Research report

A demonstration of within-subjects latent inhibition in the human: limitations and advantages

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Abstract

The magnitude of latent inhibition (LI) (a retardation of associative learning due to prior exposure to the conditioning stimulus) was measured in healthy volunteers using both a within- and a between-subjects version of the task. Reliable LI was demonstrated for the within-subjects paradigm (using a design that fully counter-balanced stimulus of pre-exposure) but the magnitude of the effect was smaller than for the between-subjects version. Measures of schizotypal personality were found to be associated with reduced LI for the between-subjects task, but not for the within-subjects task. We hypothesised that for the within-subjects task learning about the first stimulus-consequence association (usually that for the not pre-exposed (NPE) stimulus) primes learning about the second stimulus, thus reducing the effect of pre-exposure and restricting the range of LI scores. In turn, this restricted range of LI scores does not allow subtle differences on schizotypal personality dimensions to reveal their effect using this within-subjects paradigm. In conclusion, a within-subjects LI task has been developed which is not open to explanation in terms of differences in stimulus salience. However, the limited range of pre-exposure scores in the current within-subject paradigm may severely limit it is use as an indicator of subtle performance changes.
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1. Introduction

Latent inhibition (LI) refers to a retardation of learning the significance of a reinforcing event if a conditioned stimulus (CS) has first been pre-exposed (PE) without consequence. Experimental investigation of this phenomenon suggests that LI reflects an acquired inattentional response to stimuli repeatedly presented without reinforcement [23,27,28]. LI as a behavioural phenomenon is important not only for theoretical models of learning, but more recently because it is a central paradigm in evaluating cognitive dysfunction in a variety of pathological groups, most notably schizo-

phrenia, and how these cognitive abnormalities may link to neural and neurochemical abnormalities [11]. Importantly, disrupted LI in pathological groups, such as schizophrenia, results in better performance in the test phase in the patient group and thus can not be attributed to generalised deficits in ability, due to poor motivation or medication, which complicate many other experimental paradigms.

In most LI paradigms the participants are split into two groups. One of the groups is PE to some stimulus (e.g. a tone), whilst the other group is not pre-exposed (NPE). In the second stage of the task all participants have to learn a relationship between an imperative stimulus (UCS) and the presentation of the tone (CS). LI consists of slower learning in the PE group than the NPE group. Hence, for each individual we do not have a LI score and only group comparisons can be made. A within-subject design would

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be more powerful and allow detection of effects using fewer participants (desirable in rare clinical populations). Further, a within-subject design would obviate the need for matching two groups on important demographic and clinical data and allow correlation's to be conducted between LI score, severity of clinical symptoms, medication dose, length of illness duration, etc.

Given the strong advantages of using a within-subject LI design it is perhaps surprising that there have only been a limited number of published studies describing the development of such a task. The earliest attempt was by Lubow and Moore [27] in goats and sheep, who showed a small but significant LI effect. However, as Lubow himself laments [21], all subsequent LI tasks used a between-subject design until 1995 when Gray, N.S. et al. [17] modified the Ginton [10] paradigm to develop a within-subject auditory LI paradigm to investigate LI in schizophrenia. In this paradigm all participants were first PE to a white noise stimulus superimposed upon a verbal masking task. In the test phase, both white noise stimuli and tone stimuli (presented separately) predicted a counter increment on a visual display. Participants were faster to learn the tone-counter increment relationship (NPE) than the white noise-counter increment relationship (PE). This constituted a classic LI effect, the magnitude of which could also be calculated for each individual in the study. Each individual's LI score was then correlated with various neurochemical and clinical features of schizophrenia. Gray et al found a significant positive relationship between the duration of illness and LI score, supporting previous findings [15] using a between-subject auditory LI paradigm, showing abolition of LI in acute, but not chronic, schizophrenic patients.

Although Gray et al. [17] were the first to use a within-subjects LI paradigm in schizophrenia, there were some important limitations in the design of their task. The study investigated dopamine D2 receptor binding using single photon emission tomography in a group of drug naïve schizophrenic patients. Thus the study used an expensive imaging technique in a rare population. Due to these limitations, no attempt was made to counter-balance the stimulus of pre-exposure (white noise vs. tone) and instead always pre-exposed the white noise stimulus. It could, therefore, be argued that differences in speed of learning in the test phase might be due to differences in stimulus properties between the white noise and tone rather than any effect of pre-exposure to white noise. In pilot studies, Gray [13] did match the learning speeds for each stimulus presented without pre-exposure. However, as discussed by Lubow [21] they did not ensure equality of learning speeds for the two stimuli following pre-exposure of each stimulus in turn. This is necessary in order to rule out the possibility of differences in stimulus properties contributing to the results. This is one aim of the current study.

McCartan et al. [30] used the Gray et al. within-subject auditory LI paradigm to investigate the effects of neuroleptic drugs (chlorpromazine and haloperidol) upon LI in healthy volunteers. The theory of Gray et al. [11] predicts that neuroleptic drugs should increase the magnitude of LI (i.e. lead to super-LI in healthy participants). McCartan et al. successfully demonstrated this with the neuroleptic chlorpromazine (but for a discussion of the effects of haloperidol see [30]) when using the within-subjects LI paradigm. As per Gray et al., McCartan et al. also did not counter-balance the stimulus of preexposure and merely pre-exposed all participants to the white noise stimulus.

Despite the methodological worries outlined above, the within-subject LI paradigm has thus far shown itself to be sensitive to acute versus chronic schizophrenia [17] and to the effects of neuroleptic medication [30]. It has, therefore, to date, good credibility for further investigation of the LI phenomenon in pathological populations. However, to strengthen the case for this within-subject paradigm to replace the between-subject paradigms we would also require that:

1) A similar magnitude of effect is shown regardless of stimulus of pre-exposure (white noise or tone).
2) That the magnitude of the LI effect for the within-subject auditory task be comparable to that of the between-subject auditory LI task so as to provide the required greater sensitivity for use with clinical populations.
3) That manipulations known to modulate the between-subject LI effect also modulate the within-subject LI effect. For example, many studies have shown that the personality dimension of schizotypy modulates between-subject LI. As yet there is no report upon whether a within-subject LI task is similarly modulated by personality factors.

The current study has, therefore, measured LI using the within-subject paradigm [17] whilst fully counter-balancing the stimulus of pre-exposure. It has also, in a separate group of healthy volunteers and using precisely the same stimuli, measured the magnitude of the between-subjects LI effect and compared this to the magnitude of the within-subject effect. In both studies we also took measures of schizotypy in order to test whether each paradigm could produce modulation of the LI effect by personality factors.

2. Experiment 1-within-subjects task

2.1. Method

The within-subjects LI task consisted of pre-exposing the participant to one stimulus whilst they performing a

distractor task. In the test phase this PE stimulus, and a second NPE stimulus, both independently predicted the increment of a counter. The participants task was to learn what caused the counter to increment. The number of occurrences needed to learn the relationship between each stimulus and the counter increment defined a learning score for each of the stimuli. LI would be present if the participant learnt about the NPE stimulus faster than the PE stimulus.

2.1.1. Participants

Ninty-six (41 male, 55 female) healthy volunteers participated in experiment 1 (within-subjects LI). The mean age was 28.4 years (S.D. = 2.6 years). They were recruited via an advertisement in a local paper. Participants were screened for any gross abnormalities in vision or hearing, for drug or alcohol dependence, and for any history of mental illness. All participants were paid for participation in the experiment.

2.1.2. Apparatus

In order to demonstrate LI in adult humans using a behavioural test, previous work has shown that a masking task is necessary [23]. Therefore, a list of nonsense syllables, which served as the masking material, was recorded in a male voice on both tracks of a Sony tape recorder (for binaural presentation). The verbal material was set at 73 dB with an interval between syllables of 1–2 s. The 30 nonsense syllables were repeated five times successively in a fixed order for both the preexposure and test phase of the experiment. There was no indication as to the termination or restart of the list.

The pre-exposure phase consisted of the masking material plus one of the stimuli (tone or white noise) superimposed randomly 25 times on track 1 of the recording (for monaural presentation). In the test phase of the experiment 25 presentations of the white noise stimulus and 25 presentations of a low intensity tone stimulus were superimposed in a random order on track 1 of the recording. The tone and white noise stimuli had a mean duration of 1.25 s with a (randomly varying) range of 0.5–2.0 s and a randomly varying interstimulus interval. The intensity of the white noise and tone was set to vary randomly between 50 and 61 dB (mean = 58 dB). The white noise and tone stimuli were matched for equal salience in pilot experiments, so that with no preexposure both stimuli were learnt at the same rate ($N = 12$; Wilcoxon matched pairs signed ranks: $X = 0.12$, NS). This non-significant difference in salience between the two stimuli was not due to a floor effect, with most participants scoring in the mid-range (median learning score (see below) for the tone stimulus = 13; median score for the white noise stimulus = 14; range of possible scores, 5–30). The pre-exposure and the test phase lasted approximately 5 min each.

The white noise was produced by a white noise generator (Campden Instruments 530) and the tone by a Jupiter 2000 function generator (Black Star). Stimuli were presented to the participants via headphones. The 'scoreboard' showing the visual counter display was a grey plastic box measuring 22×14 cm and containing two light emitting diode number matrices, 4.5 cm in length. The scoreboard was placed 70 cm in front of the subject in the centre of the visual field.

2.1.3. Materials

Three schizotypy questionnaires were chosen for an evaluation of the effect of individual differences in personality on LI. We chose three commonly used schizotypal measures that were designed to measure different aspects of schizotypy. The first measure, the Psychoticism scale (P-scale) of the Eysenck Personality Questionnaire (EPQ; [9]) was designed to be a measure of general psychoticism and to be a dimensional measure of psychotic traits in the general population. The second measure, the Rust Inventory of Schiztypal-Cognitions (RISC; [32]) was designed to tap positive aspects of schizotypy. The RISC was deliberately designed not to correlate with the P-scale of the EPQ and is considered to measure a very different aspect of schizotypy [32]. The final schizotypal measure, the Schizotypal Personality Scale (STA; [4]), attempted to merge clinical research on the personality disorders (which reflect many shared symptoms with schizophrenia but is a trait rather than a state characteristic) with the broad based personality approach. The STA was based upon the characteristics of Schizotypal Personality Disorder as defined by the Diagnostic and Statistical Manual-Third edition (DSM-III; [1])

Some previous studies (e.g. [3,24]) have shown increasing scores on the P-scale to be related to reduced LI (thus mimicking the effect of schizophrenia on LI; [2]). However, others have failed to replicate this effect [20]. The STA has also been shown to be negatively related to LI score (e.g. [7,18,24]). The effect of RISC upon LI has never previously been tested. However, results investigating the different dimensions of schizotypy using the Oxford and Liverpool Inventory of Feelings and Experience (O-LIFE; [29]) indicate that it is the 'positive-symptom' dimension of this scale that is mostly highly associated with decreases in LI [14]. Since RISC was designed to tap the positive aspects of schizotypy we hypothesise that it should be a powerful modulator of LI.

2.1.4. Procedure

The LI task consisted of two phases: pre-exposure and test.

2.1.4.1. Pre-exposure. Participants were asked to listen to the list of non-sense syllables. They were told to listen

carefully to the recording, to pick just one syllable and to count how many times it was repeated. Monitoring of the syllables served to ensure that the participants directed their attention to the masking material. At the end of this phase, participants were asked which nonsense syllable they had chosen and how many times (in fact, five) it was repeated. Participants were to be excluded if they reported the number of repetitions to be less than three or more than seven. No participant was excluded on these criteria. Half of the participants received the white noise stimulus as the PE stimulus and half the subjects, the tone. Some previous research [16] has shown that LI can be affected by ear of presentation. We, therefore, factored ear of presentation into our experimental design, with equal numbers of participants having presentation of both auditory stimuli in the left ear, right ear, or binaural presentation. Ear of presentation remained constant across pre-exposure and test.

2.1.4.2. Test. Participants were instructed that they were starting a new task. Once again they would listen to a recording of non-sense syllables. They were told that, in addition, throughout the recording the experimenter would increase the number displayed on the scoreboard using a small control panel. Participants were shown the control panel and the experimenter demonstrated how the number would be incremented. Participants were further told to listen to the recording and to closely watch the scoreboard; that the number on the scoreboard would be incremented according to something that they would hear on the tape; and that their task was to ascertain as quickly as possible what the rule was. Participants were instructed to guess at possible rules throughout the procedure and not to wait until they were certain of the rule, or rules, before beginning to respond. As soon as the participant thought they knew the rule they were to verbally inform the experimenter.

The test phase of the paradigm was identical for both stimulus pre-exposure conditions (white noise PE and tone PE). The 30 non-sense syllables were presented five times in a set order and the white noise and tone stimuli were randomly presented 25 times each on track 1 of the recording. The number on the scoreboard was manually incremented by the experimenter just prior to the offset of each presentation of white noise and tone. The experiment was terminated when the subject had correctly verbally identified that the white noise and tone stimuli both immediately preceded the number increments, or after the termination of the recording (i.e. after 25 presentations of each stimulus). The time between the pre-exposure and test phases of the paradigm varied slightly across subjects depending upon the time taken to deliver the instructions for the test phase of the task, but was typically 2–3 min.

2.1.4.3. Scoring. Each participant obtained two learning scores: (1) speed of learning the association between the white noise stimulus and incrementation of the number display; and (2) speed of learning the association between the tone stimulus and incrementation of the number display. Each learning score consisted of the number of times the stimulus had been presented before the subject correctly identified the relationship between the stimulus and the counter increment. Thus, the faster the learning the lower the obtained score. Participants who never correctly identified this relationship were given a score of 25 for that stimulus.

2.2. Results

As the learning scores were not normally distributed we ranked the data and performed an analysis of variance (ANOVA) on the ranked data [6], with a within-subject factor of test stimulus (white noise, tone), and between-subject factors of PE stimulus (white noise, tone) and ear of presentation (left, right, both). As there were no significant effects associated with the variable of ear of presentation (in either this or the later between-subject experiment), data were collapsed across this variable and a two-way ANOVA was performed. The crucial result was the significant interaction between test stimulus and PE stimulus [$F(1, 94) = 16.69$, $P < 0.001$]. There were no significant main effects of test stimulus or PE stimulus ($P > 0.1$).

The nature of the interaction between PE and test stimulus was further explored by planned paired t-tests. The mean scores for each group are presented in Fig. 1 (note that these are the mean learning scores, so as to preserve the absolute differences between the groups, whilst the statistical tests used the ranked scores). As can be seen from Fig. 1, when the participants were PE to the white noise they learnt about the tone faster than white noise ($t(47) = 3.39$, $P < 0.001$), whilst when they were PE to tone, they learnt about the white noise faster than the tone ($t(47) = 2.28$, $P < 0.05$). In other words, we achieved significant LI for both of our PE groups. The effect-size [5] calculated from the raw scores (not ranked) of the LI effect was 0.45 for the group PE to the white noise and 0.35 for the group PE to the tone.

As discussed in the introduction we aimed to show that the LI effects from pre-exposure to white noise or tone were of similar magnitude. To further test this hypothesis we calculated the LI effect by subtracting the score for the NPE stimulus from the PE stimulus for each of the two groups, and compared them via an independent samples t-test. Whilst the LI effect appeared marginally greater for those PE to white noise, this difference was not significant either using ranked data [$t(94) = 0.62$, $P > 0.1$] or the raw data [$t(94) = 1.45$, $P > 0.1$]. Hence we could find no statistical evidence of a difference in magnitude of the LI effect after exposure to
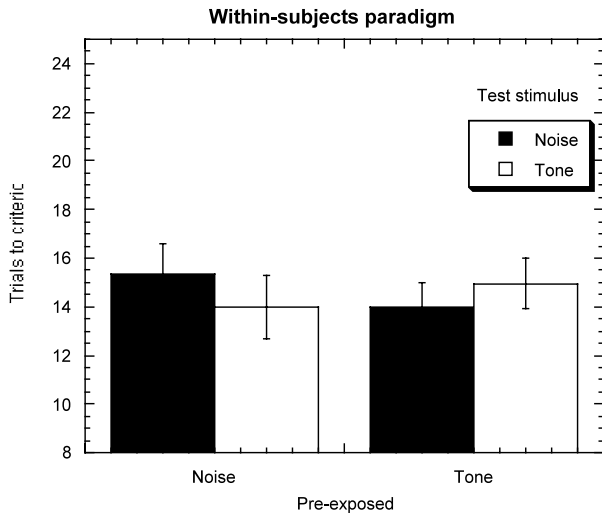
Fig. 1. The number of trials taken to learn the rule that the noise and tone indicate the counter increment is plotted for each of the test stimuli (noise-filled bars; tone-open bars) in experiment 1 (within-subjects paradigm). The columns on the left are for the participants who were pre-exposed to the noise stimulus, and the columns on the right are for those who were pre-exposed to the tone. The error bars represent ±1 standard error (S.E.) of the mean.

each of our stimuli. However, it is possible that the small difference in LI scores we found between the two groups might be genuine rather than chance fluctuations and could thus be revealed if enough data were gathered. A power caculation [5] showed that the difference in the LI effect between the groups we obtained had an effect size of 0.09 and thus would require over 1000 participants per group for an alpha value of 0.05 and power of 80% in order to reveal statistical significance.

2.2.1. Schizotypy measurements

In order to examine the relationship between LI and schizotypy we correlated the learning score against the score on the particular measure of schizotypy for each group (PE, NPE) separately. Spearman's ρ correlations were calculated in each case. The presence of a moderating effect of schizotypy on LI would be indicated by a significant difference in the correlations for the PE and the NPE groups (see [14]). Table 1 shows the correlations between the schizotypy scales and the learning scores for PE and NPE separately. The z-score difference (see [19]) between the PE and NPE correlations for each schizotypy scale are also presented. None of these correlations or z scores reached significance.

3. Experiment 2-between subjects task

3.1. Methods

3.1.1. Participants

Sixty-four (32 male, 32 female) healthy volunteers participated in experiment 2. The mean age was 24.8 years (S.D. = 7.9 years). All other details are as in experiment 1.

3.1.2. Apparatus and procedure

All stimuli and materials used were the same as used in the within-subjects version of the task (experiment 1). In the pre-exposure phase half the participants heard 25 instances of the white noise stimulus (the PE group) interpersed with the non-sense syllabes, whilst the NPE group had no such noise bursts. In the test phase all participants heard the non-sense syllables and the white noise bursts that now signalled an increment in the counter display. A single learning score of the number of trials to learn the white noise = counter increment relationship, was taken for each participant.

3.2. Results

The ranked scores were subjected to a one-way ANOVA with a between-subject factor of pre-exposure to the white noise (PE, NPE). There was a significant main effect of pre-exposure ($F(1, 62) = 8.73$, $P < 0.001$). Fig. 2 shows that the PE group learnt about the white noise slower than the NPE group. The effect-size calculated from the raw scores (not ranked) of the LI effect was 0.65.

3.2.1. Schizotypy measurements

Table 1 shows the correlations between the schizotypy scales and the learning scores for the PE and NPE groups separately. The z-score difference between the magnitude of the correlations for the PE and NPE groups are also shown. For the between-subjects task both RISC and STA were significantly associated with changes in LI score, though the P-scale was not. For the STA scale, those with greater schizotypy scores learnt more slowly if PE, with no significant effect being found for the NPE group. Thus the high STA participants showed a reduced LI effect. For the RISC scale, a higher schizotypal score was indicative of slower learning for the NPE group, with no significant effect being found for the PE group. Thus, STA is associated with the classic reduction of LI, abolishing the effect of pre-exposure while showing no effect on basic associative learning. RISC score, whilst also showing a reduced LI effect for high scorers, is associated only with changes in basic associative learning, as reflected in the NPE scores. These two results mirror those found for the Unusual

Table 1
Spearman's ρ correlation coefficients between the learning scores (and differences in learning scores) and the measures of personality

Experiment	Pre-exposed stimulus		P	RISC	STA
(1) Within	White noise	PE	−0.04	−0.19	−0.21
		NPE	0.04	−0.18	−0.20
		Difference z-score	0.30	0.04	0.04
	Tone	PE	0.09	0.21	0.18
		NPE	0.13	0.15	0.14
		Difference z-score	0.15	0.23	0.15
(2) Between	White Noise	PE	−0.22	−0.20	−0.33*
		NPE	−0.10	0.42*	0.11
		Difference z-score	0.49	2.48**	1.72*

P is the psychoticism scale of the Eysenck Personality Questionnaire [9]; RISC is the Rust Inventory of Schizoid Cognitions [32]. STA is from the Schizotypal Personality Scale [4]. *, $P < 0.05$; **, $P < 0.01$.

Experiences and the Cognitive Inhibition scales of the O-LIFE [14].

3.2.2. Comparison of tasks

Comparison of the magnitude of the LI effect for the within-subjects paradigm shows it is much smaller (mean LI effect = 1.35 trials when pre-exposed to white noise and 0.96 trials when pre-exposed to tone) than the between-subject effect (mean LI effect = 5.75 trials)[1]. We suspect that this is because, once the participant has learnt about one of the imperative stimuli in the within-subject task (most frequently the NPE stimulus), then this will greatly aid the learning of the other stimulus. This effect would thus lead to a facilitation of learning the PE stimulus in the within-subject task, leading to a smaller LI effect overall. If this were true then the major difference between the within- and between-subjects versions of the task should lie in faster learning rates of the PE condition for the within-subjects task, with no difference in learning rate for the NPE condition. A planned comparison (unpaired t-test) of the most similar conditions between the within-subject and between-subject paradigms (i.e. only the data concerning the white noise stimulus) showed that the PE condition was learnt faster in the within-subject task than in the between-subjects task ($t(78) = 3.56$, $P < 0.001$), whilst the NPE condition did not differ in speed of learning between tasks ($P > 0.1$).

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[1] Whilst the LI effects are very different in terms of absolute trials to criterion, they are more similar (0.45 and 0.35 compared with 0.65) in terms of 'effect sizes' as the within-subjects paradigm can eliminate the variance due to individual differences in overall learning speed. Thus, whilst we lose power via a reduced difference in PE versus NPE scores we gain power via a reduction in variance. For a vivid illustration of this, if the within-subjects effect sizes are re-calculated by treating the data as if they were generated by two separate groups (by using the standard deviation of the raw learning scores of the PE or NPE groups as opposed to the standard deviation of the difference scores) the effect sizes fall to 0.15 and 0.14, respectively.
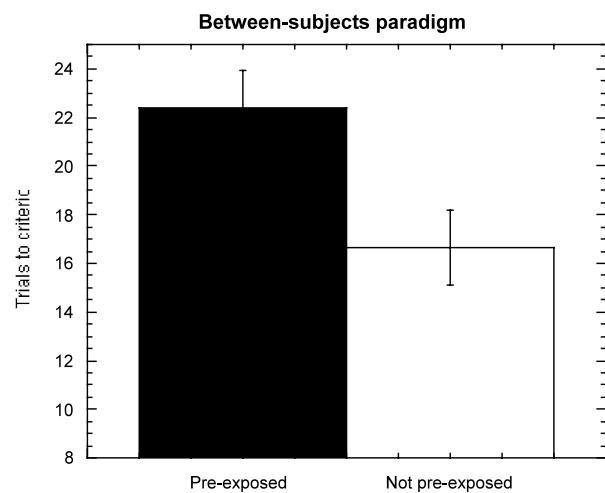

Fig. 2. The number of trials taken to learn the rule that the noise indicates the counter increment is plotted for the participant who were pre-exposed to this noise (filled bars) or who were not (open bars) in experiment 2 (between-subjects paradigm). The error bars represent $\pm$ 1 S.E. of the mean.

4. Discussion

In the introduction we outlined three aims of the present experiments. We now discuss each of these in turn in light of the data collected.

Using the within-subject LI paradigm of Gray et al. [17] we demonstrated a significant LI effect both for participants exposed to white noise or to tone. Further the magnitude of the LI effect was similar for either stimulus of pre-exposure and did not differ significantly under the present conditions. Hence the concerns expressed in other studies (e.g. [21]) and outlined in the introduction do not appear to be warranted. Thus our first hope was realised.

The magnitude of the LI effect was notably smaller for the within-subject paradigm than for the between-subject paradigm. Thus our second hope was not realised. We speculated that, in the within-subject task, once the participant had learnt about one stimulus then

this would give a strong clue as to the nature of the second stimulus causing the counter increment. Thus we predicted that participants tested on each of the two paradigms would learn about the NPE stimulus at the same rate (as this is usually the stimulus that is learnt first), but that the within-subjects participants would then be able to use this information to quickly learn about the second stimulus-thus giving smaller learning scores in the PE condition. These conjectures were supported by the data. Hence though within-subject LI can be demonstrated, its magnitude for each individual is small and thus may well limit its use as a tool for investigating individual differences. One possible factor that might eleviate this problem would be to use two conditioning stimuli that were from different modalities (e.g. one visual and one auditory). Whilst issues of stimulus salience would have to be addressed, we note that such a paradigm appears to have been successful in producing a within-subject learned irrelevance effect in humans [31].

It is also notable that there is one other difference between the within-subject and between-subject paradigms presented here. Whilst the PE conditions are similar across the two paradigms, the NPE conditions are somewhat different. In the within-subject paradigm the NPE condition consists of participants being PE to a stimulus, whilst in the between-subject paradigm the NPE group were not pre-exposed to any stimulus. The novelty of the stimulus presented at test (superimposed over the masking non-sense syllables) may contribute to the participant attending to this conditioning stimulus at test in the between-subjects paradigm compared with the within-subject paradigm. However, we note that such an explanation would predict faster learning in the NPE condition for the between-subjects paradigm compared with the within-subject paradigm, whereas we show that this condition did not differ across tasks, with differences in the tasks only appearing in the PE conditions.

Finally, we attempted to see if the within-subjects paradigm would be sensitive to individual differences in schizotypal personality. In line with previous studies [3,14,24] high scorers on some measures of schizotypal personality showed a decrease in the magnitude of the LI effect for the between-subject task. However these trends were not apparent in the data from the within-subject paradigm. As explained above we suspect that once the relationship between one stimulus and the counter increment is learnt then this acts as a clue that aids learning of the second stimulus. Thus, the LI scores from the within-subject paradigm are 'falsely restricted' and cannot be used to index individual differences in LI magnitude. Thus, weak effects of personality are ablated by this overall reduction in LI scores. However, more powerful manipulations, such as the chronicity of schizophrenia or the administration of neuroleptic drugs [17,30] may be strong enough to overcome this enhanced

learning of the PE stimulus by the previous learning of the NPE stimulus. It would be interesting to repeat the current set of experiments using these stronger manipulations to test this hypothesis.

In conclusion, we have demonstrated a within-subject paradigm that can produce reliable LI. However, we believe that the paradigm has drawbacks that limit its effectiveness in many experimental situations. Perhaps with such drawbacks in mind it is useful to review several recent attempts to develop 'new' LI paradigms in humans that might circumvent these difficulties, with several of these paradigms producing within-subject versions of the tasks. In one attempt to more closely mimic the non-human LI paradigms, Salgado et al. [33] used a conditioned suppression paradigm where the pairing of a soft tone with a loud noise burst led to the tone itself suppressing an on-going behaviour. Earlier pre-presentation of the tone alone was found to lead to a reduction of this conditioned suppression that was convincingly argued by the authors to be a demonstration of LI. Whilst this paper presents only a between-subjects comparison there seems no reason why a within-subjects version should not be attempted.

Lubow, De la Casa and colleagues have also recently introduced two novel LI paradigms [22,25,26]. The first of these uses a visual search paradigm where a target is to be spotted amongst a field of distractor elements. In later trials the elements that had been distractors now become targets (the 'PE' condition) or a new target can be used (the 'NPE' condition). Within-subjects LI-like effects have been demonstrated along with their modification in schizophrenic patients [25] and those high in schizotypy [26] when reaction time measures have been taken. In a similar vein, Lubow et al. [22] show a within-subjects LI-like effect in a task that involves letter identification. The position of the target element on some trials was predicted by the colour of the background. One such background colour was PE in earlier trials (the PE condition) whilst the other was not (NPE). Lubow et al. [22] subjects had longer RTs in the PE condition that in the NPE condition, demonstrating LI. Interestingly this within-subject LI effect was only found for the RT data. Inspection of the error data (which may be more akin to the 'trials-to-criterion' measure used in the present study) did not reveal any LI effect. Indeed the use of RT measures appears to offer new possibilities for the development of human LI paradigms that do not need a masking task [8,12] and may be repeatable across presentations. Nevertheless the issues we have identified in the present study are not eliminated by such desgins, nor in designs that use electrodermal conditioning as an index of learning [34]. A comparison of the magnitude of LI produced by within-subject and between-subject versions of these tasks would also be informative. Further, such paradigms seem to take us even further away from those used in animal studies of LI making it

more difficult to compare and contrast differential effects of psychological and pharmacological manipulations across species.

Acknowledgements

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