A new continuous within-participants latent inhibition task: Examining associations with schizotypy dimensions, smoking status and gender

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Abstract

A within-participants latent inhibition task (LI: the retardation in learning that occurs if a stimulus has first been presented without consequence) was developed that produced robust LI, using both reaction time and number of correct responses as the dependent measures. Furthermore, associations were found between the preexposed stimulus and the schizotypy dimension of unusual experiences and smoking status. There were no significant relationships with the non-preexposed stimulus. This pattern of results was found using both reaction time and number of correct responses as the dependent measures which indicates that individuals who smoke and those high in unusual experiences show reduced LI. These findings indicate that the task may have sufficient sensitivity to be used in patients with schizophrenia.

Keywords: Latent inhibition; Human; Within-participants design; Schizophrenia; Schizotypy; Smoking; Gender

1. Introduction

There have been numerous reports in the literature, from both clinicians and patients with schizophrenia, that one of the fundamental dysfunctions in this disorder is in selective attention (MacDonald, 1960; McGhie and Chapman, 1961). As a consequence of the prominence given to this deficit in schizophrenia many paradigms have been developed to assess it. Latent inhibition (LI) describes the attenuation in learning an association between two stimuli if the to-be-conditioned stimulus has first been preexposed without consequence (Lubow and Moore, 1959). The typical procedure used to test LI in humans consists of two phases: preexposure and test. In the preexposure phase participants are randomly split into two groups. Half of them are exposed to an irrelevant and inconsequential stimulus (PE group), whilst for the other participants it is absent (NPE group). Concurrently with this exposure the participant is asked to engage in a masking task. All participants then move into the test phase, where the masking task stimuli are still present, but now the participant must learn to associate the previously preexposed stimulus (which is novel for the NPE group) with some outcome. LI is demonstrated when the PE group are slower to learn this association than the NPE group.

Prominent theories of LI suggest that attentional processes underlie this effect (Lubow and Gewirtz, 1995; Mackintosh, 1975), and explain it as a consequence of less attention being paid to the irrelevant stimulus in the preexposure phase (although see Bouton, 1993; Weiner, 1990, 2003 for alternative explanations). Therefore in the test phase less attention is devoted to the preexposed stimulus, due to its being previously irrelevant to the task. As a consequence it takes longer for healthy participants to learn the association between the preexposed stimulus and the outcome. In contrast, individuals with schizophrenia are hypothesised to be unable to screen out the irrelevant stimulus from awareness in the preexposure phase. Thus when it comes to the test phase those participants with schizophrenia who were preexposed to the stimulus should be quicker to learn the association between it and some outcome than preexposed healthy volunteers. Hence individuals with schizophrenia should exhibit faster learning on this task than healthy controls. This effect cannot be attributed to alternative explanations such as poor motivation, not understanding task instructions, antipsychotic medication, etc.; which frequently complicates the interpretation of other attentional tasks.
Consistent with the view that individuals with schizophrenia have an attentional dysfunction are reports that patients in the acute phase of the disorder have reduced or abolished LI compared to participants with chronic schizophrenia or healthy controls (Baruch et al., 1988a; Gray et al., 1992a, 1995; but see also Swerdlow et al., 1996; Williams et al., 1998). Importantly, some of these studies have found this pattern of result due to differences between the groups in both the preexposed and non-preexposed conditions (Gray et al., 1992a), rather than to just the preexposed stimulus (Baruch et al., 1988a; Gray et al., 1995). Moreover, if a continuum approach to psychosis is adopted (e.g., Claridge, 1997) and schizotypy or psychosis-proneness scores are measured in healthy volunteers it is found that individuals high on these scales also have attenuated LI (Baruch et al., 1988b; Hofer et al., 1998; Lipp et al., 1994; Lipp and Vaitl, 1992; Lubow et al., 1992). Further research by Gray et al. (2002) has suggested that the positive dimension of schizotypy is associated with a reduction in LI.

Unfortunately the majority of these studies have utilised between-participants designs which have a number of limitations. First, as comparisons are made between groups (PE and NPE) it is essential that participants are matched on key demographic and clinical criteria, which can be extremely difficult with patient groups. Second, more participants are required in between-participants designs, as opposed to within-participants. The need for a larger number of participants can be problematic when using rare populations (such as first-episode drug-naive patients with schizophrenia) or expensive imaging techniques (such as fMRI or SPECT). Finally, only group effects can be measured. Thus it is only possible to conclude that the PE group was slower to learn the association than the NPE group, but no inferences can be made about individual’s performance. This is a particularly serious disadvantage with regard to patient studies. Potentially important information could be gained by conducting correlations between a participant’s LI performance and their type and degree of clinical symptoms, medication dose, duration of illness and functional outcome. Thus, research with patient groups would benefit greatly from a within-participants LI task. However those that have been developed suffer from a number of limitations, which are highlighted below.

1.1. LI

In some of the within-participants LI tasks that have been developed it is equivocal whether they actually measure LI. In a classical LI experiment the unconditioned stimulus is only presented in the test phase (see the definition of LI presented at the beginning of Section 1). This is in contrast to some published within-participants ‘LI’ tasks, where the unconditioned stimulus has been presented in both the preexposure and test phases of the experiment (De la Casa and Lubow, 2001; Lubow and De la Casa, 2002; Swerdlow et al., 2003). For example, in the Swerdlow et al. study the unconditioned stimulus (a stationary X) was presented in the preexposure phase of the experiment and in the test phase the participants were asked to predict when they thought the X would move. In the De la Casa paradigm participants were asked to track a black square in the preexposure phase of the experiment, which they then had to predict the location of in the test phase. As the unconditioned stimulus in these studies was presented in the preexposure phase it is possible that they might be measuring other learning phenomena. Further tests are needed on these paradigms to rule out this possibility.

1.2. Dependent measures

Traditionally in between-participants LI experiments the dependent variable is trials to a learning criterion or the number of correct responses. However, when using this sort of measure, and in particular trials-to-criterion, it is generally found that there is a bimodal distribution of responses in the test phase. Some participants learn the association very quickly whereas others take a long time, if ever, to learn the rule. More recent within-participants LI tasks have started to use reaction time measures of LI (De la Casa and Lubow, 2001; Lubow, 1997; Lubow and De la Casa, 2002; Lubow et al., 2000, 2001; Swerdlow et al., 2003). These have the advantage that they produce a continuous (normal) distribution of scores. However, none of these studies have found LI using both the newer reaction time measure and the more traditional measure of number of correct responses (or some other learning criterion) as the dependent variable. Swerdlow et al. (2003) found LI when it was assessed as the trial number by which participants achieved a learning criterion, but not when using reaction time. Conversely, De la Casa and Lubow (2001) and De la Casa and Lubow (2001; and Lubow and De la Casa, 2002) in a number of experiments have found LI when using reaction time as the dependent measure, but not when using number of correct responses. Thus, from the within-participants LI studies already conducted it is unclear whether reaction time is assessing the same cognitive processes as the traditional learning criterion LI measure, given the dissociations which have been found between them.

1.3. Magnitude of effect

A crucial factor in the development of a within-participants LI task is the magnitude of the effect it generates. Gray et al. (2003) found that the effect size for their within-participants LI task was considerably smaller than that obtained with a parallel between-participants version, run in separate samples of healthy volunteers. The authors argued that this was because once participants had learnt about one stimulus association this cued them to learn the other association, thus ‘falsely’ reducing the LI effect. In support of this argument relationships were found between positive schizotypal symptoms and performance on the between-participants LI task, but no associations were found with the within-participants version. Thus, Gray et al. concluded that although within-participants LI could be demonstrated its use might be limited because of the small magnitude of effect, which did not appear to be sensitive to individual differences.
1.4. Aims of this study

In light of the limitations of previous within-participants LI tasks highlighted above the aim of this study was to design an instrumental within-participants LI task that did not suffer from these shortcomings. The task designed was loosely based upon a learned irrelevance task by Young et al. (2005). In this task it was required that:

(a) The task developed would measure LI rather than other related learning phenomena, such as learned irrelevance or conditioned inhibition. Learned irrelevance describes the reduction in learning that arises from uncorrelated presentations of the conditioned stimulus and unconditioned stimulus in the preexposure phase of the experiment (Baker and Mackintosh, 1977; see Gray and Snowden, 2005 for a discussion of this phenomenon and its relationship to LI). Conditioned inhibition is when the conditioned stimulus predicts the absence of the unconditioned stimulus, which results in slower learning in the test phase of the experiment (Zimmer-Hart and Rescorla, 1974). Therefore in the design of this LI paradigm the unconditioned stimulus should not be present during preexposure. This design feature is important as all the key findings of LI, as it relates to schizophrenia and the behavioural neuroscience literature, have been found using just conditioned stimulus preexposure. It is important to be able to rely on this now extensive literature.

(b) Significant LI would be evident in healthy volunteers. Moreover, this LI effect would be evident using both reaction time and the number of correct responses as the dependent variables. This pattern of results would give increased confidence that the new within-participants LI task is assessing the same cognitive processes as the between-participants tasks (which have traditionally used learning scores as the dependent measure).

(c) The within-participants LI task would have a sufficient effect size to detect relationships with dimensions of schizotypy. Previous research examining individuals with schizophrenia has found that LI is reduced in the acute phase of the disorder (Baruch et al., 1988a; Gray et al., 1992a), which is generally associated with a predominance of positive symptoms (Ellenbroek and Cools, 2000). Furthermore, Gray et al. (2002) found that high scores on the positive dimension of schizotypy were associated with a reduction in LI. On the basis of these findings it was predicted that it would be the positive dimension of schizotypy that would moderate LI performance. In particular, it was hypothesised that there would be a relationship between the positive dimension of schizotypy and LI score, which would indicate reduced LI in those individuals high in this dimension. However, a significant relationship could also reflect differences in learning the non-preexposed stimulus association. It was therefore also hypothesised that there would be no relationship between learning the non-preexposed stimulus association and the positive dimension of schizotypy. These results were predicted using reaction time and the number of correct responses as the dependent variables.

(d) Finally, given that it has sometimes been reported that there are differences in the LI performance of males versus females (see research cited in Lubow et al., 2001) and between smokers and non-smokers (Allan et al., 1995; Della Casa et al., 1999a,b) these two variables will also be considered in the statistical analyses.

2. Method

2.1. Participants

Eighty healthy volunteers (46 females and 34 males) signed-up to take part in this experiment for course credit or payment. None of the participants had previously taken part in an LI study. Their mean age was 20.39 years (range: 18–31; S.D. = 2.34 years). Sixty-four participants were non-smokers and 16 were smokers. The smokers smoked on average 6.19 cigarettes per day (S.D. = 5.32) and had been smoking for a mean of 4.44 years (S.D. = 2.28). All participants were screened to ensure that they had not taken recreational drugs in the month prior to the experiment, were not receiving antipsychotic medication and had no history of mental illness. It was also requested that they have normal or corrected-to-normal vision and good English if this was not their first language.

2.2. Apparatus

All experimental stimuli appeared on a RM computer and were programmed using SuperLab Pro2 software (Cedrus Corporation, 1999). In the preexposure phase, black capital letters (height 7 mm and width 5 mm) were presented on a white background for 1 s each, with no interstimulus-interval. The letters D, M, T and V were presented 15 times each in a random sequence and randomly interspersed within this sequence were 20 presentations of the preexposed stimulus (S or H, counterbalanced across participants). No presentation of the X was shown in the preexposure phase.

The test phase followed continuously from the preexposure phase, with no delay. The presentation of stimulus on the computer screen was exactly the same as in the preexposure phase. This time an X (same dimensions as the other letters) appeared on screen 30 times. It was preceded on 10 occasions by the preexposed stimulus, 10 times by the novel letter (NPE stimulus) and 10 times in total by the other letters in the experiment (D, M, T and V). These letter associations with X were randomly interspersed within 128 presentations of the other letters (32 each of D, M, T and V). Thus every time the preexposed and non-preexposed stimuli (S and H) appeared on screen they were always followed by an X, whereas for the other letters (D, M, T and V) they were only infrequently followed by an X. This latter condition was termed the ‘neutral’ condition and its purpose was two-fold. First, as it could not be used to accurately predict X (predictive on 10 out of 138 trials) it was intended to give an estimation baseline reaction time to X. Second, Gray et al. (2003) found in their within-participants paradigm that as soon as participants learnt the one stimulus association they were very quick to then learn the other rule. Therefore it was felt that by having these distractor trials this would help prevent this ‘cuing effect’. The order of presentation of stimuli was kept constant for all participants, i.e. the S and H were in the same location for all participants in the test phase. The preexposure and test phase took approximately 5 min in total.

The Oxford-Liverpool Inventory of Feelings and Experiences (O-LIFE; Mason et al., 1995) was used to measure schizotypy. This questionnaire measures four dimensions of schizotypy: unusual experiences, which examines deviant perceptual and cognitive experiences; cognitive disorganisation, which describes difficulties with attention as well as social anxiety; introvertive anhedonia, which assesses the inability to experience pleasure; and impulsive nonconformity, which measures reckless and destructive tendencies. The mean schizotypy scores obtained were as follows (standard deviation in parentheses after the mean): unusual experiences, 6.30 (5.60); cognitive disorganisation, 10.98 (5.24); introvertive anhedonia, 4.06 (3.91); and impulsive nonconformity, 9.25 (3.98). The cognitive disorganisation and impulsive nonconformity scores...
are comparable to those established by Mason et al. (1995), 11.6 (5.8) and 9.1 (4.3), respectively. However the mean unusual experiences and introverted anhedonia scores are higher in Mason et al’s study, 9.7 (6.7) and 6.1 (4.6), respectively.

2.3. Procedure

The LI task consisted of two phases: preexposure and test. However, unlike in most previous experiments on human LI where there is a small delay and change of instructions between preexposure and test, in this version there was no such delay and no change of instructions. Thus at the beginning of the task, before the preexposure phase, participants were given the following instructions:

In this task I want you to watch the sequence of letters appearing on screen. Your task is to try and predict when a letter X is going to appear. If you think you know when the X will appear then you can press the spacebar early in the sequence, that is before the X appears on screen. Alternatively, if you are unable to do this please press the spacebar as quickly as possible when you see the letter X. There may be more than one rule that predicts the X. Please try to be as accurate as you can, but do not worry about making the occasional error. If you understand your task and are ready to start press the spacebar to begin.

These instructions were printed on the computer screen at the beginning of testing and the experimenter reiterated them to each participant, ensuring that they knew to respond before the X appeared on screen, if they could predict it, or as fast as possible when they saw the X if they could not. For half the participants H was the preexposed stimulus and for the other half it was S. The order of administration of the LI task and the O-LIFE questionnaire (Mason et al., 1995) was counterbalanced.

2.4. Scoring

2.4.1. Reaction time data

To assess the magnitude of LI exhibited by each participant the time it took them to predict or respond to the X was examined. As the letter prior to the X was on screen for 1000 ms and the X was also on screen for 1000 ms the range of reaction times was 0–2000 ms. Therefore if a participant predicted an X their reaction time would be less than 1000 ms, whereas if they responded on an X it would be between 1001 and 2000 ms. For each participant a mean preexposed, non-preexposed and neutral (response to the D, M, V and T trials that predicted X, 10 in total) reaction time were calculated. An LI score was also calculated (PE minus NPE) for each participant. Positive scores would indicate that LI was present, whereas zero or negative scores would indicate the absence of LI.

2.4.2. Correct response data

A correct response measure was also calculated for each individual. If the participant had predicted the X (i.e. they had pressed the spacebar on the letter immediately preceding the X) it was deemed that this was a correct response. For each participant the number of correct responses to the preexposed and non-preexposed stimuli were counted separately for each stimulus type. An LI score was also calculated (NPE minus PE) for each participant. Positive scores would indicate that LI was present, whereas zero or negative scores would indicate the absence of LI.

2.5. Excluded participants

The test data were assessed to determine the number of omissions (the absence of a response when the X was displayed) and commissions (responses other than to the letter preceding the X or the X) made by each of the participants. If a participant made an excessive number of either one of these this would indicate that they were failing to pay attention to the stimuli being presented on screen or did not understand the task instructions. Seven individuals (four females and three males, all non-smokers) were found to have excessive scores on these two measures, either more than 7 omissions or more than 14 commissions and so were excluded from data analysis (there was no significant differences between the O-LIFE scores of individuals included in the study and those excluded, p > .1). Seventy-three participants remained of which 37 were preexposed to H (22 females and 15 males) and 36 were preexposed to S (20 females and 16 males).

3. Results

Displayed in Fig. 1A are the mean reaction times of all included participants to the preexposed, non-preexposed and neutral stimuli. Importantly reaction times less than 1000 ms indicate that the participant predicted the X. It can be seen that participants quite readily learned to predict the non-preexposed stimulus but had more difficulty with the preexposed stimulus, although these latter reaction times were still less than those found to the neutral stimuli. Participants preexposed to S or H did not differ in their reaction times to the neutral stimuli [t(60.1) = 0.55, p > .1; degrees of freedom adjusted due to a violation in the assumption of homogeneity of variance]. Furthermore, examining Fig. 1B it can be seen that when number of correct responses was used as the dependent variable there were substantially more to the non-preexposed stimulus than to the preexposed stimulus.

Fig. 1. The mean responses of participants (n=73) to each of the stimulus conditions, which were presented 10 times each. In (A) using reaction time as the dependent measure and in (B) number of correct responses. The error bars represent ± 1 standard error of the mean.
3.1. LI as assessed by reaction time

An analysis of variance (ANOVA) was performed on the reaction time data, with a between-participants factor of preexposure condition (S or H) and a within-participants factor of test stimuli (mean reaction times to the preexposed and non-preexposed stimuli). The crucial result was a significant main effect of test stimuli, $F(1, 71) = 67.28$, $p < .001$. The mean reaction times to the non-preexposed stimulus were significantly less than to the preexposed stimulus [983.08 ms (31.27) versus 1251.78 ms (23.77)], standard errors in parentheses. Hence robust LI was achieved using reaction time as the dependent variable. This can clearly be seen in Fig. 1A where the mean reaction times to the non-preexposed stimulus are quicker than to the preexposed stimulus on every trial. The LI effect size was 1.12 (Dunlap et al., 1996). The Dunlap et al. method of calculating effect size was used as it takes into consideration the correlation between measures and so does not overestimate the effect size. There was no main effect of preexposure condition or a preexposure condition by test stimuli interaction ($p > .1$).

A multiple regression was completed using the four schizotypy dimensions, gender (coded: male = 0, female = 1) and smoking status (coded: non-smoker = 0, smoker = 1) as the predictor variables and LI score as the dependent variable. There were no significant relationships between any of the predictor variables and LI score ($p > .1$). As the LI score is composed of two variables (PE – NPE) multiple regressions were also completed on both of these components to check that a result had not been masked by differences taking place in both of these conditions. If any of the predictor variables are associated with LI it would be expected that a relationship would be found with the preexposed stimulus, but not with the non-preexposed stimulus. When mean reaction time to the preexposed stimulus was entered as the dependent variable there was a relationship with smoking status ($\beta = -.28$, $p < .05$) and a trend for a relationship with unusual experiences ($\beta = -.26$, $p = .08$). These results reflect faster learning to the preexposed stimulus by both individuals high in unusual experiences and in smokers. There were no relationships between mean reaction time to the preexposed stimulus and the other schizotypy dimensions or gender ($p > .1$). Finally, when mean reaction time to the non-preexposed stimulus was entered as the dependent variable there were no significant relationships with any of the predictor variables ($p > .1$). The full results of these regression analyses can be seen in Table 1. A series of independent $t$-tests found that there were no significant differences in the schizotypy scores of non-smokers versus smokers ($p > .1$).

3.2. LI as assessed by number of correct responses

A further aim was to determine if the LI effect that was obtained with reaction time would also be evident when using number of correct responses as the dependent measure (see Section 2.4 for how this was scored). As per the reaction time data an analysis of variance (ANOVA) was performed on the correct response data, with a between-participants factor of preexposure condition (S or H) and a within-participants factor of test stimuli (number of correct responses to the preexposed and non-preexposed stimuli). The crucial result was a significant main effect of test stimuli, $F(1, 71) = 65.75$, $p < .001$. The mean number of correct responses to the non-preexposed stimulus was significantly greater than to the preexposed stimulus, as can be seen in Fig. 1B. Hence robust LI was achieved using number of correct responses as the dependent variable. The LI effect size was 1.11 (Dunlap et al., 1996). There were only trends for the main effect of preexposure condition ($p = .05$) and the preexposure condition by test stimuli interaction ($p = .08$).

Three multiple regressions were then completed to determine if there were any relationships between the schizotypy dimensions, gender and smoking status using number of correct responses as the dependent variable. When LI score was used as the dependent variable there was a trend for a significant relationships with impulsive nonconformity ($\beta = .26$, $p = .08$), indicating that individuals high in this dimension exhibited enhanced LI. However there were no further significant relationships with any of the other schizotypy dimensions, gender or smoking status ($p > .1$). Next, multiple regressions were completed using mean number of correct responses to the preexposed and non-preexposed stimuli as the dependent variable. When examining correct responses to the preexposed stimulus a significant relationship was found with smoking status ($\beta = .35$, $p < .01$) and a trend for a relationship with unusual experiences ($\beta = .24$, $p = .10$). These results indicate a higher number of correct responses to the preexposed stimulus by individuals who smoked and those high in the schizotypy dimension of unusual experiences. There were no relationships between number of correct responses to the preexposed stimulus and the other schizotypy dimensions or gender ($p > .1$). Furthermore, there were no significant relationships between any of the predictor variables and number of correct responses to the non-preexposed stimulus ($p > .1$). Thus analyses using number of correct responses as the dependent measure also confirm that individuals who score highly on unusual experiences or who smoke exhibit attenuated LI.

### Table 1

<table>
<thead>
<tr>
<th>Predictor Variables</th>
<th>Reaction Time</th>
<th>Correct responses</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>PE</td>
<td>NPE</td>
</tr>
<tr>
<td>Unusual experiences</td>
<td>-.26</td>
<td>-.03</td>
</tr>
<tr>
<td>Cognitive disorganisation</td>
<td>.16</td>
<td>-.01</td>
</tr>
<tr>
<td>Introvertive anhedonia</td>
<td>.00</td>
<td>-.03</td>
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<tr>
<td>Impulsive nonconformity</td>
<td>.13</td>
<td>-.16</td>
</tr>
<tr>
<td>Gender</td>
<td>-.15</td>
<td>-.14</td>
</tr>
<tr>
<td>Smoking status</td>
<td>-.28</td>
<td>.04</td>
</tr>
<tr>
<td>$R^2$</td>
<td>.14</td>
<td>.04</td>
</tr>
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</table>

Note: PE: preexposed stimulus; NPE: non-preexposed stimulus. Gender coded 0 for male and 1 for female. Smoking status coded 0 for non-smoker and 1 for smoker. *$p \leq .1$, **$p < .05$, ***$p < .01$. Significant results are in bold.
LI. The full results from these regression analyses can be seen in Table 1.

3.3. LI and smoking

The analyses completed above indicate that individuals who smoke show reduced LI, using both reaction time and correct responses as the dependent variables. However this result is based upon an ‘any versus none’ criterion for smoking. To provide a more convincing demonstration of the effect of smoking on LI a graded approach was adopted and the duration of time since participant’s last cigarette was explored. It was hypothesised that individuals who had recently smoked a cigarette prior to completing the task would exhibit less LI compared to smokers who had a greater duration of time since their last cigarette. To test this prediction the smokers were split into two groups: recent smokers, who had smoked a cigarette within 4 h prior to completing the task (n = 8) and non-recent smokers, who had not had a cigarette for at least 10 h prior to the task (n = 8). Recent smokers had a significantly smaller LI reaction time score [t(9.5) = 2.38, p < .05] and LI correct response score [t(14) = 2.99, p = .01] compared to non-recent smokers, indicating a reduction of LI in this group. Crucially these two groups did not differ in their reaction times or number of correct responses to the non-preexposed stimulus (p > .1). The difference between the LI scores of recent and non-recent smokers can be seen in Fig. 2. These results demonstrate that smoking, and more specifically duration since last cigarette smoked, has an important effect on attenuating LI.

4. Discussion

The aim of this study was to design a within-participants LI task which did not have the limitations found in many of the other within-participant LI tasks that have been reported in the literature (De la Casa and Lubow, 2001; Gray et al., 2003; Lubow, 1997; Lubow and De la Casa, 2002; Lubow et al., 2000; Swerdlow et al., 2003). Specifically these limitations were that: (a) in some tasks it is ambiguous whether they measure LI or other related learning phenomena; (b) scoring procedures other than number of correct responses or trials-to-criterion have been used, and it is unclear whether these assess the same cognitive process as the traditional measures do; (c) the magnitude of LI effect found so far has been too small to detect relationships with dimensions of schizotypy. The success of the new within-participants LI task is reported below.

The first aim for this task was theoretical: the task must measure LI rather than any other related phenomena, such as learned irrelevance or conditioned inhibition. Whether this is important empirically; that is, changes the experimental manipulations that affect the task, has yet to be explored. However it was felt important to develop a ‘true’ LI task so that in future experiments clear predictions about the effect of experimental manipulations could be made, based on the large human and animal literature that is available on LI. This aim was successfully achieved, as the unconditioned stimulus (the X) was not presented during the preexposure phase.

A limitation of the task is that although the unconditioned stimulus was not presented during the preexposure phase participants knew from the instructions that it could occur. Therefore it is possible that in the preexposure phase participants were learning that the letters appearing on the screen were associated with the absence of X. This procedure is different from the traditional between-participants designs where participants know nothing in the preexposure phase about the task that they will be asked to perform in the test phase of the experiment. Amendments could be made to the task to overcome this problem. For example, in the preexposure phase the participant could be asked to count how many times one of the irrelevant letters appeared on screen. At the end of this phase they could be given new instructions asking them to try to predict when the X appears on screen. Further experiments would need to be conducted to determine what influence this would have on the LI effect.

It is interesting to note that in this task there was no overt masking task: the instructions that were given at the start of the preexposure phase covered the entire experiment. This is in contrast to the typical procedure employed in testing LI in adult...
Indeed, Gray et al. (2003) have previously argued that the small (see Escobar et al., 2003 for a review of this literature and also their work which did find LI with no masking task). The design of an unmasked LI task which worked successfully in adult humans would have an important practical application: it would more closely parallel the typical procedure used to elicit LI in non-humans. This is important as a great deal of pharmacological and neuroanatomical research pertaining to schizophrenia has been conducted in non-humans. However due to the procedural differences traditionally found between human and animal LI tasks the validity of this research can be questioned. The use of an unmasked LI task, such as the one described in this paper, would eliminate this particular problem in cross-species research.

The second aim of the study was to design a task that would produce significant LI, using both reaction time and number of correct responses as the dependent measures. This goal was successfully achieved which, to date, has not been previously shown. In previous work (De la Casa and Lubow, 2001; Lubow and De la Casa, 2002) although both reaction time and number of correct responses have been measured only reaction time has produced significant LI. These researchers argue that both of these dependent measures assess the process(es) that control(s) LI, but that the reaction time measure is more sensitive. Therefore if the task is relatively undemanding, like the traditional between-participants tasks (e.g. Baruch et al., 1988a), then correct response measures will be able to detect LI. However if the task is more difficult, like the within-participant tasks used by De la Casa and Lubow (2001), then reaction time measures are needed to identify LI. It appears that the task used in this study represents a compromise between these two extremes. Even though participants had to learn two rules in the presence of distractors they attained a good level of learning (82% of participants were able to predict the non-preexposed stimulus at least twice and 48% were able to predict the preexposed stimulus at least twice). Given that LI was found using reaction time and correct response measures this supports the notion that they are examining at least some of the same cognitive processes that underlie the LI effect. Moreover it also suggests that the conclusions drawn from this study can be added to the large pool of knowledge that has already been gained from using the more traditional correct response measures.

The third aim in the design of this within-participants LI task was that it should have a sufficient magnitude of effect to detect relationships with dimensions of schizotypy. The effect size of this LI task, examining both reaction time and correct responses, was of a large magnitude. This is in contrast to many other studies which have found only small to moderate effect sizes (e.g. Gray et al., 2003; Swerdlow et al., 2003). Indeed, Gray et al. (2003) have previously argued that the small effect size usually generated by within-participants LI tasks may limit their success in detecting effects of schizotypy upon LI. This does not appear to be a limitation of the within-participants LI task outlined here. The effect sizes that it generates even exceed those reported for a between-participants LI task (Gray et al., 2003).

Given the large magnitude of LI effects found it was then determined whether any schizotypy dimensions were associated with LI performance. No relationships were found between any of the schizotypy dimensions and LI score when using reaction time as the dependent measure. However, there was a trend for a relationship with impulsive nonconformity when correct response was used as the dependent measure. This result indicated that those participants high in this dimension had enhanced LI, which is in contrast to the findings of Gray et al. (2002). They found that impulsive nonconformity was associated with a reduction in LI, due to its high degree of correlation with unusual experiences.

When reaction time and number of correct responses to the preexposed stimulus were examined a trend for a relationship with unusual experiences was found. Individuals high in this dimension were quicker to learn the preexposed stimulus association than those low in unusual experiences. This, in conjunction with the fact that there was no significant association between this dimension and learning to the non-preexposed stimulus, suggests that those individuals high in unusual experiences exhibit reduced LI. This finding is consistent with the schizophrenia literature. A reduction in LI has been found to be associated with the acute stage of the illness (Baruch et al., 1988a; Gray et al., 1992a), which is when patients tend to show a greater preponderance of positive symptoms (Ellenbroek and Cools, 2000). Moreover, a number of schizotypy studies, using between-participants LI tasks, have found that a reduction in LI is associated with the positive dimension of schizotypy (Allan et al., 1995; Gray et al., 2002; Lipp et al., 1994). Hence this finding concurs with previous studies using patients with schizophrenia and measuring schizotypy in healthy volunteers. However, there are tentative signs that it can be demonstrated with a within-participants LI task, using both reaction time and correct responses as the dependent variables. No significant associations were found between any of the other schizotypy dimensions (introvertive anhedonia or cognitive disorganisation) and reaction time or correct responses to the preexposed or non-preexposed stimuli. This pattern of results is what would be predicted as the reduction in LI seen in patients with schizophrenia has been put forth as a model of the cognitive and neural associates of the positive symptoms of acute schizophrenia (Gray et al., 1991). The neuropsychological model of Gray et al. was not proposed to account for the negative or disorganised symptoms of schizophrenia.

A final aim of the present study was to examine whether there were any associations between LI and gender or smoking status. Some studies have found that males exhibit more LI than females (see research cited in Lubow et al., 2001). However no main effect of gender was found in this study. Smoking status was also assessed. Although no relationship was found with LI score there were associations when reaction time and correct responses to the preexposed stimulus were used as the dependent measures. These indicated that smokers were quicker to respond to the preexposed stimulus and were able
to predict it on a greater number of occasions than non-smokers. Importantly, smoker’s faster learning of the stimulus—outcome association was unique to the preexposed stimulus. There was no difference between smokers and non-smokers in learning the non-preexposed stimulus association. These results, in conjunction, would suggest that individuals who smoke show reduced LI.

As far as our limited sample size would allow us to determine this result did not appear to be mediated by schizotypy scores, as no difference was found between the schizotypy scores of smokers versus non-smokers. Moreover, further analyses on the smoking data revealed that those individuals who had recently (≤4 h) smoked a cigarette, prior to completing the LI task, demonstrated less LI than the non-recent smokers (≥10 h). This pattern of results was found regardless of which dependent variable was used: LI score using reaction time or LI score using number of correct responses. Critically, it did not reflect a more generalised effect as there were no differences in reaction times or number of correct responses to the non-preexposed stimulus between the recent and non-recent smokers. Thus, together these findings strongly suggest that smoking, and in particular a short duration since the last cigarette smoked, attenuated LI. The reduction of LI in smokers replicates the work of Allan et al. (1995) and follows on from the animal literature examining nicotine (Joseph et al., 1993). Moreover, it is also consistent with the findings both in man (Gray et al., 1992b) and the rat (Weiner et al., 1981) that amphetamine, which, like nicotine, is also an indirect dopamine agonist, reduces or abolishes LI. Hence it appears that this LI task might be sensitive to the effects of dopamine. However more smokers would need to be tested in order to verify this statement, given the small number in the present sample.

Finally, it is puzzling why relationships were found with unusual experiences and smoking status when reaction time and correct responses to the preexposed stimulus were the dependent variables but not LI score. It is possible that LI score is a more conservative measure of LI, compared to responses to the preexposed stimulus, and so it is harder to find associations with individual differences variables. Thus relationships might not have been found between LI score and unusual experiences because of the relatively low unusual experiences scores obtained in this study, compared to the norms established by Mason et al. (1995); and no association might have been found between LI score and smoking status because of the small number of smokers in this study. It is interesting to note that no study, to date, has reported a significant relationship between LI score and symptoms of schizophrenia or schizotypy score in a within-participants design. However a number of studies have found using a within-participants design that LI is abolished in individuals with schizophrenia and high schizotypies when responses to the preexposed and non-preexposed stimuli are examined (although there are interactions with gender; Lubow et al., 2000, 2001, 2002). Furthermore, perhaps calculating LI score as the arithmetic difference between responses to the preexposed and non-preexposed stimuli is not the most appropriate statistic and other methods would produce a more valid LI score (e.g. a ratio measurement). Clearly more research into these issues is warranted.

In summary, a within-participants LI task was developed which produced robust LI, using reaction time and number of correct responses as the dependent variables. The LI effect was moderated by the schizotypy dimension of unusual experiences and smoking status. Consistent with previous research in the area those individuals who scored highly on unusual experiences and smokers had attenuated LI. These findings suggest that the LI task developed could be an important tool for assessing attentional dysfunction in patient groups, and may be sufficiently sensitive to detect relationships with symptoms and dopaminergic manipulations.

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References


