NPO effects than those for normals. However, there is nothing in our data to support such a prediction, perhaps because the procedures were not designed for that purpose. On the other hand, Braunstein-Bercovitz (2003) reported that standard LI is attenuated in field-independent, as compared with field-dependent, individuals, as well as in high, as compared with low, schizotypals, although schizotypality and field dependence were not correlated. Relatedly, Uhlhaas, Silverstein, Phillips, and Lovell (2004) found impaired processing of visual context in high schizotypals with thought disorder (but see Tsakanikos & Reed, 2003).⁶

Switching From Automatic to Controlled Processing and Normal LI

By the end of the preexposure stage, the normal subject's visual search has moved from the fully controlled mode toward increased automaticity. In the test phase, when trials are introduced with new combinations of old targets and distractors, as well as with new targets and distractors, the mapping conditions become unstable, and efficient performance (i.e., maintaining a low error rate) requires reverting to a controlled processing mode. The switch in the weights of automatic and controlled

Figure 2. Mean target detection response times (RTs, in seconds), converted to *z* scores, for the seven test conditions in the four experiments listed in Table 2.

processing, from relatively automatic at the end of the preexposure phase to more controlled at the beginning of the test stage, can be seen in Figure 2, where RTs in the first block of trials in the test stage are elevated, as compared with the last block of the preexposure stage.

The visual search LI effect—slower target detection in the PE than in the NPE condition—can be accounted for by postulating that the relatively unattended preexposure to the distractor stimulus creates a stimulus-specific bias against the transfer from automatic to controlled processing modes when these previous distractor stimuli reappear as targets in the test stage. Thus, when the switch is made from the end of the preexposure phase to the control-demanding test phase, those test trials that contain targets that were distractors in the preexposure phase will be responded to more slowly than those trials that have novel targets, thereby providing the visual search analogue of LI. Such a proposal has been presented in CAT as the conditioning of inattention (Lubow, 1989; Lubow & Gewirtz, 1995; for a review of empirical support, see Lubow, 2005).

Disrupted LI in Schizophrenic Patients and High-Schizotypal Normals

This model will now be applied to schizophrenic patients who exhibit attenuated LI in standard and visual search LI analogue procedures and whose selective attention impairment has been characterized by high distractibility (e.g., Anscombe, 1987; Braff, 1993; Nuechterlein & Dawson, 1984). Figures 3 and 4 present preexposure and test stage RTs, collapsed across conditions, as a function of blocks, for groups of schizophrenic patients and normal subjects (E. Cohen et al., 2004; Lubow, Kaplan, et al., 2000). As can be seen, patient groups responded more slowly than their matched normal controls, in both the preexposure and the test stages. Indeed, patients responded more slowly than controls across all trial types. Although this pattern of data may be due to the inability of the schizophrenic patients to form stable contexts, such slow responding also is present in a variety of other preparations (e.g., Vinogradov, Poole, Willis-Shore, Ober, & Shenaut, 1998; for reviews, see Nuechterlein, 1977; Schatz, 1998;

Steffy & Waldman, 1993) and probably represents a general deficit condition.

A comparison of the left and the right panels in Figures 3 and 4 also indicates that detection RTs for patient and control groups were longer in the test stage than in the preexposure stage, as would be expected with the more difficult test stage task (the test stage had many more trial types than the preexposure stage did). However, patients, as compared with controls, exhibited a *disproportionate elevation* of RTs from preexposure to test stages, perhaps reflecting a generally increased sensitivity to task load by the patients (cf. Nuechterlein & Dawson, 1984).

In regard to LI, the hypothesis that high-schizotypal normals and some subgroups of schizophrenic patients are impaired in their ability to convert normally irrelevant stimuli into background context remains viable. These groups, slow to benefit from display repetitions that, for normals, produce the transfer from controlled to automatic processing, continue to show relatively controlled visual search during the course of the preexposure stage. However, it must be noted that these tentative conclusions are based on a limited sample of patients with heterogeneous symptoms and histories. Indeed, the data indicate that there are modulating effects of variables, such as sex and symptom composition. As can be seen in Table 5, male schizophrenics show more LI than do controls, and female schizophrenics show less LI than do controls. A similar pattern with low and high schizotypals also has been reported for RT in a more traditional LI task (Lubow & De la Casa, 2002). Furthermore, schizophrenic patients grouped according to combinations of positive and negative symptoms (independently of sex) indicates that patients with high levels of negative symptoms and low levels of positive symptoms actually displayed a super-LI effect, as compared with healthy controls (E. Cohen et al., 2004).

Nevertheless, those subgroups that do exhibit attenuated LI can be described as being relatively slow in making the transition from an automatic to a controlled mode of information processing. Although this may reflect a general switching problem (Weiner, 2003; Weiner & Fel-

Figure 3. Mean target detection response times (RTs, in seconds) for schizophrenic patient and matched control groups as a function of blocks of trials during preexposure and test stages. The data are from E. Cohen et al. (2004).

Figure 4. Mean target detection response times (RTs, in seconds) for schizophrenic patient and matched control groups as a function of blocks of trials during preexposure and test stages. The data are from Lubow, Kaplan, Abramovich, Rudnick, and Laor (2000).

don, 1997), we would maintain that the switching deficit is specific to automatic processing (Lubow & Gewirtz, 1995). Specifically, normal LI is dependent on the acquisition of automatic processing of the irrelevant preexposed stimulus, such that the nominally unattended stimuli are eventually processed effortlessly, rapidly, autonomously (reflexively), and in such a way that they are unavailable to conscious awareness (Logan, 1988). The attenuated LI in high schizotypals and schizophrenic patients, as compared with low schizotypals and normal subjects, is a consequence of the preexposed irrelevant stimuli continuing to engage the controlled processing mode. In other words, for schizophrenic subjects, even with continued practice in the preexposure phase, attention continues to be captured by the irrelevant stimuli. As a consequence, conscious awareness is inundated with experimentally familiar but phenomenally novel stimuli. As has been described by Frith (1979), the schizophrenic has difficulty in limiting the contents of consciousness. Indeed, the positive symptoms of schizophrenia are congruent with the notion that, for schizophrenics, short-term memory is "preoccupied" with irrelevant stimuli. Indeed, when high-schizotypals exhibit less LI than low-schizotypals do, they also have superior recall and recognition memory scores for the preexposed irrelevant stimuli, indicating that the attenuation of LI in the high-schizotypal subjects was a result of increased controlled processing of the irrelevant preexposed stimuli (De la Casa, Ruiz, & Lubow, 1993).

This analysis suggests that researchers of psychotic-prone normals and schizophrenic patient populations should examine performance on tasks in which the roles of automatic and controlled information processing are clearly delineated and in which success depends on the presence/absence of one or the other. In addition, theoretically motivated tasks should be developed in which support for a particular hypothesis would be reflected in better, rather than poorer, performance by the pathologic than by the control group (Spring & Zubin, 1978). LI and related procedures meet this criterion. In standard LI studies, high-schizotypal subjects and schizophrenic patients show *better* associative learning to a previously exposed irrelevant stimulus than do their normal counterparts.

Implications of the Visual Search Data for Theories of LI

As has already been noted, explanations of LI effects fall into two general categories: attentional decline/acquisition failure (A-theories; e.g., Lubow et al., 1981; Mackintosh, 1975; Pearce & Hall, 1980; Wagner, 1981) and retrieval-based competition (R-theories; e.g., Bouton, 1993, 1994; Miller et al., 1986; Miller & Matzel, 1988). A-theories assume that passive, inconsequential stimulus preexposure decreases attention (salience) to that stimulus, one consequence of which is a reduction in the ability of the stimulus to enter into new associations. As opposed to A-theories, R-theories propose that LI results from a retrieval-based competition between associations learned in the preexposure phase CS–0 (i.e., CS–no-consequence) and in the acquisition phase (CS–US), the latter of which has not been affected by preexposure to the CS.

Support for the R-theory account of LI comes primarily from three sources: (1) animal experiments in which the time between the acquisition and the test phases of three-stage paradigms has been increased and reduced LI has been shown, (2) experiments in which reminder treatments of the preexposure phase, administered before or during the test stage have been used and increased LI has been shown, and (3) experiments in which the context has been changed from preexposure to acquisition or test and reduced LI has been reported. Accordingly, R-theorists hold that if one varies the time between acquisition and test (or between preexposure and acquisition) and LI is found after a short delay, but not after a long one, this is presumptive evidence that with

Table 5
Latent Inhibition Scores, (PE–NPE)/NPE, from Two Studies with Schizophrenic (Schiz) and Normal Groups and One With High- and Low-Schizotypal Normals

	Lubow, Kaplan, et al. (2000)		E. Cohen et al. (2004)		Lubow, Kaplan, & De la Casa (2001)	
Gender	Schiz	Control	Schiz	Control	High	Low
Male	.12	.07	.25	.06	.21	.13
Female	.03	.17	.22	.19	.06	.17

the short delay the CS–US association was acquired, but not manifest, and that something occurred during the longer delay that allowed the *normally associated* CS–US event from the acquisition phase to be retrieved (for a review of this literature, see Lubow & De la Casa, in press). A similar logic has been used by R-theorists to interpret evidence that the presentation of a reminder stimulus before test alleviates the otherwise expected retarded learning (Kaspro et al., 1984; Killcross & Dickinson, 1996) and the fact that context change disrupts LI (e.g., Westbrook et al., 2000; Zalstein-Orda & Lubow, 1995).

Support for the A-theories of LI comes from several sources. (1) LI has been obtained with two-stage procedures, in which the second stage is both CS–US acquisition and test. Furthermore, in many cases of two-stage LI, the LI effect appears from *Trial 1 onward* (for a review, see Lubow, 1989), which, again, suggests reduced associability of the preexposed stimulus. (2) Inconsequential preexposure of a stimulus can produce LI after pairing with *either* an appetitive *or* an aversive event. (3) Similarly, LI can be obtained when the same preexposed stimulus is subsequently trained as *either* a conditioned excitator *or* a conditioned inhibitor (the preexposed stimulus signals the absence of a reinforcer; see, e.g., Best, 1975; Halgren, 1974; Reiss & Wagner, 1972; Rescorla, 1971). “It seems awkward to suppose that preexposure changes such an array of separate, and conflicting, *associative strengths*” (Rescorla, 2002, p. 370, italics added). (4) In a study in which LI was examined with a procedure designed to differentiate between initial associative strength and retardation of the acquisition of associative strength (associability), stimulus preexposure affected the rate of subsequent associative learning, but not the *initial* associative strength. This “supports the common interpretation that latent inhibition involves the reduction in salience of a stimulus, slowing any associative learning in which it is subsequently asked to engage” (Rescorla, 2002, p. 376).

Much of the controversy between the A- and the R-theories derives from the fact that data upholding the former were obtained from either two-stage procedures or three-stage procedures that conceptualized the third-stage test performance as a mere reflection of Stage 2 associative strength. On the other hand, data that support R-theories come primarily from three-stage procedures in which the few Stage 2 CS–US pairing trials are conducted off baseline, so that there is no direct measure of conditioned response acquisition (as in conditioned taste aversion and conditioned suppression protocols). The Stage 3 test performance is *assumed* to be the result of an interaction between associations acquired in Stage 1 and Stage 2, with the latter being unaffected by the former.

However, LI cannot be accounted for by appealing independently to either one or the other theoretical approach. On the one hand, LI can be generated in a two-stage procedure, with the LI effect appearing at the beginning of the second stage. This indicates that some difference be-

tween PE and NPE groups must have been acquired during the Stage 1 stimulus preexposure. On the other hand, such a demonstration of LI is disrupted if the preexposure and acquisition test phases are conducted in different contexts. Since the subject in the preexposure phase has no knowledge of the forthcoming acquisition test context, the context-same and the context-different groups cannot differ from each other *until* the context manipulation in Stage 2. It would appear, then, that although *normal* LI may be explained primarily through processes occurring in the stimulus preexposure stage (A-theory), the *attenuation* of LI requires some additional explanatory constructs (R-theory).

The visual search LI data make this assessment quite clear even within the confines of a two-stage procedure. Since reminder and context effects have been used to promote a retrieval/competition account of LI, our demonstrations that these variables also modulate attentionally based visual search LI indicates that such effects are not exclusively favorable to retrieval theories of LI, at least as currently formulated; they are also congruent with an attentional interpretation of LI. The apparent opposition between the positions can be resolved by noting that although A-theories rely on attentional constructs, they also contain a staged serial-processing component, such that the effect of the decreased attention that was acquired in the stimulus preexposure stage impedes the acquisition of the new association in the subsequent stage, when the preexposed stimulus is paired with a US. On the other hand, R-theories, with their emphasis on competition processes, eschew the processing-by-stages approach. In addition, they ignore the role of stimulus-specific attention. Given the type of data reported in the present set of experiments, as well as in more traditional LI studies, it would appear that a viable theory of stimulus preexposure effects will have to incorporate both attentional and competition constructs, most likely with an iterative recycling process by which attention affects competition, which in turn affects attention.

A theory of LI, then, must incorporate not only a postulate that allows for *different* stimulus preexposure conditions (e.g., PE and NPE) to produce different effects, but also one that allows for the *same* stimulus preexposure conditions to produce different test-dependent effects. The two sets of variables correspond to those that are manipulated during the preexposure stage and modulate the acquisition of LI (e.g., number and duration of stimulus preexposures) and those that are manipulated *after* the preexposure stage and correspond to a modulation of normal LI (e.g., context change and retention interval). The two accounts of traditional LI can be reconciled by noting that, as a rule, the effects of the preexposure stage variables map onto A-theories and the effects of the post-preexposure stage variables map onto R-theories. This conclusion is supported by data from both standard and visual search analogue LI experiments, thereby also reinforcing our initial contention that these two paradigms

tap similar processes. However, the new understanding is that these similar processes are at least two in number. One consequence of considering LI to be generated by multiple processes is that it may be necessary to reconsider the sources of LI aberrations in high-schizotypal normals and schizophrenic patients.

SUMMARY AND CONCLUSIONS

We have demonstrated that preexposure of a shape as a distractor interferes with its subsequent ability to act as a target. This stimulus preexposure effect was obtained with several variations of a procedure in which subjects were required to detect a unique target among a large set of homogeneous distractors. RTs to such targets were longer than those to new targets or to previously presented targets. In particular, the two conditions, (D→T):(T→D) and (N):(T→D), that provide a formal analogue for the traditional LI conditions, PE and NPE, elicited responses that are congruent with the position that such preexposures produce a stimulus-specific attentional decline. The robust LI-like effect was present when the two critical conditions were embedded in within-subjects designs with seven or fewer additional conditions, with a procedure that required identifying presence versus absence of a target and with a procedure in which the target was present on every trial but the subject had to indicate whether it was on the right or the left side of the screen. It was also shown that the same variables have similar effects in both standard and visual search LI preparations. Thus, both traditional LI and visual search LI are reduced when there is a change of context from preexposure to test phases and when there are no reminder trials in the test. Individual difference variables also produced the same effects in both preparations. Schizophrenic patients, as compared with normal controls, and high-schizotypal normals, as compared with low-schizotypal normals, displayed attenuated standard LI and visual search LI effects. Furthermore, in both cases, these effects interacted with gender.

Together, then, these findings encourage the following conclusions. (1) The processes that underlie target detection with LI-like visual search conditions are the same as those that subserve traditional LI in animals and humans. (2) These processes, although attentional, are modulated by reminder trial and context manipulations. (3) Any manipulation that promotes the similarity of a preexposure session, in which there is a relatively unattended irrelevant stimulus that will later become a relevant target stimulus, and the test session will increase LI. (4) Attentional and retrieval accounts of LI are not necessarily incompatible; the former is best applied to the effects of variables manipulated in the stimulus preexposure stage, and the latter to poststimulus preexposure manipulations. (5) Given that both A- and R-processes are involved in LI, it remains to be shown which one is responsible for LI aberrations in schizophrenic patients and high-schizotypal normals.

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- distractor in the preexposure phase and a distractor that had previously been a distractor, all 20 figures in the display would be the same (i.e., there would be no unique figure); the same homogeneous test phase display configuration would occur if the test phase distractor had previously been a target and the test phase target had also previously been a target.

2. Although the latter study can be discounted because of grossly unequal representations of males and females and the small number of female subjects, the remaining studies did not suffer from such problems.

3. LI studies with *healthy* human subjects frequently have a disproportionately large number of females, as compared with males (often two to one). Such a gender bias may result in an underestimate of the basic LI effect. In similar studies with schizophrenic patients, the male-to-female ratios typically are reversed.

4. The correspondence between dopamine agonists, such as amphetamine, that produce psychotic-like effects in humans and reduce LI and dopamine antagonist neuroleptics, such as haloperidol, that counteract effects of dopamine agonists and produce super-LI also can be found with atypical antipsychotic drugs, such as clozapine (e.g., Moran, Fischer, Hitchcock, & Moser, 1996; Shadach, Feldon, & Weiner, 1999).

5. All of these studies used CRs as the dependent variable. LI schizophrenia experiments also have used electrodermal responding (Vaitl et al., 2002) and event-related potentials (Guterman, Josiassen, Bashore, Johnson, & Lubow, 1996; Kathmann, von Recum, Haag, & Engel, 2000), with basically similar results.

6. The difference in results may be due to the fact that Uhlhaas et al. (2003) selected subjects from the lower and upper 20th percentiles of schizotypy questionnaire scores, whereas Tsakanikos and Reed (2003) used an unselected group. The relatively weak effect of schizotypy level on LI reported by Lubow et al. (2001) also may be attributable to using subjects from the full range of schizotypy scores.

NOTES

1. Although there are three target conditions that can be crossed with three distractor conditions (3×3), there are only seven viable types of test trial. If a test phase display had a target that had previously been a

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